AES BIOFLUX
Advances in Environmental Sciences - International Journal of the Bioflux Society

Prioritizing stresses and disturbances affecting mangrove forests using Fuzzy Analytic Hierarchy Process (FAHP). Case study: mangrove forests of Hormozgan Province, Iran

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Abstract. Nowadays, preventing and/or mitigating unfavorable consequences of increasing vulnerability of forest ecosystems has became one of the most important goals of natural resources managers all over the world. Achieving this goal requires use of methods which can provide scientific and on time decision making for managers. Among these methods, Fuzzy Analytic Hierarchy Process (FAHP), due to scientific validity and applicability at different multidisciplinary levels, is appropriate for decision making in complex conditions and in confronting to multiple criteria. In this study, this method was used for prioritizing the multiple negative factors (stresses and disturbances) affecting on mangrove forests. Results showed that regarding to current status of mangrove forests of Iran, anthropogenic stresses and disturbances generally have more importance than other negatively effective factors, so, pollutants emission and engineering interventions in coasts were placed in the first and third priority in the final ranking, respectively. Results also showed that among various climatic effective factors, sea level rise has higher importance than other factors (placed in the second rank). The results weren't unexpected at all, other scientists in the other parts of the world also expressed that sea level rise is one of the most important climatic factors affecting on current and future decrease of area and health of mangroves in all over the world. Results of this study could be used as decision making supporting tool and play an important role in efficiency and success of sustainable planning and management of mangrove forests in Iran and other similar mangroves of Persian Gulf.
Key Words: destructive factors, multi criteria analysis, mangroves, Iran.

Introduction. Nowadays, despite the high importance of mangrove forests in providing goods and services required by humans, destruction of these habitats are intensified, so that currently more than 50 percent of world mangrove forests were destroyed and this trend is still continuing (Alongi 2002; Duke et al 2007). These stresses and disturbances occurred by natural and anthropogenic factors such as storms, diseases, deforestation, changing the coastal landforms and extending cropplands and residential areas, development of coastal recreational areas, aquaculture and destructive effect of oil pollution as well as wastewaters containing various chemical materials that intrusion into mangrove forests from near urban, industrial and agricultural environments (Ong Che 1999; Schaffelke et al 2005; Binelli et al 2007; Krauss et al 2008). Direct result of these stresses and disturbances will include decreasing health and area of mangroves, intensification of global warming and other climatic changes, declining coastal water quality, decreasing biodiversity, coastal habitats destruction as well as destruction of major part of sources that human required (Mumby et al 2004; Nagelkerken et al 2008; Walters et al 2008). With regard to the consequences of mentioned stresses and disturbances which are serious threats for mangroves, mitigation of their impacts with the help of suitable planning and mitigation tools is inevitable (Mahendra et al 2011).

Achieve this goal and provide a suitable situation for taking necessary actions in the place of event need to recognizing and prioritizing of such stresses and disturbances that play an important role in creating vulnerability of mangrove ecosystems (Cutter et al 2000).

In recent years different methods and technics are developed for providing help for taking effective managerial decisions and prioritizing of various criteria which we can mention to Delphi method, ideal point, list analysis and Fuzzy Analytic Hierarchy Process (FAHP) (Kahraman et al 2003b; Li et al 2009; Hsu et al 2007; Vafai et al 2013). Among these methodes, FAHP, due to scientific validity and applicability at different multidisciplinary levels, is appropriate for decision making in complex conditions and in confronting to multiple criteria (Chen et al 2011; Lee et al 2008; Chou et al 2013). Thus, the aim of this study was to use the FAHP for prioritizing of multiple stresses and disturbances affecting on mangrove forests of Hormozgan province in Iran. In fact, this paper is the first part of a series of studies that have been conducted with the aim of vulnerability assessment of mangrove forests in Iran. Undoubtedly, the results of this study play an important role in taking effective decisions for sustainable planning and management of mangrove forest in Iran.

Fuzzy Analytic Hierarchy Process. Generally, accurate and scientific decision-making have an important role in the success or failure of a project. Therefore, application of various decision making procedures, especially multi criteria decision making approaches are common in resolving different problems (Rao 2007; Kabir & Sumi 2013). Among multi criteria decision making approaches, Analytical Hierarchy Process (AHP), which initially presented by Saaty (1980, 1994), was used as most applied multi criteria decision making tool by decision makers and authors (Tsaur et al 2002; Vaidya & Kumar 2006; Rao 2007). In this method, after converting complex decision making system into simple hierarchical system, pair-wise comparision of options instead of simultaneous prioritizing of all options using 9-folds scales was conducted and oral preferences displayed as quantitavie form (Saaty 1980). Therefore, AHP use absolute numbers for judgment and prioritizing of criteria. AHP can also provide a list of alternative solutions (Saaty 1980, 1994; Bentivegna et al 1994).

Although discrete scale used in AHP have some advanteagous like simple application, it is unable to show existing uncertainities in peoples perceptions as a number, since due to fuzzy nature of comparison process, author could not express their preferences explicitly (Deng 1999; Kahraman et al 2003b). However, in many operational instances decision making model of preferences are unknown and some of evaluation criteria are subjective or qualitative and in these conditions, decision maker might be unable to allocate accurate numerical value to comparative judgments among criteria (Kahraman et al 2003b). In order to overcoming to all these shortcomings and help to modeling of uncertainities in decision making preferences, initially Van Laarhoven & Pedrycz (1983) combined fuzzy logic principles (Zadeh 1965) with analytical hierarchy process and in addition to achieving more accurate understanding from decision making process, more correct results and closer to reality is obtained (Ayag & Ozdemir 2006). Fuzzy set theory providing a more widely frame than classic sets theory, has been contributing to capability of reflecting real world (Ertugrul & Tus 2007). Fuzzy sets and fuzzy logic are powerful tools for modelling of natural and anthropogenic systems and also facilitating logic decision making in lack of sufficient information and are very efficient in expressing complex phenomena which are not describable with traditional calculation methods (Bojadziev & Bojadziev 1998; Tsaur et al 2002).

Decision makers found that use of interval judgments are better and more reliable than judgments that done with fixed values and the preference rate of expert in regard to fuzzy nature of comparison process can not be expressed accurately by using fixed values (Kahraman et al 2003a). Therefore, FAHP gave the possibility to decision makers to express their flexibility preferences by fuzzy numbers and enter uncertainities in their judgments. Also, a membership function in fuzzy set operating on set of real numbers and usualy are in 0 to 1 range. Thus, FAHP uses the range of values for expressing uncertainities (Lee et al 2008). In this procedure, decision maker could state his/her opinion in an overall form as optimistic, pessimistic, in average and completely related

and so on (Jeganathan 2003). In FAHP, fuzzy numbers can not be directly used, but fuzzy approach along with ranked structure will be used indirectly (Van Laarhoven & Pedrycz 1983; Jankowski 1995). In this approach, priority of two A1 and A2 option compared to each other stated using triangular or trapezoidal fuzzy numbers. Generally, a triangular fuzzy number (TFN) is shown in Figure (1) (Kahraman et al 2003b).

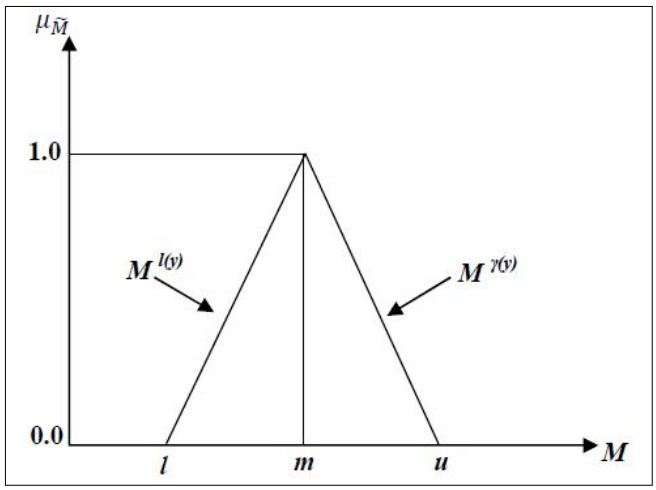

Figure 1. A triangular fuzzy number (Kahraman et al 2003b).

So, A TFN is denoted simply as three absoloute numbers (l, m, u). These parameters, respectively, denote the smallest possible value, the most promising value, and the largest possible value, which their membership can be defined as equation (1):

$$\mu(x|\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u. \end{cases} \quad (1)$$

Reviewing some of studies conducted by FAHP. Generally, FAHP was used in various investigation contexts. Li et al (2009) using FAHP and in GIS assessed the vulnerability of Danjiangkong in China. Zhang (2009) in risk assessment of Guangdone coastal area to storms, used the combination of fuzzy set and Delphi method for weighing and prioritizing of criteria. Chen et al (2011) used FAHP for weighing and determination of priority of best selection criteria or strategies for management projects in watershed. Jun et al (2013) conducted risk assessment of Korea against flooding resulted from climatic changes using multi criteria fuzzy method. Wang et al (2014) assessed risks of coupled coastal systems in China. In this study importance degree and weight of each criterion was determined using FAHP. Lee et al (2013) used fuzzy multi criteria integrated approach for risk assessment to flooding occurrence in Korea.

Material and Method

Study area. Mangrove forests of Hormozgan province is located in northern coasts of Persian Gulf and Oman Sea by 10025.55 ha (more than 90% of mangrove forests of Iran) and developed in 7 towns including Jask, Sirik, Minab, Bandar Abbas, Khamir, Qeshm and Bandar Lenge at different habitats (Danehkar at al 2008). Mangrove forests of Hormozgan province have greatest area of these forests in the country and in the entire Persian Gulf region and waters of Regional Organization for Protection Marine Environment (ROPME) region and consisted of two species including Harra (*Avicennia marina*) and Chendal (*Rhizophora mucronata*) (Danehkar 1998, 2001).

Natural mangrove forests in coastal areas of Hormozgan spread on 25°34'13'' N in Gabrig (Jask town) to 27°10'54'' N in Koulaghan (Bandar Abbas town) and 58°34'07'' E

in Himan (Jask town) to 55°22'06'' E in Bandar Lenge town (Figure 2). In mentioned area, natural sites except Syric habitat, totally covered with unmixed, irregular and uneven aged *Avicennia* associations and just in Syric habitat, *Rhizophora* species are mixed with *Avicennia* species (Danehkar 1998). Mangrove forests of Hormozgan province encompass wide range of ecological functions such as heavy metal fixation, sediment fixation, erosion control, carbon sequestration, supplying habitat for fish and shrimp as well as providing various ecosystem services such as supplying animal fodder, honey harvest, fisheries and coastal protection (Danehkar 1998; Danehkar et al 2008; Mehrabian et al 2009).

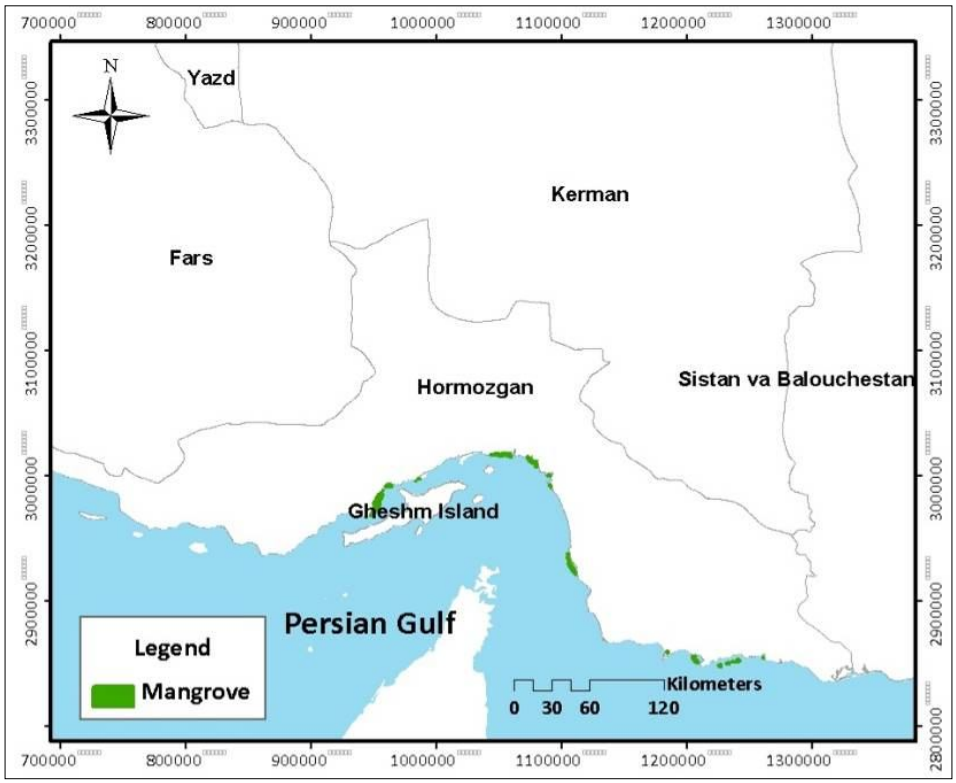

Figure 2. Geographical location of Hormozgan province mangrove forests, Iran (original).

Recognizing negative factors. Based on investigations, external environmental factors which have negative effect on plants were put into two classes including stresses and disturbances. According to definitions, stresses include all internal factors which have restrictive effect on plant photosynthesis (generally include light, moisture and/or nutrient deficiency as well as extreme temperatures) and disturbances include partial or major destruction of plant biomass by external factors e.g. herbivores, pathogens, and anthropogenic effects (cutting, plowing) or by wind destruction, freezing, drying, soil erosion and fire (Grime 1977, 1989). In fact, intensity of these factors determines amount of vulnerability, growth and surviving and also recovery and reestablishment rate of vegetation cover at different areas (Huggett 2002). From this view, different ecosystems, especially mangroves, are almost permanently and simultaneously subjected to multiple environmental stresses and disturbances (natural and anthropogenic) which vary temporarily and spatially (Smith et al 1994; Feller & McKee 1999; Sherman et al 2000; Alongi 2002, 2008; Obade et al 2009). Therefore, recognizing these stresses and disturbances has an important role in mitigating or compensating damages introduced into these forest ecosystems (Adger 2006).

Generally, recognizing and classification of stresses and disturbances by extensive review of library resources and literatures, questionnaire setting for receiving decision-makers opinion and eventually analyzing findings using computer software, were the basic procedure of this study. Therefore, firstly with extensive evaluating library literatures, the most important external environmental factors (stresses and

disturbances) which could have negative effect on structure and function of mangrove forests of Hormozgan province were recognized and classified at 4 main classes and 12 groups for building hierarchy structure (Table 1).

Table 1

Classification of various negative effective factors affecting on mangrove forests of Hormozgan province

Criteria	*Sub-criteria*	*References*
Meteorological	Sea level rise	Ellison (2000); Cahoon & Hensel (2006); McLeod & Salm (2006); Gilman et al (2006, 2007a,b)
	Storm	Cahoon et al (2003, 2006); Cahoon & Hensel (2006)
	Drought	Field (1995); Snedaker (1993); Ellison (2000)
	Air temperature	Tomlinson (1986); Duke et al (1998); Ellison (2000); Larcher (2003)
Geological	Erosion and accretion	Norkko et al (2002); Cummings et al (2003); Ellison (2006)
Anthropogenic	Unmanaged aquaculture	Primavera (1993, 1995, 1997); Valiela et al (2001); Barbier & Cox (2003)
	Pollutants emission	Mardon & Stretch (2004); Tam et al (2005); Araujo & Costa (2007)
	Unmanaged tourism activities	Longcore & Rich (2004); Groom et al (2007); Schlacher & Thompson (2008)
	Changes in the freshwater inflow into the coastal environment	Dahdouh-Guebas et al (2005); Farnsworth & Ellison (1997)
	Engineering interventions in coasts	Dugan & Hubbard (2006); Dugan et al (2008); Schleupner (2008)
Biological	Over-exploitation and Conversion of mangrove forests	Walters (2005); Hauff et al (2006); Lopez-Hoffman et al (2006); Crona & Ronnback (2005, 2007)
	Blooming of invasive species (pests)	Smith et al (1989); Osborne & Smith (1990); Cannicci et al (2008)

Application of FAHP. Generally for running FAHP and weighing as well as prioritizing of stresses and disturbances, following steps were established:

Preparing hierarchy structure. This step includes determination of goal, criteria and sub-criteria witch forming first, second and third layers of hierarchical structure of FAHP. In this step, purpose is the determination of relative weight of stresses and disturbances affecting on mangrove forests and second layer included stresses and disturbances.

Composing a comprehensive fuzzy pair-wise comparison matrix. In order to conduct this step using questionnaire, initially pair-wise comparison matrix was created considering the experts opinions in regard to criteria and by using Saaty's 1-9 scale. By considering N criteria, pair-wise comparison of i with j resulted to creating symmetry matrix of NN. In this matrix, aij represents importance (preference) of i compared to j according to experts opinions. The score of pair-wise comparison of j with i always was equal to reveres score of pair-wise comparision of i with j $\left(a_{ij} = \frac{1}{a_{ij}}\right)$ (Rao 2007).

Saaty (1980) suggests that if the Consistency Rate (CR) is smaller than 0.10, indicates a reasonable level of consistency in the pairwise comparison, if, however, the CR is greater than 0.10, there are inconsistencies and the AHP method may not yield meaningful results. In fact, CR of less than 0.1 represents awared judgment which could be attributed to expert's knowledge. So, in this study using EC software, CR of pair-wise

comparison matrices of experts judgements was determined and questionnares with CR of less than 0.1 were removed. In fact, if pair-wise comparison matrix (aij) had acceptable CR, its fuzzy pair-wise comparison matrix also has acceptable CR. In this study, according to project manager opinion, 60 experts were selected which have high scientific and operational experience (minimum 15 years) in area of conservation and restoration of mangrove forests and southern coasts of Iran and expressed their own judgements about importance level of mentioned stresses and disturbances affecting on mangrove forests. Finally, of 60 completed questionnaires, 58 of them with CR less than 0.1 were choosed for analyzing.

As stated earlier, in FAHP method instead of aij, TFN $(\tilde{a}_{ij})$ were used as equation (1) in pair-wise comparison matrix (Chen et al 2006).

$$(1) \quad a = [\tilde{a}_{ij}], \tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}), \qquad \tilde{a}_{ij} = {}^{1}/_{\tilde{a}_{ij}}, \qquad \forall i, j = 1, 2, \dots, n$$

Therefore, in the present study in order to use of all experts opinion and also prevention of weakneses of AHP in using absoloute and fixed numbers, TFNs were used and each comparison were displayed as (l, m and u) which include minimum (l), mean (m) and maximum (u) scores of experts opinions in pair-wise comparisons of criteria. So, in addition to combination of expert's opinion and creating integrated matrix (comprehensive), pair-wise comparisons of decision maker's values were converted to TFNs.

Determination of weights of all criteria using FAHP. In this step using comprehensive fuzzy pair-wise comparison matrix composed by TFNs and according to extent FAHP, which was originally introduced by Chang (1996), weight of each stress or disturbance was determined. Let $X = \{x_1, x_2, x_3, \dots, x_n\}$ an object set, and $G = \{g_1, g_2, g_3, \dots, g_n\}$ be a goal set, according to the method of Chang's extent analysis, each object is taken and extent analysis for each goal performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^{1}, M_{gi}^{2}, \dots, M_{gi}^{m} \qquad i = 1, 2, \dots, n$$

Where, $M_{gi}^{j} (j = 1, 2, \dots, m)$ all are TFNs.
In the present study for conducting Chang's extent analysis (Chang 1996), following steps were conducted:
<u>*Step 1*</u>.Calculating the value of fuzzy synthetic extent. This value is performed using equation (2) with respect to the i object is defined as:

$$(2) \quad S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, the fuzzy addition operation of m extent analysis values for a particular matrix is performed as equation (3):

$$(3) \quad \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_i \right)$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, the fuzzy addition operation of $M_{gi}^{j} (j = 1, 2, \dots, m)$ values is performed as equation (4):

$$(4) \quad \sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_1\right)$$

And finally, the inverse of the vector above is computed by equation (5):

$$(5) \quad \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

In fact, these equations show combination of fuzzy numbers resulted from pair-wise comparison of each criterion with other criteria and their normalization. So, instead of a number of TFNs for comparison of each criterion with other criteria, a synthetic fuzzy number corresponding to combination value of each critrion was obtained.

Step 2. Comparison of fuzzy synthetic extent values and determination of weights. In FAPH, weights are obtained by comparing each criterion with other criteria. In order to compare two fuzzy numbers, calculation the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is required. So, for comparison of M1 and M2, we need both values of $V = (M_1 \geq M_2)$ and $V = (M_2 \geq M_1)$. The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as equation (6):

$$(6) \quad V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right]$$

And can be expressed as equations (7) and (8):

$$(7) \quad V(M_2 \geq M_1) = hgt\,(M_1 \cap M_2) = \mu_{M_2}(d)$$

$$(8) \quad V(M_2 \geq M_1) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise} \end{cases}$$

Equation (8) represents this concept that if the lowest value of the first criterion (l1) is more than the greatest value of the second criteria (u2), the degree possibility of second criteria compared to first one would be zero. Figure (3) illustrates equation (8), where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} to compare M1 and M2. Therefore, the degree possibility for a convex fuzzy number to be greater than k convex fuzzy Mi (i = 1, 2,..., k) numbers can be defined as equation (9). In the other word, the degree of possibility of a convex fuzzy number compared to other k convex fuzzy numbers can be obtain from a comparisons between the minimal values.

$$(9) \quad d(A_i) = \min V(S_i \geq S_k), \qquad k = 1, 2, \ldots, n, k \neq i$$

Therefore, by accepting equation (9), the criteria weight vector is expressed as equation (10):

$$(10) \quad W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T$$

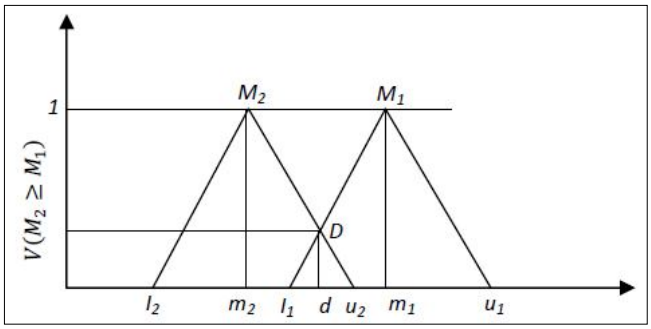

Figure 3. The intersection between M1 and M2 (Chang 1996).

Step 3. Via normalization, the normalized weight vector is computed by equation (11):

(11) $$W = (d(A_1), d(A_2), \ldots, d(A_n))^T$$

where W is a non-fuzzy number between zero and one and indicating the relative weight of each criterion (Chang 1992, 1996).

Results and Discussion. Generally, in various studies for evaluating and prioritizing of stresses and disturbances affecting on ecosystems, different tools and methods were used for analyzing opinions of experts and decision makers (Bryant et al 1998; TNC 2000; Zacharias & Gregr 2005). Among various methods, multi criteria decision making strategies provide possibilities for selection of optimum options in complex conditions (Ananda & Herath 2008). To date, many multi criteria decision making strategies were developed which among them FAHP due to scientific validity and capability of using in different multi disciplinary levels, would be appropriate for prioritizing of multiple criteria (Ertugrul & Tus 2007). In this study like other studies by Chen et al (2011), Zhang (2009), Jun et al (2013), Wang et al (2014), Chou et al (2013) and Lee et al (2013), FAHP were used to prioritizing and ranking of negatively effective natural and anthropogenic factors. So, after recognizing of existed negatively effective factors and based on analyzing experts judgments, a range of importance degrees determined for each factor and eventually by appropriate analyzing, prioritized and ranked.

As mentioned before, pair-wise comparison of stresses and disturbances was carried out by each decision maker and using Saaty's 1-9 scale. An example of these pair-wise comparisosn is shown in Table 2. So, 58 questionnaires which have CR of less than 0.1 were used for final analyzing and weighing of stresses and disturbances.

Table 2

Pair-wise comparison matrix using Saaty's scale

C12	*C11*	*C10*	*C9*	*C8*	*C7*	*C6*	*C5*	*C4*	*C3*	*C2*	*C1*	
1/9	1/8	1/6	1/4	1/8	1/7	2	1/9	1/2	1/7	1/5	1	C1
1/7	1/6	1/2	2	1/4	1/8	6	1/5	4	1/3	1	5	C2
1/5	1/4	2	4	1/2	1/6	8	1/3	6	1	3	7	C3
1/9	1/8	1/5	1/3	1/7	1/9	3	1/8	1	1/6	1/4	2	C4
1/3	1/2	4	6	2	1/4	9	1	8	3	5	9	C5
1/9	1/8	1/7	1/5	1/8	1/9	1	1/9	1/3	1/8	1/6	1/2	C6
2	3	6	7	5	1	9	4	9	6	8	7	C7
1/4	1/3	3	5	1	1/5	8	1/2	7	2	4	8	C8
1/8	1/7	1/3	1	1/5	1/7	5	1/6	3	1/4	1/2	4	C9
1/6	1/5	1	3	1/3	1/6	7	1/4	5	1/2	2	6	C10
1/2	1	5	7	3	1/3	8	2	6	4	6	8	C11
1	2	6	8	4	1/2	9	3	9	5	7	9	C12

Table 3 shows the comprehensive fuzzy pair-wise comparison matrix resulted from integrating 58 decision makers' pair-wise comparison matrix through equation (1). By this way, decision makers'pair-wise comparison values are transformed into TFNs. In the comprehensive fuzzy pair-wise comparison matrix, TFNs include minimum (l), average (m) and maximum (u) values of expert's judgments.

Table 3

Comprehensive fuzzy pair-wise comparison matrix

C12	*C11*	*C10*	*C9*	*C8*	*C7*	*C6*	*C5*	*C4*	*C3*	*C2*	*C1*	
0.049	0.045	0.11	0.07	0.07	0.053	0.064	0.058	0.21	0.064	0.08	1	C1
2.24	1.85	1.70	2.10	1.07	0.10	0.32	1.02	1.99	0.93	1.34	1	
6.43	6.43	5.79	6.43	5.14	0.21	1.29	3.21	5.14	2.57	3.21	1	
0.09	0.064	0.09	0.053	0.058	0.045	0.049	0.08	0.21	0.11	1	0.31	C2
1.92	1.81	2	1.65	1.13	0.13	1.17	0.61	2.62	0.62	1	0.75	
5.79	5.14	4.50	5.14	4.50	0.32	3.86	2.57	8.36	1.93	1	12.5	
0.13	0.07	0.07	0.058	0.064	0.049	0.058	0.09	0.32	1	0.52	0.36	C3
2.39	2.55	2.13	2.05	1.67	0.15	1.75	0.71	3.45	1	1.61	1.075	
5.79	5.79	5.14	4.50	4.50	0.32	5.14	1.93	7.07	1	9.10	15.63	
0.058	0.053	0.09	0.064	0.07	0.045	0.058	0.053	1	0.14	0.12	0.19	C4
1.19	1.04	0.90	1.45	0.58	0.07	0.33	0.47	1	0.29	0.38	0.50	
5.14	4.50	2.57	5.79	3.86	0.13	1.93	1.93	1	3.13	4.76	4.76	
0.21	0.07	0.11	0.09	0.08	0.058	0.064	1	0.52	0.52	0.39	0.31	C5
2.38	2.35	3.15	2.52	1.64	0.16	1.98	1	2.23	1.41	1.64	0.98	
5.14	5.14	6.43	4.50	3.21	0.32	6.43	1	18.87	11.11	12.50	17.24	
0.053	0.058	0.09	0.13	0.07	0.049	1	0.15	0.52	0.19	0.26	0.77	C6
3.65	2.75	3.3	2.93	1.83	0.21	1	0.50	3.03	0.57	0.85	3.13	
7.07	7.07	6.43	7.07	5.79	0.32	1	15.63	17.24	17.24	20.41	15.63	
0.32	0.21	3.86	1.93	2.57	1	3.12	3.12	7.69	3.13	3.13	4.76	C7
4.74	4.21	5.46	4.66	3.62	1	4.76	6.25	14.29	6.66	7.70	10	
7.71	7.71	7.71	7.07	6.43	1	20.41	17.24	22.22	20.41	22.22	18.86	
0.13	0.11	0.21	0.21	1	0.15	0.17	0.31	0.26	0.22	0.22	0.19	C8
2.33	1.61	2.60	1.87	1	0.28	0.55	0.61	1.72	0.60	0.88	0.93	
5.79	4.50	4.50	3.86	1	0.39	14.29	12.50	14.29	15.62	17.24	14.29	
0.08	0.07	0.16	1	0.26	0.14	0.14	0.22	0.17	0.22	0.19	0.15	C9
1.87	1.28	1.78	1	0.54	0.21	0.34	0.40	0.69	0.49	0.60	0.48	
5.14	3.86	5.79	1	4.76	0.52	7.69	11.11	15.62	17.24	18.87	14.29	
0.07	0.064	1	0.17	0.22	0.13	0.15	0.15	0.39	0.19	0.22	0.17	C10
1.51	0.73	1	0.56	0.38	0.18	0.30	0.32	1.11	0.47	0.50	0.59	
4.50	2.57	1	6.25	4.76	0.26	11.11	9.09	11.11	14.29	11.11	9.09	
0.13	1	0.39	0.26	0.22	0.13	0.14	0.19	0.22	0.17	0.19	0.15	C11
1.85	1	1.37	0.78	0.62	0.24	0.36	0.43	0.96	0.39	0.55	0.54	
6.43	1	15.62	14.29	0.09	4.76	17.24	14.29	18.87	14.29	15.62	22.22	
1	0.16	0.22	0.19	0.17	0.13	0.14	0.19	0.19	0.17	0.17	0.15	C12
1	0.54	0.66	0.53	0.43	0.21	0.27	0.42	0.84	0.42	0.52	0.45	
1	7.69	14.29	12.50	7.69	3.12	18.87	4.76	17.24	7.69	11.11	20.41	

After forming comprehensive fuzzy pair-wise comparison matrix, weights of all criteria are determined by the help of Chang's extent analysis. According to this method, firstly, synthesis values must be calculated using Table 3 and equation (2). Table 4 shows synthesis values (Si) for each criterion.

Table 4

Synthesis values obtained by comprehensive fuzzy pair-wise comparison matrix

C12	*C11*	*C10*	*C9*	*C8*	*C7*	*C6*	*C5*	*C4*	*C3*	*C2*	*C1*	
0.002	0.004	0.003	0.004	0.005	0.031	0.003	0.004	0.002	0.002	0.002	0.001	Si
0.040	0.051	0.040	0.050	0.072	0.260	0.100	0.093	0.037	0.089	0.070	0.067	
1.450	1.728	0.978	1.215	1.239	1.801	1.401	1.086	0.526	0.834	0.716	0.640	

Fuzzy synthesis values were compared by using equations (8) and (9). Results of comparison are shown in Table 5.

Table 5

Comparison of synthesis values

S12	*S11*	*S10*	*S9*	*S8*	*S7*	*S6*	*S5*	*S4*	*S3*	*S2*	*S1*	
0.93	0.99	0.97	0.99	1	1	1	1	0.85	1	1		S1
0.91	0.89	0.87	0.98	1	1	1	1	0.94	1		0.89	S2
0.97	0.98	0.95	0.97	0.89	1	1	1	0.81		0.89	0.97	S3
1	1	1	1	1	1	1	1		0.91	1	1	S4
0.96	0.98	0.85	0.97	0.97	1	1		0.90	0.99	0.87	0.93	S5
0.95	0.95	0.94	0.96	0.95	1		0.99	0.89	0.98	0.96	1	S6
0.85	0.88	0.81	0.84	0.87		0.89	0.86	0.70	0.82	0.78	0.76	S7
0.98	0.97	0.97	0.98		1	1	1	0.94	1	0.85	0.87	S8
0.89	1	0.99		1	1	1	1	0.88	1	1	1	S9
1	1		1	1	1	1	1	0.89	1	1	1	S10
1		1	1	1	1	1	1	0.80	1	1	1	S11
	1	1	1	1	1	1	1	0.79	1	1	1	S12

By choosing least synthesis values for each criterion using equation (9) and Table 5, criteria weight vector resulted according to equation (10):

$$W' = (0.76, 0.78, 0.82, 0.70, 0.86, 0.89, 1, 0.87, 0.84, 0.81, 0.88, 0.85)$$

Finally, by normalizing the weight vector (equation 11), relative priority weight of each criterion (W) was obtained as non-fuzzy numbers between zero and one (Table 6).

Table 6

Relative priority weights of criteria

C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	
0.074	0.077	0.071	0.073	0.076	0.088	0.078	0.075	0.061	0.072	0.068	0.066	W

Results of prioritizing of stresses and disturbances in mangrove forests of Hormozgan Province are displayed in Figure 4.

Investigation of obtained relative priority weights of stresses and disturbances showed that pollutants emmision has highest weight (0.088) among all studied factors and thereafter, sea level rise and engineering interventions by having 0.077 and 0.078 weights, placed in second and third ranks, respectively (Figure 4). Results also showed that blooming of invasive species, storm and air temperature with 0.068, 0.066 and 0.061 weights, placed in latest ranks, respectively. Geological factors including erosion and accretion along with drought, placed in mean ranks. Overall comparison of final prioritizing showed that many of negative factors in higher ranks are composed of anthropogenic factors (four factors of first 5 factors) (Figure 4).

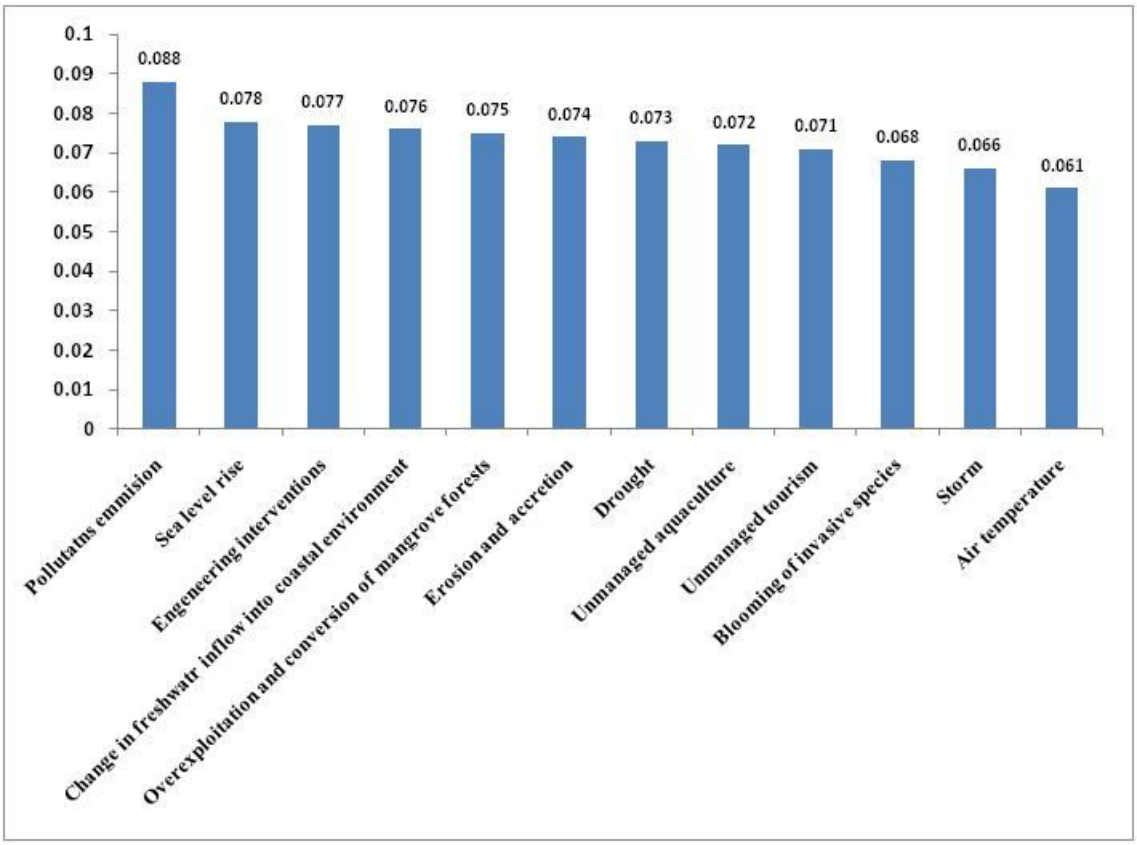

Figure 4. Final prioritizing of stresses and disturbances affecting on mangrove forests of Hormozgan Province.

Results of this study showed that based on expert's knowledge about current position and status of mangrove forests, stresses and disturbances from anthropogenic activities have higher importance than other negative factors while other studies in some of coastal areas of the world showed that natural stresses and disturbances have higher importance and priority (Lee et al 2013; Wang et al 2014). Results of final ranking showed that climatic factores such as storm, drought and air temperature placed in latest priorities. While sea level rise has more importance and priority which represents experts affinity to allocating more weight to this environmental factor than other climatic factors. The results weren't unexpected at all, experts and authors stated among various meteorological factors, sea level rise is the most important factor in current and future decrease in area (10-20 percent decrease in total area of mangrove forests) and health of mangroves in all over the world (IUCN 1989; Cahoon & Hensel 2006; McLeod & Salm 2006; Gilman et al 2006, 2007a, b).

Results of analyzing the experts' opinions showed that pollutants having most importance among all studied stresses and disturbances are most negatively effective and destructive factors in mangrove forests. Results of various studies in the world showed that pollutants caused considerable vulnerability and sensitivity in mangrove forests (Levings et al 1997; Defeo & Lercari 2004; Tam et al 2005).

Results of final prioritizing showed that after sea level rise and among all studied anthropogenic stresses and disturbances, enginnering interventions in coasts and change in fresh water inflow into coastal environment, in regard to unfavorable consequences for mangrove forests, were placed in third and fourth rank, respectively. Results of different studies showed that rapid and unplanned development of various infrastructures in coastal areas through changes in natural hydrodynamic system and sediments transportation caused uncompensated damages to the integrity of coastal ecosystems (Hsu et al 2007; Dugan et al 2008; Vaselli et al 2008). Excessive constructions in coastal areas of Hormozgan province such as ship-building and chalk and cement factories caused destruction and fragmentation of habitats and reducing effective size of mangrove

species population and converted them into vulnerable ecosystesm (Danehkar et al 2008). In fact, awareness about unfavorable consequences of industries and structures development caused experts allocate greatest importance degree to this factor after pollutants among various stresses and disturbances and introduced it as one of the most important negative factors affecting on mangrove forests of Iran.

Surface freshwater stream is one of the most effective landscape processes which having the seasonal, volumetric and biochemical unique characteristics, are affecting on structure and function of mangrove ecosystems (Gilman et al 2006 & 2007a; Berger et al 2008). Activities such as canal building, dam construction, dredging, ground water exploitation, waste management, agriculture development, mining and removal of vegetation could cause destructive effects on mangrove forests by changes in salinity level, nutrients, sediments and soluble oxygen of surface freshwaters (Dahdouh-Guebas et al 2005). As results showed, decrease in fresh water inflow into coastal areas caused 11 percent declining in area of mangrove forests in the world (Farnsworth & Ellison 1997). Based on this fact, results of this study showed that change in surface freshwaters inflow into mangrove forests of Iran by great importance degree, placed in the fourth rank in the final ranking.

Historically, main anthropogenic effects on natural environments are resulted from overexploitation and destruction of ecosystems (Jackson et al 2001). Among these, mangrove ecosystems has subjected to most threats, so, average destruction rate for mangroves is 1.52 percent per year (Valiela et al 2001; Alongi 2002) and continuing this trend could cause anticipation of no-mangroves world (Duke et al 2007). Studies showed that relative welfare of coastal communities is effective more than population amount in destruction of mangrove ecosystems (Valiela et al 2001). Local communities permanently use mangroves as wood source for cooking, house-making, board making and so on (Primavera 1997; Vedeld et al 2004). In Iran, great dependency of coastal communities to mangroves for providing fuel and grasses for livestocks, caused incompensatable damages into mangroves integrity and caused to placing this factor in fifth rank in final ranking results.

Considering to unfavorable temporal and spatial changes resulting from erosion and accretion process in all coastal areas of the world, controlling this process in coastal area and studying their reasons (such as sea level rise, storm and anthropogenic interventions) became the most important issues in coastal area management (Ellison 2006; Van Santen et al 2007). Recognizing consequences of erosion and accretion process on mangrove forests have considerable importance (Hauff et al 2006). Unfavorable consequences of these proceses were observed as individual or wide mortality of mangrove trees and eventually their migration to upstream lands (Naidoo 1983; Ellison 1993, 2000, 2006). Mangrove forests of Iran are not excluded from these destructive consequences. Studies in coast areas of Iran showed high erosion and accretion rate and awareness of country experts from this issues cause to placing this factor in 6th rank in final prioritizing.

It is important to say that lower importance coefficient of some stresses and disturbances don't represent no effect of them on mangrove ecosystems, so occurring some of these factores such as storm and air temperature which placed in latest priorities, could have destructive effect on structure and functions of these ecosystems, while based on experts opinion they are not priority in country management operations.

Conclusions. Finally it can be said that even though in different studies, existing of different opinions of experts and decision makers caused different classification and prioritizing for natural and anthropogenic stresses and disturbances, but results of this prioritizing, acting as supporting decision-making tool, play an important role in efficiency and success of natural resources restoration and management programs. Undoubtedly, taking effective management solutions in the context of environmental stresses and disturbances and strategic planning for protected areas including mangroves and other dependent ecosystems caused enhancement in adaptability and resiliency of these ecosystems to different environmental stresses. Also, accurate predictions about changes occurred in area and health of mangrove forests, in response to stresses and

disturbances, have an important role in capability of habitats and mitigating or compensate of damages.

Acknowledgements. We acknowledge the Iranian National Institute for Oceanography and Atmospheric Science' experts, who helped us in pairwise comparisons process.

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Received: 04 March 2015. Accepted: 22 May 2015. Published online: 31 May 2015.
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How to cite this article:
Mafi-Gholami D., Feghhi J., Danehkar A., Yarali N., 2015 Prioritizing stresses and disturbances affecting mangrove forests using Fuzzy Analytic Hierarchy Process (FAHP). Case study: mangrove forests of Hormozgan Province, Iran. AES Bioflux 7(3):442-459.