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Selecting Sustainable Development Criteria for Effective Watershed Governance: Study Area of Kashafrud Watershed

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ABSTRACT: In recent years, inappropriate governance within the watersheds have caused to qualitative and quantitative degradation of water resources and unbalanced allocation of resources amongst the beneficiaries. Therefore, one of the most important challenges for stakeholders is the selection of final sustainable development criteria, which affects the planning and management for water supply scenarios and leads to effective watershed governance. Selection of final criteria depends on the stakeholders' preferences and the decision-making risk attitudes. The risk attitudes related to the importance of viewpoints associated with stakeholders' number within the watershed. This paper has developed a comprehensive approach based on the risk analysis to calculate the group weights and the group consensus measurements of criteria, which leads to selecting final decision-making criteria. Accordingly, in the first step, the initial criteria are determined by the group of DMs. In the second step, the group criteria weights have been calculated and in the third step, the group consensus measurements of criteria have been measured in several risk attitudes using the Hybrid Weighted Averaging (HWA) operator and the distance-based group consensus method. Finally, the most important criteria have been selected from the initial criteria based on the group consensus measurements, compared with an acceptable threshold level. This approach has been developed for the Kashafrud watershed, to select the final sustainable criteria in 2040. The results showed that the number of the final criteria depends on the risk attitudes of decision-making. Development of this method is recommended for watershed governance in the world.

KEYWORDS: Sustainable Development Criteria, Effective Watershed Governance, Group Consensus, Risk Analysis, Hybrid Weighted Averaging Operator

1. Introduction

In recent decades, sustainable supply of water resources for several demands have changed into one of the most important problems among stakeholders and beneficiaries within the watersheds (GWP 2004, 7-23). To solve this problem and achieve an effective watershed governance, several water supply scenarios should satisfy the sustainable development criteria. Indeed, the water resources scenarios should be evaluated with respect to the sustainable development criteria for selecting the most desirable scenario (Yue 2011, 1926-1936). Therefore, one of the most important challenges for stakeholders and beneficiaries, named decision-makers (DMs), is the selection of final sustainable development criteria. The selection of final criteria affects the planning and management for water supply scenarios.

Over recent years, the complexities of the sustainable development criteria associated with the socio-economic, environmental, and water resources objectives, have been increased within the watersheds (Javidi Sabbaghian et al. 2016, 260-272). Therefore, by using the group decision-making (GDM) process, all DMs can collaborate on each phase of the process to achieve a group consensus for selecting the best solution for water supply (Nejadhashemi et al. 2009, 1-8). One of the most important phases of the GDM process is the selection of final sustainable development criteria from the initial criteria. The selection of final sustainable criteria depends on the DMs' preferences and the group decision-making risk attitudes.

In the risk-based GDM problems, DMs have different viewpoints, preferences and levels of influence. In addition, the group of DMs may have several risk attitudes, which affect the final results of the decision-making for the watershed (Mianabadi et al. 2014, 1359-1372). The decision-making risk attitudes for selecting final criteria, are expressed by some linguistic statements such as "selecting the final criteria based on considering all DMs' preferences" in the completely risk-averse viewpoint, "selecting the final criteria based on considering at least one of DMs' preferences" in the completely risk-prone standpoint, and the other linguistic statements and the corresponding risk attitudes. Therefore, it is essential to use a consensus-based GDM methodology, which considers the risk assessment and its effects on the selection of the final criteria for the watershed implementation plan.

In general, some of the GDM methodologies have been developed for selecting the final sustainable development criteria. The differences between these methods are associated with their strategies for the selecting phase. (Aravossis et al. 2003, 1433-1443), proposed a trial approach for selecting the final criteria based on the Analytic Hierarchy Process (AHP) methodology. (Yu and Lai 2011, 307-315) used a method for selecting a subset of several criteria, which includes all sets of criteria.

In the watershed management context, some of the GDM methods have been applied for selecting the final sustainable criteria for effective watershed management. (Ardakanian and Zarghami 2004), provided a hierarchy tree of sustainable criteria for Iran water supply projects based on the sustainable development criteria from the other watersheds in the 15 countries. (Karamouz et al. 2008), evaluated the sustainable criteria for water supply development scenarios by using value management approach. (Javidi Sabbaghian et al. 2015; Javidi Sabbaghian et al. 2016), selected the final sustainable criteria for Mashhad watershed, by using the group consensus measurements among DMs.

Many of these studies have not considered the risk attitudes of the selecting phase. The last two papers have considered the risk analysis in selecting final criteria, while ignored the DMs' power weights in the criteria weighting and consensus measuring steps.

In this paper, a comprehensive approach is applied for selecting the final sustainable development criteria for effective watershed governance, in which the main sustainable objectives are considered limitations of the existing methods are resolved. Correspondingly, in the first step of the selecting phase, the initial criteria are determined by the group of DMs. In the second step, the group weights of the initial criteria are calculated in several risk attitudes using the Hybrid Weighted Averaging (HWA) operator (Xu and Da 2003, 953-969). Finally, in the third step of the selecting phase, the group consensus measurements of criteria are measured in several risk cases using the distance-based group consensus method (Zarghami and Szidarovszky 2010, 2239-2248) in this triple-stepped method, the criteria importance, DMs' power weights and the risk attitudes are considered in the selecting phase, simultaneously. Finally, the most important criteria are selected from the initial criteria based on the group consensus measurements, compared with an acceptable threshold level. The proposed selecting methodology has been developed for the Kashafrud watershed in Iran, to select the final sustainable development criteria in 2040.

This paper is organized as follows: Section 2 introduces the risk-based GDM method and the corresponding diagram. In Section 3 the proposed methodology in the is illustrated. In Section 4 the proposed method is applied for the watershed governance, and the results are obtained, and the final sustainable development criteria are determined in the several risk cases. Finally, Section 5 describes the conclusions.

2. Risk-based criteria selection process

In the criteria selection process, the proposed risk-based GDM algorithm features the three important steps, including: recognition, group weighting, and group consensus measuring. The steps of this algorithm are presented in the proposed diagram in Fig. 1:

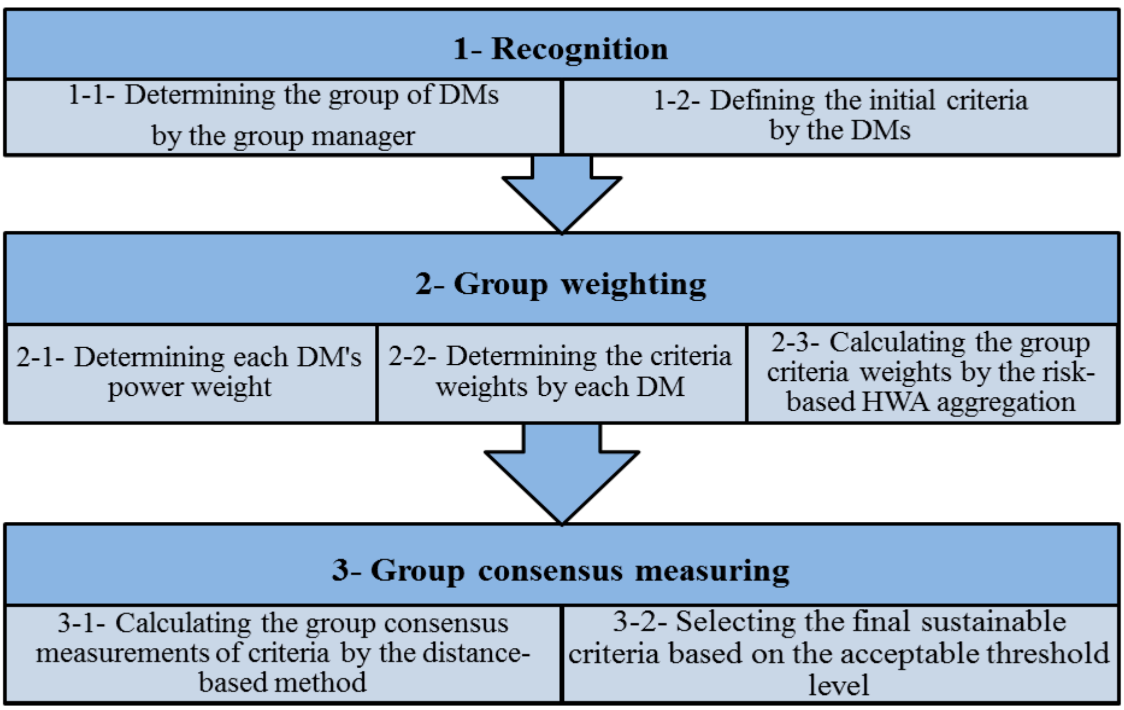

Fig. 1 The proposed diagram for the risk-based criteria selection process

3. Methodology

3.1. Recognition step

In Step 1, the group of DMs are determined by the group manager, and the initial criteria are defined by the group of DMs based on the sustainable development objectives, including social, economic, environmental, and water resources sustainability within the watershed. In this step, n represents the number of initial criteria $C=\{C_1,\ldots,C_i,\ldots,C_n\}$; and p represents the watershed DMs $DM=\{DM_1,\ldots,DM_k,\ldots,DM_p\}$. $\lambda=(\lambda_1,\ldots,\lambda_p)^T$ is the DMs' power weights vector, where $\lambda_k \geq 0$, $\sum \lambda_k=1$; and $w^{(k)}=(w_1^{(k)},\ldots,w_n^{(k)})^T$ is the criteria weights vector in k^{th} DM's viewpoint, where $w_i^{(k)} \geq 0$, $\sum w_i^{(k)}=1$.

3.2. Group weighting step

In Step 2, the weights of the initial predefined criteria are determined. In decision-making problems, there are several methods for determining criteria weights (Pomerol and Romero 2000, 75-104; Aras et al. 2004, 1383-1392; Chatzimouratidis and Pilavachi 2009, 778-787). In this study, each DM determines the degree of criteria importance by one of the linguistic members from the set of S={None, Very low, Low, Slightly low, Medium, Slightly high, High, Very high, Perfect} (Herrera et al. 1996, 175-190). Also, the DMs' power weights are assigned by the group manager in order to consider their influence in the decision-making, using the linguistic members form the set of S.

The linguistic criteria weights and the linguistic DMs' power weights are fuzzified by using the trapezoidal-triangular fuzzy number, which is one of the most commonly used fuzzy membership functions (Ross 2009, 89-111).

After fuzzification, the weights are defuzzified by using the method of centroid, which is one of the most reliable defuzzification methods, (Zekai 2010, 50-75). The linguistic variables, the related fuzzy numbers, and the corresponding defuzzified values are presented in Table 1:

Table 1. The linguistic variables and the defuzzified values

Linguistic Variable	Fuzzy number (interval value)	Defuzzified value
None (N)	(0.00, 0.00, 0.00, 0.01)	0.001
Very low (VL)	(0.00, 0.00, 0.00, 0.20)	0.063
Low (L)	(0.00, 0.10, 0.00, 0.20)	0.106
Slightly low (SL)	(0.20, 0.20, 0.20, 0.20)	0.200
Medium (M)	(0.50, 0.50, 0.20, 0.20)	0.500
Slightly high (SH)	(0.80, 0.80, 0.20, 0.20)	0.800
High (H)	(0.90, 1.00, 0.20, 0.00)	0.894
Very high (VH)	(1.00, 1.00, 0.20, 0.00)	0.937
Perfect (P)	(1.00, 1.00, 0.01, 0.00)	1.000

Therefore, the fuzzified weights of the initial criteria in each DM's viewpoint are determined ($w_i^{(k)}$, $i=1,\ldots,n$; $k=1,\ldots,p$), which $w_i^{(k)}$ is the i^{th} criterion weight in k^{th} DM's viewpoint. In addition, the fuzzified power weights of DMs are determined (λ, $k=1,\ldots,p$), that λ_k is the power weight of the k^{th} DM.

In the risk-based GDM process, the group of DMs usually has several risk attitudes. In this paper, the risk attitudes for the proposed risk-based criteria selection process are expressed by some linguistic statements such as "selecting the final criteria based on considering all DMs' preferences" in the completely risk-averse viewpoint, "selecting the final criteria based on considering at least one of DMs' preferences" in the completely risk-prone standpoint. In addition, the other risk attitudes including "most of, many of, half of, some of, and few of" are applied between these two limits of risk attitudes. Therefore, the risk-taking degree of θ was introduced to describe the various risk attitudes (Liu and Han 2008, 77-97). The several risk attitudes, equivalent linguistic statements, and the corresponding values of the risk-taking degree are presented in Table 2 (Zarghami and Szidarovszky 2011, 10-30):

Table 2. Risk attitudes and corresponding risk-taking degrees

Risk attitude	Equivalent linguistic statement	Risk-taking degree ($\boldsymbol{\theta}$)
Completely risk-averse	Considering all DMs' preferences	0.001
Risk-averse	Considering most of DMs' preferences	0.091
Fairly risk-averse	Considering many of DMs' preferences	0.333
Risk neutral	Considering half of DMs' preferences	0.500
Fairly risk-prone	Considering some of DMs' preferences	0.667
Risk-prone	Considering few of DMs' preferences	0.909
Completely risk-prone	Considering at least one of DMs' preferences	0.999

Regarding Step 2, the initial criteria weights should be aggregated for calculating the group criteria weights based on the risk analysis. The risk attitude of decision-making, is determined by the group manager and the group of DMs.

In the risk assessment literature, for each risk attitude, a corresponding order weights vector of $v=(v_1,\ldots,v_p)^T$ is determined, where $v_k\geq 0$, $\sum v_k=1$. The order weights are frequently calculated for several cases of risk attitudes and the corresponding risk-taking degrees of θ by using (Zadeh 1983, 149-184; Yager 1996, 49-73):

$$v_k = (k/p)^{(1/\theta)-1} - (k-1/p)^{(1/\theta)-1} , k=1,\ldots,p \quad (1)$$

The order weights are applied in aggregation process to calculate the group criteria weights in several risk attitudes. Accordingly, by using a p-dimensional mapping function of F: $I^p \rightarrow J$, the DMs' viewpoints about each criteria weight are aggregated to calculate the corresponding group criteria weight. In this mapping function, I denote the set of DMs' opinions related to each criteria weight, and J represents the corresponding group weight.

Therefore, based on the risk-based HWA operator, the DMs' viewpoints about each criteria weight are aggregated to calculate the group weight of that corresponding criteria in several risk cases by using (2) (Xu and Da 2003, 953-969):

$$w_i^{(G)}=\Sigma_{k=1} v_k.b_k=\Sigma_{k=1}\{(k/p)^{(1/\theta)-1}-(k-1/p)^{(1/\theta)-1}\}.b_k\ , i=1,\ldots,n\,; k=1,\ldots,p \qquad (2)$$

where $v=(v_1,\ldots,v_p)^T$ is the order weights vector related to the p DMs, where $v_k \geq 0$, $\Sigma\ v_k=1$. b_k is the k^{th} largest value of the vector of $(p\lambda_1 w_i^{(1)},\ldots,\ p\lambda_p w_i^{(p)})$ associated with the criteria weights matrix; and p is the balancing coefficient. Finally, $w_i^{(G)}$ is the group weight of the i^{th} criterion. In (2), the group weights of the initial criteria can be calculated for several types of risk attitudes.

3.3. Group Consensus measuring step

The consensus measuring is one of the most important steps in GDM process, in which the level of agreement among the group of DMs is determined for each decision-making variable, including each scenario or criterion. Therefore, in the risk-based criteria selection process regarding as Step 3, the consensus measurement for each criterion should be measured in order to calculate its consensus measurement.

Recently, several methods have proposed for determining the consensus measurement (Fairhurst and Rahman 2000, 39-46; Chiclana et al. 2013, 110-123; Wang et al. 2014, 28-30; Bouzarour-Amokrane et al. 2015, 1759-1772). Some of these methods calculate the consensus measurement based on the distances between the DMs' individual viewpoints and the group overall opinion. In this paper, the distance-based method is applied for calculating the difference between each DM's viewpoint related to each criterion weight and the group weight for that corresponding criterion.

In the distance-based method, the power parameter of p is applied to express how strongly each difference is emphasized. The case p=1 describes the simple average; the case p=2 implies a simple squared weighting, while in the case p=*infinity*, the largest deviation among DMs is considered (Bender and Simonovic 2000, 35-44).

In this study, a weighted distance-based method is applied to determine the consensus measurement for each criterion based on the risk analysis by using the power parameter of $p=2$. In this method, for several risk attitudes, DMs' individual viewpoints associated with each criterion weight ($w_i^{(k)}$, $i=1,\ldots,n$; $k=1,\ldots,p$), is compared with the group weight for that corresponding criterion ($w_i^{(G)}$, $i=1,\ldots,n$). Therefore, the consensus measurement for each criterion is calculated based on the weighted mean deviation by using under several risk cases (3):

$$Cons.^{(G)}(w_i)=1-\{\sum_{k=1}\lambda_k.|\, w_i^{(G)}- w_i^{(k)}\,|^2\}^{(1/2)}\ ,\ i=1,\ldots,n\ ;\ k=1,\ldots,p \tag{3}$$

where λ_k , $k=1,\ldots,p$ is the k^{th} DM's power weight; $w_i^{(k)}$ and $w_i^{(G)}$ are the k^{th} DM's viewpoint and group standpoint related to the i^{th} criterion weight, respectively, and $Cons.^{(G)}(w_i)$ is the group consensus measurement for the i^{th} criterion.
According to (3), we consider that the smaller distances between DMs' individual viewpoints and the group overall opinion associated with each criterion, leads to stronger agreement and consequently greater group consensus measurement for that criterion.

Finally, the group consensus measurements of the initial criteria are obtained under several risk attitudes. The initial criteria, which the corresponding consensus measurements are greater than the Acceptable Threshold Level (ATL) and satisfy the condition of $Cons.^{(G)}(w_i)\geq ATL$, are selected in the final set of sustainable development criteria within the watershed. This selection process can be implemented depending on the risk attitude of decision-making.

4. Application and results

4.1. Study area

This study has been performed based on the proposed methodology for effective governance of Kashafrud watershed, which is located in northeastern Iran in the longitude of 58° 20′ up to 60° 08′ and latitude of 35° 40′ up to 36° 03′ (Fig. 2) (Tooss Ab Co. 2007)*[29]*. The Kashafrud watershed is one of the largest and most densely populated watersheds in the country.

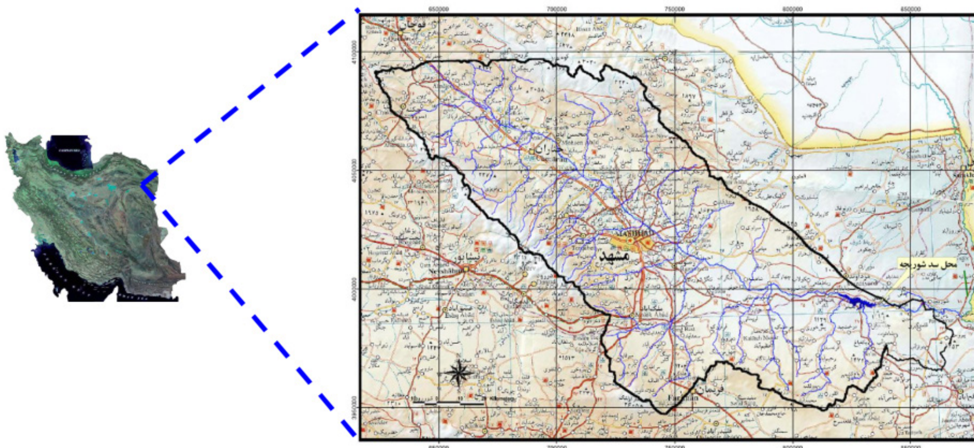

Fig. 2 Location of Kashafrud Watershed in Iran

This watershed has a total area of 16500 Km^2 with the mean annual precipitation of less than 250 mm (Tooss Ab Co. 2013). This watershed has been selected for this study, due to one of its most important challenges is the evaluation of water supply scenarios with respect to the sustainable development criteria in 2040. Therefore, choosing the most preferable criteria by using the consensus among the several beneficiaries and stakeholders is so important for effective planning and governance within the watershed. Selection of the most preferable criteria depends on the DMs' preferences and risk attitudes.

4.2. Recognition step in the study area

In Step 1 of the proposed risk-based process, the group manager and also group of DMs have been determined. The state regional water company is the group manager within the watershed. The stakeholders, that have the important role in the group decision-making within the watershed, are included:

The state agricultural organization; The state water and wastewater company; The urban water and wastewater company; The rural water and wastewater company; The state industrial township company; The state environmental protection agency; and the representative of the people.

In addition, based on the value engineering management, and also considering the social sustainability, economic sustainability, environmental sustainability, and water resources sustainability objectives within the watershed, the DMs firstly have selected the following 26 initial criteria, represented in Table 3:

Table 3. The initial sustainable criteria for Kashafrud watershed

Objective	Criterion	Criterion No.
Water resources sustainability	Water stress	C_1
	Groundwater dependency	C_2
	Irrigation efficiency	C_3
	Adjustable protentional of Surface Water Resources	C_4
	Development of groundwater	C_5
	Supply percentage for agricultural water demand	C_6
	Supply percentage for drinking water demand	C_7
	Supply percentage for Industrial water demand	C_8
	Supply percentage for Environmental water demand	C_9
	Renewable water resources per capita	C_{10}
	Drinking consumption per capita	C_{11}
	Industrial consumption per capita	C_{12}
	Reliability for water supply	C_{13}
	Balancing between use of surface water & groundwater resources	C_{14}
	Groundwater unsustainability	C_{15}
	Surface water dependency on other watersheds	C_{16}
Environmental sustainability	Refined sewerage ratio	C_{17}
	Environmental supply	C_{18}
Economic sustainability	Unmeasured water in Drinking Water Sector	C_{19}
	Agricultural water productivity	C_{20}
	Benefit per cost ratio	C_{21}
	Variety of financial resources	C_{22}
Social sustainability	Public participation in water supply	C_{23}
	Conflict resolution among stakeholders	C_{24}
	Creating job opportunities	C_{25}
	Social equity	C_{26}

4.3. Group weighting step on the study area

In Step 2, firstly the DMs' power weights have been assigned by the group manager, using the linguistic variables. Also, the importance degrees of the 26 initial predefined criteria are determined by the 8 DMs within the Kashafrud watershed. Table 4, represents the linguistic power weights of DMs and the initial criteria degree of importance:

Table 4. Importance degrees of criteria and DMs' power weights

		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}
DM_1	P	P	VH	VH	SL	VH	H	H	H	H	H	SH	SH	VH
DM_2	H	P	P	P	M	VL	P	SL	SL	H	SH	L	M	P
DM_3	M	P	P	P	M	VH	H	SH	SH	SH	SH	H	M	SH
DM_4	VH	P	SH	P	SL	H	P	SH	VH	SH	VH	VH	H	P
DM_5	SL	P	P	H	L	P	P	L	L	VL	H	SH	SL	VH
DM_6	M	VH	VH	VH	M	N	VH	SL	VL	SL	VH	L	VH	VH
DM_7	SL	P	SH	H	H	H	H	SH	H	SH	H	VH	H	VH
DM_8	SH	P	P	H	L	M	VH	SH	H	SH	VH	H	H	SH
		C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
DM_1	P	VH	P	SH	H	H	H	VH	H	VH	H	SH	SH	VH
DM_2	H	P	P	M	P	H	L	P	P	VH	VH	H	VH	P
DM_3	M	VH	H	SH	SH	SH	P	P	H	VH	VH	VH	SH	VH
DM_4	VH	P	VH	H	VH	H	H	P	VH	VH	VH	VH	H	VH
DM_5	SL	H	P	L	L	L	M	M	H	H	VH	H	SH	VH
DM_6	M	SL	VH	M	VH	VH	L	VH	VH	SH	VH	M	M	VH
DM_7	SL	H	P	SH	H	H	SH	H	M	SH	H	SH	M	M
DM_8	SH	H	P	M	H	SH	VL	VH	H	SH	SH	H	M	H

After that the linguistic variables have been fuzzified and defuzzified, and the initial criteria weights and the DMs' power weights have been determined. In the risk-based aggregation process, the group criteria weights have been calculated by using the HWA operator in several risk attitudes. The group criteria weights have been presented in Fig. 3 for several risk attitudes:

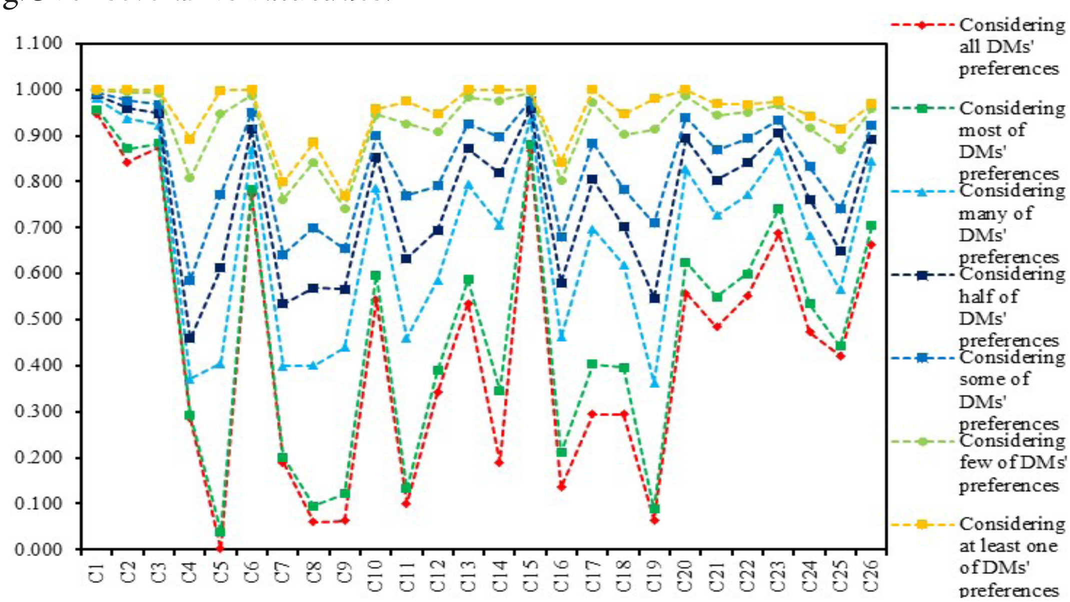

Fig. 3 Group criteria weights in several cases of risk attitudes

According to the results of Fig. 3, the group criteria weights have been increased from the completely risk-averse viewpoint "considering all DMs' preferences", into the completely risk-prone standpoint "considering at least one of DMs' preferences". It is due to the fact that in the in the completely risk-averse (completely pessimistic) viewpoint DMs tend to emphasize on negative properties of decision-making, while in the completely risk-prone (completely optimistic) standpoint DMs tend to focus on positive properties of decision-making. Furthermore, considering all DMs' preferences within the watershed is the most difficult decision-making case, which caused to the smaller group weights for criteria. While considering at least one DM's preferences within the watershed is the easiest decision-making case, which caused to the greater group weights for criteria.

4.4. Group consensus measuring step in the study area

In Step 3, the group consensus measurements of criteria have been calculated in several risk attitudes by using the distance-based method. The results have been presented for the four cases of risk-averse viewpoints in Fig. 4:

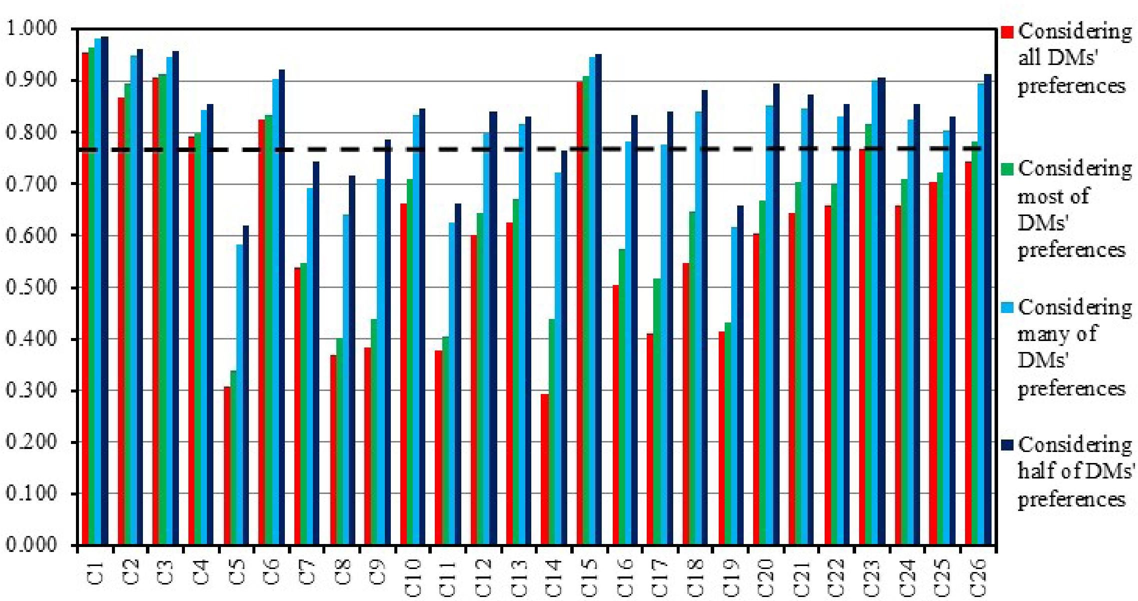

Fig. 4 Group consensus measurements of criteria in several risk cases

As represented in the results of Fig. 4, from the completely risk-averse viewpoint "considering all DMs' preferences", into the neural risk standpoint "considering half of DMs' preferences", the group consensus measurement of each criteria has been increased. It means that in the completely risk-averse viewpoint, in order to consider all DMs' preferences, achieving an agreement is more difficult and consequently the consensus measurements for scenarios are smaller.

To determine the final sustainable development criteria, the group manager has selected a TLA index by the linguistic variable of "High" (equivalent to 0.767), which represented by a dashed line in Fig. 4. Concerning the group consensus measurement values of the criteria presented in Fig. 4, the criteria which have the values above the dashed line are selected as the final criteria. The final selected sustainable development criteria within the Kashafrud watershed have been determined for the four risk cases in Table 5:

Table 5. Final selected criteria in several risk cases

Case 1: Considering all DMs' preferences
The final criteria C_1, C_2, C_3, C_4, C_6 and C_{15} have been selected (6 criteria).
Case 2: Considering most of DMs' preferences
The final criteria C_1, C_2, C_3, C_4, C_6, C_{15}, C_{23} and C_{26} have been selected (8 criteria).
Case 3: Considering many of DMs' preferences
The final criteria **C_1, C_2, C_3, C_4, C_6, C_{10}, C_{12}, C_{13}, C_{15}, C_{16}, C_{17}, C_{18}, C_{20}, C_{21}, C_{22}, C_{23}, C_{24}, C_{25} and C_{26} have been selected** (19 criteria).
Case 4: Considering half of DMs' preferences
The final criteria C_1, C_2, C_3, C_4, C_6, C_9, C_{10}, C_{12}, C_{13}, C_{15}, C_{16}, C_{17}, C_{18}, C_{20}, C_{21}, C_{22}, C_{23}, C_{24}, C_{25} and C_{26} have been selected (20 criteria).

In this study, the group of DMs have proposed the risk case 3, which consider many of DMs' preferences in selecting the final sustainable criteria within the watershed. Finally, the selected sustainable development criteria have been represented in Table 6:

Table 6. The final sustainable development criteria for watershed

Objective	Criterion	Criterion No.
Water resources sustainability	Water stress	C_1
	Groundwater dependency	C_2
	Irrigation efficiency	C_3
	Adjustable protentional of Surface Water Resources	C_4
	Supply percentage for agricultural water demand	C_6
	Renewable water resources per capita	C_{10}
	Industrial consumption per capita	C_{12}
	Reliability for water supply	C_{13}
	Groundwater unsustainability	C_{15}
	Surface water dependency on other watersheds	C_{16}
Environmental sustainability	Refined sewerage ratio	C_{17}
	Environmental supply	C_{18}
Economic sustainability	Agricultural water productivity	C_{20}
	Benefit per cost ratio	C_{21}
	Variety of financial resources	C_{22}
Social sustainability	Public participation in water supply	C_{23}
	Conflict resolution among stakeholders	C_{24}
	Creating job opportunities	C_{25}
	Social equity	C_{26}

5. Conclusion

In real-world group decision-making, there are various stakeholders and beneficiaries with several preferences, viewpoints and risk attitudes to select the most favorable sustainable criteria. This paper demonstrated a mathematical approach to determine the final sustainable criteria, considering socio-economic, environmental and water resources objectives based on a risk-based group decision-making. Therefore, the distance-based HWA methodology has been applied for calculating the group criteria weights and group consensus measurements.

In this paper, we utilized the HWA aggregation operator to calculate the group criteria weights, for which the importance degrees of criteria, the DMs' power weights, and the risk attitudes of the DMs have been considered, simultaneously. Moreover, in the group consensus measuring, the DMs' weights and the decision-making risk attitudes have been considered to determine the consensus measurements for criteria. The final selected sustainable development criteria were determined based on the group consensus measurements comparing with the acceptable threshold level.

The proposed methodology has been developed on the real study area of Kashafrud watershed, in which the final sustainable criteria were selected based on the group consensus among DMs in several risk attitudes.

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