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An Ultimatum Game Theory Based Approach for Basin Scale Water Allocation Conflict Resolution

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Abstract Increasing water consumption via competitive demands has resulted in serious water conflicts and the subsequent environmental crisis in the Gavkhouni Watershed with the Gavkhouni swamp in the most downstream located in the central part of Iran. In this research, a two-player ultimatum game theory approach is adopted to not only address the water conflicts with the purpose of environmental reclamation of the drying swamp, but also to ensure economic satisfaction for the upstream landowners and farmers. The Ministry of Energy (MoE) and its subsidiary regional water authority represent the responsible organizations for providing water while the Ministry of Agriculture (MoA) is the primary body in charge of water consumption in the watershed. MoE and MoA are considered as two players in the game, whereas MoE has more power than MoA in terms of allocating water. Five strategies are studied namely: 1 and 2) decreasing water allocation to irrigated agriculture as much as the annual shortage of the Gavkhouni swamp with and without compensation to MoA (D-L), 3 and 4) decreasing water allocation to irrigated agriculture twice as much the annual shortage of the swamp with and without compensation for MoA (D-2 L) and 5) giving up Gavkhouni swamp's reclamation plan (D). Moreover, three scenarios regarding the relations between environmental and agricultural utilities are designated. According to the results, D-2 L with paying compensation to MoA is chosen as the best alternative in scenario 1 when the environmental utility was assumed to be greater than the agricultural utility. Ultimatum Game Theory has no final solution for scenarios 2 and 3 where the environmental utility is considered to be equal and smaller than agricultural utility. The swamp's annual environmental water shortage as 324 million cubic meters is supplied by application of both strategies D-L and D-2 L. Ultimatum Games are efficient in assessment of water conflicts to resolve them through careful and planned negotiations.

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1 Introduction

Water resources management is involved with various beneficiaries that may have conflicting interests (Veeren & Tol 2003; Wei et al. 2010). Game theory-based models have been used in water resources management to address water conflicts and are recognized as appropriate methods, providing an analytic framework comprising primary elements of conflicts (Wei et al. 2010). Game theory and its mathematical background were proposed and used in economics for the first time by Neumann Von and Morgenstern (1953). Different forms of games have been suggested by many researchers to address water conflicts alongside other conflict resolution methods such as Extensive Game Theory (P'ng 1983), Graph Model for Conflict Resolution (GMCR) (Kilgour 1995), Adjusted Winner (Massoud 2000), and Fuzzy Cognitive Maps (Giordano et al. 2005). Game theory-based methods help researchers to study and analyze strategic behavior and actions taken by different stakeholders and aid decision and policy makers to choose the best alternative to solve the existing conflicts.

One of the very facts about conflicts and agreements is that the benefit of one party is not necessarily losses to the other (Rogers 1969). All of the game theory methods share the obvious disadvantage of requiring detailed information about costs and benefits (Young et al. 1982). Therefore, making every endeavor to make game theoretical methods simpler is justifiable. Dinar et al. (1992) whom used cooperative game theory to question reasonableness and acceptability of cooperation in the use of irrigation water claimed that the number of publications reporting the difficulties aroused in the process of water conflicts is not enough despite the necessity of critical view toward problems. Parrachino et al. (2006) assessed both strengths and shortcomings of cooperative and uncooperative games, where the former searches coalitions, and the players of the latter see only their own objectives. Therefore, reaching a deadlock is possible in both cases. Maximization of economic benefits and minimization of negative environmental impacts are two decisive goals in water resources management, and game theory is able to assess different alternatives affecting the involved stakeholders (Raquel et al. 2007; Mahjouri and Ardestani 2011; Kucukmehmetoglu 2012). Safari et al. (2014) who compared the leader-follower and bargaining as two types of games in an Iranian watershed claimed that in negotiations the party who plays the role of the leader has more advantages, and it is always recommended to have a leader in negotiations to reduce the chance of stalemate. With reference to cooperation and cooperative games, Mehrparvar et al. (2015) stated that the formation of a grand coalition (complete cooperation by all involved stakeholders) is the best solution for a region with water scarcity like Zayandehroud Watershed in central Iran. Organizational structure of both cooperative and uncooperative games is the key element in negotiation processes (Adams et al. 1996; Li et al. 2015). More recently, Dinar and Hogarth (2015) published a review of cooperative and uncooperative games in water resources and their contributions, progress and remaining challenges.

Comparing the present study with the above publications, the innovation of the this research apart from the simplicity is the interdisciplinary use of game theory in negotiations over water allocations (with special environmental considerations) between main stakeholders. This paper provides new insights into the link between water management and the necessity of effective communication through negotiations. Although game theory needs more developments for the field of water resources management and other related fields, it is still a well-known method to reflect various important behavior of involved parties while other methods, such as multi-criteria decision analyses, are incapable of considering a variety of factors (Madani 2010). This paper demonstrates the utility of the Ultimatum Game Theory, a specific form of the extensive games (Osborne and Rubinstein 1994) and new to water resources management field, to address water conflicts in the Gavkhouni Watershed in the center of Iran. The investigation of an applicable negotiation mechanism using the ultimatum game theory considering stake-holders' strategies and behavior with possible gains and losses are the main objectives of the present research.

2 Gavkhouni Basin Study Area

The Gavkhouni Basin with an area of 42,000 km^2 is located in centre of Iran (Fig. 1). Gavkhouni Swamp, which is the sink of the watershed, is mostly supplied by inflows from the Zayandehroud River, with an approximate length of 400 km, representing the major surface runoff supplier to the swamp (Nikouei et al. 2012). Surface and groundwater resources in Gavkhouni Watershed and the agricultural demands which are spread out in four provinces of the watershed are considered in this paper. It should be noted that the irrigation water

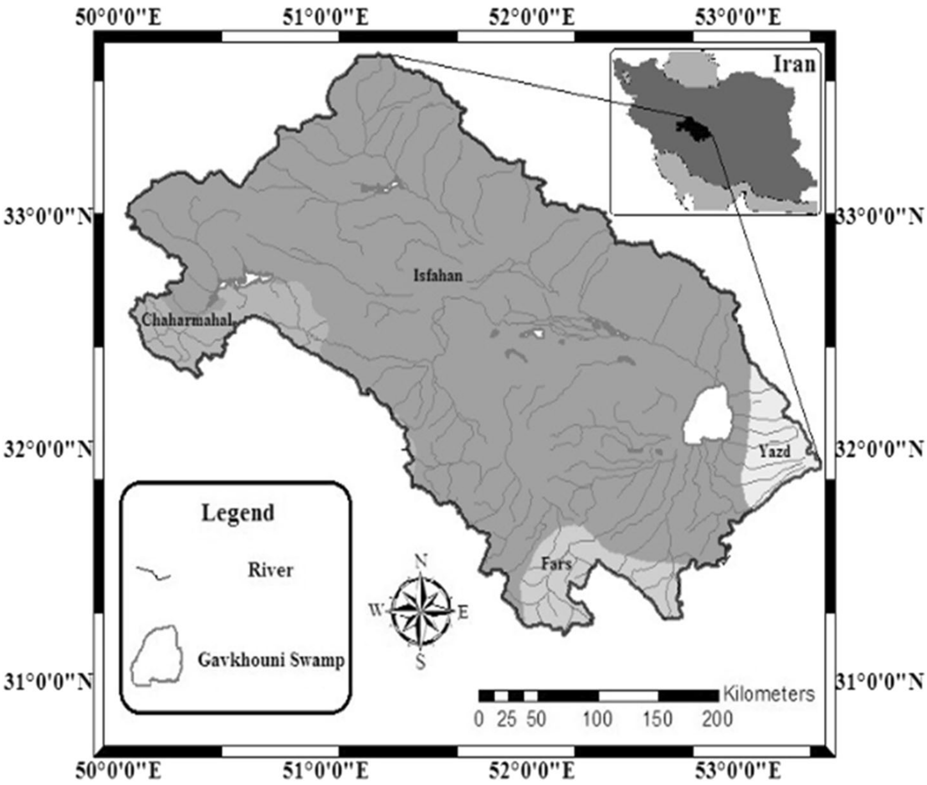


Fig. 1 Location of the Gavkhouni Basin in Iran

demands account for 85% of total water consumptions in the watershed and the main water resources conflicts in the watershed have been reported in this sector (Safavi et al. 2015).

Total agricultural water requirement for irrigation in the Gavkhouni Basin is 5024 MCM that 67% of that (3366 MCM) is supplied by the groundwater and the rest 23% (1156 MCM) is provided by the surface water resources in the watershed. Environmental water requirement for the Gavkhouni swamp based on previous studies is assumed to be 350 MCM annually (Iran's Ministry of Energy 2013). Groundwater resources have a critical role in the whole system of water cycle of the watershed. On the other hand, for reaching water to the swamp, applying allocation reduction strategies and consequent analysis of the swamp in downstream we needed to consider the surface water resources of the watershed. But in simulation, all water consumption supplied by both surface and groundwater resources have been considered.

The main strives over water resources in Gavkhouni Basin are between agricultural water consumptions and the worsening downstream environmental situation where the crisis-hit Gavkhouni Swamp is located. Agricultural, industrial, municipal and environmental demands have all been considered in simulation model though the study revolves around the encounter between irrigational agriculture and environmental issues of the study area. The swamp has been fed with much less water than its environmental requirement during the past decade. Agricultural production for the purpose of self-sufficiency, food security and improving the economic and social welfare in Gavkhouni Basin has been the main goal for the Ministry of Agriculture (MoA) that represents the major water consumer in the watershed. On the other hand, Ministry of Energy (MoE) is the responsible organization in charge of reviving the Gavkhouni swamp. We say MoE to speak generally about a responsible organization for water allocations through regional water authorities in the country which are the ministry's subsidiaries that have this duty. Proposing an applicable conflict resolution for the watershed is pivotal as the water crisis has brought serious emergency situation to the study area. It is also worthy to mention that MoE and MoA are representatives of all involved stakeholders that are absolutely affected by any positive or negative decision made by the main players. Hence, the present study has a perspective of macro management to resolve water conflicts in an Iranian arid watershed with huge environmental and agricultural crises.

3 Ultimatum Game Theory

Similar to the majority of games, ultimatum games are based on rational preferences and choices made by the players (Thaler 1988). In general, there are two types of ultimatum games including single-step and bargaining ultimatum games. They are described below.

4 Single-Step Ultimatum Game Theory

An ultimatum game is a type of extensive game in the form of bargaining that two or more parties are trying to have a just amount of a resource under conflict through effective negotiations. Unlike simultaneous games, players have sequential moves in extensive forms. Such characteristics in ultimatum are suited for modeling water resources conflicts. Each stakeholder announces his/her decision first while others have the chance to think about their strategies/responses, plan and then take actions according to the fluid situation. The first player to make the first move may be determined randomly or by setting some rules. For instance, offering the first move to the more powerful player. The latter approach is adopted in this study. Moreover, in a 2-player ultimatum game, the first player starts the game while the second player ends the game. In a single-step ultimatum game with two players, an amount of the shared/conflicted wealth is proposed by the first player whereas the second player has the right to either accept or reject the proposal. If the second player accepts the proposed share of the wealth, the remaining wealth is left to the first player. On the contrary, if the second player rejects the proposal, both players gain nothing (zero) and, therefore, there will be no compromise and the conflict would remain unresolved (Fig. 2) with no alternative proposal. Hence, in a single-step game, the first proposal by the first player must be put forward thoroughly to make it likely to be accepted by the second player after careful review of the past, current and future situations that were led mostly by the first player who has more power (Kagel et al. 1996).

There are two ways to solve extensive games (Perea 2001) including Nash Equilibrium (NE) and Backward Induction (BI). According to Eq. 1, S^* is a strategy profile (a list of all possible actions in a special situation for each player) and is also an NE when the utility of choosing S^* for player i is greater than or equal to the utility of other choices possible for player i while the other players have selected S^*.

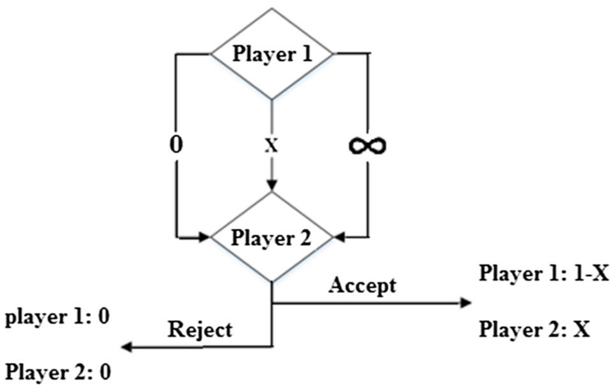
$$S^* = \left(S_1^*, \ldots, S_n^*\right) \Leftrightarrow U_i\left(S^*\right) \geq U_i\left(S_i^{/}, S_{-1}^*\right) \forall S_i^{/} \in S_i \tag{1}$$

Finding equilibrium of the game using BI is a comparison-based process of the outcomes in a backward direction from the smallest sub-game to the main game as the last comparison. In other words, BI is a pairwise comparison of the results in each sub-game. For instance, in Fig. 2, the top outcomes in each pair of results are the benefits for player 1 that according to BI, 1-X is greater than 0 and the bottom outcomes, which are the benefits for player 2, X is greater than 0. Therefore, the right pair answer which is the outcome of the acceptance of the proposal, in this case, is the equilibrium for the game without using NE.

5 Bargaining Ultimatum Game Theory

If the right of negotiating and proposing counter proposal for player 2 in the case of rejecting the first player's proposal is retained, then a single-step game turns into a bargaining ultimatum

Fig. 2 A single-step ultimatum game



game. The difference is that after initial rejection of player 1 proposal, in bargaining game, player 2 proposes his offer (Y in Fig. 3) and the rest of the wealth would be left for player 1. The sequence of the bargaining between two players continues until one of the proposals is accepted by both players. Fig. 3 presents a two-stage bargaining ultimatum game.

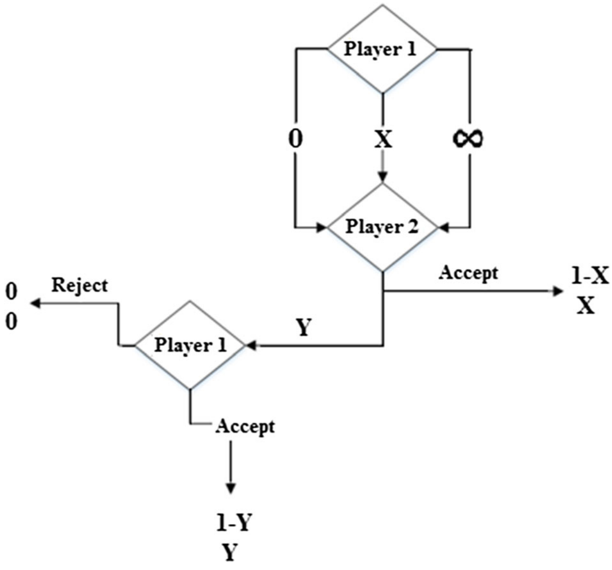
The importance of conflict resolution through active negotiations calls for some efficient mechanisms to persuade involved stakeholders to discuss their interests and try to assert and protect their water rights alongside environmental conservation.

6 Game Players, Utilities and Conflict Resolution Strategies in the Gavkhouni Basin

As explained before, two players consisting of Ministry of Energy (MoE) and Ministry of Agriculture (MoA) are the main beneficiaries in the Gavkhouni Basin, while MoE has more power over water resources allocation schemes in the future. That was the reason for choosing a two player game. Thus, this player should start the game. Indeed, MoE is responsible for reclamation of the Gavkhouni swamp and the rivers of the watershed and MoA is in concerned with the farmers' income and food production in the Gavkhouni Basin. The players' utilities are estimated based on the relations and interactions between the water resources and the benefits that each one gains by allocating more water. MoE may receive a number of advantages through reclamation of the swamp and rivers like advantages involve the development of the tourism industry in the region (Tangapo et al. 2012).

Three main strategies were investigated in a discrete space for each scenario in the ultimatum games for resolving the water allocation issue in the Gavkhouni Basin. The conflict is between the MoE, representing the Gavkhouni swamp in downstream, and the MoA, representing the agricultural demands in upstream. The first strategy is leaving off the swamp and the reclamation plans meaning that all agricultural demands would be supplied as much as possible. The second strategy is to determine a

Fig. 3 A bargaining ultimatum game



water shortage for the swamp and then impose this water deficit to be supplied from the MoA share. In this strategy, no compensation is paid to farmers and landowners, keeping them jointly responsible for swamp's reclamation. The third strategy is similar to the second one except paying compensation to farmers and landowners for reduction of their water uses. The fourth strategy is similar to the second one but with consideration of a greater shortage for the swamp (two times greater than shortage of the second strategy is assumed) to the benefit of the Gavkhouni swamp with paying no compensation to farmers and landowners. The fifth strategy is similar to the fourth one with paying compensation to farmers and landowners. Those strategies that require paying compensation to MoA are interpreted as fair strategies while those without compensation constitute dictatorial strategies.

7 Assessment Scenarios Definition

Estimation of the environmental financial utilities is not as straightforward and available as the calculation of the agricultural financial benefits. Therefore, some simplifying assumptions are required to be made in game theory based analysis. In general, there are three possibilities including environmental utilities greater than agricultural utilities, environmental utilities equal agricultural utilities, and agricultural utilities greater than environmental utilities. Therefore, for the sake of simplicity, financial coefficients of Table 1 were assumed for the agricultural and environmental utilities per cubic meter of water. These coefficient are used in games to distribution the benefits and later analyze the outcomes. Also, 10% of the utility coefficient of agriculture was designated for the unit cost of supplying the required water and energy for cultivation.

In Table 1, U_E is Environmental Utility, U_A is Agricultural Utility, EUC is Environmental Utility Coefficient, AUC is Agricultural Utility Coefficient, and CUC is Cost Unit Coefficient.

8 Simulation Model

Elaborate simulation of the basin and its water resources is necessary for general assessment of the watershed, strategy design for stakeholders, and analysis of the implementation of the game results. MODSIM-DSS (Labadie 2010) was employed to simulate the water resources, demands and allocations in Gavkhouni Watershed. The network Flow Programming (NFP) provides an efficient tool for allocating flows in a watershed in every time step with respect to specified water rights and other priority rankings, including economic valuations (Shourian et al. 2007). MODSIM simulates

Table 1 Simplifying coefficients for game theoretic analysis of the Gavkhouni Basin water conflicts

Scenario	1 ($U_E > U_A$)	2 ($U_E = U_A$)	3 ($U_E > U_A$)
EUC	40	20	20
AUC	20	20	40
CUC	2	2	4

water allocation mechanisms in a watershed through sequential solution of the following network flow optimization problem for each period where $t = 1\ldots\ldots T$:

$$Minimize \sum_{l \in A} c_l q_l \tag{2}$$

Subject to:

$$\sum_{l \in O_i} q_l - \sum_{k \in I_i} q_k = \beta_{it}(q) \text{ for all nodes } i \in N \tag{3}$$

$$l_{lt}(q) \le q_l \le u_{lt}(q) \quad \text{for all links } l \in L \tag{4}$$

where L is the set of all links (arcs) in the network; N the set of all nodes; O_i the set of all links originating at node i (i.e., outflow links); I_i the set of all links terminating at node i (i.e., inflow links); β_{it} is the (positive) gain or (negative) loss at node i at time t; q_ℓ is flow rate in link ℓ; $l_{\ell t}$ and $u_{\ell t}$ are lower and upper bounds, respectively, on flow in link ℓ at time t. If the c_ℓ (cost per unit of water flow in each link) is unknown due to the absence of economic data, it is considered as a weighting factor (Triana et al. 2009) or water right priority manually set by the user. Therefore, consumption nodes with smaller c_ℓ have priority over nodes with greater c_ℓ in the water allocation process.

The simulation was performed using the hydrological data from 1987 to 2007 for 252 months (21 years). Monthly time steps were applied to the study area's surface water resources simulation but the results of both simulation and game theoretical evaluations are in annual scale. The simulation model was validated using Root-Mean-Square Deviation (RMSD) as follows:

$$RMSD = \sqrt{\frac{1}{T} \sum_{i=1}^{T} (x_i - y_i)^2} \tag{5}$$

Where x_i and y_i are observed and simulated flows in each simulation time step i, respectively and T is the number of time steps in the simulation period.

9 Simulation Results

Observed and simulated time series of the swamp inflow via Zayandehroud River is presented in Fig. 4. The RMSD turned out to be 0.13. Use of RMSD in water resources models' validation has been quite rare. But in general and according to some studies an RMSD less that 0.2 is acceptable and shows that the simulated data and observations have a valid and meaningful overlap. For example, the study conducted by Arora et al. 2007 who evaluated the productivity of wheat irrigation and fertilizer-nitrogen regimes in a semi-arid sub-tropical environment using the CERES-Wheat model. As seen in the figure, the time series of inflows to Gavkhouni Swamp is decreasing during the simulation period, while the swamp water shortage has increased in the last decade. This implies a severe situation for the swamp and the need for immediate reclamation actions to prevent further

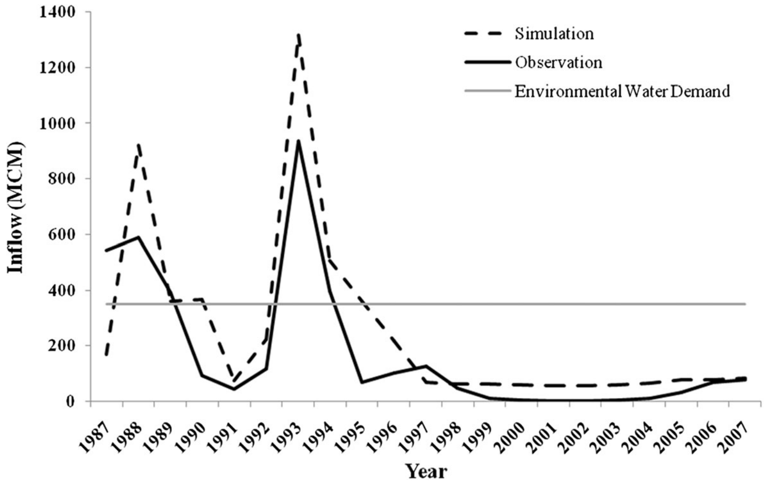


Fig. 4 Observed versus simulated times series of inflow to the Gavkhouni Swamp

environmental degradation. The average annual shortage of the swamp is 175 MCM in the period of simulation, but 324 MCM in the last ten years. Water problems including conflicts are more intense in the dry seasons. Therefore, the necessity of a decent management and planning system is bold during summer and as from June to September. The last 60 months (five years) of the monthly simulation is shown in Fig. 5.

The significant decrease in the flow and also relatively constant flow in the second half of the simulation period of Fig. 4 shows a turning point toward water crisis and droughts due to many reasons such as increased water consumptions (due to increased population and demands), water projects, climate change, and even defects in water resources management system of the watershed. All the mentioned reasons are influential in creation, progress and sequel of conflicts over water resources, and we cannot put all the blame on one single event and neglect other issues which have been involved, e.g. the study by Iglesias et al. 2007 that concluded the influence of many factors in water scarcity in the Mediterranean.

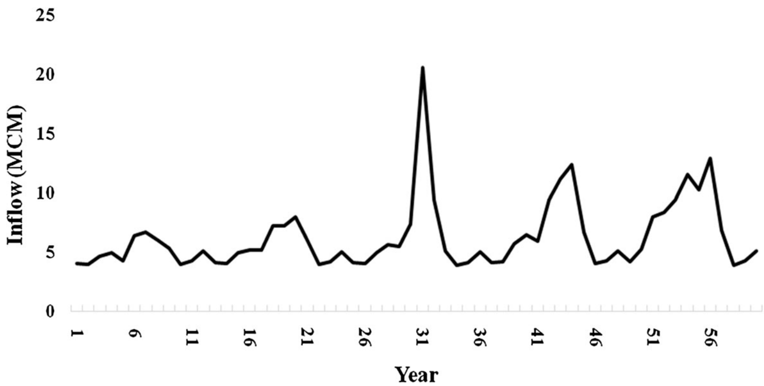


Fig. 5 Monthly inflow to the Gavkhouni Swamp in the last six years of the simulation period

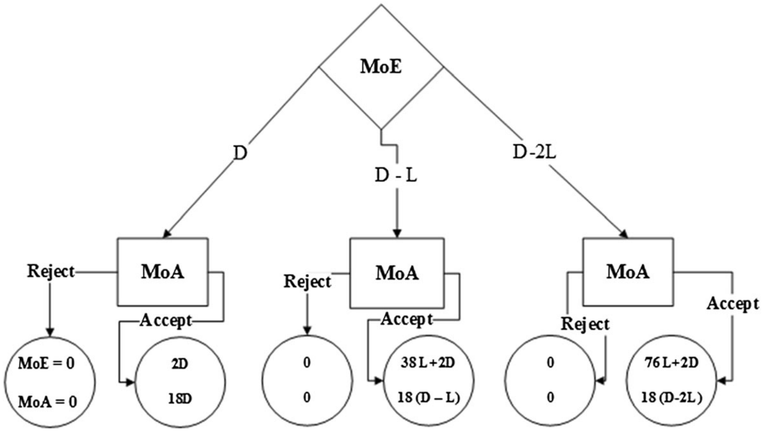


Fig. 6 Single-step ultimatum game with no payment to MoA by MoE in scenario 1 ($U_E = 2U_A$)

10 Water Allocation Conflict Resolution Results

Agricultural water demand, shown by D, is required by MoA in the first strategy. The second strategy is represented by D-L, L being the annual shortage of the swamp that is subtracted from D. In the case of the first financial strategy put forward by MoE based on not paying to agriculture (dictatorship strategy), the structure of the ultimatum game is presented in Fig. 6 where player 1 has three strategies consisting of D, meaning that MoE allocates the whole water demanded by MoA and leaving off the reclamation process. Another possible strategy is D-L, which implies the allocation of D-L to MoA and paying nothing for the reduction of L representing the shortage of the swamp. The last strategy is allocating D-2 L to MoA that is interpreted as a dictatorial strategy as there is no payment made by MoE for the decreased amount of 2 L.

As it was stated in Table 1 the environmental utility is two times greater than the agricultural utility. In Fig. 6, MoE propose D in the left branch, allocating the whole irrigational demand to MoA. In the case of accepting the proposal by MoA, according to the defined coefficients of Table 1, there must be 2D as cost unit given to MoE. There is no environmental consideration in this strategy, so the payoff for MoE is 2D. Also, MoA earns 20D but was ruled to pay 2D as the cost, so its gross payoff is 18D. The central branch is D-L. If MoA accepts the proposal, 20(D-L) is earned, but 2(D-L) was to be the cost. Therefore, the gross payoff of MoA is 18(D-L). MoE earns 40 L at first but this player is 2(D-L) was paid to this player by MoA. So, the final payoff for MoE in this branch is 38 L + 2D. The right branch is calculated like the central one.

Table 2 Nash Equilibrium corresponding to Fig. 6

Player 1 (MoE)	Player 2 (MoA)			
	$N_{D-2L}\,Y_{D-L}\,Y_D$		$Y_{D-2L}\,Y_{D-L}\,Y_D$	
D	2D	18D	2D	18D
D - L	38 L + 2D	18(D-L)	38 L + 2D	18(D-L)
D - 2 L	0	0	76 L + 2D	18(D-2 L) → Incredible

Table 3 Comparison of the utilities for the players by backward induction

Scenario	Without paying compensation to MoA	With paying compensation to MoA	Final between with and without paying compensation to MoA
1	76 L + 2D > 18D > 18(D-L) > 38 L + 2D > 18(D-2 L) > 2D	40 L + 2D > 20 L + 2D & α18D > 18D	40 L + 2D > 38 L + 2D & 18D > 18(D-L)
2	18D > 18(D-L) > 36 L + 2D > 18(D-2 L) > 18 L + 2D > 2D	2D = 2D & α18D > 18D	18 L + 2D > 2D & 18D–L < 18D
3	36D > 36(D-L) > 36(D-2 L) > 32 L + 4D > 16 L + 4D > 4D	4D-20 L > 4D-40 L 36D < α36D	-

Table 2 reports the comparison of the utilities gained by the players. Mathematically, though there are two Nash Equilibriums for the presented game in Fig. 6, one of them is not credible (called Incredible Nash Equilibrium) as there is no logical reason and compatibility with the real situation. The acceptance of D-2 L strategy, with no protest, that requires no compensation paid to MoA for the reduction of water allocation is illogical and far from the reality and logic. So, the only acceptable NE for this game is the D-L strategy proposed by MoE and accepted by MoA.

Y and N are "Yes" and "No" representing acceptance or rejecting by the second player (MoA). It is worthy to mention that only possible strategies for the second player have been mentioned in Table 2. Conventional NE method as in Table 2 may be directly replaced by Table 3 which is backward induction and pairwise comparison of the benefits.

As shown in Fig. 7, through the paying policy (to avoid dictatorship and bringing justice), there will be two strategies left for MoE, while strategy D is omitted because allocating D and paying at the same time makes no logical sense.

According to Table 3, backward induction used for the NE shows that the D-2 L strategy, as selected by MoE and accepted by MoA, represents the best solution for this game. The coefficient α is an indicator that distinguishes two 18D gained by player 2 in the event of the strategy D-2 L and D-L both proposed by player 1 and accepted by player 2. With $\alpha > 1$,

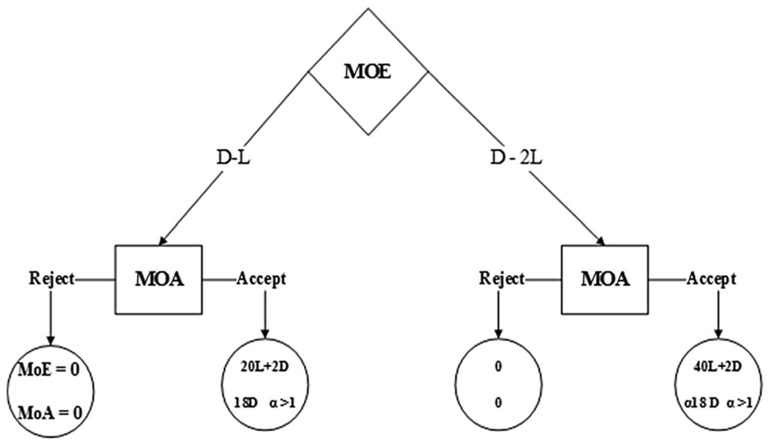


Fig. 7 The single-step ultimatum game with payment to MoA by MoE in Scenario 1

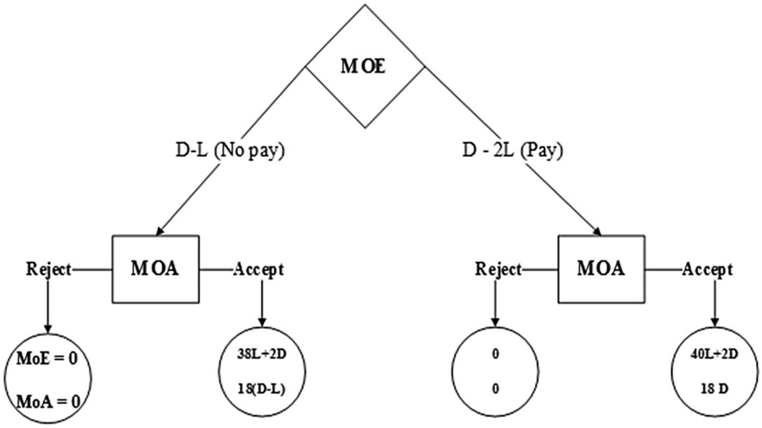


Fig. 8 Final single-step ultimatum game between payment and no payment to MoA by MoE in Scenario 1

there is a natural inclination of player 2 to be more inclined to wait for the D-2 L proposal put forward by player 1. Therefore, farmers gain the same benefit under (D-L), while with the D-2 L strategy, they receive the promised benefits paid by MoE and save their effort and gained cash to invest in other businesses.

Now there are two solutions in each game: one reached by no payment (Fig. 6), and one attained by the financial payment strategy (Fig. 7) to MoA by MoE. However, one single solution is preferable. For final selection between two winner strategies consisting of D-L with no payment and D-2 L with payment, there must be a final game between the two candidates. The final game is illustrated in Fig. 8.

According to Table 3 and also Fig. 8, the final winner between two candidates is the strategy D-2 L that means the best alternative is proposing the purchase of more water rights greater than L from MoA by MoE in Scenarios 1. Therefore, it may be observed that the ultimatum game theory was a fruitful approach to resolving the problem conflict in Scenarios 1. But this approach is not reliable in all situations. For instance, and according to Table 3 conditions in Scenario 2 are the same as in Figs. 6, 7 and, 8 that are all captioned for the scenario 1. In Scenario 2 the winner solution is D-L without paying compensation and D-2 L for paying compensation to MoA by MoE. However, the difference is in the final game (Fig. 9)

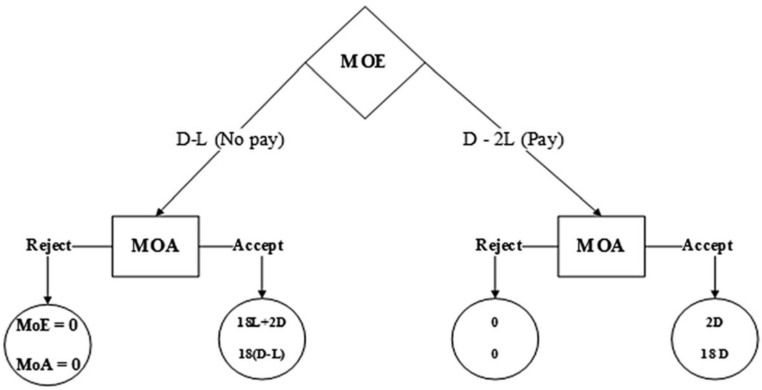


Fig. 9 Final single-step ultimatum game between payment and no payment to MoA by MoE in Scenario 2

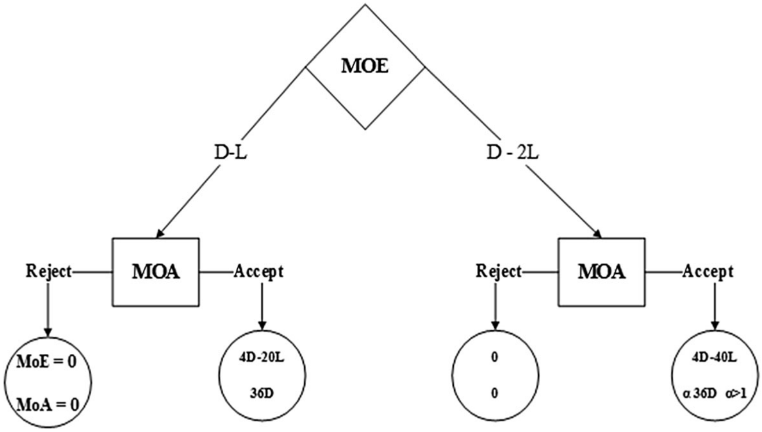


Fig. 10 Final single-step ultimatum game with payment to MoA by MoE in Scenario 3

and, as shown in Table 3, there is no definitive solution for the game as each of players prefers one of the two strategies. MoE prefers D-L without paying to the MoA, whereas the MoA selects D-2 L with payment by MoE. Thus, the ultimatum game has no final solution for scenario 2 although it proposes one of the strategies in each of the conditions. This failure may be interpreted as the major weakness of the ultimatum game theory in comparison with the Multi-criteria Decision Models (MCDMs) that provide a solution in all cases.

In Scenario 3, as Table 3 shows, like other scenarios the winner strategy for not paying decision is proposal of D-L by MoE and acceptance by MoA. But as Fig. 10 indicates there is no solution found by ultimatum game in this scenario for paying compensation to MoA as each of the players prefers different strategies. So the only concluded result in this scenario is that D-L allocation to MoA without any payment.

Accordingly, the results of the ultimatum games for solving the water conflicts in the Gavkhouni Basin between MoE and the MoA are summarized in Table 4.

According to Table 4, the only situation that the ultimatum game theory has a final solution is Scenario 1 where the utility for environment is greater than the agriculture. A centipede game (the name centipede is only for the structure and appearance of the game) is used to illustrate the bargaining form of the ultimatum game explained in the methodology section. According to Fig. 10 and its utility comparisons, the best suggestion for player 2 (MoA) is to avoid bargaining as the only NE of the game is attained at the first step when player 1 (MoE) proposes the exact amount of D-L to player 2. As long as player 1 suggests D-L and not less and with the assumption that player 2 ends the game, the best solution is the D-L proposal made by the MoE and accepted by the MoA.

In Fig. 11, the gray parts are proposals drawn by each player in their turns, and black crosses show the failure of each proposal after backward induction assessment (thin gray

Table 4 Results of the ultimatum game for the Gavkhouni Basin water conflict resolution

Scenario	1	2	3
Solution	Proposal of D-2 L with paying compensation to MoA by MoE	-	-

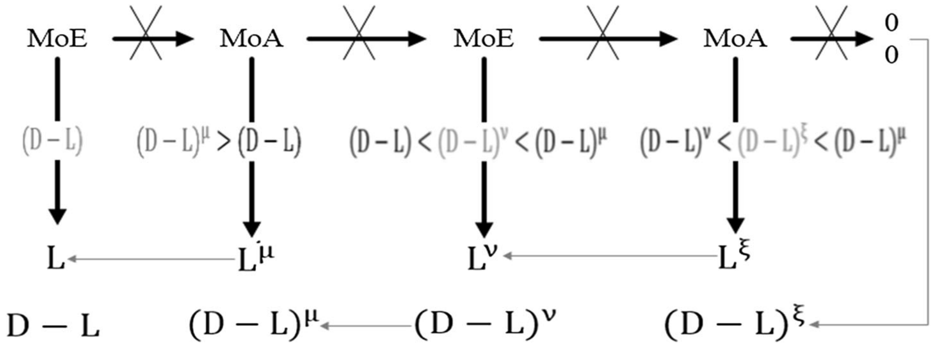


Fig. 11 Bargaining ultimatum game for the Gavkhouni Basin water conflict resolution

lines). Moreover, μ, ν and ξ are randomly selected symbols to distinguish each player's proposals and utilities in each step. Application of D-L and D-2 L scenarios throughout the watershed both overcome the average annual shortage of Gavkhouni swamp, being 175 MCM (and 325 MCM in the ten years of the simulation period) and 148 MCM (Fig. 12).

Successfully-solved Scenario 1 with the D-2 L strategy based on the decrease of 2 L in water allocation to the irrigated agriculture with paying compensation to MoA and the corresponding times series subject to the current situation (without reduction of the irrigated agriculture) and implementation of the winner strategy (reduction of the irrigated agriculture) are illustrated in Figs. 13.

It is worthy to mention that there are other significant factors such as environmental issues, socio-economic aspects, and political factors which influence the selection among various alternatives. Therefore, having economic dimension as the only attribute for the final decision is not sufficient while the winning alternative must be logical and acceptable to all and subject to successful implementation. However, the ability of the game theory-based models in evaluating different factors in a single package is in question due to difficulty in assessing the economic value for all of the benefits (outcomes) as well as the existence of other hidden factors such as technical, social and environmental aspects of different strategies and various behaviors exhibited by involved players.

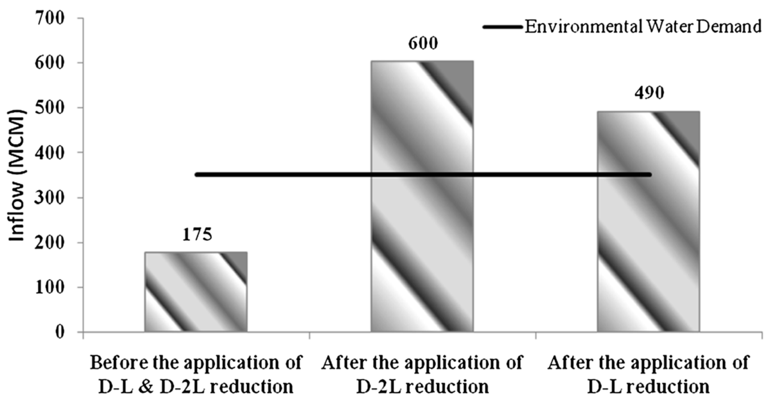


Fig. 12 Inflow to the Gavkhouni Swamp in current situation and with application of the winner strategies

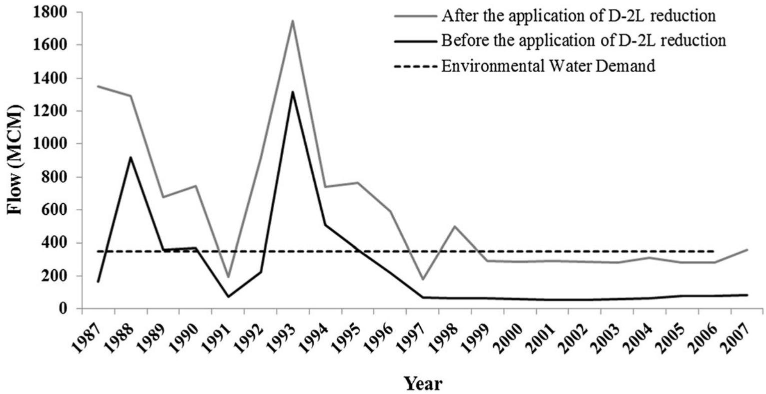


Fig. 13 Inflow to the Gavkhouni Swamp before and after application of the D-2 L strategy

11 Conclusion

In this paper, the efficiency of the ultimatum game theory is assessed to resolve water conflicts between agricultural and environmental water needs in the Gavkhouni Basin, in the center of Iran. Irrigated agriculture and its water needs are to be adjusted in order to mitigate the downstream Gavkhouni Swamp drying condition. The great need of food production in the region and in the whole country in one hand and the worsening environmental and economic impacts due to the drying swamp, on the other hand, are clearly conflicting issues.

Extensive ultimatum game theory with two financial strategies consisting of the purchase of irrigation water versus cutting off water allocation to irrigated agriculture without any payment (dictatorship strategy) is evaluated. Furthermore, three other strategies consisting of two kind of the shrinkage of the farmland for the sake of swamp conservation based on the shortage of the swamp, and giving up on the swamp's reclamation plans are mixed with the two aforementioned financial strategies. Available choices for MoA are acceptance or rejection in response to each strategy demonstrated by MoE. The results of the game for scenario 1 are the shrinkage of irrigated agriculture after applying D-2 L decrease in water allocation to MoA and paying compensation by MoE to MoA. The ultimatum game theory reached no final solution in scenarios 2 and 3 as there is a dilemma in comparison of the players' benefits although there is a solution in each monetary step of the game.

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