Game Theoretic Insights for Sustainable Common Poll Water Resources Governance (Case Study: Lake Urmia Water Conflict)

Amir Safaee [1*], Bahram Malek Mohammadi[2]

1. Ph.D. candidate, Environmental Planning, Faculty of Environment, University of Tehran, Tehran, Iran.
2. Assistant professor, Department of environmental planning and Management, Faculty of Environment, University of Tehran, Tehran, Iran. (malekb@ut.ac.ir)

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Introduction
Common pool water resources (CPWRs) face overuse and congestion due to increased competition for the non-excludability and subtractability nature of their use. In the CPWRs conflicts, beneficiaries base their actions on individual rationality which negatively affect all users eventually due to the lack of trust between them, their self-optimizing tendencies, and inadequate information about the consequences of their actions. Game theory provides a formal mathematical framework to strategic analysis of such conflict and to able presenting some institutions to prevent tragedy of commons. Lake Urmia is the most valuable ecosystem located in the same name basin in Iran. In the recent years, the basin's upstream water resources faced to overuse due to an increase in the attitudes of parties to gain more economic benefits from agriculture activities which led to conflicts as well as threats to Lake Urmia's life. The literatures which studied this environmental crisis are limited with respect to understanding strategic interactions between the actors and how such interactions may affect the results of the Lake Urmia water conflict.

Materials and methods
In order to study the Lake Urmia water conflict, basic information were prepared through a review of the relative literatures, the technical documents, and the news reports. These collected data were completed by referring to experts opinions and finally the conflict was modeled and analyzed based on the GMCR process of resolving conflicts. As a non-cooperative game theoretical model, the Graph model for conflict resolution (GMCR) was developed through a combination of extensive form of conflict analysis and graph theory. Figure 1 outlines the GMCR process of resolving conflicts which involves two main stages including modeling and analyzing. The modeling stage includes defining decision makers and their options, removing infeasible states of the conflict, specifying allowable transitions from each state for each player, and finally defining the relative preferences of each player over each state. In the analyzing stage, stability of the feasible states for each player is first analyzed using the formal mathematical definitions named non-cooperative solution concepts. The second stage is followed by finding the equilibria or likely outcomes of the conflict (states which are stable for all stakeholders under a given solution concept). If a given state is known as equilibrium under a range of solution concepts, then it is a strong equilibrium with a higher likelihood of being the final outcome of the game. After that, some alternative scenarios are defined in order to examine the sensitivity of the results to changing input information. Finally, strategic insights from decision makers' interactions are presented to help them for better decision making.

Discussion of results and conclusions
As can be seen in Table 1, there were five decision makers with seven options in the Lake Urmia water conflict. The number of total states of the conflict was 128 which reduced to 72 after infeasible states were removed. Then, allowable moves from a given state to each other and the player's preferences were defined respectively. Based on the DM's preferences, the Ministry of Agri-Jihad (MAJ) has preferred to continue its new agriculture development projects while it has tended to protect the basin's farmers to improve their cultivation and irrigation styles. Although the Ministry of Energy (MOE) has interested to implement interbasin water transformation projects but it has not liked to stop its new water resources development plans. The Basin's Provinces (BP) have disagreed to stop their new local water and agricultural development plans. Farmers of the basin (F) have liked to continue their illegal overuse from upstream water resources of the basin and the Central Government (CG) has preferred to take no action to force MAJ, MOE, and BP to stop their new development plans. After the conflict

* Corresponding Author: Tel: +98-9127585668 E-mail: a_safaee@ut.ac.ir

was modeled, the stability analysis was applied through non-cooperative solution concepts followed by an alternative preference scenario developed in order to find how changes in decision makers' preferences affect the initial results. According to Table 2, eight outcomes became known as the game equilibria. The results indicated that the state 6, which is current situation of the real world conflict as well as selected as status quo of the analysis, was suggested as the most likely outcome of the game in the initial analysis by GMCR. It means that Lake Urmia crisis mainly rooted in individual rationality based behaviors of beneficiaries which appeared as they persisted on increasing their shares from common poll resources of the basin upstream. Also, it proposed GMCR as an effective and applicable tool for strategic analysis and sustainable common poll water resources governance. Based on the results of sensitivity analysis to move out the status quo, the Central Government should change his initial preferences through strong interference in the conflict and force the parties to stop their upstream new developments. If such situation occurs, the state 68 will be chosen as the final resolution of this conflict.

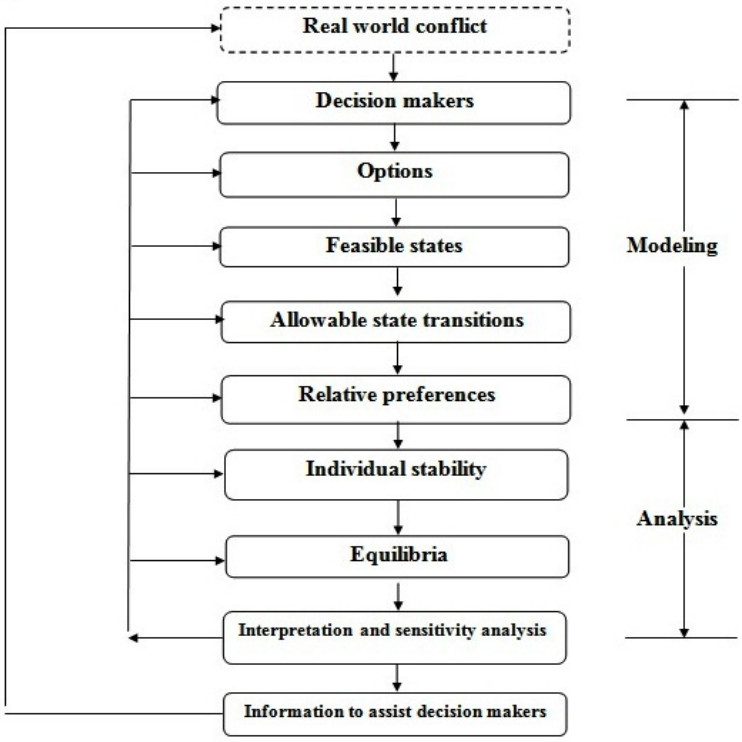

Figure 1. The GMCR process of conflict resolution (Fang et al., 1993)

Table 1. DM's, options and status quo in Lake Urmia water conflict

DM's	Options		Status Quo*
MAJ	1	Protect the farmer of the basin to improve their cultivation and irrigation styles	Y
	2	Stop new agricultural activities and watershed management development plans	N
MOE	3	Release more water from dam reservoirs into the lake, executing interbasin water transfer projects	Y
	4	Stop new water resources development plans	N
F	5	Stop illegal overuse from basin's upstream water resources	N
BP	6	Stop their new local development plans (accept allowed water rights)	N
CG	7	Order MAJ, MOE and BP to stop their new upstream development plans	N

* Note: Y= YES: option is taken by player; N= NO: option is not taken by player

Table 2. Most likely outcomes of Lake Urmia water conflict

DM's	Options	Equilibria							
		Initial analysis				Sensitivity analysis			
		1	2	5	6	68	67	66	65
MAJ	1	N	Y	N	Y	Y	N	Y	N
	2	N	N	N	N	Y	Y	Y	Y
MOE	3	Y	Y	Y	Y	Y	Y	N	N
	4	N	N	N	N	Y	Y	Y	Y
F	5	N	N	N	N	N	N	N	N
BP	6	N	N	N	N	Y	Y	Y	Y
CG	7	N	N	N	N	Y	Y	Y	Y

Keywords: common poll water resources, Lake Urmia, Game theory, graph model for conflict resolution, sustainable governance.