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Development of a dynamics-based model for analyzing strategic water–environmental conflicts: systems thinking instead of linear thinking

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ABSTRACT

A new evolution in graph modeling for conflict resolution (GMCR), a robust methodology for conflict resolution, is presented in this research to incorporate the systems thinking concept into the conventional paradigm of GMCR so that the dynamic nature of water–environmental conflicts can be modeled, and better outcomes obtained. To achieve this objective, a methodology is developed in three phases: static, dynamic, and outcome-based analyses. To develop the methodology, the Tigris–Euphrates basin conflict in the Middle East over the past 30 years, as a real-life case study, is used to show the robustness and capabilities of the proposed approach. Finally, a sustainable resolution to the current conflict is proposed, and the results are discussed. The proposed methodology benefits from improving the existing and often static-based conflict resolution developments by considering the dynamic nature so that the true root causes of complex conflicts are addressed, better strategic insights achieved, and comprehensive resolution provided.

Key words: Dynamic GMCR, Game theory, Hydro-environmental politics, Middle East, Sustainable development, Systems thinking

HIGHLIGHTS

- A new method was developed to study the dynamics of water–environmental conflicts.
- The water conflict of the Tigris and Euphrates basins was studied using the developed methodology.
- The results showed this conflict with the current trend will take a destructive path in the future.
- A suitable management platform was proposed to take the conflict off the destructive path and create a sustainable development.

INTRODUCTION

Conflict is a phenomenon that does not have an explicit definition, but to a great extent, there is a consensus among scholars and industry experts about its concept. Conflict is generally defined as an interactive state in which the behaviors or goals of one actor are in some degree incompatible with the behaviors or goals of some other actors (Tedeschi, 2017). Conflicts do not necessarily have a negative aspect and they might be useful to some degree and within certain conditions (Daoudy, 2008). Each specific conflict has different aspects and occurs within different themes, including political, economic, military, cultural, social, or a combination of these. One of the current types of conflicts in the world is in the field of water and environmental controversies. Water–environmental conflicts

have been studied using a variety of approaches. Hydropolitics is one of the most interesting subjects that has been fairly defined by Allan (2001): it refers to the mission of the state in solving the issue of water scarcity through large projects and hydraulic infrastructural development. In so doing, it also aims at increasing its socioeconomic and political stability. It can also be defined as the study of conflict and cooperation over shared water resources (Hussein & Grandi, 2017). For example, Xia *et al*. have discussed the relationship between precipitation change and transboundary hydropolitics (Hof, 1998; Cascão, 2008; Xia *et al*., 2021). In another study, hydropolitics has been examined, issue-linkage along the Orontes River Basin was studied, and the Lebanon–Syria and Syria–Turkey hydropolitical relations were scrutinized (Conker & Hussein, 2020). Hussein *et al*. have reviewed the literature on why states' elites promote hydraulic megaprojects, examining the policies and tools used by states' elites to promote such projects which can be so important in hydropolitics (Hussein *et al*., 2020). They have presented a conceptual framework that shows states having the geographical advantage, economic power, technical potential, and political influence may consider their wide hydraulic development programs as a foreign policy strategy (Conker & Hussein, 2019). On the other hand, some studies of transboundary water conflicts have been conducted under the title of hydro-hegemony, and it is argued that these water conflicts can have both beneficial and harmful aspects (Feitelson, 2000; Fischhendler, 2004). In these studies, considering hegemony and its positive and negative forms, the intensity of the conflict, and the power of the parties involved in the conflict as the main features of such water conflicts, a framework for analyzing water conflicts is provided (Zeitoun & Warner, 2006). In another paper, Hussein and Grandi examine the evolving patterns of hydropolitical relations in the dynamic contexts of Yarmouk and Blue Nile Rivers emphasizing the role of the broader context in the analysis of power dynamics in transboundary waters. They argue that in these case studies, the lack of a basin-wide vision over the control and use of shared waters has resulted in disputes among the basin states and ultimately in an unsustainable, unfair, and unwise utilization of the resources (Hussein & Grandi, 2017). However, some other studies have attempted to examine water–environmental conflicts using conflict analysis methods. One of these methods is the graph model for conflict resolution (GMCR), which is a powerful, flexible, and practical way of modeling and analyzing real-world conflicts (Kilgour *et al*., 1987; Fang *et al*., 1993; Xu *et al*., 2018). Within two decades, this game theory-based approach has been expanded and evolved in different aspects. For instance, for conditions where uncertainty can affect decision-makers' (DMs) preferences, studies such as uncertain preference (Li *et al*., 2004; Yu *et al*., 2016), multilevel strength of preference (Hamouda *et al*., 2004; Xu *et al*., 2009), and fuzzy preference (Hipel *et al*., 2011; Bashar *et al*., 2012) have been conducted. Moreover, other very interesting studies have been conducted using the GMCR framework and for its development, such as studying how DMs' attitudes affect the outcome of conflict (Yousefi *et al*., 2010; Yousefi *et al*., 2018), assessing actors' preferences under the influence of their emotions (Obeidi *et al*., 2005), addressing the power asymmetry between actors and its effects on conflict (Yu *et al*., 2015), and examining third-party systematic intervention in disputes (Kinsara *et al*., 2014).

Few research efforts, however, have been carried out to investigate the dynamic nature of conflicts. In an interesting research effort in this regard, Hussein and Grandi argue that a broader assessment of the specific context in which water disputes occur could shed light upon subtle and hidden dynamics that affect transboundary water management, through the identification of issues linkages and wider interstate relationships. They state that the political and social changes that have recently taken place in the Middle East and North Africa have impacted the hydropolitical dynamics in the cases considered. They emphasize that the urgency of broadening the focus of analysis beyond the managerial aspects of technical solutions for water policies leads to the identification of heterogeneous variables. Those variables are of social, economic, political, economic, and environmental character, and they account for the very nature of the specific topic to be addressed in the analysis (Hussein & Grandi, 2017). In another good study, Diehl (2006) state that while conflict over time goes through different interdependent stages, and what happens at one stage of conflict has downstream consequences in a later stage, researchers assume deal with conflicts at only very narrow time frames. He adds that the reason for this could probably be the

lack of attention of DMs to the long-term consequences of decisions made and the attention to a limited time frame (Diehl, 2006).

GMCR, as a robust methodology, has also been used to study the dynamic nature of water conflicts. Some research efforts that use the GMCR approach have addressed more than one stage in conflict but the emphasis is more on the existence of different frames in conflict and less on how conflict changes over time and how a conflict moves from one stage to another. In other words, these studies focus more on the evolution of conflict than on the dynamics of conflict. For example, Ali *et al*. have proposed an evolutional approach to conflict resolution within the paradigm of GMCR, and they have perused two levels of a conflict evolutionarily (Ali *et al*., 2019). In another study, Hipel *et al*. have investigated three frames of historical disputes over the Euphrates river using the GMCR method (Hipel *et al*., 2014). Shahbaznezhadfard *et al*. have presented a new paradigm within the GMCR framework for the dynamic study of conflicts (Shahbaznezhadfard *et al*., 2020). They have also investigated the dynamics of water–environmental conflicts by combining GMCR and system dynamics (Shahbaznezhadfard *et al*., 2021a, 2021b).

Ignoring the dynamic nature of conflicts (particularly long-term complex disputes) deprives analysts of a broad strategic insight that can significantly help in understanding the dynamics of conflicts more in-depth. One can argue that the main reason for paying less attention to the dynamic nature of conflicts by scholars is their linear perspective that leads to a static and event-oriented view of the world. This thinking model assumes that specific causes are acting together linearly to result in an effect or event (Sterman, 2002). In contrast to this thinking paradigm, there is a systems thinking paradigm that provides a better and more systematic picture of changes over time, taking into account feedback structures (Hitchins, 2008).

The main purpose of this research is a shift in the thinking paradigm in conflict investigations from linear thinking to nonlinear one, which manifests itself in systems thinking. To achieve this objective, this research attempts to incorporate systems thinking into the GMCR paradigm to develop a new method for dynamically studying conflicts. This research is organized as follows. The conflicts over the Tigris–Euphrates basin between periods 1985–1990 and 2015–2020, as a real-life case study and one of the most stressful basins in the Middle East, are introduced in the section 'Introducing the real-life case study' followed by the section 'Proposing the evolved methodology' which presents the development of the proposed methodology. The section 'Dynamic study of the Tigris–Euphrates conflict using the proposed methodology' deals with the dynamics-based conflict study of the Tigris–Euphrates case, where the evolvement of this complex conflict is examined over time, and finally, some concluding remarks are provided in the section 'Concluding remarks'.

INTRODUCING THE REAL-LIFE CASE STUDY

The Tigris–Euphrates Basin is located in the Middle East, one of the driest regions in the world. The two rivers originate in a similar area in southeastern Turkey, and eventually they are connected in Iraq. Of course, before this juncture, a few tributaries within the countries of Iraq and Syria and then some through Iran are added to them (Al-Ansari & Knutsson, 2011). The Euphrates enters Syria through Turkey and then flows into Iraq and the Tigris after crossing Turkish territory, forms part of the border between Turkey and Syria, and then enters Iraq. The two rivers form the Shatt al-Arab river by connecting in Iraq (Kibaroglu, 2014). A few tributaries that originate from the Zagros Mountain range in Iran move toward Iraq and join the Shatt al-Arab, creating the Arvandrud river, which is part of the border between Iran and Iraq. The Arvandrud river eventually flows into the Persian Gulf (Al-Ansari, 2019). A picture of the Tigris–Euphrates river flow map is shown in Figure 1.

Before World War I, the entire Tigris–Euphrates basin was under the control of the Ottoman Empire. Therefore, the issue of the international dispute over this basin did not exist. After the end of the First World War and the collapse of the Ottoman Empire, parts of these rivers were placed within the territory of the countries of Turkey, Syria,

Fig. 1. | Tigris–Euphrates river flow map (*Source*: Republic of Turkey Ministry of Development southeastern Anatolia regional development organization).

and Iraq (Beaumont, 1998). Since then, the decisions of the riparian states of the river basin on how to use them led to infighting issues among them, which did not cause any particular conflict until the early 1960s (Kibaroglu & Scheumann, 2013). But after this decade, the water needs of the countries in the basin to these two rivers increased, and larger water developments were begun by these countries. This was exacerbated when Turkey as an upstream country began designing and implementing the GAP project, which, with 22 dam projects and 19 hydroelectric power plants, has always been one of the world's largest water development programs (Akanda *et al.*, 2007). The GAP project is in fact one of the most intensive causes of increasing dispute among the benefiting countries. These controversies after many tensions reached their peak almost between 1985 and 1990, resulted in the conclusion of two bilateral protocols between Turkey–Syria and also Syria–Iraq in those years to divide Euphrates water between those countries. Subsequently, the current legal framework for water governance in this basin is essentially defined by these protocols (Kibaroglu *et al.*, 2005). After about 30 years, the feedback effects of the outcome of the conflict at that period, as well as the effects of some exogenous factors over the past 30 years, have caused real changes in the interaction atmosphere around the basin, and recent changes have formed a conflict between 2015 and 2020 with its own characteristics and specifications, which is considerably different from the previous conflict. The conflict introduced above is modeled and analyzed using the methodology developed in this paper, and its dynamics over these 30 years is examined. It should be mentioned that there are many approaches applied for international water controversies such as the Putnam's two-level game approach. Such a model considers international negotiations between parties as consisting of simultaneous negotiations at both the intranational level (domestic) and the international level (between countries). Warner and Zawahri, for example, have applied this approach to transboundary rivers (Warner & Zawahri, 2012; Rigi & Warner, 2020).

PROPOSING THE EVOLVED METHODOLOGY

The proposed framework for the research methodology is displayed in Figure 2. The framework consists of three phases. The first phase (Figure 2(a)) displays the scheme of conflict modeling using the linear thinking concept inherent in the conventional GMCR. The second phase (Figure 2(b)) displays the scheme of the conflict modeling using the proposed nonlinear thinking inherent in the systems thinking concept. The third phase (Figure 2(c))

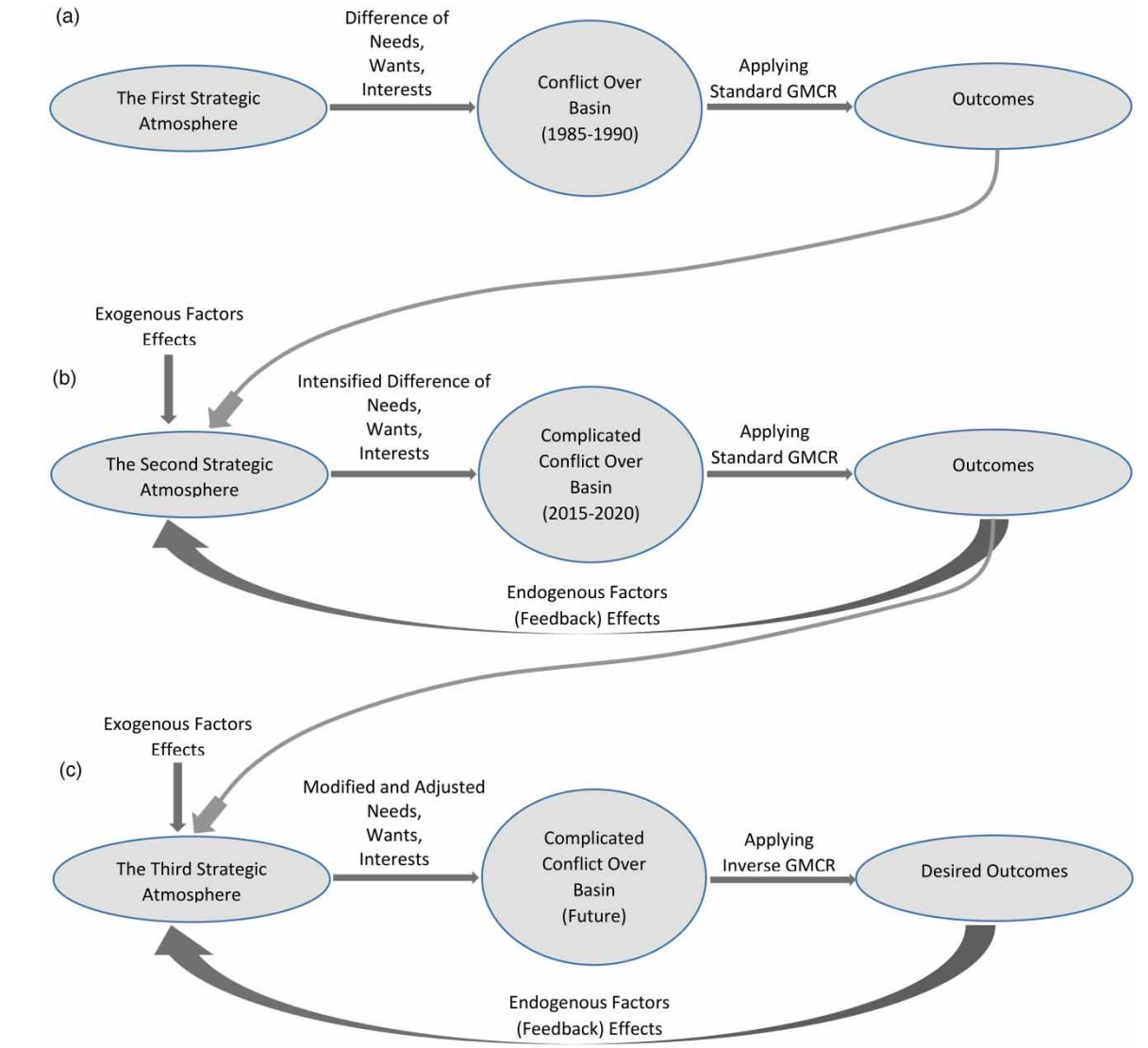

Fig. 2. | Proposed methodology framework. (a) Linear thinking (Event-oriented thinking) conflict modeling, (b) Nonlinear thinking (systems thinking) conflict modeling, (c) Outcomes-based conflict modeling.

displays the scheme of the outcome-based conflict modeling using the inverse GMCR tool. Each phase is fairly introduced and discussed in the following sections.

Dynamics of the conflict process

Each decision problem takes place in a specific 'context', for example, decision-making in the context of using a given river. On the other hand, this decision-making context lies in a 'strategic atmosphere' where possible interactions around the decision-making context from different participants occur in this atmosphere. This strategic atmosphere may create differences of interests, wants, and needs among participants or DMs which lead to

conflict. Each conflict is characterized by its DMs, their options, and their preferences (Xu *et al.*, 2018). When a conflict arises with its three essential characteristics, then it can be analyzed to achieve the resulting outcomes.

Dynamics in a conflict means changes in the three key elements (DMs, options, and preferences), which appear in a new stage of the conflict at the relevant period of time. As each conflict arises from its strategic atmosphere, any dynamics in the conflict results from changes in the relevant strategic atmosphere. In other words, any conflict is formed from within a dynamic atmosphere called strategic atmosphere, and any change in this atmosphere leads to dynamics in the conflict related to this atmosphere at any time. It should be emphasized when it is talked about dynamics in a conflict, meaning that the conflict modeling outcome is different in every time period. In general, any change in the strategic atmosphere can trigger dynamics of conflict, and this can also change the outcome of the conflict.

Shift in thinking paradigm

It is often common to use a linear causal model of thinking to explain different phenomena. This thinking model assumes that specific causes are acting together linearly to result in an effect or event, and this outcome of the event is assumed not to affect the input (Sterman, 2002). This model has been shown in Figure 3.

The linear thinking paradigm leads to a static and event-oriented view of the world and focuses less on trends and dynamics over time. The approach of this model in solving a problem is either through control of the processes that lead to the problem or through the improvement of the problem after it appears. However, the real-world conditions are often much more complicated than simplifying a problem linearly and solving it with such assumptions (Hjorth & Bagheri, 2006).

Senge emphasizes: 'Reality is made up of circles, but we see straight lines' (Senge, 2006). Contrasting to the linear thinking model is the nonlinear thinking model which views the world as made up of feedback loops, such that cause and effect chains loop back upon themselves (Hitchins, 2008), as shown in Figure 4. Feedback is one of the main elements of this thinking paradigm, which helps in addressing the phenomena and their dynamics over time. Feedback is the same endogenous factors that are generated from within the system and affect it again. The systems thinking approach provides a mechanism to apply nonlinear causal thinking to planning and management problems (Mirchi *et al.*, 2012).

Of course, in these circular structures, one factor may be effective, but not have generated from within the system. In other words, it can be 'Cause' but not 'Effect'. This is called the exogenous type of factor or variable.

Fig. 3. | Linear causal thinking (event-oriented thinking).

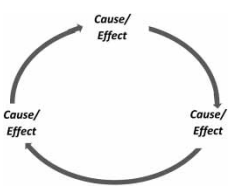

Fig. 4. | Nonlinear causal thinking (systems thinking).

The use of systems thinking in the study of various phenomena can well describe the process of creating problems over time and create a broader understanding that can prevent DMs from making decisions with a short-term view that have long-term destructive effects.

Graph model for conflict resolution

The GMCR (Kilgour *et al*., 1987; Fang *et al*., 1993) is a comprehensive and game theory-based approach for systematically modeling, analyzing, and understanding strategic conflicts. One of the most important benefits of this method is the use of relative data. The process of studying a conflict using this methodology basically involves two steps: modeling and analysis (Xu *et al*., 2018).

In the modeling stage, by studying and examining a strategic atmosphere in which a 'differences of interests' has arisen, the DMs of the respective conflict and the options under their control are identified. Each DM can choose or not choose any of the options under its control. Combining different choices of options from all DMs creates possible states of the conflict. Of course, some of the possible states are not feasible in the real world. Therefore, it is reasonable to continue the study of the conflict with feasible states by eliminating the infeasible states. In the continuation of modeling, the feasible states of the conflict are ranked according to the preferences of each DM (Xu *et al*., 2018). To do this, in small disputes, direct ranking can be used, and in larger disputes, various methods can be used, such as option weight and option prioritization (Bashar *et al*., 2014).

After modeling, the stage of conflict analysis begins. At this stage, using stability definitions (solution concepts), the stability of feasible states is evaluated one by one. Stability definitions, based on moves and countermoves, describe different behavioral patterns in conflicts, such as foresight, knowledge of preferences, dis-improvement, and strategic risk (Xu *et al*., 2018). To simulate and reflect the more diverse behavioral characteristics of DMs in strategic conflict, various stability definitions have been proposed, the most important of which are Nash, general metarationality (GMR), symmetric metarationality (SMR), and Sequential Stability (SEQ) (Madani & Hipel, 2011). To assess the stability of a feasible state, its stability must be examined from the perspective of all DMs. A feasible state, which is stable for all DMs under a given stability definition, is an equilibrium, representing a likely outcome of the dispute. If a given feasible state is stable for all DMs under a range of stability definitions, it is a stronger equilibrium and a better-proposed solution for the conflict (Madani & Hipel, 2011).

Due to the repetitive and automotive nature of the GMCR procedures, a number of decision support systems have been designed to implement the modeling and analysis stages of conflicts. One of them is GMCR+ (Kinsara *et al*., 2015). This program has been used to study the intended conflicts in this research.

From conventional GMCR to dynamic GMCR

As mentioned earlier, most conflict studies and their methods follow a linear thinking paradigm. Specifically, the GMCR approach, by studying a strategic atmosphere related to a decision-making context, extracts the conflict in the event of a difference of interest in that atmosphere. A simplified conflict is characterized by its three key elements, namely actors, their options, and their preferences (Xu *et al*., 2018). This phase of the study in the GMCR approach is called modeling (Xu *et al*., 2018). In other words, in this approach, modeling is the extraction of the three main elements of conflict from the strategic atmosphere having a difference of interests. At this phase, of course, states and feasible states of conflict, which are a function of the options, are also determined. As with most other methods, GMCR begins the analysis phase after the modeling phase. According to this method, at this phase, stability definitions are used to evaluate feasible states, as well as to determine the possible outcomes of the conflict (Xu *et al*., 2018).

With some reflection, one realizes that the process under consideration in various methods, including GMCR for studying conflict, follows a linear thinking paradigm, as shown in Figure 2(a). This figure illustrates the process

of examining conflict and its outputs according to linear thinking. In other words, it shows that a strategic atmosphere having a difference of interests leads to a conflict that is characterized by its three key elements in the modeling stage, and that conflict leads to an outcome that resulted in the analysis stage. According to this viewpoint, it can be argued that conflict is an effect of the strategic atmosphere having a difference of interests, and the outcome of the conflict is an effect of conflict.

Linear thinking in the conflict studies leads to an event-oriented perspective, which deprives scholars of examining the trends and dynamics of conflicts and the extensive strategic insights drawn from it. This is due to the incomprehension of nonlinear and systems thinking in the real-world conflicts. The reason for this is that the effects and downstream consequences of the outcome of a conflict at a given stage are ignored and also, the time on the strategic atmosphere which itself could be the cause of a new stage of conflict at the next time is not considered (Diehl, 2006). Therefore, by incorporating the intended feedback (endogenous factors), one should replace systems thinking with linear thinking and use it to study the conflict dynamically. This is done by creating a closed-loop that can evaluate and describe all the changes and dynamics of a strategic atmosphere of a decision-making context, and its associated conflicts and outcomes over time. This proposed closed-loop is shown in Figure 2(b).

If there is a difference of interests in a strategic atmosphere, it leads to a specific status of the conflict, specified by three key characteristics of its own (Figure 2(b)). This status of the conflict will also have its own outcome which (according to GMCR) is a set of DMs' options. The resulting outcome at this stage also has downstream effects on the strategic atmosphere, and this new atmosphere can follow the path above, thereby creating new stages of conflict and related outcomes over time. Repeating these subsequent events creates a loop that changes over time. Within the context of the dynamics of conflict, the strategic atmosphere of a specific decision-making context is influenced not only by the consequences of conflict but also by surrounding factors known as exogenous factors. Exogenous factors, unlike endogenous factors that originate from the outcome of the conflict in the previous stages, have external origins.

DYNAMICS-BASED STUDY OF THE TIGRIS–EUPHRATES CONFLICT USING THE PROPOSED METHODOLOGY

A real-life and complex water case study is used in this section to extensively lay out the process of methodology development in three main steps: The conflict related to the strategic atmosphere in the first period is discussed in the first step, followed by the second step which scrutinizes the strategic atmosphere in the second period and analyzes the changing environment after 30 years. The third step proposes a convenient approach to achieve the desired resolution of the conflict using the third strategic atmosphere. They are explained in the following subsections.

Strategic atmosphere in the first period

Prior to the 1960s, the atmosphere of water interactions between the riparian countries in the Tigris–Euphrates basin was not stressful (Kibaroglu & Scheumann, 2013). With the start of design and implementation of the GAP project by Turkey in the 1960s, which includes 22 dams and 19 hydropower plants projects, one of the world's largest water development projects (Akanda *et al*., 2007), the downstream countries became concerned about the possibility of a reduction in water flow and repeatedly expressed their disagreement to these policies. This concern was heightened by the construction of large dams such as the Ataturk Dam on the Euphrates as part of the GAP project, which is one of the largest dams in the world and has a very large reservoir volume (Kibaroglu, 2019). This threat from Turkey was such great that the Syrian Prime Minister said in 1986: 'The Euphrates is vital to us, and if Turkey maintains a large amount of water during the GAP project, Syria can

retaliate in other ways' (Bolukbasi, 1993). He said this matter in some way that any action by Turkey that would reduce the flow of downstream water would lead to Syria's support for the Kurdistan Workers Party (PKK) militants against Turkey (Bolukbasi, 1993). After these remarks, some people (backed by Syria) were arrested on charges of sabotage operations in Turkey (Medzini & Wolf, 2006). Following these events, in 1987, a protocol was signed between Turkey and Syria, in which Turkey promised to release an average of 500 m^3/s water flow from the Euphrates river into Syria, and in return, Syria promised not to support the PKK and insurgents (Kibaroglu, 2019). Of course, this promise was not fully fulfilled by Syria at that time (Kibaroglu, 2019). During these events, given that there was a confidential and informal agreement between Syria and Iraq since 1975 on how to divide the Euphrates (Wasinger, 2015), their focus was on Turkey's policies and actions. However, given the unofficial nature of that agreement, this was not a reason for the two countries not to worry about escalating tensions between themselves. In 1989, Turkey announced the completion of the Ataturk Dam on the Euphrates, adding that it would begin its reservoir impoundment at the beginning of 1990 (Starr, 1991). Although Turkey tried to show its commitment to the 1987 protocol by increasing water flow into the downstream in the months leading up to the impoundment, the continued impoundment was considered a deliberate hostility despite the severe drought (Bolukbasi, 1993; Shapland, 1997). Iraqi and Syrian officials strongly criticized Turkey's behavior. In addition, there were reports of serious military threats from downstream (Bolukbasi, 1993; Zentner, 2011). However, with the completion of the dam impoundment, Turkey adjusted the downstream flow according to the same 1987 protocol and eased tensions (Barkey, 1996). It was during these events that Syria, in the form of an official protocol in late 1990, ensured the release of 58% of the Euphrates water received from Turkey to Iraq (Kibaroglu, 2019), which, along with the 1987 protocol, defined the formal and legal framework for governing water in the Euphrates (Kibaroglu *et al.*, 2005). However, Turkey did not accept any restrictions on water policies and the GAP project and continued to do so (Al-Ansari, 2019).

Conflict related to strategic atmosphere in the first period: modeling and analysis

DMs and their options in this conflict are presented in Table 1. The DMs of this conflict were Turkey, Syria, and Iraq. Turkey has three options: continue the GAP project, guarantee a certain amount of flow into downstream, and hard response to downstream countries. Syria has four options in the conflict, including supporting the PKK, hard opposition to Turkey, guaranteeing a certain amount of flow into Iraq, and escalating water tensions with Iraq. Finally, Iraq has two options: hard opposition to Turkey and escalating tensions with Syria.

Table 1. | DMs, their options, and descriptions for the conflict's first period.

DM	Option	Description
Turkey	Continue GAP	Continuation of water policies with a focus on the GAP project
	Guarantee a flow to Syria	Official guarantee of a certain amount of the Euphrates flows to the downstream country
	Hard response to downstream	Responding to any kind of hard action from downstream countries
Syria	Support PKK	Supporting Kurdish rebels against Turkey
	Hard opposition to Turkey	Hard political positions that are accompanied by military action
	Guarantee a flow to Iraq	Official guarantee of a certain amount of the Euphrates flows to the downstream country
	Escalate with Iraq	Increased political and possibly military tensions
Iraq	Hard opposition to Turkey	Hard political positions that are accompanied by military action
	Escalate with Syria	Increased political and possibly military tensions

Given that in this model, the total number of DMs' options, each of which can be selected or not (Yes (Y) or No (N)), equals 9, and the total number of possible states will be mathematically $2^9 = 528$. However, for the convenience of investigation, a number of states that were not actually feasible are eliminated. By eliminating infeasible states, the total number of feasible states of this conflict will be 70. The list of feasible states of this conflict is given in Supplementary Material, Appendix A.

In the continuation of the modeling process, it is time for the preferential ranking of feasible states from the perspective of each of the DMs. To do this, the option prioritization method is used, in which each DMs' preference statements are listed in order of priority, often represented vertically from the most important to least, and the ranking of feasible states from the DMs' point of view is constructed accordingly. To verify these rankings, the opinions of various political and water experts have been used. Preference prioritization information for the conflict in the first period is presented in Supplementary Appendix B. Also, the ranking created based on this information is given in Supplementary Material, Appendix C.

Careful consideration of the DMs' options in this conflict model and the outcome that historically has been achieved shows that at that time, Turkey continued its water policy in the form of the GAP project and by signing the 1987 Protocol with Syria, guaranteed a certain flow into the downstream. Syria did not completely cut off its support for the PKK, and by signing the 1990 protocol, guaranteed a certain flow into Iraq officially. However, during that time, no hard action was taken by the three countries, and no significant escalation of tensions took place that would lead to any direct action by any of the countries. As shown in Supplementary Material, Appendix A, it is clear that state 14 is exactly aligned with the historical outcome of this conflict. In other words, state 14 is where the conflict reached its final equilibrium in the first period.

The performance of GMCR in the analysis stage is based on the stability definitions. These definitions are based on moves and countermoves of DMs, describing different behavioral patterns in conflicts and can assess how to stabilize a certain state (Xu *et al*., 2018). According to these concepts, a state is not in equilibrium unless it is stable to all DMs. Analysis of this conflict using GMCR+ shows that state 14, which was the historical outcome of the conflict, has been in equilibrium at that period based on the three definitions GMR, SMR, and SEQ. State 14 means that Turkey continued its water policy in the form of the GAP project and by signing the 1987 Protocol with Syria, guaranteed a certain flow into downstream. Syria did not completely cut off its support for the PKK, and by signing the 1990 protocol, guaranteed a certain flow into Iraq officially. However, during that time, no hard action was taken by the three countries, and no significant escalation of tensions took place that would lead to any direct action by any of the countries. Results related to the stability of this state are shown in Table 2, where in the table, 'S' stands for stable and 'U' stands for unstable. Table 2 also indicates that state 14 has not been merely based on the 'Nash' definition in equilibrium. According to this definition, each of the countries of Turkey and Iraq, with a unilateral move, can move to a better state and improve their own situation. However, given that this is a state of equilibrium in the other three definitions (GMR, SMR, and SEQ with different risk tolerances and human behaviors), state 14 represents a relatively strong equilibrium state, and DMs have generally no motivation to move from this state. Equilibrium is a stable state for all DMs and represents a possible solution for a given conflict under the study of GMCR.

Changes in the strategic atmosphere of the conflict over 30 years

Endogenous factors effects

During the last 30 years, Turkey's continued the construction of dams and water developments within the framework of the GAP project and released a limited flow into the downstream. Such actions on the part of Turkey severely impacted the water and environmental situation in Iraq and Syria (Adamo *et al*., 2020). In addition to water scarcity, with the drying up of various wetlands in downstream countries, especially Iraq, dust storms

Table 2. | Resulting outcomes of the conflict in the first period (state 14).

Stability definition	Stability description	Historical outcome (state 14) analysis	
		DM	Equilibrium
Nash	DM cannot unilaterally move to a more preferred state	Turkey: U Syria: U Iraq: S	×
GMR	All DMs' unilateral improvements are sanctioned by subsequent unilateral moves by others	Turkey: S Syria: S Iraq: S	✓
SMR	All DMs' unilateral improvements are still sanctioned even after possible responses by the original DM	Turkey: S Syria: S Iraq: S	✓
SEQ	All DMs' unilateral improvements are sanctioned by subsequent unilateral improvements by others	Turkey: S Syria: S Iraq: S	✓

have become a major environmental problem throughout the region. These storms have severely affected the western parts of Iran, a country that has been somehow involved in this conflict (Gerivani *et al*., 2011; Hamidi, 2020).

Turkey's insistence on continuing the GAP project has been accompanied by the continuation of the construction of water facilities in the country during this period, as far as Turkey is now on the brink of exploiting its largest dam on the Tigris called Ilisu, which has now become a major concern for the countries of Iraq and Iran (Adamo *et al*., 2020). This dam is very important for Iraq in terms of the Tigris river water issue (Adamo *et al*., 2020), and for Iran, in terms of the possibility of intensifying dust storms (Gerivani *et al*., 2011; Hamidi, 2020).

Exogenous factors effects

Syria has been facing a deep and complex crisis since 2011 when a series of political demonstrations took place following the so-called Arab Spring movements in various Arab countries. However, as a result of a series of events, the situation developed in such a way that various terrorist groups such as ISIS emerged in this country and bloodshed as well as civil war pervaded the whole country (Slackman, 2011; Rodgers *et al*., 2016). The combination of these factors has caused the country to be unable to play a role as an effective actor in the water conflicts in the basin and, during its deep crisis, has not participated in any talks around the basin issues (Kibaroglu, 2019). In other words, the exogenous factor of crisis in Syria has caused this country not to take any action during these years for this long-term water and environmental conflict.

With respect to Iraq, this country has experienced several military wars since 1990. In addition, the country has experienced almost constant political instability during this period. In recent years, it has also been involved in security issues caused by the emergence of terrorist groups (BBC News, 2018). The set of these factors has weakened the country economically, militarily, and particularly politically over these years. As such, Iraq has not been able to advance its position in the basin negotiations relying on its political and military power, as it was in the past (Al-Ansari, 2019).

Iran has not previously been involved in major disputes over the use of the Tigris–Euphrates waters. Of course, there has been a relatively long debate over the demarcation of its border with Iraq in the Arvandrud river

(Al-Ansari, 2019), which is not the subject of this paper. But the country, due to its water problems, has constructed several dams on the Tigris tributaries in recent years. Therefore, Iran has also been involved in this conflictual issue.

Strategic atmosphere in the conflict's second period

As described in the previous section, the strategic atmosphere of the conflicting basin has changed under the influence of several factors in recent years, and thus, a new strategic atmosphere is prevailing over the interactions of this basin. Given the issues raised, it can be said that in this period, Syria, due to its conditions and the involvement in the civil war (Slackman, 2011; Rodgers *et al.*, 2016), is not able to play an effective role in the conflict related to the basin issues and, during the years involved in this war, has not participated in any meetings or negotiations around the basin theme (Kibaroglu, 2019). On the other hand, Iran has a significant role to play in this strategic atmosphere for two reasons: (1) due to the issues related to the construction of dams on the tributaries of the Tigris and Arvandrud river in its territory (Al-Ansari, 2019) and Iraq also has held talks with Iran about the issue (Al Tamimi, 2018) and (2) due to the dust storm in the west part of Iran caused by the drying up of Iraqi wetlands by Turkish actions (Gerivani *et al.*, 2011; Hamidi, 2020). Iraq, as a downstream country on the Tigris river, is still a major DM due to very serious concern about the Ilisu Dam project and severe water shortages (Adamo *et al.*, 2020). However, this country has been weakened due to many political reasons (Al-Ansari, 2019). It is not possible for Iraq to use military tools and options in the form of hard actions to advance its positions in the water negotiations. Therefore, in this situation, this country can only take soft actions against other DMs, such as expressing political positions and international complaints. Along with this option, the poor water conditions in Iraq (Adamo *et al.*, 2020) cause the country to consider economic incentives to encourage other DMs to cooperate and increase the flow of water to improve the situation in Iraq. It should be mentioned, however, that Iraq is not economically viable enough to provide significant economic incentives. Turkey, as a country at the top of a major part of the Tigris, which has constructed the huge Ilisu Dam on the river and is ready to exploit it (Adamo *et al.*, 2020), continues to play a key role in issues related to the Tigris with the decisions it can make. As it can be witnessed, the second strategic atmosphere is totally different from the first strategic atmosphere, which was often around the Euphrates river. In fact, the second one is mostly about the current state of the Tigris river and how to use it. On the other hand, it is obvious that Syria has almost no choice in the second strategic atmosphere as the main DM, Iran has a more prominent role to play in this atmosphere, Turkey's decision on how to exploit the Ilisu Dam is on the table, and Iraq has been greatly weakened and is not able to take hard actions and can only make economic proposals and incentives or take soft actions.

Conflict related to strategic atmosphere in the second period: modeling and analysis

DMs and their options in the conflict of the second period are presented in Table 3. As shown, Iran is now added to the DMs of the first conflict, and Syria is eliminated from that. Turkey, which is now on the verge of exploiting the Ilisu Dam on the Tigris river, has two options: to exploit the dam with or without full cooperation with the downstream. Iraq could have four options: two options relate to soft opposition to Turkey and Iran (including international complaints and political positions) and the other two options relate to offering economic incentives to Turkey and Iran for water cooperation with Iraq. Iran also has three options: two options relate to the exploitation of constructed dams on the tributaries of the Tigris and Arvandrud river in its territory with or without cooperation with Iraq, and one option relates to the acceptance of environmental conditions of this basin and not objecting to it, particularly, in terms of dust storm issue.

Given that in this model, the total number of DMs' options reaches 9, so the total number of possible states will be mathematically equal to $2^9 = 528$. After removing the states that are not feasible in practice, the total number of

Table 3. | DMs, their options, and descriptions for conflict in the second period.

DM	Option	Description
Turkey	(1) Exploitation with collaboration	Exploitation of Ilisu Dam with full cooperation with downstream
	(2) Exploitation without collaboration	Exploitation of Ilisu Dam without cooperation with downstream
Iraq	(3) Soft opposition to Turkey	Soft opposition to Turkey which can include international complaints, taking political positions, and so on
	(4) Soft opposition to Iran	Soft opposition to Iran which can include international complaints, taking political positions, and so on
	(5) Offer incentive to Turkey	Offering incentive to Turkey that could include economic cooperation packages
	(6) Offer incentive to Iran	Offering incentive to Iran that could include economic cooperation packages
Iran	(7) Exploitation with collaboration	Exploitation of the constructed dams with full cooperation with downstream
	(8) Exploitation without collaboration	Exploitation of the constructed dams without cooperation with downstream
	(9) Accept environmental situation	Accepting the environmental situation (dust storm) of the basin and not objecting to it

feasible states reaches 50 states. The list of feasible states of this conflict model is given in Supplementary Material, Appendix D.

The option prioritization method has also been used to rank states based on the preferences of DMs. Preference prioritization information for the conflict in the second period is presented in Supplementary Material, Appendix E, and the ranking of each DM is shown in Supplementary Material, Appendix F.

Once the modeling steps are completed, the analysis stage is begun using the GMCR+ software. Table 4 displays the states that are defined as equilibrium states, at least according to more than two stability definitions.

Table 4. | Resulting outcomes of the conflict in the second period.

		Possible outcomes (equilibrium states)			
DM	Option	9	15	19	25
Turkey	Exploitation with collaboration	N	N	N	N
	Exploitation without collaboration	Y	Y	Y	Y
Iraq	Soft opposition to Turkey	Y	Y	Y	Y
	Soft opposition to Iran	Y	Y	Y	Y
	Offer incentive to Turkey	N	Y	N	Y
	Offer incentive to Iran	N	N	Y	Y
Iran	Exploitation with collaboration	N	N	N	N
	Exploitation without collaboration	Y	Y	Y	Y
	Accept Environmental situation	N	N	N	N
Nash		√	√	√	√
SEQ		√	√	√	√
GMR		√	√	√	√
SMR		√	√	√	√

As shown in Table 4, states 9, 15, 19, and 25 are states that, according to all four stability definitions, are considered equilibrium states with strong equilibria. In all states 9, 15, 19, and 25, Turkey and Iran will operate their water facilities without full cooperation with Iraq, and Iran will not accept the environmental conditions of the basin. Also, in all these states, Iraq opposes the policies of the upstream countries. The only difference between these states is merely on the Iraqi decision to offer or not to offer economic proposals to Turkey and Iran. It can be interpreted that no matter how the choices of Iraq are changing, the position of Iran and Turkey will remain constant. In other words, both countries know that Iraq cannot offer substantial incentives or take hard opposition, and therefore, both countries would develop their own water development projects as their rights. Of course, Iraq will continue to oppose their actions, but they would consider this situation as their own right. That may intensify the tensions among the neighboring countries in the future.

Discussion of obtained results in the first and the second strategic atmosphere

In the previous sections, the water and environmental disputes of the Tigris–Euphrates basin over the past 30 years were examined using the concepts of the developed method. For this purpose, two important phases of this conflict, one related to about 30 years ago and the other related to the current situation, were modeled and analyzed, and the dynamics of these 30 years that moved this conflict from the first phase to the second phase was also scrutinized. In fact, such dynamics are created over time by endogenous and exogenous factors and, consequently, change the strategic atmosphere. In other words, from the perspective of systems thinking, it is endogenous and exogenous factors that affect and change the strategic atmosphere over time, and it could lead to a new stage of the conflict. The achieved results indicate that the current strategic atmosphere of the basin (conflict), regardless of the future impacts of the exogenous factors, will not evolve in the right direction as in the past. This direction is a continuation of the previous one, which was led to major water and environmental problems in the region. Therefore, the valuable resulting outcomes of the second strategic atmosphere raises a legitimate question for this ongoing environmental conflict: what would be the desired and sustainable solution for this complicated conflict and how can it be achieved? In other words, how the current destructive strategic atmosphere can be diverted to a more appropriate direction so that deleterious and harmful tensions among DMs are reduced and hydro-economic cooperation between countries is boosted? A brief explanation about responding to these questions is the subject of the next section below.

THIRD STRATEGIC ATMOSPHERE OF THE CONFLICT: ACHIEVEMENT OF A DESIRED RESOLUTION

As shown in Figure 2(c), the third phase of the research methodology presents what would be the most rational decisions made by DMs so that the best-desired results are obtained. An outcome in which, in addition to full hydro-economic cooperation, there is no tension among the countries, can be a desired resolution of the future for this complicated ongoing conflict. In examining the conflict in the second strategic atmosphere, state 28 represents almost this situation. In this state, hydro-economic cooperation is offered by Iraq and accepted by both Turkey and Iran, and there is no opposition from any country. Such a proposal for this conflict can also keep the relationship out of any kind of tension. The key question is how this preferred condition (state 28) can take place as a resulting equilibrium? The answer to this question depends on the DMs' preferences in order for this state to become an equilibrium and this can be studied using the inverse GMCR tool (Kinsara *et al*., 2014) (Figure 2(c)).

This tool, which is embedded in the GMCR+ framework (Kinsara *et al*., 2015), allows one to provide the preferences needed to stabilize a state (desired state). Considering state 28 as the desired state, the preferences required to achieve the desired stability using this tool have been examined. In this investigation, the definition of Nash has been used as the strongest stability definition. The results of this process are presented in Table 5. As shown, in order to equilibrate this state according to Nash's definition, Turkey should prefer state 28 instead of

Table 5. | Resulting outcomes of applying inverse GMCR program.

		DMs' preference changes needed to achieve the desired stability (state 28) according to the Nash definition					
		For Turkey			For Iran		
DM	Option	State 29	<	State 28	State 20	<	State 28
Turkey	Exploitation with collaboration	N		Y	Y		Y
	Exploitation without collaboration	Y		N	N		N
Iraq	Soft opposition to Turkey	N		N	N		N
	Soft opposition to Iran	N		N	N		N
	Offer incentive to Turkey	Y		Y	Y		Y
	Offer incentive to Iran	Y		Y	Y		Y
Iran	Exploitation with collaboration	Y		Y	N		Y
	Exploitation without collaboration	N		N	Y		N
	Accept Environmental situation	Y		Y	N		Y

state 29, and Iran should prefer state 28 instead of state 20. In other words, under the conditions set out in this table, Turkey should prefer cooperation in the exploitation of the Ilisu Dam instead of non-cooperation, and Iran, in addition to preferring cooperation instead of non-cooperation in the exploitation of its dams, should also stop its opposition to the environmental conditions in the basin. This change in preferences seems hard to achieve, as long as Iraq's economic proposals are not significant, and in fact, Iraq does not have the resources and facilities to better manage its environmental situation.

Under these circumstances, the intervention of a neutral third party that can remove the obstacles in the way of achieving the desired equilibrium can be constructive. In addition to strengthening Iraq's economic incentive proposals to attract the cooperation of Turkey and Iran, the third party should be able to provide the necessary technical assistance to better manage the environment in Iraq. This can provide the basis for changing the preferences needed to stabilize the desired state. Given the experience of similar cases in the past (Al-Ansari, 2019), the World Bank seems to be the best third party to the conflict to intervene in order to create a sustainable atmosphere and prevent the continuation of the previous destructive path. This well-known international institution, with its financial and technical capabilities, as well as its experience of similar roles in the past, can strengthen Iraq's economic options, create a platform for better environmental management, and provide a favorable roadmap for hydro-economic cooperation in the conflicting basin. This can be a subject of new research efforts in the future for this ongoing complicated environmental conflict.

CONCLUDING REMARKS

An innovative methodology was presented in this research to take into account the real nature of real-life conflicts. Many conflict resolution approaches analyze complicated water–environmental conflicts in a static manner and in only one time frame. Although these approaches provide some results and are one step forward, they often ignore the real dynamic atmosphere that is inherent in real-life conflicts and dictate the resulting outcomes. It can be argued that one of the reasons causing less attention to the dynamic dimension of conflict studies is the dominance of linear thinking in the study process that leads to a static and event-oriented view of the world. A more comprehensive look at conflict dynamics can provide a broader understanding of the process of creating the related problems. As a consequence, DMs will be capable of making their decisions from a longer-term perspective. In other words, in this situation, DMs avoid making short-term decisions that can have destructive long-term effects. To overcome this challenge, the methodology, developed in this research effort, incorporates the

systems thinking concept into the conventional paradigm of GMCR, a well-known and robust conflict resolution approach. The conventional GMCR uses the linear thinking concept and mainly studies the conflicts in one time frame (static approach), whereas the dynamics-based GMCR, as the proposed methodology in this research, uses the systems thinking concept within the GMCR paradigm to study a conflict in different subsequent time frames. The proposed methodology benefits from a key advantage in assessing the evolvement of conflicts in various time frames, due to this fact that conflicts have totally different characteristics from one time period to another one. The proposed methodology strives to consider the exogenous and endogenous factors affecting the conflict in each time frame and examines the results of different time frames. In fact, the resulting outcomes emphasized that the study of dynamic nature of conflicts indeed provides a broader view of complicated conflicts and may lead to a better understanding of what is going on in the real-life conflicts and, of course, offer a more sustainable resolution for increasing water and environmental conflicts.

Within the structure of the proposed methodology, a concept called strategic atmosphere has been introduced. The term refers to the atmosphere in which possible interactions take place around a decision context, and if there is a difference of interests among parties involved, a conflict arises. In other words, conflicts are formed from within this atmosphere, and the dynamics influencing this atmosphere affects conflicts that may arise in the context of the relevant decision in this atmosphere and, thus, change the DMs, their options, and their preferences. The proposed methodology showed that the conflict's outcomes change the strategic atmosphere, and these changes may lead to a new conflict with its own characteristics (DMs, options, and preferences). The real-life Tigris–Euphrates basin controversy over the past 30 years was used to develop the methodology and show its robustness and capabilities to elaborate the concept of dynamics in complex and complicated water and environmental conflicts.

Last but certainly not least, this research contributes significantly to the provision of managerial tools that have the potential benefit of supporting the resolution of complicated conflicts by incorporating the systems thinking concept into GMCR and developing dynamic-based GMCR. The proposed methodology can help DMs tackle real-world water and environmental controversies to sustainably solve them and save enormous time and cost.

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The author(s) declare(s) that there is no conflict of interest.

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All relevant data are included in the paper or its Supplementary Information.

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