

Use of Game Theory as a tool for identifying and mitigating conflicts over water use in the area covered by the Estreito HPP - MA - Brazil

Uso de la Teoría de Juegos como herramienta para identificar y mitigar conflictos por el uso del agua en el área cubierta por la UHE Estreito - MA - Brasil

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ABSTRACT

Game Theory (JT) is a mathematical theory that assesses in the strategy games the understanding and interaction of the actors, being an important tool in the identification and analysis of conflicts. Therefore, the objective was to analyze conflicts over water use and propose mitigating measures in the Hydrographic Region of the Middle Tocantins, applying after the identification of possible conflict-generating agents, the JT. This made it possible to identify the conflict scenarios and the degree of intensity in which they occur, varying at high, medium, and low levels. The players reported that many environmental impacts and conflicts could be avoided if communication were better, emphasizing the need to create a basin committee, which will allow greater interaction between users. Therefore, the JT when used as a tool to identify conflict scenarios due to the use of water, proves to be quite effective, enabling the modeling of scenarios to minimize conflicts.

KEYWORDS: Water conflicts, Game Theory, Water management.

RESUMEN

La Teoría de Juegos (JT) es una teoría matemática que evalúa la comprensión e interacción de actores en juegos de estrategia, siendo una importante herramienta en la identificación y el análisis de conflictos. Nuestro objetivo fue analizar los conflictos por el uso del agua y proponer medidas de mitigación en la Región Hidrográfica del Tocantins Medio, aplicando la JT tras identificar posibles agentes generadores de conflictos. Esto permitió identificar los escenarios de conflicto y el grado de intensidad con que ocurren, variando en niveles alto, medio y bajo. Los actores informaron que muchos impactos y conflictos ambientales podrían evitarse si la comunicación fuera mejor, enfatizando la necesidad de crear un comité de cuenca, que permitirá mayor interacción entre los usuarios. Por tanto, la JT, cuando se utiliza como herramienta para identificar escenarios de conflicto por el uso del agua, resulta bastante efectiva, permitiendo la modelización de escenarios para minimizar conflictos.

PALABRAS CLAVE: Conflictos por el agua, Teoría de juego, Administración del Agua.

Utilisation de la Théorie des Jeux comme outil pour identifier et atténuer les conflits liés à l'utilisation de l'eau dans la zone couverte par l'UHE Estreito - MA - Brasil

RÉSUMÉ

La théorie des jeux (JT) est une théorie mathématique qui évalue la compréhension et l'interaction des joueurs dans les jeux de stratégie, étant important pour identifier et analyser les conflits. L'objectif était d'analyser les conflits d'usage de l'eau et de proposer des mesures d'atténuation dans la région hydrographique du Moyen Tocantins, appliquant, après avoir identifié les agents générateurs de conflits, le JT. Cela a permis d'identifier les scénarios de conflit le degré d'intensité dans lequel ils produisent, variant à des niveaux élevés, moyens et faibles. Les « acteurs » ont signalé que de nombreux impacts et conflits environnementaux pourraient être évités la communication était meilleure, soulignant la nécessité de créer un comité de capture, ce permettra une plus grande interaction entre les utilisateurs. Ainsi, JT, utilisé comme outil d'identification des scénarios de conflits pour l'usage de l'eau, s'avère très efficace, permettant la modélisation de scénarios pour minimiser les conflits.

MOTS CLÉS: Conflits liés à l'eau, La théorie des jeux, Gestion de l'eau.

Uso da Teoria dos Jogos como ferramenta para identificar e mitigar conflitos pelo uso da água na área coberta pela UHE Estreito - MA - Brasil

RESUMO

A Teoria dos Jogos (JT) é uma teoria matemática que avalia nos jogos de estratégia a compreensão e interação dos atores, sendo uma importante ferramenta na identificação e análise de conflitos. Portanto, o objetivo foi analisar os conflitos pelo uso da água e propor medidas mitigadoras na Região Hidrográfica do Médio Tocantins, aplicando após a identificação de possíveis agentes geradores de conflitos, o JT. Isso permitiu identificar os cenários de conflito e o grau de intensidade em que ocorrem, variando em níveis alto, médio e baixo. Os "atores" relataram que muitos impactos e conflitos ambientais poderiam ser evitados se a comunicação fosse melhor, ressaltando a necessidade de criação de um comitê de bacia, o que permitirá maior interação entre os usuários. Portanto, o JT quando utilizado como ferramenta para identificar cenários de conflito devido ao uso da água, mostra-se bastante eficaz, possibilitando a modelagem de cenários para minimizar conflitos.

PALAVRAS-CHAVE: Conflitos pela água, Teoria do jogo, Gerência de água.

Utilizzo della Teoria dei Giochi come strumento per identificare e mitigare i conflitti per l'uso dell'acqua nella zona coperta da UHE Estreito - MA - Brasile

SOMMARIO

La teoria dei giochi (JT) è una teoria matematica che valuta la comprensione e l'interazione dei giocatori nei giochi di strategia, essendo uno strumento importante per identificare e analizzare i conflitti. L'obiettivo era analizzare i conflitti sull'uso dell'acqua e proporre misure di mitigazione nella regione idrografica del Medio Tocantins, applicando, dopo aver individuato gli agenti che generano conflitti, il JT. Ciò ha permesso di identificare gli scenari di conflitto e il grado di intensità in cui si verificano, variando tra alti, medi e bassi livelli. I "giocatori" hanno riferito che molti impatti e conflitti ambientali potrebbero essere evitati se la comunicazione fosse migliore, evidenziando la necessità di creare un comitato di cattura, che consentirà una maggiore interazione tra gli utenti. Pertanto, il JT, utilizzato come strumento per identificare scenari di conflitto per l'uso dell'acqua, si dimostra molto efficace, consentendo la modellazione di scenari per ridurre al minimo i conflitti.

PAROLE CHIAVE: Conflitti d'acqua, Teoria del gioco, Gestione delle risorse idriche.

Introduction

Game Theory emerged from the work of French mathematician Antoine Augustin Cournot published in 1838, entitled “*Recherches sur les Principes Mathématiques de la Théorie des Richesses*”¹, and served as the basis for the Game Theory which was originally consolidated by Neumann and Morgenstern in 1944 in the “Theory of Games and Economic Behavior”². It gained notoriety after 1950 when John Nash created the concept known as the Nash Equilibrium, which made it possible to demonstrate that the result in a game cannot be changed from time-to-time by just one of the parties due to the interdependence and collisions already established³.

Game Theory is a mathematical theory which deals with and models competitive situations that involve decision-making processes when one or more “agents” interact with each other⁴. It contributes to better understanding the types of behavior of organizational subjects, especially those who constantly make decisions and whose positive results are essential, since organizations need to create strategic alliances to obtain individual and collective benefits and served as a basis for the Theory of Games⁵.

State that this is a mathematical theory which assesses the understanding and interaction of the players in strategy games, and which aims to help strategic reasoning. In this sense, Game Theory can be an extremely important tool for identifying and analyzing conflicts in several knowledge areas⁶.

In a study on water allocation in the Syrdarya basin, namely Kyrgyzstan and Uzbekistan, used the Theory of Cooperative Games to solve such problems, concluding that this theory can be greatly beneficial in resolving conflicts, provided that the language used is understandable to stakeholders in the process⁷.

In a study on the Langat River basin in Malaysia, worked with the coupled simulation-optimization modeling method based on a combination of system dynamics and Game Theory, with the aim of resolving multi-reservoir and multi-objective conflicts through two different deterministic optimization models with increasing levels of complexity⁸. They identified that

the Game Theory method surpassed the system dynamics method, as it presented substantially better performance in the ability to deal with the dynamics, complexity and uncertainty in the river system.

Report that the literature on the concept of conflict is vast, and many of its aspects have a strong link with the positivist tradition, especially with the perception that conflict is an anomic and dysfunctional element to be removed or tamed⁹. Agree that a conflict is characterized by being multi-causal and multidimensional, and may result from a combination of political and institutional, socioeconomic and environmental factors¹⁰. Therefore, it is natural to have conflicts regarding access, allocation and management of water resources, notably due to their importance for human life, increasing demand and the spatio-temporal variability of supply¹¹.

The conflict can often be linked to the type of occupation and land use. Reported that imprecision in property titles, measuring instruments and the lack of qualified professionals in the region of Córdoba during the first half of the 19th century evidenced the State’s incapacity to guarantee, control and intervene in conflicts which arose around the water¹². This further evidenced that conflicts could occur due to personality differences or past rivalries. It can originate to negotiate before the opportune moment or the necessary information is available¹³.

In a study on the Pong River basin, reports the existence of large industries, water and cellulose mills and sugarcane mills which consume a large amount of water, which consequently becomes a conflicting factor¹⁴. In another study carried out in the Pong river basin, report that the biggest conflicts between water users were found downstream of the Ubonratana reservoir for the Nong Wai irrigation reservoir due to the large amount of water used by the paper and cellulose industry¹⁵.

Describes that the concept of intergovernmental conflict for water refers to any interaction-litigation and jurisdiction which follows an emergency and development process, sometimes hostile, between two or more agents, through multiple acts which are inscribed in a logical causal sequence of events over time¹⁶.

When there is conflict, there is a need to try to find possible solutions to mediate them. Emphasize that the

¹ Fiani, 2015.

² Silva, 2019.

³ Souza & Valentim, 2016.

⁴ Soares & Lira, 2016.

⁵ Oliveira et al., 2018.

⁶ Rocha et al., 2016.

⁷ Melniková, 2017.

⁸ Zomorodian et al., 2017.

⁹ Wenzel et al., 2017.

¹⁰ Guedes & Ribeiro, 2017.

¹¹ Amorim, Ribeiro & Braga, 2016.

¹² Ferreyra, 2017.

¹³ Correia, Studart & Campos, 2012.

¹⁴ Chanya, Prachaak & Ngang, 2014.

¹⁵ Apipalukul, Wirojangud & Ngang, 2015.

¹⁶ Rojas-Ramírez, 2018.

use of mediation can improve procedural justice and transfer decisions to conflicting parties¹⁷. The negotiation process emerges as one of the best ways to avoid or minimize potential interstate conflicts, and they emphasize the need to use conflict resolution tools as support for decision-making¹⁸.

Therefore, many factors have been raised based on the need to analyze the reasons which may influence generating conflicts over water use to explain the lack of or minimization of the water level in the Tocantins and Manuel Alves Grande e Pequeno river channels. Among these factors are the constant population demand for water, the generation of hydroelectric power, agricultural and forestry crops, climate change, and the correct destination of solid waste treatments, among others. Thus, this study is a priori based on the principle of investigation through questioning in the cities upstream and downstream of the Estreito (MA) hydroelectric power plant (HPP) to try to explain this conflict in order to address all aspects inherent to the management of water resources, such as its main users¹⁹.

In this context, the trade-off analysis presents itself as a tool which aims to balance the different uses of natural resources based on the construction of scenarios and their possible impacts, thereby enabling to identify the social actors involved, the interests of each social actor, their views, knowledge, and values which are involved in the management system, to then modify it²⁰.

Explain that the trade-off is a flexible analysis which can be modified according to the preferences of the social actors due to new information which can influence the interests of these actors and is built “through the combination of deliberative processes, impact assessment and consensus building”²¹.

Water management in Brazil is a conflict which is historic and involves generating electricity in the reservoirs of hydroelectric plants and other multiple uses of water²². According to, river fragmentation is the biggest impact on a system whose main characteristic is the dynamic flow of its waters and seasonal periodicity²³. The dams fragment habitats, alter biodiversity and prevent reproductive migration of fish, in addition to retaining water, nutrients and sediments, altering the

natural flow of these fundamental elements for the dynamic functioning of a floodplain.

In this context, the Estreito hydroelectric power plant (MA) is present in the médio Tocantins (MA) hydrographic basin area, which is a run-of-river power plant and has a reservoir with sufficient accumulation to provide daily or weekly regularization. Furthermore, according to, it directly uses the affluent flow of water use²⁴. It was inaugurated on October 17, 2012. Authors such as report that the construction of this hydroelectric plant generated numerous discussions and consequent conflicts in the impacted society because there are a countless number of people who live in the surrounding region²⁵. They have a close relationship with the river, mainly in maintaining their food by fishing, and above all in their ebb and flow of producing the subsisting agriculture necessary to maintain their family.

Report that authors such as and confirm the negative effects of hydroelectric projects on the fishing activity of riverside communities²⁶. Another relevant factor pointed out by is that hydroelectric enterprises will cause socio-environmental conflicts through the control and appropriation of natural resources for exclusively private purposes by triggering changes in the environment, as it will suppress the biosphere and the affective and symbolic bonds of the place which had been existing until that time²⁷. Given the above, the objective of this study is to analyze conflicts over water use and propose mitigation measures in the Hydrographic Region in Médio Tocantins by applying Game Theory.

Material and methods

This study was conducted out in eight municipalities located in the hydrographic basin of Médio Tocantins, which has a total area of 70,615.11 km². Approximately 130 km were traveled upstream of the Estreito HPP-MA to carry out information surveys related to conflict identification, comprising the municipalities of Carolina (MA); Filadélfia (TO), Babaçulândia (TO) and Palmeiras do Tocantins (TO), and 130 km downstream of the Estreito HPP-MA comprising the municipalities of Aguiarnópolis (TO), Estreito (MA), Porto Franco (MA) and Imperatriz (MA) (Figure 1). The choice of this distance

¹⁷ Dhiaulhaq et al., 2017.

¹⁸ Rufino, Lucena & Ribeiro, 2006.

¹⁹ Silva, 2019, 16.

²⁰ Brown, Tompkins & Adger, 2002. Soares & Lira, 2016.

²¹ Policarpo & Santos, 2008. Soares & Lira, 2016.

²² Galvão & Bermann, 2015.

²³ Calheiros, Castrilon & Bampi, 2018.

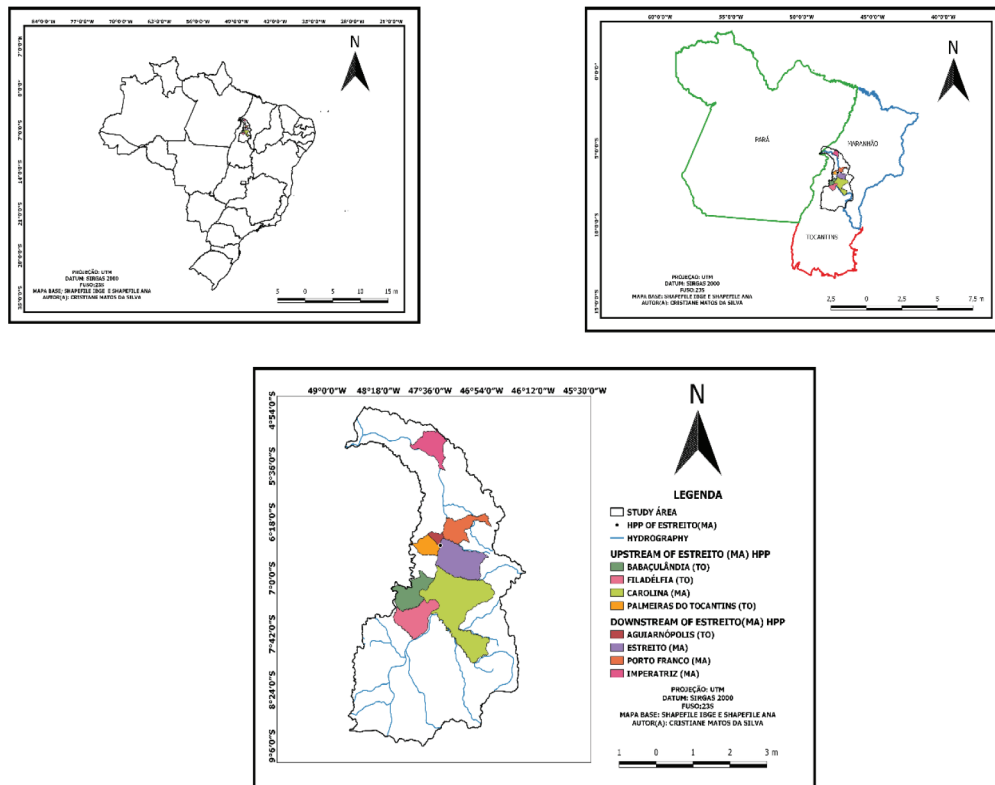
²⁴ ANEEL, 2019.

²⁵ Melo & Chaves, 2012.

²⁶ Agostinho, Gomes & Pelicice, 2007. Carvalho & Marques, 2018. Hess, Ribeiro & Wieprecht, 2016. Magalhães, Silva & Vidal, 2016.

²⁷ Thé & Azevedo, 2018.

Figure 1. Study area and boundary of municipalities



Source: Silva, 2019.

is due to the greater impact of the HPP on the lake coverage area both upstream and downstream.

After delimiting the study area, it was decided to divide the methodology into three stages:

First stage: consisted of identifying the main water users upstream and downstream of the Estreito HPP (MA). To this end, the federal grant data related to the Tocantins and Manuel Alves Grande and Pequeno rivers were collected on the National Water Agency (ANA) website from October 2017 to January 2019 through access to the data available on the HIDROWEB platform (Figure 2).

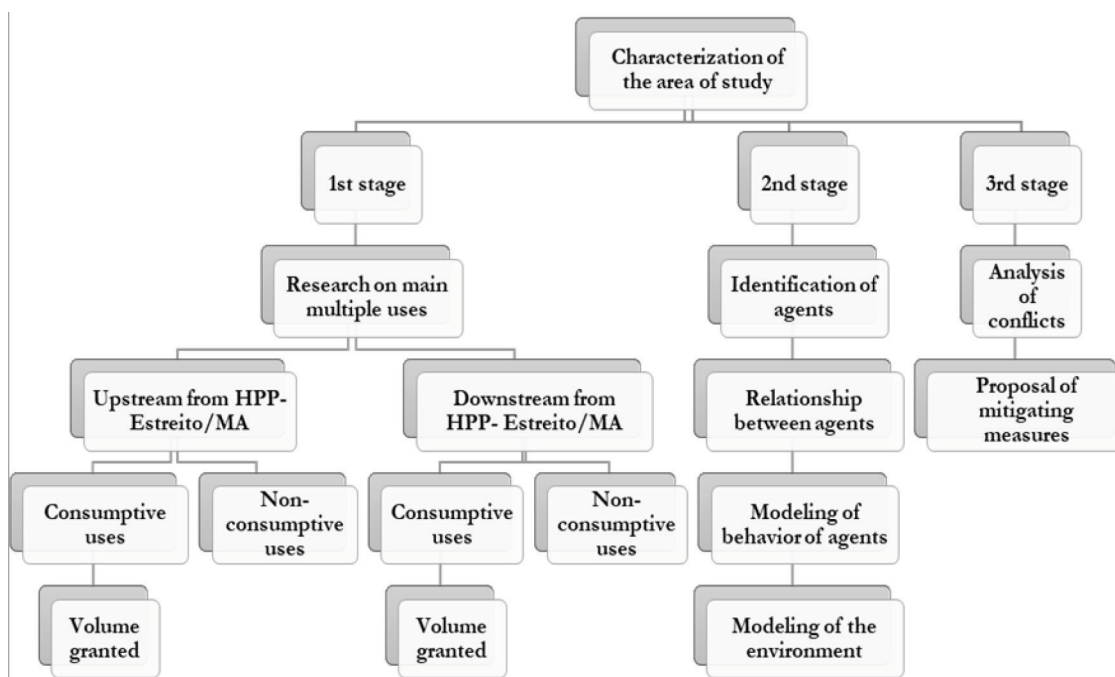
Second step: the “agents” were identified and the interrelation between them, determining how one user sees the other and vice versa; to do so, 50 semi-structured questionnaires were applied upstream and 50 downstream from the Estreito HPP (MA) containing 11 (eleven) questions related to the water uses and conflicts in the basin, aiming to assess the existence or not of conflict over water use in the selected municipalities and also those who are mainly responsible for this conflict in the perception of the interviewees. The questionnaires were applied to the following bodies and entities: State Secretariat for the Environment, City Halls, Agricultural Defense Agencies, the Association and Colony of Fishermen, representatives of the

trade sector, and the community in general. The interviewees were selected at random, taking care in each municipality to interview the same number of people and in the same bodies and entities in aiming to identify possible agents and factors which could directly and indirectly be generating conflict over water use.

In addition, the objective was to listen to the largest number of people who could be directly or indirectly connected to possible conflict scenarios, and then from this research to be able to independently analyze people’s perception of the existence or not of conflict in cities upstream and downstream of the HPP, and to analyze which areas are most sensitive to possible conflicts over water use, to verify the existence or not of similarity of conflicts in the municipalities both upstream and downstream of the HPP, in addition to generating and/or compare existing indices in the design of conflicting areas.

A modeling was subsequently performed with the collection of these data through applying the questionnaires based on an interpretative analysis of the obtained results, aiming to assess the behavior of the environment and identify the main conflicts over water use, thus providing support for completing the third and last stage of this methodology. After analyzing the data obtained by the questionnaires and modeling the environments, it is possible to verify which are

Figure 2. Methodology for analyzing conflicts over water use based on the Game Theory



Source: Silva, 2019.

the main players that will compose the third and last methodological stage.

Third and last step: Game Theory based on the Trade-off model proposed by; and presented by through a stakeholder analysis, multicriteria analysis and consensus building was applied after identifying possible conflict-generating agents to analyze conflicts over water use and its intensity degree, and later to propose mitigating measures^{28,29,30}. The Trade-off model enables integrating qualitative research with quantitative research in a more transparent way, which justifies the choice of this model for applying Game Theory.

Results and discussion

After analyzing the data extracted from the ANA website through the HIDROWEB platform regarding the federal water use grant, it was found that there is a difference in relation to the type of water consumption uses upstream and downstream of the Estreito HPP (BAD). The largest water use upstream was for irrigation, with the main types of systems used being irrigation by conventional system (99.77 %), drip/micro-sprinkler (0.19 %)

and micro-sprinkler (0.04 %). Mentions that irrigated agriculture can promote the following impacts: upstream interfere with dams, channels and transmission lines; downstream, due to the quality and availability of water to users, flora and fauna; contamination by the intensive use of agrochemicals; salinization; surface runoff and erosion, among others³¹. In addition, it can be said that conventional sprinkler irrigation tends to consume more water, since from the moment it simulates artificial rain it tends to be directly influenced by climatic variations such as wind and evapotranspiration. On the other hand, localized irrigation tends to consume a smaller amount of water because it applies small volumes of water under pressure and with high frequency in an extremely limited area.

It was identified that the largest water user downstream from the Estreito HPP (MA) was industrial use, with the paper and cellulose industry followed by the food industry as segments, in addition to other industrial segments. In comparing the main industrial segments which hold water use licenses downstream from the HPP, it is observed that the paper and cellulose industry has the highest percentage of use with 99.55 %, while the food industry has 0.30 %, and other branches of industry 0.15 %.

²⁸ Brown, Tompkins & Adger, 2002.

²⁹ Policarpo & Santos, 2008.

³⁰ Soares & Lira, 2016.

³¹ Schmidt, 2007.

The grant data presented corroborate with other studies already carried out in the country, as they present the largest water users in the irrigation and industry sectors. The volume percentages granted by these sectors in this study were quite similar, meaning that both had a percentage greater than 90 % both upstream and downstream of the dam, which can characterize them as potential conflict agents over water use.

Regarding non-consumptive users, there was a similarity of the Estreito HPP both upstream and downstream with the water use for fishing, leisure and navigation being reported in a percentage equal to 33.33 %.

Reports that the abundance of water in the lakes formed by dams in normal periods of rain and the possibility of opening and closing gates when necessary cover up contradictions and conflicts which only arise in periods of scarcity³². Therefore, when questioning the various bodies and sectors directly or indirectly involved with water use about the possible factors or agents which could generate or be generating conflict by using it in the area covered by the Estreito HPP, it was found that the main conflicting agents found upstream were: the Estreito HPP (30.30 %), followed by the company responsible for public water supply (21.21 %), the municipal public power (18.18 %), the population itself for the indiscriminate use of water (6.06 %),

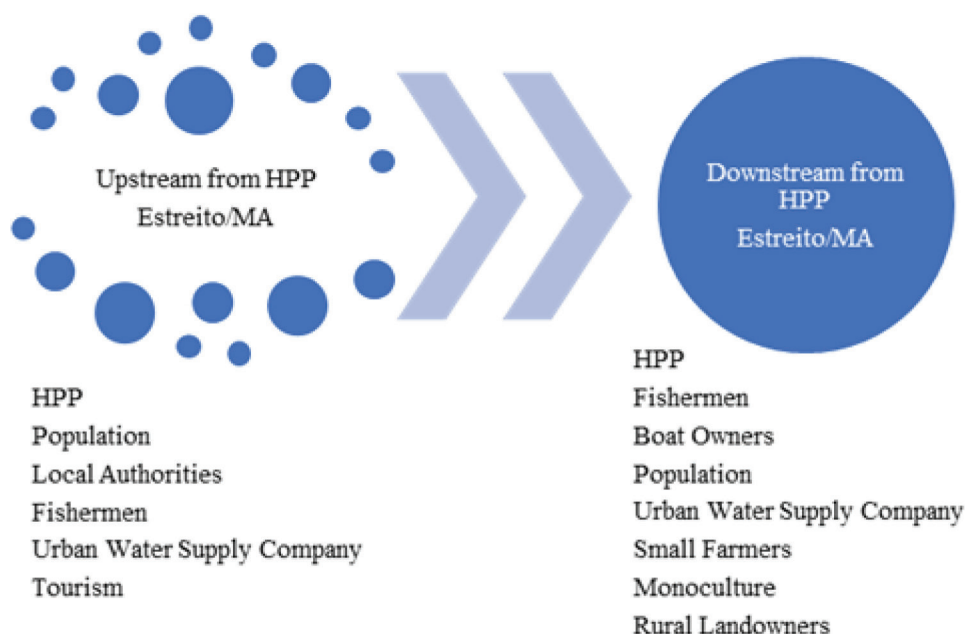
and deforestation (6.06 %). The Municipal Public Power (25.0 %) was indicated as the main cause of the conflict downstream, followed by the Estreito HPP (18.8 %), deforestation (9.4 %), forestry (6.3 %) and the water supply company (6.3 %). Other actors appeared in addition to these tied at 3.1 %, such as irrigation, the environment, artesian wells, lack of rain, river dredges and agriculture as conflict generators. With these results it is also observed that there are several agents which can directly and indirectly cause conflicts over water use.

After identifying these possible agents, applying the Game Theory based on the Trade-off model proposed by; and presented by, led to revealing the main conflict scenarios and their intensity degrees (Figure 4)³³.

In Figure 3 it is possible to observe that it was possible to identify the conflict scenarios and the intensity degree in which each occurs after application of the Game Theory, and varying them, at high, medium, and low levels.

The population, the urban supply company, the municipal agencies and the HPP were one of the scenarios with the highest levels of conflict due to a lack of dialogue between the sectors, high charges for supply rates and urban sanitation, and deficient resource application. These reports show that a high degree of conflict occurs when one or more agents do not dialogue

Figure 3. Main players upstream and downstream of the HPP - Estreito MA

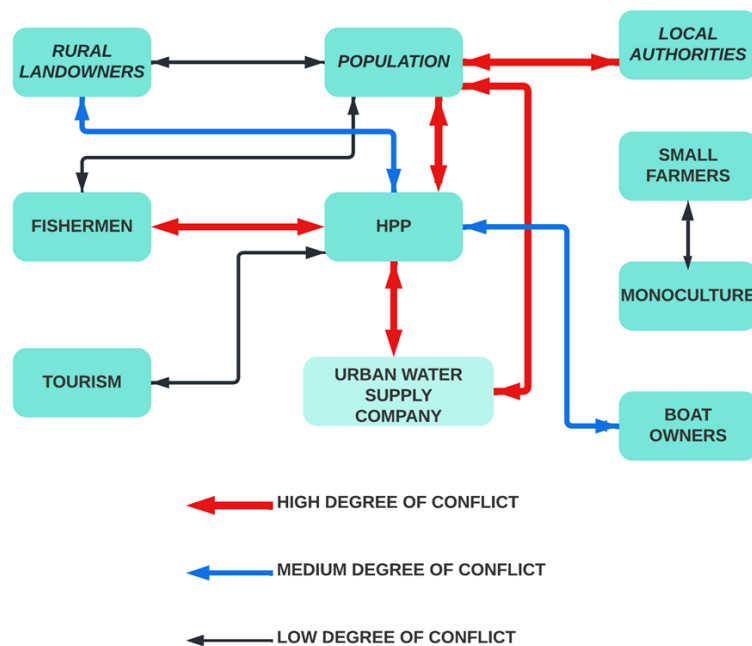


Source: Silva, 2019.

³² Moreira, 2017.

³³ Brown, Tompkins & Adger, 2002. Policarpo & Santos, 2008. Soares & Lira, 2016.

Figure 4. Conflict scenarios identified in the area covered by the Estreito HPP-MA and their respective intensity degrees



Source: Silva, 2019.

efficiently, or when there is no prospect of improving the scenario in the short, medium or long term. For example, the conflict between fishermen and the HPP which occur due to a lack of fish ladders and an increase in fish mortality due to water level variations from regularizing the flow in energy production.

A similar report was found by in the Médio Tocantins hydrographic basin in cities downstream from the Luís Eduardo Magalhães Hydroelectric Plant, which is located approximately 630 km upstream of the Estreito HPP³⁴. The authors of this study report that an alteration in the flood and ebb cycle and inefficient hydrological control intervened in the natural cycle of the river water level due to the constant environmental changes in the post-dam period, which caused a decrease in some varieties of fish species.

A medium degree of intensity occurred when there was a possibility of dialogue between the parties, with prospects for improving the scenario in the short and/or medium term. In this case, the conflicts which presented a medium degree of intensity were between the rural landowners and the HPP due to the prohibition of cultivation on the riverbanks, an activity which was very common before filling the HPP lake. In addition,

conflict between boat owners and the HPP because there is a greater variation in the river elevation with the opening and closing of the floodgates, thereby altering the berthing and navigation locations of boats and ferries, especially during the dry season, causing disturbances with changes in the places for passenger embarkation and disembarkation.

On the other hand, conflict with a low intensity degree were those which provide the understanding through dialogue and minimized conflict scenarios in the short and/or medium term. In the case of this study, the conflicts characterized with a low intensity degree were between landowners and the population; fishermen and the population; tourism and the HPP; and among small farmers and monoculture crops. all of these conflicts can be minimized in a short period of time when there is the possibility of dialogue; therefore, they are less impactful when compared to the other conflict scenarios presented above.

With everything now presented, it appears that Game Theory can be an especially useful tool for identifying agents, scenarios and degrees of conflict over water use, also helping in the possibility of arbitrating and mitigating these conflicts. To this end, it is worth noting that the evaluator's perception of possible agents and conflict scenarios built from Game Theory must

³⁴ Castro & Barros, 2015.

be impartial and suitable to ensure that all players (or agents) have all the possibilities analyzed, so as not to affect injuries which may generate conflicts in a scenario where previously there were none.

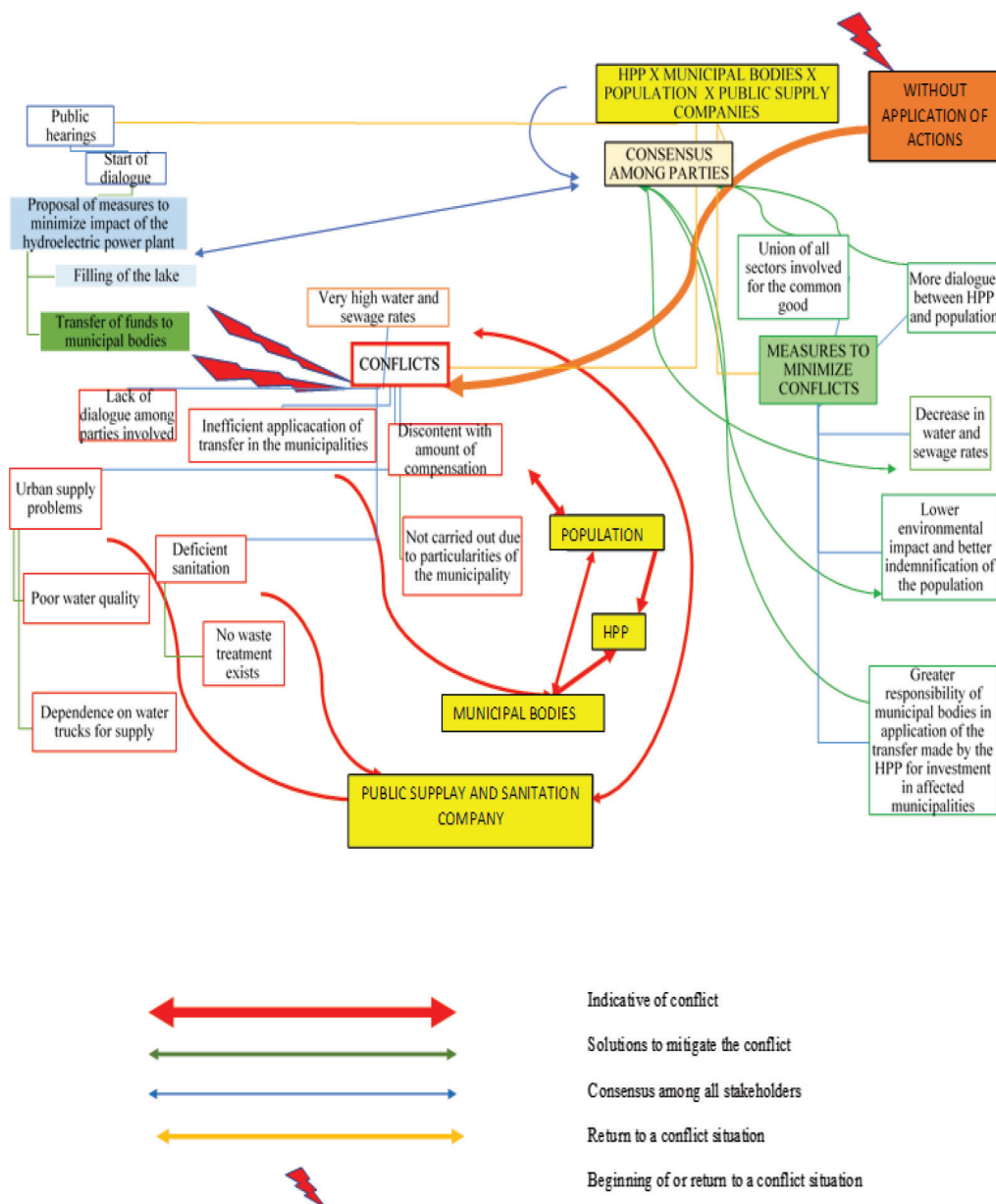
The mechanisms for regulation and management of water resources provided for in Law 9,433/97, which directs the integration and management of water resources, provided the following scenarios when applied in conflict scenarios using Game Theory:

Scenario 1: Conflict between the population and the HPP over the prohibition of drawing water from the hydroelectric lake: If a citizen who wants to draw water

from the river to implement an irrigation system had a grant for use granted by ANA or by the competent environmental agency, there would probably be no conflict. In this case the user would have an official document which authorizes them to perform this activity. Consequently, the HPP would have no reason to prevent the use of water resources (Figure 5).

Scenario 2: Conflict between the population and the urban sanitation company: the urban sanitation company in possession of a water use grant and which applied the charging mechanisms for this use would be obliged to carry out the proper treatment and disposal

Figure 5. Scenario 1 and Scenario 2: Conflict between the HPP, the Municipal Agencies, the Population and the Public Supply Company



Source: Silva, 2019.

of effluents, because this practice would imply in easing the amounts charged for the granting of water use, and consequently generating lower pollution levels of rivers and lower signs of conflict with the population (Figure 5).

Scenario 3: Conflict between the HPP and fishermen: both activities fall into the category of non-consumptive uses, and so they are exempt from being granted. In order to resolve conflicts through the use of grant instruments, it would be necessary for the Basin Water Resources Plan to include the mandatory implementation of a fish ladder in the dam of the hydroelectric plant (for example), in addition to providing restocking of native fish species in case of verification of their decrease and/or extinction, which in turn would alleviate the conflict scenarios (Figure 6).

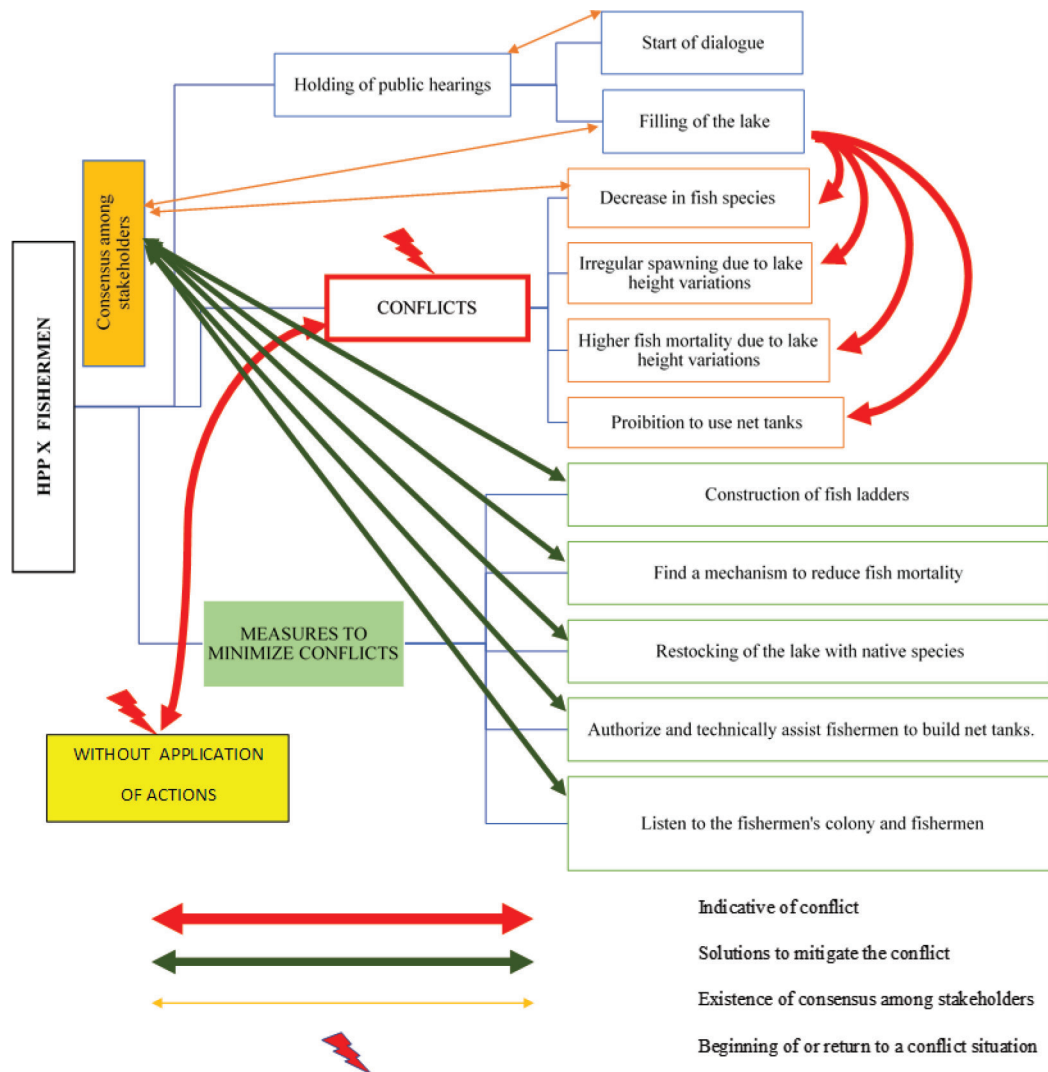
Scenario 4: Conflict between the population and the pig farmers: in application of water resource management and management instruments, pig farmers would

have to carry out the treatment of solid residues from animal waste before discarding them in the environment, as the pollution caused by this activity impacts underground water sources and nearby rivers. Therefore, if the disposal of this residue is foreseen in the Basin Water Resources Plan and the application of inspection with the grant of discharge of effluents, the conflict would be minimized.

There are mechanisms for regulation and management of water resources for this provided for in Law 9,433/97 which direct the integration and management of water resources. A summary of the application of these instruments is provided in Figure 7 in a scenario of consensus and/or conflict over water use which can be used in any hydrographic basin.

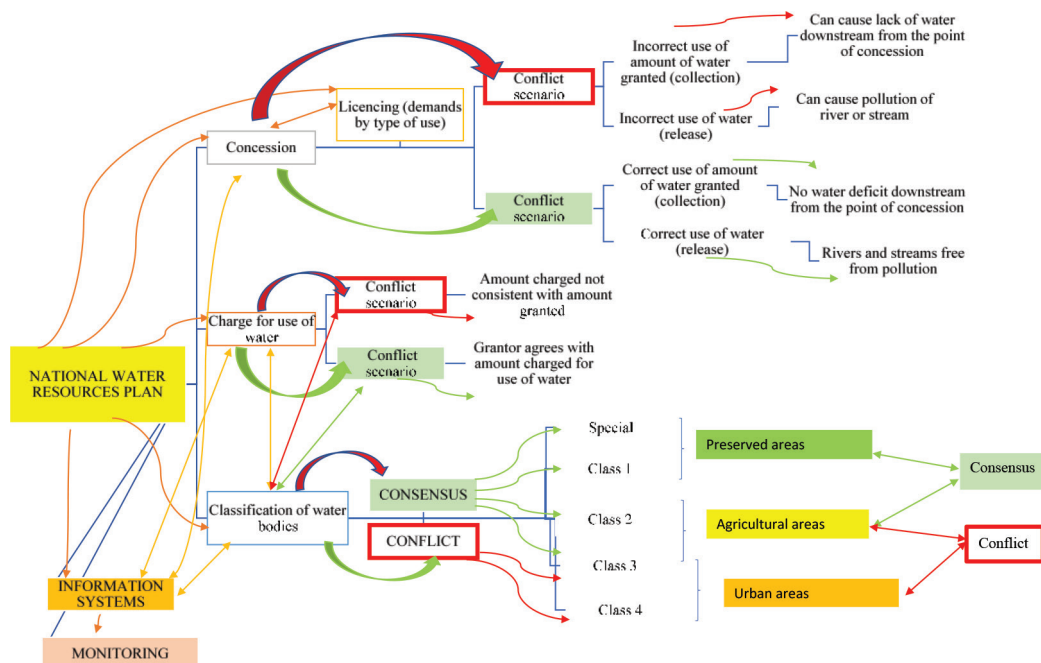
In a study on the importance of the instruments of the National Water Resources Policy, states that the integration of these policies with their respective

Figure 6. Scenario 3: Conflict between the HPP and the Fishermen



Source: Silva, 2019.

Figure 7: Application of the instruments provided for in the regulation of water resources as a trigger of conflict or consensus for water use



Source: Silva, 2019.

incorporating instruments is important for the evolution and progress of society, as they assist in planning and work as a roadmap for the public administrator in its sustainable management³⁵.

State that when civil society participates in collegiate bodies, instances and entities, which deal with issues of collective interest and of general scope, the result is a successful process regarding the democratic management of water resources³⁶.

However, the instruments provided for in Law 9,433/97 are of no use if there is not a correct and intense inspection of Organs management bodies in its applicability, because only in this way will there be the possibility of conciliation between the interested parties, in turn easing the existing conflict scenarios.

Furthermore, state that the individual assessment of each of the conflicts raised should be taken to the Hydrographic Basin Committee so that discussions can seal agreements between uses and guarantee their priority³⁷. They also highlight the need for the institution of the National Water Resources Policy Instruments to mediate the conflicts in the basin.

Considering that the hydrographic basin of the Médio Tocantins does not have a Committee installed to

perform conflict arbitration, the beginning of a discussion about the importance of creating a Hydrographic Basin Committee for Médio Tocantins is suggested, as it would enable dialogue and interaction among users, would be a mediating instrument for the management of water resources in this basin, and would facilitate implementation of the Instruments of the National Water Resources Policy, favoring conflict mediation over the use of water in the Médio Tocantins Hydrographic Basin.

Conclusion

It is concluded with this study that the use of Game Theory as a tool to identify conflict scenarios due to water use proved to be quite effective, making it possible to characterize the intensity degrees with which they can occur.

It was also verified that there are possibilities for the analyzed conflict scenarios by the Game Theory to be mitigated when the instruments foreseen in Law 9,433/97 are applied, thus showing that modeling the conflict scenarios for water use made with this tool in applying the regulation instruments and management of water resources is highly effective in minimizing conflicts over water use in a basin.

³⁵ Gomes, 2018.

³⁶ Melo et al., 2018.

³⁷ Passos et al., 2018.

The importance of the discussion about creating a Hydrographic Basin Committee for Médio Tocantins is emphasized to guarantee conflict mediation and arbitration over the use of water, since this study demonstrated that the lack of dialogue between users is the main trigger of conflicts in the basin both upstream and downstream of the Estreito HPP.

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