Conflict analysis in implementing water resources management instruments

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Abstract Water resources management instruments are often pointed out as resolution tools for conflicts caused by water scarcity (first-order conflicts). However, the very tools adopted in order to manage water scarcity may indirectly cause second-order conflicts. This paper describes second-order conflicts, which can occur from implementing water permits and bulk water fees (according to the new Brazilian Water Law), analysing the conflict (urban supply *vs* irrigation) over a reservoir located in a semi-arid region of northeastern Brazil. Scenarios are built, based on: (a) conflict history, climate and hydrological regional conditions; (b) institutional, social and economic reality in the reservoir influence area; (c) three water management stages; and (d) different water permits and bulk water fees systems. Scenarios comparison gives information about management instruments attenuation/synergism potential, in relation to first-order conflict. Results presented by second-order conflict modelling can drive political decision-making for effective first- and second-order conflicts management.

Key-words Brazil; bulk water fees; second-order conflicts; semi-arid; water permits

INTRODUCTION

Water resources management instruments are often pointed out as resolution tools for conflicts over access to scarce water resources (first-order conflicts). However, the very tools adopted in order to manage water scarcity may induce second-order conflicts, due to a failure in introducing the correct kind, or the sufficient amount, of adaptive measures to that scarcity (Ohlsson, 1999).

Brazilian Water Law (Law 9433/1997) recognizes water as a public and finite good with economic value, and establishes five instruments in order to attain efficient and sustainable water use, ensuring decentralized and participatory water resources management: water resources plans, water bodies' classification, water permits, bulk water fees, and water resources information systems. Among these instruments, water permits (for assuring water uses, quantitative and qualitative control and effective access to water, through temporary administrative licenses conditioned to uses priorities) and bulk water fees (for giving users an indication of water's economic value, inducing rational water use, and obtaining financial resources to support programmes and interventions included in water resources plans; the fees must be applied to water volumes allowed by water permits)—as they contradict Brazilian peoples perception of water as a free good, introduce water allocation rules, and present economic consequences—have high potential to induce second-order conflicts.

Although Brazil has the largest volume of freshwater on the globe, in its semi-arid and drought-prone northeastern region the competition over limited water resources increases, aggravated by low social and economic development. These conditions emphasize the urgency of better water management and expand the risk for second-order conflicts.

This paper analyses the consequences of implementing water management instruments to manage a first-order conflict over water uses (urban supply *vs* irrigation), based on the case of a reservoir located in the semi-arid region of Paraíba River basin, State of Paraíba, northeastern Brazil. Considering different water management stages and instruments, and using the GMCR II (Hipel *et al.*, 1997) implementation of the graph model for conflict resolution methodology (Fang *et al.*, 1993), scenarios are built and modelled in order to drive political decision-making for effective first- and second-order conflict management.

FIRST-ORDER CONFLICT (STATUS QUO)

The Epitácio Pessoa reservoir (412×10^6 m^3 gross capacity) is the second largest water reserve in the State of Paraíba; it is located in the semi-arid portion of the Paraíba River basin, in the driest region of Brazil, where (a) the average annual rainfall is 494 mm; (b) rainfall is concentrated into four months of the year and presents high inter-annual variability; and (c) evaporation rates are very high. The reservoir provides water for human supply, irrigation, tourism, and fisheries.

The conflict over water uses had started by the end of 1998; due to a severe drought period (from 1998 to 2000) and withdrawals (1 m^3 s^{-1}) for irrigation upstream of the reservoir, the reservoir storage was around 15% of its capacity; consequently, 500 000 people—in 17 cities, including Campina Grande, the second largest city in the State of Paraíba, and an important educational, industrial and technological centre in northeastern Brazil—were submitted to a tight water rationing (November 1998 to March 2000). Downstream releases (0.25 m^3 s^{-1}) had already been interrupted (July 1998) and irrigation was forbidden, due to a court decision, in February 1999 (see Galvão *et al.* (2001), for detailed crisis description).

The water crisis caused social and economic problems: (a) to the cities, where water rationing penalized their poorest inhabitants, restricted industrial production, and caused financial losses for all economic sectors; (b) to the farmers, since the irrigation suspension caused loss of livelihoods and incomes, and forced migration to cities; and (c) to fishery and tourism activities, due to the very poor water quality of the reservoir water.

Since January 2004, wet rainy seasons have kept the reservoir storage near to capacity. Nowadays, the situation is as follows: (a) the reservoir regularized discharge is defined as 1.23 m^3 s^{-1} (guarantee of 100% for human supply, which demands 1.08 m^3 s^{-1}); (b) clandestine withdrawals amount to 0.80 m^3 s^{-1} for irrigation upstream of the reservoir; cultural and economic reasons (for 90% of the farmers, family income is lower than US$ 318 month^{-1}) impeding most of the farmers from adopting saving technologies, and keeping them practicing flood irrigation, which demands more water; (c) at the reservoir margins, including the legal preservation zone (100 m), uncontrolled use of pesticides, along with other pollution sources (pigsties, domestic effluents, solid waste, etc.), affect the reservoir water quality; (d) the lack of institutional articulation (DNOCS—National Department for Drought Control manages the reservoir and the lands around it; AESA—Executive Agency for Water Management in State of Paraíba manages the rivers which feed the reservoir; CAGEPA—Paraíba Water Supply and Sewage Company is the main user of the reservoir water; and three municipalities (Barra de São Miguel, Boqueirão and Cabaceiras) are responsible for implementing infra-structures on the reservoir region obstructing integrated water management; and (e) network leakages vary from 22.68% to 74.65% of the water withdrawn for urban supply (the average leakage is 51.73%); for Campina Grande supply such leakages amount to 49.62% (corresponding to 1.20×10^6 m^3 $month^{-1}$) of treated water.

The absence of concrete measures to solve the problem, in addition to the facts mentioned above, show that the first-order conflict over water uses still exists (although it is hidden by suitable hydrological conditions) and can rise out of a new severe drought period.

MANAGEMENT SCENARIOS

Focusing on the reservoir water quantity issue, management scenarios were built based on: (a) the status quo: (b) several water management stages and measures; and (c) the results of interviews carried out with farmers and institution representatives.

Scenario I: Minimum management

This scenario adopts only one water management measure: the *definitive suspension of irrigation* upstream of the reservoir; this measure is a possible court decision and constitutes the urban sector's most preferred option. So, institutions (DNOCS and AESA) must exercise a rigorous control, in order to guarantee the measure's execution; and the farmers can: (a) accept suspension—based on the consequences of irrigation suspension, from February 1999 to April 2000 (when control was reduced), one can foresee serious economic losses, both to the farmers and the municipalities where they live, due to loss of livelihoods, migration, unemployment rates increasing, etc.; or (b) not accept suspension—civil disobedience would intensify the first-order conflict, and would affect both the farmers and the cities supplied by the reservoir; the farmers argument that they cannot accept irrigation suspension because "they cannot pay for CAGEPA network leakages and urban consumers' water wastes".

Scenario II: Implementing water permits and bulk water fees

Three alternative scenarios were considered, comprising two water permits systems and one bulk water fees system.

Scenario II.1 water permits without bulk water fees (very rainy years) The reservoir storage is considered near to its capacity. Water permits for urban supply and irrigation are granted for the present withdrawals (1.08 and 0.80 $m^3 s^{-1}$, respectively), but the latter must be renewed annually. Irrigation will be suspended when the reservoir storage is inferior to 80% (i.e. $330 \times 10^6 m^3$) of its capacity.

In relation to the status quo, this water permit system just legalizes the reservoir usage situation that occurs at present, and increases the need for withdrawals control. The absence of bulk water fees makes it difficult to punish infringements (withdrawals beyond allowed volumes). Eventual water permits suspension sends the situation to Scenario I and its consequences.

Scenario II.2 water permits without bulk water fees (rainy years) Water permits for urban supply consider the same withdrawals taken at present (1.08 $m^3 s^{-1}$); water permits for irrigation are granted, annually, but withdrawals amounts will be reduced as the reservoir storage diminishes. Irrigation will be suspended when the reservoir storage is inferior to 50% ($206 \times 10^6 m^3$) of its capacity.

In relation to Scenario II.1, this one presents the advantage of expanding the irrigation practice time; however, it requires even more withdrawals control. Very dry years—when the reservoir storage reduction demands the irrigation suspension—will send the situation to Scenario I.

Scenario II.3 implementing water permits and bulk water fees Related to Scenario II.2, the sole difference for irrigation water permits is that bulk water fees implementation (putting bigger values on withdrawals which exceed the allowed volumes) will restrain abuses. Water permits for water supply still consider the same withdrawals (1.08 $m^3 s^{-1}$), but they must be reduced through time. Bulk water fees for water supply are to be paid by: (a) the consumers, according to the effectively consumed water volume (micro-measurement); and (b) the water company (CAGEPA), according to the difference between total withdrawals (macro-measurement) and total micro-measured volumes. This bulk water fees system intends to induce consumers to use water rationally, as well as the water company to reduce network leakages, leading to smaller abstractions from the reservoir (for example, reducing leakages to 25% of total withdrawals for water supply is equivalent to taking 0.29 $m^3 s^{-1}$ less water from the reservoir).

Second-order conflicts may result, mainly, from: (a) failures on controlling withdrawals for irrigation and water supply, and on implementing bulk water fees (collection, adopted values, etc.); (b) users' lack of investment (and/or payment) capacity; and (c) low acceptance of the bulk water fees system. If withdrawals (for water supply and/or irrigation) are not reduced, the irrigation suspension may become necessary, sending the situation to Scenario I.

Scenario III: Integrated management

Water permits and bulk water fees (as in Scenario II.3) will be implemented after a river basin committee has been installed and the water resources plan for the Paraíba River basin has been approved.

Second-order conflicts can be induced by: (a) the same difficulties already identified at Scenario II.3; (b) failures in river basin committee actuation; and (c) insufficient institutional articulation. Such factors can send the situation to Scenario II.3 and, probably, to Scenario I.

Scenarios comparison

Kepner-Trigoe multicriterial methodology (Kepner & Trigoe, 1981) was used, based on the following criteria: (a) lack of institutional capacity to implement the management measures; (b) existence of negatively affected social groups; (c) economic impacts seriousness; (d) social impacts seriousness; (e) possibility of tension between social groups; (f) lack of measures to mitigate impacts; (g) groups' incapacity to adopt mitigating measures; and (h) scenario dependence on climate. Criteria points ranged from 0 to 10 and were attributed in a subjective manner. The scenarios were ranked, according to the criteria points sum, from the biggest score (more synergism, Scenario I) to the smallest one (more attenuation, Scenario III), as indicated in Table I.

Table 1 Scenarios comparison: first-order conflict synergism/attenuation.

Criterion	Scenario				
	I	II.1	II.2	II.3	III
Institutional incapacity	7	6	5	5	4
Affected social groups	10	8	8	6	5
Economic impacts	10	8	6	6	6
Social impacts	10	8	5	5	6
Intergroup tension	10	8	6	4	3
No mitigating measures	10	10	10	10	2
Social groups incapacity	10	10	10	10	8
Dependence on climate	10	10	8	5	3
Score	77	68	58	51	37
	Synergism	←================→			Attenuation

I, Irrigation suspended; II.1, Water permits (reservoir storage > 80%); II.2, Water permits (reservoir storage > 50%); II.3, Water permits (as in II.2) and bulk water fees; III, Water permits, bulk water fees and river basin committee and water resources plan.

MODELLING AND RESULTS

Conflict resolution model

Conflicts modelling utilized The Graph Model for Conflict Resolution, GMCR (Fang *et al.*, 1993), which is an abstract game model mathematically based on Game Theory and on Graph Theory. The decision support system GMCR II (Hipel *et al.*, 1997) implements the graph model methodology within a Windows environment, based on the following structure: (a) the *modelling subsystem*, which allows users input players (decision makers), options (actions available to each player), patterns of infeasible states (a state is a possible combination of players' options), allowable transitions (players' unilateral moves, from a state to another) and preference information (the players' relative preferences in connection with any feasible state the conflict may take up), and generates the required inputs for stability analysis, including feasible states, and ranking of states for each player; (b) the *analysis engine*, which performs a thorough stability analysis on the conflict model, based on the information generated at the modelling stage and on various solution concepts (the players behavioural standards), in order to calculate the individual stability of each state for each player; and (c) the *output interpretation subsystem*, which presents the results from the analysis engine in a user-friendly manner, allowing them to be easily identified and compared, and defining the equilibria of the game (states which are stable for all players), i.e. the possible solutions to the conflict.

Modelling management scenarios

Prior to modelling second-order conflicts induced by management measures, the GMCR II was used to model the management scenarios, in order to identify the equilibria one could expect.

At first, the management scenarios were modelled, without considering the role played by institutions, and the following results were obtained: (a) irrigation suspension, in any scenario, is unaccepted by the farmers; (b) water permits, while in force, are a possible solution to the first-order conflict, even when withdrawals for irrigation are reduced; (c) bulk water fees for water supply are accepted (with reluctance) by urban users (consumers and the water company), and approved by the farmers; bulk water fees for irrigation are highly rejected by the farmers, and approved by urban users; and (d) river basin committee installation and water resources plan approval can change the farmers' position in relation to bulk water fees on irrigation. Such results make it clear that irrigation suspension and bulk water fees for irrigation present a high potential to become second-order conflicts sources.

Secondly, institutions' influence was modelled based on their institutional capacity (staff and equipment) and articulation; it was assumed that "high capacity and high articulation" lead to "rigorous control", while "low capacity and/or low articulation" lead to "control failure". Modelling results analysis indicate that: (a) "rigorous control": (i) irrigation suspension induces farmers' migration, resulting in serious economic losses; (ii) all users comply with water permits; (iii) bulk water fees (water supply and irrigation) are accepted, but, in the long run, the farmers have a tendency to not pay them; and (b) "control failure": (i) irrigation suspension induces clandestine irrigation; (ii) in the short run, all users comply with water permits, but, in the long run, the farmers tend to practice clandestine irrigation; (iii) in the short run, bulk water fees are accepted; in the long run, the water company tends to not reduce leakages and not pay fees, and the farmers tend to not pay fees. Again, results analysis makes clear the potential of irrigation suspension and bulk water fees (irrigation) to induce second-order conflicts; it also indicates two situations which act as catalysts for such conflicts, namely, "low institutional capacity/articulation" and "low farmers' representation within the river basin committee". Figure 1 shows the kind of second-order conflicts which can be induced by these management measures and catalyst situations. River basin committee installation, either in (a) and (b), alters farmers' tendency to not pay bulk water fees, since their representation is high; and, in (b), it alters the water company tendency to not reduce leakages and not pay fees; so, river basin committee already appear as a solution to avoid or to minimize some second-order conflicts.

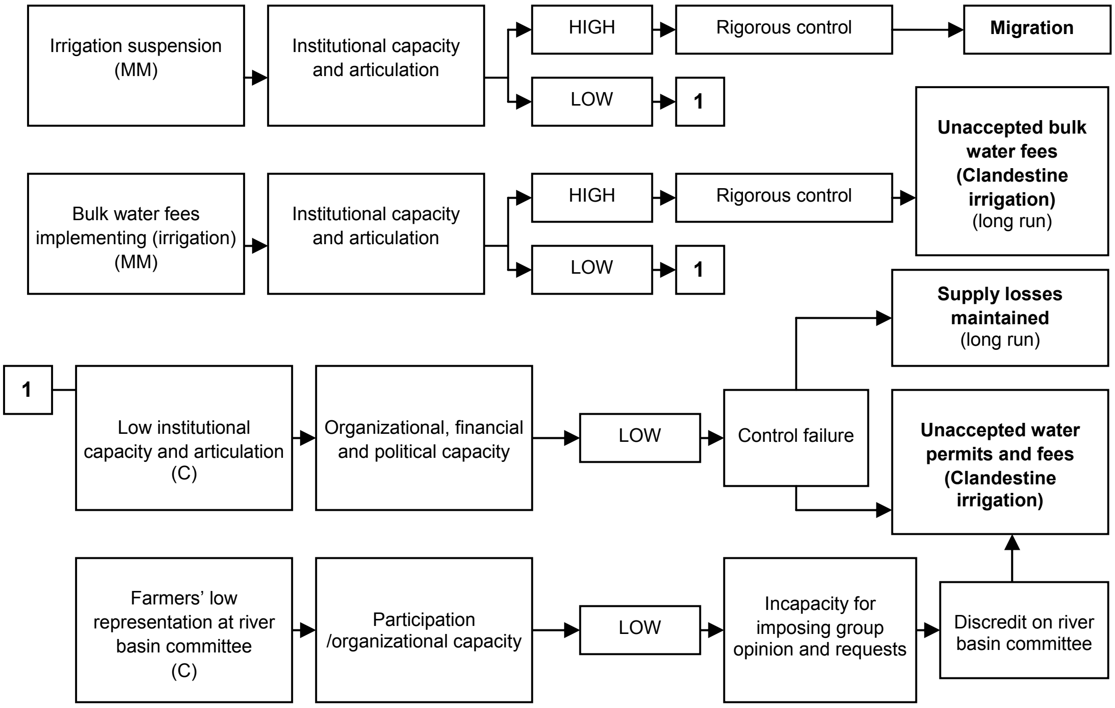

Fig. 1 Second-order conflicts (boldface) induced by management measures (MM) and catalysts situations (C).

Modelling second-order conflicts

Based on second-order conflicts identified by management scenarios modelling, the GMCR II was used to verify which actions must be adopted in order to avoid/minimize such conflicts. Considering the results obtained with river basin committee installation (along with farmers' high representation), and assuming that "failure control", consequences can be avoided by strengthening institutions (by making their organizational, financial and political capacities greater), the second-order conflicts modelled were "migration" and "unaccepted water permits and bulk water fees" (this latter, caused by farmers' discredit of the river basin committee).

Since migration only occurs in a high institutional capacity/articulation environment, it was assumed that the actions would be adopted, in a complementary manner, by state and municipalities governments. So, migration was modelled based on some actions directed at the farmers, the reservoir margins (legal preservation zone) reforestation; education and technical capacitating for other economic activities; incentives to change economic activity; inclusion in minimum income programmes or guarantee of access to market and financial resources), and on the farmers' total or partial acceptance/rejection of such actions. Modelling results analysis indicates that: (a) total or partial acceptance of any action occurs when the action is adopted along with "inclusion in minimum income programmes or guarantee of access to market and to financial resources"; (b) "incentives to change economic activity" is the most rejected option (due to cultural factors, mainly); and (c) "the reservoir margins (legal preservation zone) reforestation" presents total acceptance when controlled irrigation ($0.15\ m^3\ s^{-1}$) is allowed along with it.

"Unaccepted water permits and bulk water fees (irrigation)" modelling considered some river basin committee's actions in order to stimulate farmers' participation (environmental education programme; financial resources to facilitate saving technologies adoption; technical support to increase productive efficiency; water prices adequacy in order to reduce impacts), and the farmers' total or partial acceptance/rejection of them. Results analysis shows that: (a) "water prices adequacy to reduce impacts" is the most preferred option; (b) "technical support to increase productive efficiency" is totally accepted when accompanied by "financial resources to facilitate saving technologies adoption"; and (c) "environmental education programme" is partially rejected by the farmers, independently of the other actions adopted along with it.

CONCLUSIONS

Modelling scenarios allowed a systematic analysis of the consequences (second-order conflicts) which could occur from implementing water management measures. The interpretation of results made evident: (a) the risks of suspending irrigation; (b) water permits potential as a solution to the first-order conflict; and (c) the role that can be played by the river basin committee—mainly when the farmers participate in the decision-making process—and how important and necessary are institutions' strengthening and articulation, as a means to avoid some kinds of second-order conflicts. Modelling second-order conflicts made clear: (a) how costly avoiding/minimizing migration can be; (b) the need for an adequate bulk water fees system, in order to raise users' acceptability; and (c) how important the economic aspect (minimum income, financial resources, etc.) is for conflict resolution. "Environmental education programme", despite its low acceptance, appears as a necessary action in order to help water management institutions to modify the (unacceptable) irrational water use patterns, which are now practiced by farmers and urban users. These results can support political decision-making for solving the conflict over the Epitácio Pessoa reservoir.

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