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Empowering small stakeholders groups in selecting a long-term water management plan

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ABSTRACT

Strategic water management on a river basin scale requires the inclusion of stakeholders from different sectors and the use of methodologies based on scientifically sound models and techniques, keeping in mind that the power of smaller and larger subgroups of stakeholders should be equal. In this paper, we present an approach to tackle this problem based on two Social Choice Theory (SCT) methods: preferential Borda Count and no-preferential Approval voting method. Two different scenarios of grouping members of the water committee of the San Francisco River Basin in Brazil are simulated, by interested sectors and by interested delegates from the states where the river passes through, five long-term management plans are evaluated and voted in either scenario. Results indicated that if members of the committee demonstrate reasonable competency and consistency while setting their judgments on management plans, the final group decision is the same or similar, regardless the method used. One of the conclusions is also that the voting of small subgroups may have the same power as the voting of a large subgroup in the social choice-based decision-making processes. SCT methods can thus be recommended as an equity framework to empower small groups in selecting long-term water management plans.

Key words: Approval voting, Borda count, Empowering a small group, Management plans, Voting, Water committee

HIGHLIGHTS

- Water management is, in many cases, a participatory process.
- The decision-making process should enable equity and fairness.
- Small stakeholders groups often do not have the same power as large ones.
- Social choice-based decision-making has been found as a suitable framework to empower small stakeholders groups.

1. INTRODUCTION

Managing water resources is a complex process that influences the lives and activities of people, sustainability of nature, effects of climate changes, etc. As such, it is recognized as a process that requires delegating the decision process not only to technical experts but also to different stakeholders. Participation of stakeholders is set as suggested or is mandatory in many international legal documents, and it is realized in different ways – water committees at various levels, water user associations, community participation, workshops for selected prescreened participants, advisory groups, citizens juries, etc. Although committees should ensure improvement of the decision-making process, there are various problems that committees face. Using stakeholder and complexity theories, Barbosa *et al.* (2017) evaluated the interactions of different stakeholder groups present in river basin committees in São Paulo, Brazil, and concluded that committees are not enabling adequate interaction between

stakeholders. Besides the need to manage consensus building and conflict, ensuring the perception that benefits from participation exceed costs, and identifying the criteria for a legitimate process and decision, Car (2015) also emphasized the importance of managing asymmetrical power relationships between participants. Similarly, Butler & Adamowski (2015, p. 3) stressed that 'equitable solutions, wherein resources are distributed in such a way that ensures a sufficient quality of life for all, cannot come out of an inequitable process; they can only be achieved if anti-oppressive practices are implemented'. Concerning this, it is of utmost importance to create a collaborative platform that gives equal power to all stakeholders and stakeholders groups.

Approaches that can ensure equality of different stakeholders' groups are the use of Social Choice Theory (SCT) methods (Arrow, 1951), particularly Borda Count (BC) (De Borda, 1781; Emerson, 2013), and Approval Voting (AV) (Brams & Fishburn, 1978; Kelly, 1988). More on the theory of these two methods can be found in Ishida & Oguro (2017), Srdjevic (2007), D'Angelo *et al*. (1998), Goetz *et al*. (2007), and Srdjevic *et al*. (2019), and on their applications in solving different group decision-making problems in reported studies (Srdjevic & Srdjevic, 2013; Madani *et al*., 2014; Mahjouri & Pourmand, 2017).

Borda Count and Approval Voting belong to the classes of preferential and non-preferential methods, respectively. To use these 'election' methods in the initial phase of the voting process, participants should be identified and briefed about relevant criteria and alternative plans. Then, an appropriate evaluation sheet should be prepared and distributed to individuals and subgroups. By ranking (Borda Count) and ticking (Approval Voting) offered options in a sheet, participants in different decision-making scenarios set their preferences and approvals. This way it was possible to collect and 'aggregate' their votes and come up with the required ranking of criteria and alternative management plans.

To verify the approach to empower small groups of stakeholders, the committee of the San Francisco River (SFR) Basin in Brazil has been selected as the case study. A workshop during the training course on water management at the School of Polytechnic of the Federal University of Bahia (Salvador, State of Bahia) was organized to simulate the decision-making process within the committee. A selected group of postgraduate students and professionals from different water-related sectors acted as stakeholders groups relevant to assessing and deciding about the best long-term development plan for the basin. For simulation of the decision-making process during the workshop, two different scenarios of grouping workshop members were simulated, first by interested sectors for using water in the basin, and second by interested delegates from the states where the river passes through. In either scenario, five long-term management plans were evaluated and voted on. In the case study application, Section 3, only the outcomes – ranks of five assessed management plans – are discussed in more detail. Intermediate results, such as assessment and evaluation of criteria set in different scenarios and at the individual, subgroup, and group level, are intentionally omitted in order not to infer any political misunderstanding or provide misleading information.

This paper is organized in the following way. After the introduction (Section 1), preliminaries on SCT methods used in this study are given in Section 2. An application of the SCT-based methodology within a simulated paradigm set up for the San Francisco Basin and its water committee which is responsible for adopting water management plans is described in Section 3. Concluding remarks and recommendations are given in Section 4.

2. BORDA COUNT AND APPROVAL VOTING METHODS

Collective choice is an often-discussed problem area in the social-science literature, and many authors have suggested solution methods to find the best decision under conflicting preferences of the decision-makers and/or interest groups (IGs). For solving a particular case, it is a very difficult problem to select the right method, since there are a large variety of methodologies to choose from, and the different methods are based on different concepts and mathematical formulations of justice and fairness. Therefore, the use of two different solution

concepts and methods usually gives different results. This is the main reason why the comparison of different methods applied to the same problem is useful to both scientists and practitioners since the detailed analysis of the results helps to find the most appropriate solution methodology in similar cases.

Herein, two social choice procedures are presented as a possible method of democratic decision about water management problems in the SFR Basin (D'Angelo *et al*., 1998; Srdjevic, 2007; Srdjevic *et al*., 2019). The first one is Borda Count which belongs to the class of preference voting methods. The second one is Approval Voting which belongs to a class of no-preferential methods.

2.1. Pay-off table

Application of SCT elective methods such as Borda Count commonly requires creating a pay-off table and enabling the mathematical formulation of a large class of decision problems (including the problem presented in Section 3). Consider a set of n alternatives to select from, and let m denote the number of criteria to be used for evaluating the quality of alternatives. The alternatives can be ranked concerning each criterion, and based on the ranking, a mxn pay-off table (Table 1) can be constructed, with rows corresponding to criteria and columns corresponding to alternatives. Each row represents the ranking of the alternatives concerning the criterion corresponding to this row.

Let i be a row, and let a_{ij} denote the jth element (rank of jth alternative) of this row. If j is the best alternative concerning this criterion, then $a_{ij} = 1$; if j is the second-best alternative, then $a_{ij} = 2$, and so on; if jth is the worst alternative, then $a_{ij} = n$. This way each row of the pay-off table is a permutation of integers 1,2,…, n. Based on the rankings (or equivalently on the pay-off table), one preferential and one no-preferential method applicable to find the overall best alternative are outlined below.

2.2. Preferential voting method Borda Count

Points have to be awarded to each preference list (that is, to each column of the pay-off table) in the following way. The worst alternative gets zero points, the second-worst alternative gets one point, the next up gets two points, and so on, and the very best alternative gets $n - 1$ points. For each alternative, these points should be added up, and the alternative with the highest sum is declared to be the social choice. More details on this method, as well as its mathematics can be found in D'Angelo *et al*. (1998), Srdjevic (2007), and Srdjevic *et al*. (2019).

Table 1 | Pay-off table.

	Alternatives					
Criteria	**Alt. 1**	**Alt. 2**	**…**	**Alt. *j***	**…**	**Alt. *n***
Crit. 1	a_{11}	a_{12}		a_{1j}		a_{1n}
Crit. 2	a_{21}	a_{22}		a_{2j}		a_{2n}
…						
Crit. i	a_{i1}	a_{i2}		a_{ij}		
…						
Crit. m	a_{m1}	a_{m2}		a_{mj}		a_{mn}

2.3. No-preferential Approval Voting method

Among voting methods that are no-preferential, the Approval Voting procedure is the most used one in which voters can vote for as many candidates as they wish. Each approved candidate receives one vote with the method, and the candidate with the most votes wins. Approval Voting can be separately applied to the criteria set and alternatives as two different sets of candidates. The method does not use information from a preference schedule like the preferential method Borda Count (Kelly, 1988; D'Angelo *et al*., 1998; Kangas & Kangas, 2003).

Approval Voting has several compelling advantages over other voting procedures because it gives voters more flexible options and it helps to elect the 'strongest' candidate; in certain contexts, 'strongest' may mean 'most qualified' or 'most popular' (candidate). Adding or removing candidates does not change the point totals of the other candidates. If the candidate is dropped out, it is enough to simply remove that candidate from the list. If added, vote totals for the original candidates stay the same and voters only have to give their approval or disapproval of the candidate that is added. The same applies if more than one candidate is dropped out or added.

Note that we avoid here broader mathematical elaboration of the SCT methods Borda Count and Approval Voting. Listed references, including ours, provide details on SCT principles and its methods such as majority, fairness, and consistency. We believe that it is not necessary to repeat here mathematics, which are simple; rather, we concentrate on methodological aspects and assure a concise presentation of the results and main findings of the work done.

3. SIMULATION OF THE DECISION-MAKING PROCESS: BASED ON THE USAGE OF VOTING METHODS

3.1. Case study

The SFR is the fourth largest river in Brazil after the Amazon, the Paraná, and the Madeira. Its length is 2,914 km and it is the longest river that runs entirely in Brazilian territory. The SFR is also the fourth-longest river in South America. The river originates in the Canastra mountain range in the central-western part of the state of Minas Gerais. It runs generally north in the states of Minas Gerais and Bahia, behind the coastal range, draining an area of over 630,000 square kilometers, before turning east to form the border between Bahia on the right bank and the states of Pernambuco and Alagoas on the left one. After that, it forms the boundary between the states of Alagoas and Sergipe and discharges into the Atlantic Ocean. In addition to the five states in which São Francisco directly traverses or borders, its drainage basin also includes tributaries from the state of Goiais and the Federal District (Figure 1).

The SFR is an important river for Brazil, often called 'the river of national integration' because it unites diverse climes and regions of the country, in particular, the southeast with the northeast. The river is partly navigable between the cities of Pirapora in Minas Gerais and Juazeiro in Bahia, and between Piranhas in Alagoas and the mouth of the ocean. However, traditional passenger navigation has all but disappeared in recent years due to changes in the river flow.

During the workshop related to hierarchical decision-making processes, held at the School of Polytechnic of the Federal University of Bahia (UFBA) in Salvador, Brazil, a special session was organized to exercise possible decision-making processes within the water committee of the SFR Basin and select the most desired long-term management plan of its water and related resources within the collaborative platform that gives equal power to all stakeholders and stakeholders groups. Following the research published in Srdjevic (2007), a decision-making process was simulated for two different group contexts, once to elicit judgments as interests of different sectors related to water uses, and then to elicit judgments from a participant in the workshop as if they represented states through which the river passes. All participants (fluctuating between 21 and 24) took part in a

Fig. 1 | The San Francisco River.

session that lasted about 4 h, including two half-hour breaks. Participants involved in the process had different backgrounds in engineering, management, and policymaking.

3.2. Statement of the decision problem and assumptions (The paradigm is the Sao Francisco Water Committee)

The problem was stated as to select the most desired long-term water management plan by an authorized institution such as the SFR Basin Water Committee (WC).

The WC was considered to be a decision body (global group), and the 'the group choice' will be 'the WC choice'. By assumption, the WC in certain situations may split into several interest subgroups, subgroups representing states, or in another way. If the decisions will be made by individuals in subgroups, the final decision should certainly be made at the WC level democratically concerning the preferences derived by participating subgroups and/or their delegates.

Each simulated decision-making process corresponded herein to evaluating and selecting the best long-term water management plan for the basin. All management plans were ranked appropriately to define the possible second, third, and other choices, if necessary.

The decision problem shown in Figure 2 is stated as a three-level hierarchy with (1) a goal is at the top of the hierarchy, (2) five evaluating criteria under the goal, and (3) five alternative management plans under the criteria level, that is at the bottom of hierarchy. Criteria are settled down as: (1) political influence, (2) economic criterion, (3) social issues, (4) environmental protection, and (5) technical criterion. Five decision alternatives are long-term management plans. Both criteria and plans are described in Srdjevic (2007).

The hierarchy is adopted after each decision element is briefly described to all participants at a plenary part of a session. The hierarchy is assumed to be unchangeable throughout the whole decision-making process, and the main decision elements (criteria set and alternatives) are briefly described below.

It is important to note that the criteria set for assessing water management plans of the SFR Basin are treated during the voting session identically as alternative plans. The voting results of participants and IGs for criteria are presented in the next sections along with the results for plans, but they are not discussed with participants. The reason for this was that we believe that criteria are the responsibility of the 'upper structures' such as politicians or representatives of agencies. More concern about criteria will be the subject of a future research agenda, which will include possible combinations of MCDM and SCT techniques such as that one presented in Srdjevic (2007). Worth noting is that ranking of criteria is performed in two scenarios of voting, however, the results are not particularly discussed and analyzed in more detail with the participants during this study.

Participants represent (simulate) various entities depending on two defined decision-making scenarios, simulated in two separate sessions. In each scenario, a single participant belongs to either one of:

Three main interest subgroups (1 – Public Authorities; 2 – Civil Society; 3 – Water Users)
Six states (1 – Minas Gerais; 2 – Goiais; 3 – Bahia; 4 – Pernambuco; 5 – Alagoas; 6 – Sergipe)
or to
Federal District (DF – Distrito Federal)
National Water Agency (ANA – Agencia Nacional das Aguas).

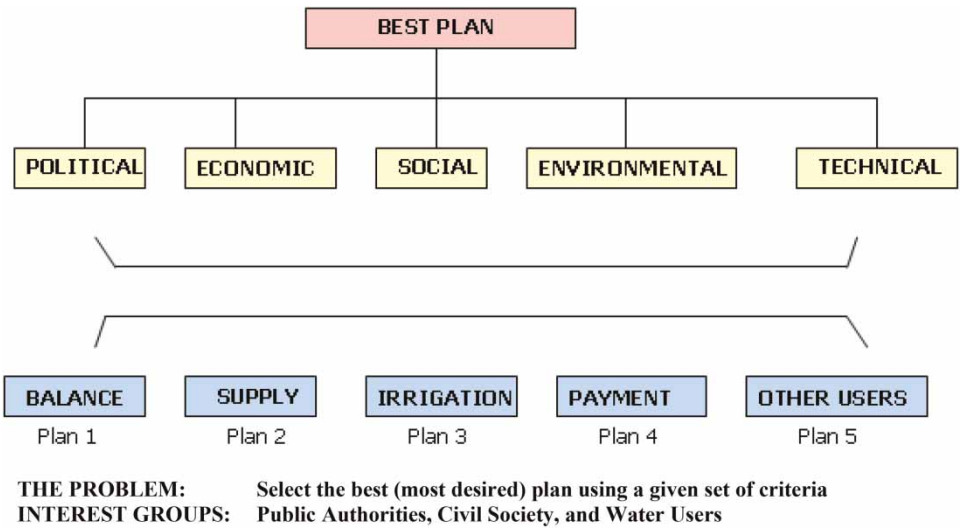

Fig. 2 | Hierarchy of the problem.

Each participant is treated as an individual decision-maker.

Participants can split into subgroups in two different ways to enable full implementation of two pre-defined scenarios of group decision-making. Namely, subgroups can play a role of either dominant IGs within the whole basin or can be representatives of states and federal government. Within one water committee as a global group, subgroups may gather individuals in different ways for differently organized decision-making processes.

In both contexts of focused interests that are analyzed here, a group is by assumption the entire body of a water committee where 'delegated' decisions, made in subgroups, have to be interpreted, justified, aggregated (by consensus or not), and put in power.

The following assumptions are adopted to simulate the decision process at the WC level:

- WC consists of delegates that each belongs to only one entity at the moment (Interest Group, State, DF, or ANA). The number and structure of entities changes depending on the decision-making scenario.
- WC decides by applying scientifically sound election methods, Borda Count and Approval Voting, followed by common aggregating techniques.
- WC recognizes panel meetings as a principal means of its work where mediating rules must be adopted by consensus, and where the final decisions are to be made. WC also recognizes the 'decentralized part' of the decision process performed at separate meetings of each entity. Entities are by assumption authorized to make their own decisions and forward them to be aggregated at the WC level.
- Each entity has 'its point of view' while evaluating possible decision alternatives and ranking them appropriately. An outcome of the decision process conducted through each entity is forwarded to the WC level (for aggregation) as it is. That means that no changes, interpretations, or justifications are permitted.
- The method used by each entity in assessing evaluating criteria and offered management plans is Borda Count + Approval Voting. Subgroup consensus is assumed where logical and/or appropriate. Only ordinal information received from voting by the two methods is used, that is ranking of criteria and alternative plans.
- Each entity (individual or specific subgroup) assesses the same set of management plans across the same criteria set.
- By considering entities as 'criteria' in the pay-off table, and by applying one of two selected voting methods, it is possible to come up with the final decision: the winning management plan. Furthermore, an extended ranking procedure enables the total ranking of all management plans.

3.3. The first session – decision-making under Scenario 1 (Focus on Interest Groups)

The main characteristic of this scenario is that WC is divided into three different IGs where two voting methods are used separately to synthesize the opinions of involved individuals. After these, the first level synthesis is performed for each interest group; their decisions are forwarded to an upper level, which is the WC level, for the final aggregation and interpretation of the result. The decision procedure and outcomes of the first session are given below.

A total of 21 participants split into three IGs, namely:

- Public Authorities (7),
- Civil Society (5), and
- Water Users (9).

Each individual within a given IG performed either as a delegate of one of five states where SFR passes through or as a delegate representing both states of Goiais and DF. Some states had more than one representative in the same IG.

3.3.1. Borda Count

In the first part of this scenario, Borda Count voting is performed within each of the three IGs. Participants individually assessed the hierarchy given in Figure 2 and separately ranked all criteria within the criteria set, and then alternatives within the alternatives set. The ranking is based on individuals' understanding of the importance of these decision elements for the SFR basin. Participants expressed their individual (ordinal) preferences by filling-in appropriate boxes with integers 1–5 as presented in the evaluation sheet in Supplementary Material, Appendix. Borda Count computations were straightforward afterward and the individual and final ranking of criteria and alternative plans derived within each interest group are summarized in Tables 2–4.

Table 2 | Borda Count assessments in the IG #1: PUBLIC AUTHORITIES.

Ranking criteria and alternatives

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1	1	4	2	3	5	2	3	5	4	1
2	5	3	2	1	4	4	1	2	5	3
3	4	3	1	2	5	5	1	3	4	2
4	5	4	3	2	1	2	3	1	5	4
5	5	2	1	3	4	2	1	5	4	3
6	5	3	1	2	4	2	3	4	5	1
7	5	2	3	4	1	2	1	3	5	4
Sum of points	30	21	13	17	24	19	13	23	32	18
Ranking	**5**	**3**	**1**	**2**	**4**	**3**	**1**	**4**	**5**	**2**

Number of participants = 7.

Table 3 | Borda Count assessments in the IG #2: CIVIL SOCIETY.

Ranking criteria and alternatives

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1	2	1	3	5	4	1	3	4	5	2
2	5	4	3	1	2	1	2	4	3	5
3	2	1	3	5	4	1	3	4	5	2
4	2	1	3	5	4	1	3	4	5	2
5	5	3	1	2	4	2	3	5	4	1
Sum of points	16	10	13	18	18	6	14	21	22	12
Ranking	**3**	**1**	**2**	**4–5**	**4–5**	**1**	**3**	**4**	**5**	**2**

Number of participants = 5.

Table 4 | Borda Count assessments in the IG #3: WATER USERS.

Ranking criteria and alternatives

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1	2	4	3	1	5	4	1	3	5	2
2	4	2	1	5	3	3	1	4	5	2
3	5	3	1	2	4	3	2	5	4	1
4	2	5	3	4	1	1	2	3	5	4
5	3	4	1	2	5	3	4	5	2	1
6	5	3	4	2	1	4	3	2	1	5
7	4.5	4.5	1.5	1.5	3	3	1.5	4.5	4.5	1.5
8	1	2	5	4	3	3	2	5	4	1
9	1	3	4	5	2	2	5	1	3	4
Sum of points	27.5	30.5	23.5	26.5	27	26	21.5	32.5	33.5	21.5
Ranking	**4**	**5**	**1**	**2**	**3**	**3**	**1–2**	**4**	**5**	**1–2**

Number of participants = 9.

Obtained rankings received from IGs are aggregated at the WC level by following the same Borda Count procedure and assuming the equal weight of each IGs' ranking. The summary of voting is shown in Table 5. Note that the addition of ordinal information (here ranks) at the WC level is a permitted mode of aggregation.

The final result of this part of the voting session shows that:

- There is a tie for the two best-ranked alternatives: Plan 2 (Supply) and Plan 5 (Other Users). Assuming no additional voting is allowed, both plans could be considered the WC's final choice.
- Third-ranked is Plan 1 (Balance).
- The least desired is Plan 4 (Payment).

Voting of the criteria is performed and the results shown in the above tables indicate that criteria ranking can be critical in conducting the decision process in the WC because it is more related to political than a technical

Table 5 | Final Borda Count assessment at the WATER COMMITTEE level.

Aggregating ranking of criteria and alternatives

	Criteria					Alternatives (Plans)				
Interest groups	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
Public Authorities	5	3	1	2	4	3	1	4	5	2
Civil Society	3	1	2	4–5	4–5	1	3	4	5	2
Water Users	4	5	1	2	3	3	1–2	4	5	1–2
Final aggregate	12	9	4	8.5	11.5	7	5.5	12	15	5.5
Final ranking	**5**	**3**	**1**	**2**	**4**	**3**	**1–2**	**4**	**5**	**1–2**

Number of groups = 3; total number of participants = 21.

framework in organizing and conducting the decision-making processes and deriving any relevant decision. It is interesting that in voting during this session social criterion received the most recognition by the participants followed by the environmental protection in the second place (which is almost tied with the economic criterion in the third place). Political and technical criteria are considered as least important which is in complete contradiction with expectations. This once more indicates the necessity to very carefully assess criteria before setting preferences on alternative management plans.

3.3.2. Approval Voting

Approval Voting part of the session required each individual in each interest group to refer to the hierarchy given in Figure 2 and only to approve certain criteria and alternatives, regardless of their mutual importance. Participants are required to put ticks into appropriate boxes (see evaluation sheet in Supplementary Material, Appendix) and approve criteria or alternatives they consider desired or acceptable; an additional requirement was set that at least one item must be ticked.

Approved criteria and alternatives are presented in Tables 6–8. Ticks are represented by the sign '+'.

Table 6 | Approval Voting in the IG #1: PUBLIC AUTHORITIES.

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1	+			+		+				+
2			+	+		+	+			+
3		+	+	+			+	+	+	+
4	+			+	+	+	+	+	+	+
5	+	+	+	+	+	+	+	+	+	+
6		+	+	+		+	+	+		+
7		+	+		+	+	+			
No. of approvals	3	4	5	6	3	6	6	4	3	6
Ranking	**4–5**	**3**	**2**	**1**	**4–5**	**1–3**	**1–3**	**4**	**5**	**1–3**

Number of participants = 7.

Table 7 | Approval Voting in the IG #2: CIVIL SOCIETY.

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1			+	+	+	+				+
2				+		+				
3			+	+	+	+				+
4			+	+	+	+				+
5		+	+	+	+	+				+
No. of approvals	0	1	4	5	4	5	0	0	0	4
Ranking	**5**	**4**	**2–3**	**1**	**2–3**	**1**	**3–5**	**3–5**	**3–5**	**2**

Number of participants = 5.

Table 8 | Approval Voting in the IG #3: WATER USERS.

	Criteria					Alternatives (Plans)				
Participants	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
1	+	+	+	+		+		+		
2	+	+	+	+	+	+	+			+
3		+	+	+		+	+			+
4			+		+	+	+			
5			+	+						+
6	+	+			+			+	+	+
7		+	+	+		+	+	+	+	+
8	+	+	+	+	+	+	+	+	+	+
9			+	+			+			+
No. of approvals	4	6	8	7	4	6	6	4	3	7
Ranking	**4–5**	**3**	**1**	**2**	**4–5**	**2–3**	**2–3**	**4**	**5**	**1**

Number of participants = 9.

It is easy to see that if Approval voting is employed, three IGs approved criteria and alternatives differently. Looking at only top-3 ranked criteria and alternatives in each group, a situation is as follows:

- Public Authorities:	*Plan 1*, *Plan 2*, and *Plan 5* (tied)
- Civil Society:	*Plan 1*, then *Plan 5*; other plans not approved
- Water Users:	*Plan 5*, then *Plan 1*, and *Plan 2* (tied)

If rankings obtained by IGs are additionally aggregated at the WC level (without any new voting), in a way that only top-3 ranked are newly approved, then according to Table 9, the final result is:

- There is a tie for two best-ranked alternatives: Plan 1 (Balance) and Plan 5 (Other Users). Assuming no additional voting is allowed, both plans could be considered the WC's final choice.

Table 9 | Final Approval Voting assessment at the WATER COMMITTEE level.

	Criteria					Alternatives (Plans)				
IG	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
Public Authorities		+	+	+		+	+			+
Civil Society			+	+	+	+				+
Water Users		+	+	+		+	+			+
Final aggregate	0	2	3	3	1	3	2	0	0	3
Final ranking	**x**	**3**	**1–2**	**1–2**	**x**	**1–2**	**3**	**x**	**x**	**1–2**

Number of groups = 3; total number of participants = 21.

- Third-ranked is Plan 2 (Supply).
- The least desired are Plan 3 (Irrigation) and Plan 4 (Payment).

Regarding the criteria set, the result obtained by Borda Count is mostly confirmed by Approval Voting. The least important are political and technical criteria, the most important (approved by all three IGs) are societal and environmental criteria, and the economic criterion is approved by two IGs.

3.3.3. Summary of Scenario #1

Scenario #1 of decision-making is simulated so that members of the global group (WC) split into three IGs (Public Authorities, Civil Society, and Water Users) to vote on criteria and water management plans. Once IGs made their decisions, they are aggregated at the WC level. Aggregated decisions (without additional assessments or voting) are declared as the WC's final choice:

Borda Count

- The two plans are tied as the best: Plan 2 (Supply) and Plan 5 (Other Users).
- Third-ranked is Plan 1 (Balance).
- The least desired is Plan 4 (Payment).
- In any future assessments of plans, criteria to be respected more than others are societal, environmental, and economic (in that order).

Approval Voting

- The two plans are tied as the best: Plan 1 (Balance) and Plan 5 (Other Users).
- Third-ranked is Plan 2 (Supply).
- The least desired are Plan 3 (Irrigation) and Plan 4 (Payment).
- In future assessments of plans, criteria to be respected more than others are societal and environmental (tied approvals) and then economic (in that order).

The following conclusions are obvious:

1. In all assessments, it is indicated that Plans 1, 2, and 5 are superior to Plans 3 and 4.
2. Among superior plans, Plans 1 and 5 seem to be slightly more acceptable than Plan 2. They can be considered by Water Committee as eligible for additional analysis, negotiations, possible improvements toward compromise solutions, etc. However, all additional evaluations must respect the characteristics of Plan 2 where possible compromises could be found. Criteria that should be more important than the others are societal, environmental, and economic, while political and technical should be considered as 'shadow' criteria.

3.4. The second session – decision-making under Scenario 2

(Focus on states and DF – Federal District)

In this scenario, the delegates of the WC are divided into five groups: three corresponding to states Minas Gerais, Bahia, and Pernambuco, one corresponding to the state of Goiais and the Federal District (DF), and one to states Alagoas and Sergipe. Distribution of the 21 participants among groups was as follows: Minas Gerais (5), Bahia (5), Pernambuco (4), Alagoas and Sergipe (4), and Goiais and DF (3).

Again, the two voting methods were used separately to synthesize the opinions of involved individuals. Each group had a separate, 30 minutes long 'consensus meeting', i.e. discussion and assessment of criteria and alternatives. Each group ranked by importance criteria and alternatives (Borda Count), and afterward, approved certain decision elements in both criteria and alternatives set (Approval Voting).

3.4.1. Borda Count

Voting results obtained in each state group are presented in Table 10. Aggregating collected lists of preferences showed that again Plan 5 can be declared as most desired, that second best is Plan 1, etc.

Regarding criteria, preferences by states are the same as in the first scenario (cf. Table 5).

3.4.2. Approval Voting

Approval of criteria and alternatives is performed after reaching a consensus in each state group, Table 11. The final ranking of alternatives corresponds to simulated aggregation at the WC level, and it declares Plan 5 as a winner. The second best is Plan 1, etc.

Aggregation of criteria approvals indicates that the importance of environmental management is approved by all states, followed by economic criterion with four approvals (all except the state of Bahia). The remaining three criteria are tied with three approvals received by different states.

3.4.3. Summary of Scenario #2

Scenario #2 puts a focus on state interests delegated into related groups accordingly. Once state groups made their decisions, they are directly aggregated at the WC level, without additional assessments or voting.

Table 10 | Borda Count assessment by states.

	Criteria					Alternatives (Plans)				
STATES	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
Minas Gerais	5	4	1	2	3	2	3	4	5	1
Bahia	5	2	1	4	3	3	2	4	5	1
Pernambuco	1	3	2	4	5	2	1	3	5	4
Alagoas + Sergipe	5	3	1	2	4	2	3	4	5	1
Goiais + DF	2	5	4	1	3	2	3	5	4	1
Sum of points	18	17	9	13	18	11	12	20	24	8
Ranking	**4–5**	**3**	**1**	**2**	**4–5**	**2**	**3**	**4**	**5**	**1**

Number of participants = 21.

Table 11 | Approval Voting by states.

	Criteria					Alternatives (Plans)				
STATES	**POL**	**ECO**	**SOC**	**ENV**	**TEC**	**BAL**	**SUP**	**IRR**	**PAY**	**OTH**
Minas Gerais	+	+	+	+	+	+				+
Goiais + DF	+			+		+				+
Pernambuco	+	+		+	+	+	+	+	+	+
Bahia		+	+	+	+			+		+
Alagoas + Sergipe		+	+	+		+	+			+
No. of approvals	3	4	3	5	3	4	2	2	1	5
Ranking	**3–5**	**2**	**3–5**	**1**	**3–5**	**2**	**3–4**	**3–4**	**5**	**1**

Number of participants = 21.

Aggregated decisions can be declared as the WC's final choice. The final result for both SCT voting methods is unique:

- The best is Plan 5 (Other Users).
- Second-ranked is Plan 1 (Balance).

The following conclusions are obvious:

1. A consensus among individuals in state groups provides encouraging improvement in creating final decisions at the WC level.
2. In all three methodologies Plan 5 and Plan 1, as the two best-ranked alternatives, differentiate between each other very little. Both can be considered as most promising for possible additional evaluations, searches for intermediate solutions, etc.
3. Similar to Scenario #1, Plans 5 and 1 are more acceptable than Plan 2.

4. FINAL REMARKS AND CONCLUSION

This paper presents the results of the simulated group decision-making process that could be applicable as a part of decision-making processes in the Water Committee of the San Francisco River Basin (WC-SFC) in Brazil. The problem is stated to select the most desired management plan among the five offered, by assessing plans with background information about major (more or less) conflict criteria, while respecting the equity principle, and hearing the voice of smaller subgroups of stakeholders as well.

The presented approach is based on the application of two efficient elective methods from the Social Choice Theory area – Borda Count and Approval Voting. In the context of a strictly social choice, an approach recognizes the importance of the inclusion of individuals as members of different IGs (Scenario 1), and as representatives of different Brazilian states where the Sao Francisco River passes. Worth pointing out is that, from the practical point of view, when applying SCT methods in river basin committees, one must be aware of having very different individuals and very rarely real experts, particularly if groups (and subgroups) are large. Experience says that in large committees (such as the one for the SFR), a decision-making process related to planning and overall water management will expectedly be performed with the participation of 'oriented committee members' bringing particular backgrounds and mostly narrowed interests from the social, political or economic environments they are coming from. These facts have also been a part of our research, but are not discussed in detail in this paper.

It should be noted that the final ranking, obtained in any of two simulated scenarios and any of two selected voting methods, does not necessarily depend on the number of voters, and the size of the subgroups. In the SCT-based decision-making processes, a fair election commonly means that the voting of a small subgroup has the same power as the voting of a large subgroup. An issue of the number of members in groups or subgroups, the importance of individuals (experts) within subgroups and across representatives on a group level, and related problems of preserving fairness, competence, and consistency – are always the subject of discussion in practical applications. The presented approach is not immune to it.

We believe that the presented methodology can be used, with proper adjustments, in similar water resources decision-making frameworks. People like to vote on few criteria and/or few alternatives, rather than being overburdened with many decision elements and subjected to complicated mathematical models. The preparation of the options and decision elements (goals, objectives, criteria, and alternative solutions) is crucial before voting starts. Simulated two voting scenarios undoubtedly proved efficient in both preparation, conducting, and summarizing the voting results. Participants were informed about outcomes and in panel discussion reached an agreement that the results are intuitive as expected. The final rating of the results was from 'very good to 'fully acceptable'. In a way, this can be understood that applied methodology based on SCT voting methods can be invaluable in similar decision-making processes elsewhere.

A possible new direction of research and professional work could be to combine strict SCT and multi-criteria decision-making (MCDM) methodologies into the flexible new methodology of decision-making within river basin water committees, having in mind the requirement to avoid early confrontation of individuals and sub-groups by putting different weights based on competences, i.e. expert knowledge, education, attitude, willingness, political impacts, etc.

DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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