DETERMINATION OF THE MOST APPROPRIATE POLICY FOR RIVER BASIN MANAGEMENT

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ABSTRACT

The Parliament of the Salgado River provided actions and recommendations for the future of the Salgado River Basin which is in the south of Ceara State, Brazil. These recommendations were obtained through a democratic process, with the involvement of around 100 participants from private companies, public organizations and the third sector. The intention was to define a model that is compatible with the aspirations of society regarding the use and quality of the water, as well as define necessary decision actions and strategies. The main goal of this article is to determine, with a multi-criteria decision analysis, an appropriate policy for the river basin management. Therefore, the Analytic Hierarchy Process (AHP) was applied. The criteria are a combination of economic, environmental, and social issues; the alternatives were defined as essentially

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preservationist policy, sustainable policy, and essentially economic policy. The AHP application was effective in this decision analysis.

Keywords: AHP; environmental policies; river basin management.

1. Introduction

Disordered growth associated with the process of water quality degradation has caused serious problems to the Salgado River Basin in the Brazilian state of Ceara. River basins in Northeast Brazil are affected by the intermittence of rivers, rainfall irregularity and the lack of an efficient and participative management policy. Multi-criteria decision analysis (MCDA) may help the assessment of environmental impacts and in turn improve the management of river basins.

The Parliament of the Salgado River provided actions and recommendations for the future of the Salgado River Basin, through a democratic process, with around 100 participants from private companies, public organizations and also from the third sector. The objective of this research was to define an MCDA model compatible with the aspirations of society regarding the use and quality of the water, as well as to define the necessary actions and strategies. The main goal of this article is to determine, with MCDA, the appropriate policy for the river basin management. Therefore, the Analytic Hierarchy Process (AHP) was applied.

Section 2 highlights some works from MCDA literature on environmental management. Section 3 discusses methodological issues which resulted in the MCDA model. In Sections 4 and 5, the AHP application and results are presented and discussed. Section 6 ends this article with conclusions, limitations and a proposal for future works.

2. Literature review

In the past, environmental management has been regarded as a constraint for companies and has even been considered an obstacle to competitiveness. Nowadays, however, it is treated differently, with increasingly more companies adopting strategies and making decisions towards environmental management (Frondel et al., 2007). River basin management is a major issue in environmental management.

AHP has been applied to rank alternatives when several criteria and sub-criteria are present in the decision (Tahriri et al., 2008). AHP has proved itself a suitable method for pondering judgments in complex decisions (Awasthi & Chauhan, 2011; Bottero et al., 2011; Gao & Hailu, 2012). With AHP, decision-making problems are structured in hierarchies, and qualitative or quantitative data can be used to derive ratio scales among the decision elements in each hierarchical level (Bello-Dambatta et al., 2009), which makes it one of the most preferable approaches for MCDA. There are several software models (e.g. Expert Choice and Super Decisions) already used in environmental management problems (Contreras et al., 2008).

According to Saaty (2008), an MCDA method such as AHP balances the interactions between decision criteria and synthesizes information into a vector of priorities for the

alternatives. AHP is often used to solve complex decision problems, being widely used to determine the weights or priorities (Dong et al., 2010; Xie & Tang, 2010; Vidal et al., 2011).

AHP has many environmental management applications such as ecotourism (Ok et al., 2011), natural resources (Schmoldt et al., 2001), forestry (Samari et al., 2012) coastal systems (Ryu et al., 2012), and disaster risk measurement (Carreño et al., 2007; Chen, et al. 2009).

An Expert Choice model was developed to prioritize alternatives of water utilization from a Brazilian power plant (Larrubia, 2010). SWOT (Strengths-Weaknesses-Opportunities-Threatens) Analysis was integrated with AHP in another watershed application, a Turkish Lake Basin (Yavuz & Baycan, 2013). SWOT Analysis is a multi-criteria framework for strategic planning (Humphrey, 2005). The BOCR (Benefits-Costs-Opportunities-Risks) which is similar to SWOT framework is a usual model in AHP applications (Wijnmalen, 2007). PEST (Political-Economic-Social-Technological) Analysis is a framework to evaluate environmental factors in business planning (MacGinty et al., 2013).

3. Research methodology

This article aims to present the best policy from a group of alternatives that is capable of meeting the aspirations of society regarding the Salgado River. There are many environmental problems on this river basin which can be addressed with a participatory application of the AHP.

One of the authors has participated in the meetings of the Parliament of the Salgado River, and has played a dual role in the process. At first, he spoke to the parliament about how MCDA and AHP could be useful in the study of policies for the river basin management. Then, he heard and collected opinions about the importance of criteria and alternatives to the policies. This article is more than a case research as it presents the MCDA modeling with AHP for this important environmental decision problem.

For this study, a total of seven meetings were conducted. The first and the last were plenary meetings, in the main city of Juazeiro do Norte. Five meetings were conducted with only the local participants in a single city: Barbalha, Caririaçu, Crato, Juazeiro do Norte and Missao Velha. According to the Brazilian Institution of Geography and Statistics, the population of these cities sums more than half a million inhabitants, the area is around 5,500 km^2, and their gross domestic product, in 2011, was 2.6 million dollars (http://www.ibge.gov.br/english/).

Figure 1 presents the criteria hierarchy obtained from the Parliament of the Salgado River. This hierarchical structure was validated by the parliament in the final plenary meeting.

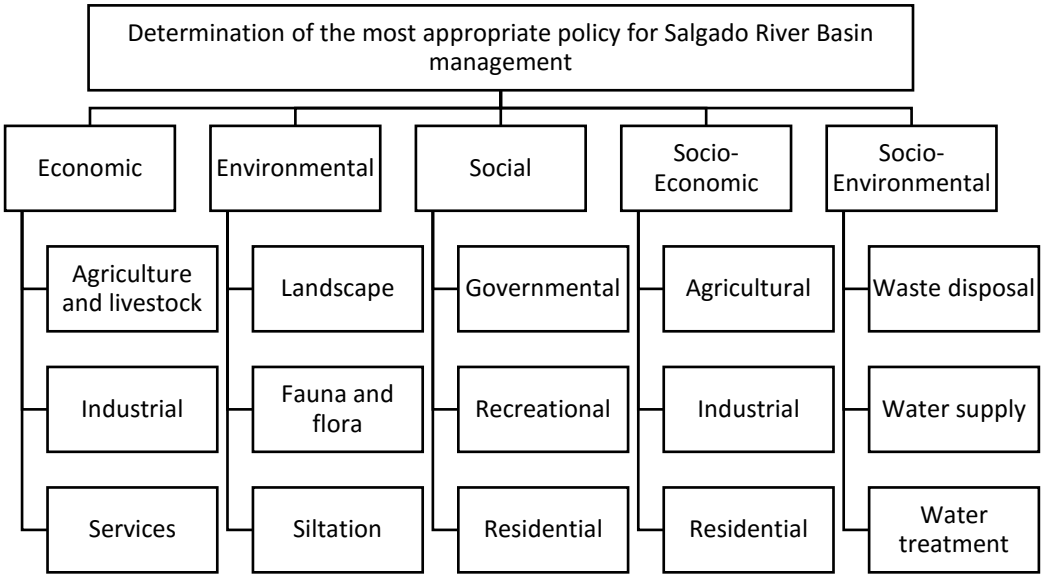

Figure 1. Criteria and sub-criteria for the Salgado River Basin management.

As can be observed, there are two homonymous sub-criteria named "Residential"; one below the "Social" criterion and another below the "Socio-Economic" criterion. This is because the resident's point-of-view was considered regarding these two criteria. As a matter of fact, this repetition may suggest dependence or influence among the hierarchy's components. In this case, the Analytic Network Process (ANP) may be the proper multi-criteria decision method. However, due to innovative application in the local river basin management, AHP application was maintained, since it was considered a simpler method.

The hierarchy focuses on two (social and economic) of the four factors from the PEST Analysis which also include political and technological factors (MacGinty et al., 2013). Political factors are considered in the bottom of the hierarchy with the alternatives. Technological factors were not considered in this case. One reason for this is that society was not concerned with this major issue at that moment. That is, Social and Economic problems were greater than Political or Technological ones.

An Expert Choice model was developed for AHP application. Judgments and priorities are presented in Section 4.

4. AHP Application

Table 1 presents the judgments of the relative priorities for the criteria, according to the Parliament of Salgado River based on the Fundamental Scale of Absolute Numbers (Saaty, 2014).

Table 1
Priorities for the criteria

Criterion	EC	EN	SO	SC	SN	Priority
Economic (EC)	1	2	8	7	7	50%
Environmental (EN)	1/2	1	4	6	6	31%
Social (SO)	1/8	1/4	1	1/2	1/2	5%
Socio-Economic (SC)	1/7	1/6	2	1	1	7%
Socio-Environmental (SN)	1/7	1/6	2	1	1	7%

The pairwise comparison matrix presented in Table 1 has an inconsistency ratio around 3%. It is assumed that an inconsistency ratio value lower than 10% is an indication of the reliability of information (Saaty, 1977; Garuti & Salomon, 2011). Economic factors have the highest priority with 50%. They are followed by environmental factors with 31%. Social factors have the lowest priority with only 5%.

Table 2 presents the judgments on the relative priorities for the economic sub-criteria, also according the Parliament of Salgado River and based on the Fundamental Scale of Absolute Numbers. The inconsistency ratio was around 5%. 'Services' has the highest priority which indicates that it is the economic sector preferred by society.

Table 2
Priorities for economic sub-criteria

Sub-criterion	A	I	S	Priority
Agriculture and livestock (A)	1	3	1	40%
Industrial (I)	1/3	1	1/6	10%
Services (S)	1	6	1	50%

Similar judgments were conducted for the other four criteria. Table 3 summarizes the local and overall priorities for the sub-criteria. No comparison matrix has an inconsistency ratio greater than 10%. Sub-criterion 'Services' has the highest overall priority.

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Table 3
Priorities for all sub-criteria

Sub-criterion / Criterion	Local Priority	Overall Priority
Agriculture and livestock / Economic	40%	20.0%
Industrial / Economic	10%	5.0%
Services / Economic	50%	25.0%
Landscape / Environmental	40%	12.5%
Fauna and flora / Environmental	40%	12.5%
Siltation / Environmental	20%	6.0%
Governmental / Social	44%	2.2%
Recreational / Social	50%	2.5%
Residential / Social	6%	0.3%
Agricultural / Socio-Economic	67%	4.7%
Industrial / Socio-Economic	22%	1.5%
Residential / Socio-Economic	11%	0.8%
Waste disposal / Socio-Environmental	14%	1.0%
Water supply / Socio-Environmental	29%	2.0%
Water treatment / Socio-Environmental	57%	4.0%

Three alternatives policies were defined by the Parliament of Salgado River. These policies are an essentially preservationist policy, a sustainable policy, or an essentially economic policy. Table 4 presents the judgments on the relative priorities for the alternatives policies regarding the economic sub-criterion A (agriculture and livestock). The comparison matrix is 100% consistent.

Table 4
Local priorities for alternatives policies regarding agriculture and livestock

Policy	P	S	E	Priority
Essentially preservationist (P)	1	3	3	69%
Sustainable (S)	1/3	1	1	23%
Essentially economic (E)	1/3	1	1	8%

Similar judgments were conducted for the other four criteria. Table 5 summarizes the local priorities for alternatives policies regarding economic sub-criteria.

Table 5
Local priorities for alternatives policies regarding economic sub-criteria

Policy	A (40%)	I (10%)	S (50%)	Priority
Essentially preservationist	69%	78%	60%	65%
Sustainable	23%	14%	20%	21%
Essentially economic	8%	8%	20%	14%

5. Results and discussion

Table 6 summarizes the local and overall priorities for alternative policies regarding all criteria. Essentially preservationist policies have the highest overall priority with 60%.

Table 6
Priorities for alternatives policies regarding all criteria

Policy	EC (50%)	EN (31%)	SO (5%)	SC (7%)	SN (7%)	Overall priority
Essentially preservationist	65%	60%	67%	36%	42%	60%
Sustainable	21%	21%	22%	48%	40%	24%
Essentially economic	14%	19%	11%	16%	18%	16%

Figure 2 presents the variation of overall priorities for alternatives as a function of priority for socio-economic criterion. This is the only criterion where the essentially preservationist policy has a local priority lower than another policy. However, the priority for the socio-economic factor shall be increased to more than 75%, and then the sustainable policy will have an overall priority higher than essentially preservationist policy.

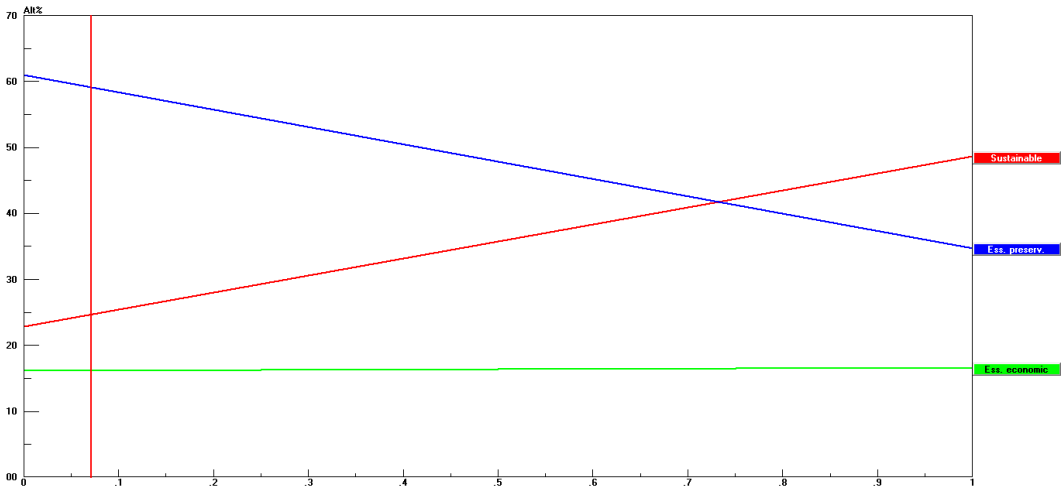

Figure 2. Sensitivity analysis (Expert Choice software)

6. Conclusions

The essentially preservationist policy has the highest priority. After a sensitivity analysis was performed this priority was confirmed. This result was presented to all the members of the Parliament of Salgado River, and they agreed to pursue essentially preservationist policies. However, the economic criterion was the most relevant and was a result of the need for infrastructure to ensure the achievements of environmental yearnings.

A large number of publications applying AHP, or another MCDA method in river basin management do not exist. In this sense, environmental management was used as a background theory. It is clear that the study of river basin management linked to Brazilian policy management instruments is a challenge that must be faced every day. Therefore, the AHP applications are useful in contributing to the carrying out of the purposes and the policies to be adopted. One of the main benefits of the AHP application

was the lack of political bias when prioritizing alternatives and criteria. The judgments were impartially conducted.

The results of this study have implications for the use of a suitable alternative for the estimation of the benefits of river basin management improvements. The AHP with its hierarchy structure was an effective method for studying the problem. The AHP established priorities to alternative policies according to the Parliament of Salgado River.

The essentially preservationist policy must be the policy for river basin management in Brazil. This may not be the solution for other countries. Thus, the application of this study is preliminarily bound to places with similar culture and laws as Brazil.

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