# MULTI-CRITERIA ANALYSIS FOR WATER MANAGEMENT: A CASE STUDY IN RURAL COMMUNITIES OF BRAZIL

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**Abstract**

Programmes aimed at solving the water needs of the poor in developing countries are complex in nature, as they involve social dimensions and are based on technology transfer and implementation in the development sector. Suitable decision-making processes for water programmes in developing countries must simultaneously consider technical, environmental, economic and social aspects to ensure the effectiveness and appropriateness of solutions. Multi-criteria analysis (MCA) is suitable for evaluating human development programmes to improve living quality and access to basic needs, such as water. The aim of this paper is to apply MCA to select the most appropriate programme for water supply in rural communities of Brazilian semi-arid region. The results permit to individuate the most suitable project for water supply and to highlight the advantages of using MCA technique for water management in developing contexts, taking into account social, environmental and economic criteria. The multidisciplinary nature of the approach is very significant for developing countries, where environmental projects aim to improve living standards and human development.

**Keywords**: Analytic hierarchy process; appropriate technologies; decision-making; water supply.

## Introduction

The Brazilian semi-arid region, which extends over almost one million square kilometres in the north eastern part of the country, is made up of 11 states and has a population of 24 million people. It is the poorest region of Brazil, and its economy is based on self-sufficient farming. During dry periods, women and children often have to walk long distances in search of water for human consumption. The Brazilian semi-arid region is characterized by highly irregular rainfall mainly concentrated in six months and rainwater catchment is seen as an important factor of sustainable development. In particular, the study described in this paper was carried out in the Jequitinhonha Valley, a region located in the northern part of the state of Minas Gerais. During the 1990s, many NGOs and grassroots organizations working in this region focused on rainwater catchment systems implementation as an essential contribution to people's quality of life under the region's climatic conditions; however the

implementation of these systems was carried out as isolated projects without a systematic environmental planning and management strategies. The lack of decision making and planning is one of the most important causes of projects' failures.

The aim of this study is to assess two particular water programmes in Jequitinhonha Valley: the "One Million Cisterns Project" (P1MC) and the "Spring Assessment Programme" (SAP) using Multi-criteria analysis (MCA) to identify the most appropriate alternative for the region and to ensure its success in providing safe water to rural communities.

## Methods

MCA is a family of evaluation tools that rank or score the performance of options against multiple social, environmental and economic criteria that may have different units (Nijkamp *et al*, 1990). In particular, the multi-criteria tool used in this paper is the Analytic Hierarchy Process (AHP) (Saaty, 1980), which is considered appropriate for environmental project assessment in developing countries (Garfí *et al,.* 2009). AHP is a mathematical technique that approaches decision-making by arranging the important components of a problem into a hierarchical structure similar to a family tree. It consists of three main phases: (1) criteria identification and selection, (2) calculation of the relative weight of each criterion, and (3) the comparison of alternatives. In this study criteria selection is made by literature review and discussion with stakeholders; relative weight are determined by pairwise comparison (Saaty, 1980); the comparison of alternatives is carried out by ordinal ranking (CIFOR, 1999). AHP is applied to compare and select the most suitable from the following two programmes:

- One Million Cisterns Project (P1MC). It aims to supply drought-proof drinking water through the construction of cisterns to collect rainwater from rooftops. A family cistern enables the collection of rainwater during the rainy season. This water can then be used during the long dry season for drinking, personal hygiene and cooking.

- The Spring Assessment Programme (SAP). It aims to improve degraded soils and water quality by means of reforestation with native species, mainly in areas adjacent to springs. The general aim was to reduce the pollution of water and land caused by the use of chemicals and the environmental impact caused by the massive replacement of native forests with eucalyptus monoculture.

## Results and discussion

In the first phase of AHP the criteria are selected by literature review and by a survey to stakeholders (Table 1) that is composed by the families of the communities involved in the programme, the NGOs, the workers who implemented and financed the programme, and the cooperation programme's technical staff. Criteria represent stakeholders' concerns through which alternatives performance must be assessed; especially criteria CGD, CGE, CGF, CGG, C7, C8, C10 have been emphasized by beneficiaries.

The next step in the AHP is to determine the relative weights of criteria using pairwise comparisons (Saaty, 1980). Two different pairwise matrices were built to calculate relative weights for technical water supply criteria (C) and for general human development project criteria (CG). Pairwise comparisons were undertaken with a focus on the results of interviews with stakeholders. Figure 1 shows the relative weights of criteria, obtained by pairwise comparison. According to the results the most important criteria are: migration due to poverty and lack of access to resources (CGG); health (CGH) and life expectancy (CGM); compliance with drinking water standards (C2); standards of water needed for human consumption (C6); free and independent access by the community (C10); constancy in resource availability during the day and the seasons (C12).

The results of the comparison between the two alternatives indicated that P1MC was the most appropriate alternative, with a final score of 3.7 in comparison to 1.7 for the SAP. The analysis of the results permits to understand the criteria and aspects that make P1MC the most appropriate solution for water supply in the Jequitinhonha Valley. In fact the higher final value of P1MC is due to: a participatory approach (CGE); a better capacity to provide safe water resources during all seasons (C6 and C12); a better water quality (C2) and a decentralized nature (C7 and C8).

## Conclusions

MCA and AHP applied to water programmes in semi-arid region of Brazil permitted to identify that the P1MC represent the most appropriate solution to drinking water supply in rural communities. Moreover thank to the methodology is possible to understand the criteria and aspects that make P1MC the most appropriate solution for water supply in the Jequitinhonha Valley: a participatory approach; a better capacity to provide safe water resources during all seasons; a better water quality and a decentralized nature. From a methodological point of view we can state that MCA and AHP are suitable to solve decision making problems in developing contexts.

*Table 1 General and technical criteria for human development projects in water sector*

| General criteria for human | | Technical Criteria for water supply projects | |
|---|---|---|---|
| CG A | Technical characteristics | C1 | Compatibility with environmental and geological characteristics |
| CG B | Environmental impacts | C2 | Compliance with standards for drinking water |
| CG C | Natural resources consumption | C3 | Maintenance of water quality over time |
| CG D | Management | C4 | Maintenance of water quality from storage at supply water point |
| CG E | Local community participation | C5 | Organoleptic properties |
| CG F | Respect for local culture | C6 | Standards of water needs for human consumption |
| CG G | Migration due to poverty and lack of access to resources | C7 | Distance from any household to the nearest water point |
| CG H | Health | C8 | Location with easy access for all members of the community, away from sources of pollution |
| CG I | Access to technology | C9 | Maximum numbers of people per water source |
| CG L | Income and employment | C10 | Free and independent access by the community |
| CG M | Life expectancy | C11 | Queuing time at a water source |
| | | C12 | Constancy in resource availability during the day and the seasons |

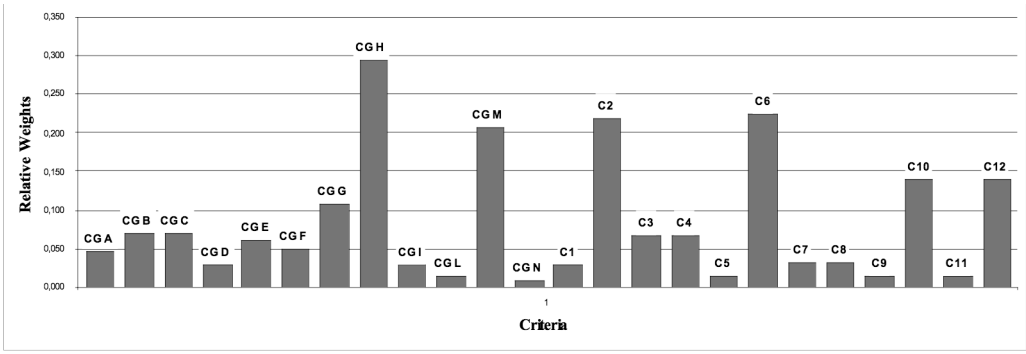


*Figure 1 Importance of criteria expressed by their relative weights.*

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