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Multi-criteria Decision Analysis (MCDA) for Integrated Water Resources Management (IWRM) in the Lake Poopo Basin, Bolivia

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Abstract Integrated Water Resources Management (IWRM) is a relatively new approach in Bolivia. However, it is now generally accepted that this approach needs to be established in order to find sustainable solutions for development and is actively promoted by the Water Ministry, especially in environmentally fragile regions, such as the Lake Poopo basin. The Lake Poopo basin is one of the poorest regions in the Bolivian Altiplano. It is confronted with severe water scarcity during the dry season, leading to low water quality, a high water-poverty index and low values of the watershed sustainability index. Furthermore, salinization and environmental degradation of soil and water are forcing people to migrate to urban areas. These are some of the factors underlying an ever-increasing complexity in integrated water resources management in the region. This paper proposes and develops a Multi-criteria Decision Analysis (MCDA) in the Lake Poopo basin, based on economic, social and environmental criteria in an uncertain decision environment in order to support stakeholders in managing their water resources. Saaty's analytical hierarchy process (AHP) theory is applied here to solve the MCDA and to identify the alternatives using the highest expected utility value. The paper identifies the best solutions for existing conflicts, while promoting interaction with stakeholders and instruments in order to reach a sustainable strategy for water resources management in this water-scarce region.

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1 Introduction

The IWRM paradigm has been recognized worldwide as the only currently feasible way to ensure a sustainable perspective in planning and managing water resources systems (Castelleti and Soncini-Sessa 2007). It is the main reference for all water related activities in third world countries. Sufficient water supply might be considered to be one of the most important factors for improving quality of life in these countries. "As pointed out by the United Nations (UN), one third of the Millennium Development Goals (MDGs) depend on water." (Phumpiu and Gustafsson 2009). However, real-world attempts of implementing IWRM often fail due to the lack of a systematic approach and the inadequacy of adopted tools and techniques to address the intrinsically complex nature of water systems. According to one of the principles of the IWRM, the equitable allocation of water resources implies an improved decision-making process, which is technically and scientifically informed and can facilitate the resolution of conflicts over contentious issues, balancing social, environmental and economic consideration. Because for "an integrated water resources management (IWRM), as demanded for instance by the European Water Framework Directive (EU-WFD 2000), the ecological, social, and economic functions of the water cycle have to be taken into consideration" (Koch and Grünewald 2009).

2 IWRM in the Lake Poopo Basin

Integrated Water Resources Management (IWRM) is defined as: "... a process to promote the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (UN 1992). IWRM can be strengthened through the integration of environmental impact assessment, water resources modeling, and land use planning. The watershed approach implies that water should be managed alongside the management of co-dependent natural resources: water, soil, air, forest, and all other biota. Examples for watershed management strategies can be found in Baloch and Tanık (2008) and in Reyes et al. (2004).

In the rural area of Bolivia, water resources constitute a fragile element of the landscape. In general, there is a fresh water deficit spanning more than half of the country (Van Damme 2002). The Lake Poopo basin in the southern Bolivian Altiplano does not escape this reality. The basin is confronted with severe water scarcity during the dry season, which leads to low water quality combined with extreme poverty, a low water poverty index and low values of the watershed sustainability index. Furthermore, salinization and environmental degradation of soil and water are forcing people to migrate to faraway urban areas. The water bodies and regional rivers in the basin have, for a very long time, been polluted both naturally and by heavy metals from mining activity, by spilling crude petroleum into rivers contaminating hundreds of acres of farmlands, etc. These are some of the factors underlying an ever-increasing complexity in IWRM in the region.

The rural economy of the Lake Poopo basin strongly depends on the availability of water resources in time and space, and for this reason it is extremely urgent to apply integrated water resources planning and management based on active participation of stakeholders (native population, farmers, municipalities, and small water supply system operators). The lack of water and water rights in the Lake Poopo basin lead to water and land conflicts. Due to increasing water demand, different sectors compete for access to fresh water resources. The simultaneous water use by different sectors is not compatible and can generate conflicts (Mattos and Crespo 2000). The majority of conflicts in the basin may be delineated from the different vision and conception of the use of fresh water. In the north-eastern parts of the basin, for example, there are serious water and land conflicts between mining and agriculture sectors and in some cases with the domestic users.

We are actually facing a veritable water crisis. “But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people and environment suffer badly” (Cosgrove and Rijsberman 2000). In general, it is important to promote the guiding principles for water resources management and best practices. According to the Dublin Statement on Water and Sustainable Development (UN 1992), these include the followings guiding principles: (1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels; (3) women play a central part in the provision, management and safeguarding of water; and (4) water has an economic value in all its competing uses and should be recognized as an economic good. Point (2) is relevant to IWRM as it regards *stakeholders* and their involvement in decision processes. Principle (4) involves the water vision according to the local native culture; however, this principle of water as an “economic” good may not be in line with all cultures and may be, therefore, a source of conflict with respect to water rights, water use, and water management.

In general, the rural population of Bolivia has an integrative view of the use of water, representing a source of life in coherence with the general Andean water vision. People do not exclude water from the remaining natural surrounding. They reject the idea that water can be managed through a mercantilist point of view. The major problems are further aggravated by a general lack of water management awareness by the population and authorities and also a lack of clearly established water rights, generating sector conflicts. To improve the situation, there is a need for the establishment of water resources planning in accordance with environmental sustainability objectives.

Therefore, efforts should be devoted to increasing the reliability of existing water resources availability and to utilizing these in a more efficient way. With consideration to this point of view, the objective of this paper is to establish a model of multi-criteria decision making (MCDM) and participative interaction by stakeholders towards developing a strategy for sustainable water resources management with the sustainability of the basin’s ecosystem in focus.

2.1 Sources of Water-Conflict in the Lake Poopo Basin

Following Kampragou et al. (2007) “Water resources management has been widely discussed in the recent years as water scarcity has become a prominent problem with increasing populations suffering from water scarcity and water quality deterioration". Water provides essential living conditions to human beings and to flora and fauna in the basin. The water-conflict sources related to water resources management issues have been grouped into five main categories: extreme weather events, socio-economic situation, deficient water regulations, environmental degradation and the lack of sufficiently organized stakeholder involvement. One example of conflict deriving from deficient water regulations and environmental degradation is the existing one between the mining and farming sectors in the north-east of the basin. Generally, the mining sector receives more political support in the definition of water rights. This illustrative example shows that most water conflicts between stakeholders are based upon water-using rights. However, this is only one example of why adequate water regulations are strongly necessary.

A causal network of Rontentalp et al. (2005) of water-related processes and problems was adapted to the conditions of Lake Poopo basin. The causal network was structured on an environmental platform with two sub platforms: (a) geography and hydrology and (b) socio-economic. This clearly shows the inter-relation between parameters and indicators and the relevant geographic region with its specific hydrologic, socio-economic and environmental conditions. As a consequence, floods, drought, and salinization are the main impacts on natural resources, while socio-economic behavior in particular aggravates poverty and the fragile environmental situation.

Land property and fragmentation in the region contribute to the existence of water conflicts. Currently, agriculture and livestock breeding are the main sources of income for the rural population in the Lake Poopo region, and are mainly carried out on small-scale and dispersed parcels of land. The main areas of cultivation are located on flat land and soft relief hills bordering the lakes. After the land reformation of 1953, the rural property was fragmented to a large extent, and land parcels were sometimes limited to a few square meters. In such conditions only small-scale subsistence agriculture is possible. In the basin, only one small community with international cooperation can afford the newer water saving irrigation technique (spray and dripping) and very few farmers can also afford modern land cultivation equipment.

Pollution of water resources is another of the most important factors aggravating water-related conflicts. Over a long period of time, rivers and lakes have been contaminated by heavy metals from the mining companies. On the other hand, spills of crude petroleum infiltrating the Desaguadero River have practically exterminated the native species of fish existing in Lake Poopo, which had devastating social, economic and cultural consequences. Fishing was the way of survival for the native culture of Uru-Muratos, a tribe that has since had to resort to leaving their land and working for local farmers to secure their livelihood. Negative impact of pollution on the local environment will be felt for many years to come (Montoya and Mendieta 2006).

2.2 Integration of Stakeholder in IWRM Decision Making (DM) Processes

Water resources management involves various stakeholders with multiple objectives. Therefore, all individual, groups or community-based organizations should be included in related decision-making processes. Stakeholders are all individuals, communities, irrigation organizations, local and municipality authorities, etc., that have interest (stake) in the use or the management of water resources (households, farmers, companies, and others). The question is how to support stakeholders in managing their water demands in connection with increasing competition, interdependency and land fragmentation in order to guarantee the sustainability of water resources management (Feng 2001). According to Hermans (2006) of the FAO, “supporting stakeholders in managing their water resources means supporting stakeholders to make choices and to reach a common understanding on the necessary arrangements for sharing and equitable allocation of water related goods and services”. Evaluating different strategies in water management (water valuation) is implicit to this process. Water valuation means expressing the value of water related goods and services in order to inform sharing and allocation decisions (Hermans 2006).

The decision makers normally disregard the perceptions of the problem by the stakeholders due to the complexity of related water issues. For this reason, the participation of the Lake Poopo basin stakeholder’s at this level has been helpful in the identification of the main relevant criteria and their societal targets in the DM process. However, the stakeholders also have problems identifying these criteria and assessing priorities for indicators. Supporting the stakeholders in this process has been successfully achieved through the conduction of workshops and seminars in the rural communities. This path of analyzing the problem in the Lake Poopo basin helped to attain a proper structure of the problem. This is a pre-condition of good DM (Greeno 1976). Thereby, we followed the DM process for the IWRM and sustainable development of Feás et al. (2004), where stakeholders are explicitly included into the whole DM process.

3 Methodology—Analytic Hierarchy Process (AHP)

According to Feás et al. (2004), a DM process implies the following steps:

(a) Identification of alternatives that can solve the problem;
(b) Selection of the criteria on the basis of which alternatives or instruments are going to be compared;
(c) Estimation of the priorities of the alternatives related to the criteria;
(d) Selection of the information derived from performances;
(e) Relative importance of criteria must be clear in order to be able to select alternative(s).

These steps are comparable with other models of decision processes, like Davis and Cosenza’s (1993) model, where each decision (and evaluation) process starts with problem recognition, followed by information search, problem analysis, alternative evaluation and finally the decision, i.e. the phase of implementation. A review of multi criteria decision methods for IWRM purposes can be found in Hajkowicz and Collins (2007). In our study the AHP has been selected to approximate the preferences of the objectives and alternatives of the proposed MCDA model. Our procedure is comparable to the evaluation process conducted by Zhang (2009).

The AHP is a methodology developed by Saaty (1980) for DM. The AHP is very often applied when complex DM situations occur, in project management (e.g. Al-Subhi Al-Harbi 2001), strategic planning (e.g. Oeltjenbruns et al. 1995), all kinds of alternative selection (e.g. Gibney and Shang 2007), etc. Bana e Costa and Vansnick (2008) provide an overview over real-world applications of the AHP.

Usually, the application of the AHP requires the following steps (Saaty 2008; see also Saaty 1980, 1990, 1995):

1. The problem has to be defined, the necessary information and data requirements (knowledge) has to be identified.
2. The problem has to be structured; as a result we get a decision hierarchy. The main goal, the criteria influencing the decision, and an evoked set of alternatives are determined.
3. Pairwise comparison matrixes of the elements are constructed to estimate priorities. "Pairwise Comparison (PC) method is a powerful inference tool that permits the building of a global rank from local ones by using matricial algebra" (González-Pachón and Romero 2004; comp. also Wei 1952). PCs are used as long as no quantitative information is available and as long as no rating mode is applied (Saaty 2008, 90). The rating method is less accurate, but a decision maker is able to consider more criteria and get results faster.
4. The PC matrixes are used to approximate the absolute priorities of the elements (in combination with a consistency and sensitivity analysis). By multiplying these priorities with the overall weight of the relevant element of the hierarchy level above we get the *relative* priority vectors. Decision makers continue with this evaluation process until the final level of the hierarchy is reached. Priorities are then summed up to obtain the priority vectors of the alternatives.

Confirming Saaty (1980) a PC matrix is obtained by use of a semantic scale ranging from 9 (extreme importance) to 1 for equal and the reciprocal value 1/9 which represents the other end of the scale, the lowest possible evaluation point (extreme unimportance). There are other scales available, e.g. the transitive calibration scale by Finan and Hurley (1999), or the geometric scale by Dong et al. (2008).

To approximate priority vectors Saaty (1980) suggests the eigenvector method. Let A represent a reciprocal n·n-judgment matrix containing all pairwise comparisons a_{ij} between elements i and j for all $i, j \in \{1, 2, ..., n\}$

$$A = (a_{ij}) = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{pmatrix} \tag{1}$$

where $a_{ji} = a_{ij}^{-1}$. The priority vector $\mathrm{w} = (w_1, w_2, ..., w_n)^T$ represents the importance of the relevant elements compared within the PC matrix. It may be derived from matrix A. Saaty (1980) proved that the principal right eigenvector could be used to approximate w even in cases where A is not completely consistent by solving the quotation

$$Aw = \lambda_{\max} w, \ \ \lambda_{\max} \geq n \tag{2}$$

It is easy to understand that if, and only if A is a consistent matrix, $\lambda_{\max} = n$ otherwise $\lambda_{\max} > n$. Other approximation methods were introduced. Examples for these methods are the least-squares-method or the method of the row geometric means (González-Pachón and Romero 2004). "Several methods have adopted an approximation perspective; i.e., they try to search a reciprocal and consistent matrix, W, that differs from M 'as little as possible', and then obtaining weights from W. Saaty's eigenvector method may be considered one of them" (González-Pachón and Romero 2004). Furthermore, methodological extensions were introduced (e.g. fuzzy logic with geometric means method for the fuzzy AHP, presented by Buckley 1985). There is still an ongoing discussion on approximation methods; this point is still unresolved. A critical analysis of the eigenvector method can be taken from Bana e Costa and Vansnick (2008).

Following Saaty's (2003) argumentation concerning the necessity of the eigenvector method, the AHP was applied as proposed by Saaty (1980). This implies the use of the fundamental 9–1–$^1/_9$ scale and the use of the principal right eigenvector representing the priority vector w. Furthermore, we will present methodological considerations concerning the AHP, in particular, hierarchical extensions (with the introduction of "actors", i.e. the institutions, organizations and persons who shall implement a decision) and consistency (in connection with the aspect "culture"). The latter are close to considerations of Linares (2009) and González-Pachón and Romero (2004).

4 Structure of the Decision Hierarchy of the Lake Poopo Water Management

Following von Winterfeldt (1980), structuring a decision problem may be described as "... an imaginative and creative process of translating an initially ill-defined problem into a set of well defined elements, relations, and operations". According to Feás et al. (2004) IWRM is usually characterized by the involvement of *numerous decision-makers* operating at different levels and a *large number of stakeholders* with conflicting preferences and different value judgments. This makes the development of implementation strategies and DM a very complex issue.

The structure of the suggested model for MCDA has been set up on the basis of three principal *major objectives*: economic, social, and environmental issues and inter-relation between them. This involved the identification and selection of lower level attributes that have an impact on these issues. In fact, these are ten *conflicts* together with the identification and selection of seven *instruments* to confront and solve the conflicts. Finally, a number of possible implementing organizations were included in the decision hierarchy (Fig. 1). Explicitly including implementing organizations, we named them *actors*, is a methodological extension of the AHP. The results of this evaluation process are twofold: (1) the approximation of the importance of specific instruments to solve water resource conflicts and (2) the estimation of the capability of different actors to implement these instruments.

The hierarchical model (Fig. 1) was designed through various stages and facilitated by workshops with the active participation of stakeholders and groups of key players. The authors have played an impartial role as facilitators in this process. This has involved guiding the stakeholder groups through various stages of the MCDA. The stakeholders were chosen to represent all key perspectives of water interests throughout the basin. The three workshops carried out in the towns of Challapata, Quillacas and El Choro were lively and creative sessions with much exchange and feedback of information between stakeholders whose areas of expertise differ from the traditional to the innovative. Between 250 and 800 people took part in these

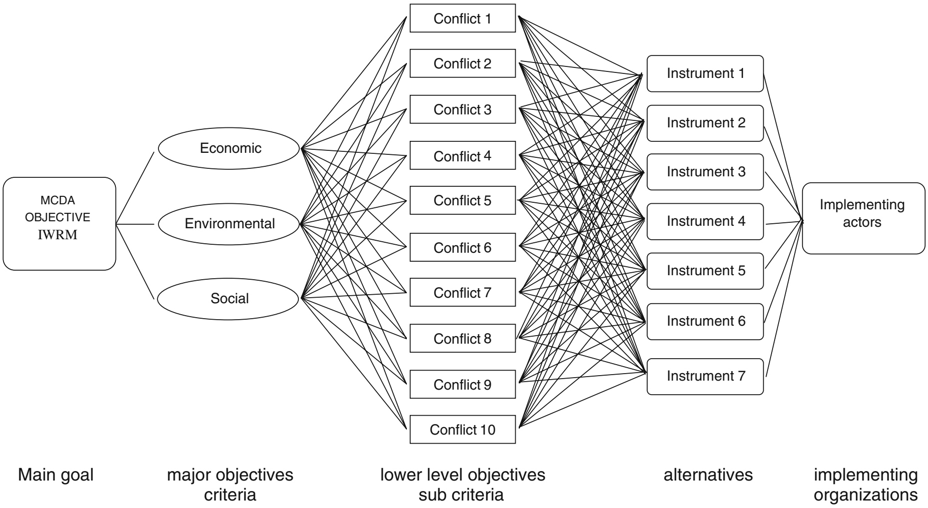

Fig. 1 Proposed structure of multi criteria analysis model for Lake Poopo basin

workshops. The authors aggregated the related evaluations to derive evaluation matrixes presented in Chapter 5. Three factors account for this performance: impartial facilitation, a structured modeling process, and use of information technology to provide on the spot modeling and display the results and scenarios.

4.1 Identifying Criteria

For the IWRM strategy in the Lake Poopo basin, three basic criteria (i.e. major objectives confirming Keeney and Raiffa 1993) were identified: economic (C1), environmental (C2) and social criteria (C3). These criteria represent the summarized variables positively or negatively influencing water conditions (in the Lake Poopo basin, but also in general). They relate to the MDGs defined by the UN to be reached by 2015, aiming for a better world in the twenty-first century, i.e. poverty reduction, environmental sustainability, development (Phumpiu and Gustafsson 2009) (Table 1).

Table 1 Criteria

Abbreviation	Description
C1	Environmental: to implement the administration instruments that generate minimal environmental impact in the basin
C2	Social: to implement the administration instruments that generate less social conflict in the basin
C3	Economic: Implementation of administrative instruments that generate an adequate economic well-being in the basin

Table 2 Conflicts

Abbreviation	Description
Co1	Extreme weather events
Co2	Socio-economic situation
Co3	Cultural aspects
Co4	Stakeholder involvement
Co5	Deficient regulation of the water resources
Co6	Lack of basic information
Co7	Water law and water rights
Co8	Land fragmentation
Co9	Migration
Co10	Pollution

4.2 Identifying the Conflicts in the Basin

Many authors have been dealing with water conflicts in water resources management (e.g., Babel et al. 2005; McNulty 1986; Just and Netanyahu 1998; Opricovic 2009). As shown in the conflict framework (Chapter 2.1) the most important conflicts in the basin were identified and discussed by the stakeholders (Table 2).

Saaty (1995) suggests to build homogeneous groups between five to nine elements at each hierarchy level. We exceeded this limit. It was not possible to delete one of these elements in advance (without knowing their relevant priorities) as all of them belong to the same homogeneous group (the conflicts). The only restriction is, to use Saaty's words "that any element in one level must be capable of being related to some elements in the next higher level" (Saaty 1995). This precondition is given. In total, at this stage 45 pairwise comparisons were necessary to complete the pairwise comparison matrix. Although leading to a satisfying result, this evaluation procedure was demanding. Partial inconsistencies could not be eliminated. We will discuss this point in Chapter 5.6.

Table 3 Instruments

Abbreviation	Description	
I1	Monitoring hydro-meteorological parameters	Participatory/multidisciplinary data collection, analysis and process of database
I2	Base line with stakeholder involvement	Integral diagnostic with active participation of the stakeholders of basin
I3	Implementation of infrastructure	Identification/selection of sub-project (dams, rainwater harvesting, irrigation, etc.)
I4	Implementation of legal statements	Enabling environment (policies, legislation, regulation)
I5	Formation of WMLO	Formation of Water Management Local Organization (WMLO)
I6	Education and training programs	Education, training and diffusion programs in the whole basin on Water Resources Management
I7	Environment audit	Environment audit, especially of mining activities

Table 4 Actors

Abbreviation	Description
A1	ALT (Bi-National Authority of Lake Titicaca)
A2	Bolivian Operating Unit (ALT)
A3	Prefecture of Oruro (Regional Government)
A4	Regional municipalities
A5	Water management local organizations
A6	Recently conformed basin coordination for defense of the BIOTA
A7	Institutions (NGO's, Universities, etc.)
A8	Mining companies

4.3 Identifying the Alternatives (Instruments)

Seven alternatives influencing the conflicts were selected; confirming the very nature of these alternatives to solve water resource related conflicts we named them "instruments". Stakeholders in their communities intensively discussed these instruments. Consequently, the variables were completely validated by them (Table 3).

4.4 Identifying Implementing Organizations (Actors) of IWRM Strategies

In total, eight important organizations (actors A1 to A8 in Table 4) were identified to implement the IWRM strategy. They were also key players participating in the design of the MCDA process and in the evaluation of the whole decision hierarchy. The actors have been identified because one main purpose of this study is to reveal those actors who are more or less able to effectively implement the instruments I1 to I7.

5 Evaluation of the Decision Hierarchy of the Lake Poopo Water Management by Use of the AHP

To carry out the MCDA for the Lake Poopo basin, four basic PC matrixes were developed. The matrixes were used to determine the importance of the instruments as possible solutions for the conflicts and to evaluate the possible contribution of the actors. The basic matrixes comprise all necessary pairwise comparisons at each level of the hierarchy:

1. Matrix M_1—criteria vs. criteria. Prospective result: priorities for the selection of criteria over criteria for the decision-maker as a function of the relative importance of one criterion over another criterion.
2. Matrixes $M_{2.1}$ to $M_{2.3}$—conflicts vs. conflicts with respect to criteria. Prospective result: priorities for the selection of conflicts as a function of the relative importance of each conflict over the criteria.
3. Matrixes $M_{3.1}$ to $M_{3.10}$—instruments vs. instruments with respect to conflicts. Prospective result: priorities for the selection of instruments as a function of the relative importance of each instrument over the conflicts. Expected result: ranking of priority for the selection of instruments, based on how each instrument

helps to solve each conflict, and of what element affects each conflict to maximize or to diminish the general criteria (economic, environmental and social)

4. Matrixes $M_{4.1}$ and $M_{4.7}$—actors vs. actors implementing instruments. Prospective result: ranking of priority for the selection of instruments as a function of the relative importance of each instrument over the implementing actors.

The idea of each MCDA is to construct scales representing preferences for the consequences, to weight the scales for their relative importance, and then to calculate weighted averages across the preference scales (including all relevant criteria within the evaluation process). The setting of weights brings to the fore the question of whose preferences counts the most. The process of deriving weights is thus fundamental to the effectiveness of an MCDA. Pursuant to this, matrixes and weighting were established according to the results of the workshops with the stakeholders. As stated by Dodgson et al. (2000), the criteria weights reflect both the range of option differences, and how much that difference matters. Any numbers can be used for the weights, as long as their ratios consistently represent the valuation of the differences in preferences between the top and bottom scores of the scales being weighted. As mentioned above, for this MCDA valuation, Saaty's fundamental rating scale was applied (Saaty 1980).

5.1 Matrix M_1—Criteria vs. Criteria

The set of criteria $A_1 = \{C1, C2, C3\}$ was evaluated by the stakeholders using pairwise comparisons (C1 environmental criteria, C2 social criteria, C3 economic criteria). The corresponding matrix M_1 was elaborated according to the preferences for the consequences; thus, the stakeholders have played a central role in the scoring process. The following matrix, $M_{1,}$ represents the pairwise weighting concerning the three criteria. Of course, only the upper diagonal elements were assessed directly. As we can easily see from these comparisons, the weightings are not completely consistent (concerning consistency see Chapter 5.6).

$$M_1 = \begin{pmatrix} 1 & 3 & 7 \\ 1/3 & 1 & 9 \\ 1/7 & 1/9 & 1 \end{pmatrix}$$

5.2 Matrixes $M_{2.1}$ to $M_{2.3}$—Conflicts vs. Conflicts with Respect to Criteria

The matrixes of 10 selected conflicts ($A_2 = \{Co1, Co2, ...Co10\}$) have been evaluated with respect to the three criteria, in order to determine the importance of each conflict with respect to the environmental, social, and economic criteria. Below we indicate only $M_{2.1}$, i.e. the pairwise comparisons of all conflicts with respect to *environmental* criteria; matrixes $M_{2.2}$ and $M_{2.3}$ provide a comparable picture for social and economic criteria. From these matrixes we may estimate the relevance of each conflict.

$$M_{2.1} = \begin{pmatrix} 1 & 5 & 5 & 5 & 3 & 3 & 5 & 5 & 5 & 1 \\ 1/5 & 1 & 1/3 & 3 & 3 & 3 & 1/3 & 1 & 5 & 1/5 \\ 1/5 & 3 & 1 & 3 & 5 & 1 & 3 & 5 & 5 & 1 \\ 1/5 & 1/3 & 1/3 & 1 & 5 & 3 & 5 & 9 & 7 & 1 \\ 1/3 & 1/3 & 1/5 & 1/5 & 1 & 1 & 1 & 1/3 & 1/3 & 1 \\ 1/3 & 1/3 & 1 & 1/3 & 1 & 1 & 3 & 1 & 1/5 & 1 \\ 1/5 & 3 & 1/3 & 1/5 & 1 & 1/3 & 1 & 1 & 3 & 1/5 \\ 1/5 & 1 & 1/5 & 1/9 & 3 & 1 & 1 & 1 & 5 & 1/5 \\ 1/5 & 1/5 & 1/5 & 1/7 & 3 & 5 & 1/3 & 1/5 & 1 & 1/5 \\ 1 & 5 & 1 & 1 & 1 & 1 & 5 & 5 & 5 & 1 \end{pmatrix}$$

5.3 Matrixes $M_{3.1}$ to $M_{3.10}$—Instruments vs. Instruments with Respect to Conflicts

The matrixes $M_{3.1}$ to $M_{3.10}$ represent the pairwise comparisons of the seven selected instruments ($A_3 = \{I1, I2, ...I7\}$) under the umbrella of each of the 10 conflicts in order to determine the importance of each instrument with respect to the conflicts. The estimation of priorities can then show the ability of each instrument to solve a relevant conflict. The following matrix, $M_{3.1,}$ contains the pairwise comparisons of the instruments with respect to the conflict Co1 (extreme weather events). Here too, we refrain from displaying the other matrixes $M_{3.2}$ to $M_{3.10}$.

$$M_{3.1} = \begin{pmatrix} 1 & 7 & 7 & 9 & 5 & 3 & 5 \\ 1/7 & 1 & 1/5 & 5 & 3 & 3 & 1 \\ 1/7 & 5 & 1 & 7 & 1 & 5 & 3 \\ 1/9 & 1/5 & 1/7 & 1 & 1/5 & 1/5 & 3 \\ 1/5 & 1/3 & 1 & 5 & 1 & 5 & 3 \\ 1/3 & 1/3 & 1/5 & 5 & 1/5 & 1 & 5 \\ 1/5 & 1 & 1/3 & 1/3 & 1/3 & 1/5 & 1 \end{pmatrix}$$

5.4 Evaluation of the Relative Importance of the Elements of the Decision Hierarchy

We estimated the relevant priorities w by applying Saaty's eigenvector method using formula (2) (Saaty 1980). At the first level of the decision hierarchy, the stakeholders consider mainly environmental criteria ($w_{C1(Env)} = 0.62$) and (with less intensity) social criteria ($w_{C2(Soc)} = 0.33$) to be crucial for the implementation of IWRM principles. Economic variables seem to be of much less significance ($w_{C3(Eco)} = 0.06$) (Table 5).

Table 5 Absolute priorities of MCDA (major criteria, conflicts, and instruments)

Level 1 and 2			Level 3						
w_{Ii}			w_{I1}	w_{I2}	w_{I3}	w_{I4}	w_{I5}	w_{I6}	w_{I7}
$w_{\mathrm{C1(Env)}}$	0.620								
w_{Co1}		0.243	0.429	0.113	0.185	0.033	0.122	0.076	0.041
w_{Co2}		0.089	0.054	0.106	0.414	0.074	0.152	0.138	0.063
w_{Co3}		0.142	0.035	0.189	0.036	0.107	0.357	0.201	0.075
w_{Co4}		0.136	0.042	0.307	0.029	0.062	0.184	0.343	0.033
w_{Co5}		0.037	0.085	0.104	0.330	0.080	0.213	0.151	0.037
w_{Co6}		0.057	0.357	0.184	0.026	0.047	0.102	0.131	0.152
w_{Co7}		0.053	0.017	0.146	0.027	0.461	0.118	0.175	0.056
w_{Co8}		0.053	0.018	0.252	0.078	0.175	0.175	0.201	0.101
w_{Co9}		0.045	0.019	0.119	0.291	0.040	0.146	0.330	0.055
w_{Co10}		0.146	0.017	0.075	0.068	0.161	0.114	0.391	0.174
$w_{\mathrm{C2(Soc)}}$	0.324								
w_{Co1}		0.042	0.429	0.113	0.185	0.033	0.122	0.076	0.041
w_{Co2}		0.214	0.054	0.106	0.414	0.074	0.152	0.138	0.063
w_{Co3}		0.240	0.035	0.189	0.036	0.107	0.357	0.201	0.075
w_{Co4}		0.213	0.042	0.307	0.029	0.062	0.184	0.343	0.033
w_{Co5}		0.018	0.085	0.104	0.330	0.080	0.213	0.151	0.037
w_{Co6}		0.059	0.357	0.184	0.026	0.047	0.102	0.131	0.152
w_{Co7}		0.078	0.017	0.146	0.027	0.461	0.118	0.175	0.056
w_{Co8}		0.071	0.018	0.252	0.078	0.175	0.175	0.201	0.101
w_{Co9}		0.037	0.019	0.119	0.291	0.040	0.146	0.330	0.055
w_{Co10}		0.028	0.017	0.075	0.068	0.161	0.114	0.391	0.174
$w_{\mathrm{C3(Eco)}}$	0.056								
w_{Co1}		0.034	0.429	0.113	0.185	0.033	0.122	0.076	0.041
w_{Co2}		0.154	0.054	0.106	0.414	0.074	0.152	0.138	0.063
w_{Co3}		0.089	0.035	0.189	0.036	0.107	0.357	0.201	0.075
w_{Co4}		0.079	0.042	0.307	0.029	0.062	0.184	0.343	0.033
w_{Co5}		0.079	0.085	0.104	0.330	0.080	0.213	0.151	0.037
w_{Co6}		0.051	0.357	0.184	0.026	0.047	0.102	0.131	0.152
w_{Co7}		0.048	0.017	0.146	0.027	0.461	0.118	0.175	0.056
w_{Co8}		0.130	0.018	0.252	0.078	0.175	0.175	0.201	0.101
w_{Co9}		0.181	0.019	0.119	0.291	0.040	0.146	0.330	0.055
w_{Co10}		0.154	0.017	0.075	0.068	0.161	0.114	0.391	0.174

By multiplying the priorities of all elements of the hierarchy by the relevant priorities of the upper hierarchy level elements, we get the relevant weights of the decision hierarchy. By aggregating the priorities at the instruments' hierarchy level, we can assume that I6 (education and training programs) and I5 (formation of Water Management Local Organization (WMLO)) will be the most important for the implementation of IWRM principles, followed by I2 (Lake Poopo basin with stakeholder involvement) (see Table 6). Thus, it seems to be advisable that the first step for the IWRM will be to establish training programs for the stakeholders connected to the basin.

A deeper analysis of the results shows that the conflicts are frequently connected to one specific criteria of the hierarchy; e.g., Co1 (extreme weather events) is seen to have mainly environmental outcomes while conflicts Co8 (land fragmentation) and Co9 (migration) are mainly economically relevant. Co2 (socio-economic situation) is considered to have impacts on the criterion "Economy" as well as on "Society", while

Table 6 Relative priorities of MCDA (criteria, conflicts, and instruments) and total weighting of instruments I1 to I7

Level 1 and 2			Level 3						
w_{Ii}			w_{I1}	w_{I2}	w_{I3}	w_{I4}	w_{I5}	w_{I6}	w_{I7}
$w_{C1(Env)}$	0.620								
w_{Co1}		0.150	0.065	0.017	0.028	0.005	0.018	0.011	0.006
w_{Co2}		0.055	0.003	0.006	0.023	0.004	0.008	0.008	0.003
w_{Co3}		0.088	0.003	0.017	0.003	0.009	0.031	0.018	0.007
w_{Co4}		0.084	0.004	0.026	0.002	0.005	0.015	0.029	0.003
w_{Co5}		0.023	0.002	0.002	0.007	0.002	0.005	0.003	0.001
w_{Co6}		0.035	0.013	0.006	0.001	0.002	0.004	0.005	0.005
w_{Co7}		0.033	0.001	0.005	0.001	0.015	0.004	0.006	0.002
w_{Co8}		0.033	0.001	0.008	0.003	0.006	0.006	0.007	0.003
w_{Co9}		0.028	0.001	0.003	0.008	0.001	0.004	0.009	0.002
w_{Co10}		0.091	0.002	0.007	0.006	0.015	0.010	0.035	0.016
$w_{C2(Soc)}$	0.324								
w_{Co1}		0.014	0.006	0.002	0.003	0.000	0.002	0.001	0.001
w_{Co2}		0.069	0.004	0.007	0.029	0.005	0.011	0.010	0.004
w_{Co3}		0.078	0.003	0.015	0.003	0.008	0.028	0.016	0.006
w_{Co4}		0.069	0.003	0.021	0.002	0.004	0.013	0.024	0.002
w_{Co5}		0.006	0.001	0.001	0.002	0.000	0.001	0.001	0.000
w_{Co6}		0.019	0.007	0.004	0.000	0.001	0.002	0.002	0.003
w_{Co7}		0.025	0.000	0.004	0.001	0.012	0.003	0.004	0.001
w_{Co8}		0.023	0.000	0.006	0.002	0.004	0.004	0.005	0.002
w_{Co9}		0.012	0.000	0.001	0.003	0.000	0.002	0.004	0.001
w_{Co10}		0.009	0.000	0.001	0.001	0.001	0.001	0.004	0.002
$w_{C3(Eco)}$	0.056								
w_{Co1}		0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
w_{Co2}		0.009	0.000	0.001	0.004	0.001	0.001	0.001	0.001
w_{Co3}		0.005	0.000	0.001	0.000	0.001	0.002	0.001	0.000
w_{Co4}		0.004	0.000	0.001	0.000	0.000	0.001	0.002	0.000
w_{Co5}		0.004	0.000	0.000	0.001	0.000	0.001	0.001	0.000
w_{Co6}		0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000
w_{Co7}		0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.000
w_{Co8}		0.007	0.000	0.002	0.001	0.001	0.001	0.001	0.001
w_{Co9}		0.010	0.000	0.001	0.003	0.000	0.001	0.003	0.001
w_{Co10}		0.009	0.000	0.001	0.001	0.001	0.001	0.003	0.002
Total weighting			0.119	0.166	0.137	0.107	0.181	0.214	0.075
Rank			5	3	4	6	2	1	7

Co10 (pollution) has environmental and economic outcomes (for all other details see Fig. 2). Therefore, along with other considerations (like scientific results referring to the water management situation in comparable regions) we now have a picture of the situation confirming the estimation of the stakeholders.

Comparable conclusions can be made concerning the instruments. From Table 5 we can learn that instrument I1 (monitoring hydro-meteorological parameters) is especially useful for improving negative impacts of conflict Co1 (extreme weather events; $w_{I1}(\text{Co1}) = 0.43$) and Co6 (lack of basic information; $w_{I1}(\text{Co6}) = 0.36$). The same may be said for:

- I3 (implementation of infrastructure) for Co2 (socio-economic situation) and Co5 (Deficient regulation of the water resources)

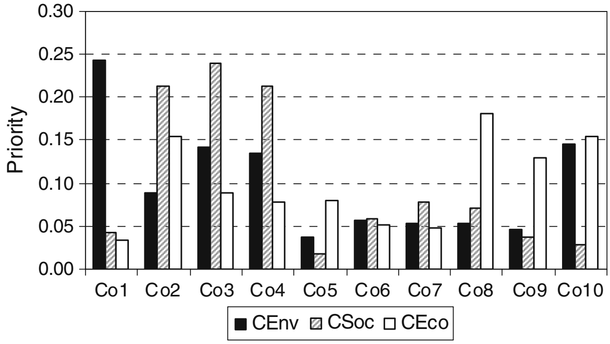

Fig. 2 Absolute priorities of conflicts referring to criteria

- I5 (formation of WMLO) for Co3 (cultural aspects)
- I4 (implementation of legal statements) for Co7 (water law and water rights)
- I6 (education and training programs) for Co10 (pollution)

(For all other details connected to instruments and conflicts see Table 5.)

Therefore, we may assume that, depending on the problem we are considering, different instruments seem to be more or less appropriate. Moreover, one must take into account which problem-field should be dealt with in general. For instance, if we want to improve mainly the *environmental* situation, I1 may be assumed to be the most effective instrument (together with I5, I6 and I2).

5.5 Matrixes $M_{4.1}$ and $M_{4.7}$—Actors vs. Actors Implementing Instruments

To evaluate the actors' ability to participate in the implementation process, the same pairwise comparison valuation was done, as described in the above chapter. From the set of actors $A_4 = \{A1, A2, \ldots A8\}$ we need seven different matrixes in order to estimate the relevant priorities referring to the implementation of instruments. The following, exemplary matrix, $M_{4.1,}$ was also produced by the participating stakeholders; matrixes $M_{4.2}$ and $M_{4.7}$ provide a comparable illustration.

$$M_{4.1} = \begin{pmatrix} 1 & 1 & 1/3 & 1/5 & 3 & 3 & 1/3 & 5 \\ 1 & 1 & 1/3 & 1/3 & 3 & 3 & 1/3 & 7 \\ 3 & 3 & 1 & 7 & 9 & 9 & 7 & 9 \\ 5 & 3 & 1/7 & 1 & 3 & 5 & 3 & 7 \\ 1/3 & 1/3 & 1/9 & 1/3 & 1 & 1 & 3 & 5 \\ 1/3 & 1/3 & 1/9 & 1/5 & 1 & 1 & 3 & 7 \\ 3 & 3 & 1/7 & 1/3 & 1/3 & 1/3 & 1 & 5 \\ 1/5 & 1/7 & 1/9 & 1/7 & 1/5 & 1/7 & 1/5 & 1 \end{pmatrix}$$

The relative importance of each actor may be estimated from these pairwise comparisons (here too, we used Saaty's eigenvector method for the approximation of

Table 7 Absolute priorities of MCDA (actors, instruments)

	w_{A1}	w_{A2}	w_{A3}	w_{A4}	w_{A5}	w_{A6}	w_{A7}	w_{A8}
I1	0.085	0.090	0.414	0.183	0.063	0.064	0.086	0.016
I2	0.021	0.056	0.091	0.162	0.282	0.308	0.053	0.028
I3	0.041	0.063	0.095	0.195	0.375	0.137	0.077	0.017
I4	0.152	0.110	0.371	0.203	0.028	0.045	0.068	0.023
I5	0.033	0.032	0.133	0.127	0.296	0.297	0.064	0.018
I6	0.047	0.137	0.495	0.069	0.031	0.029	0.111	0.082
I7	0.073	0.138	0.460	0.081	0.036	0.089	0.060	0.062

priorities). The following table represents the absolute priorities for the actors with respect to the relevant instruments.

According to this table, we may assume, for example, that if I1 is considered appropriate for implementation, then one should mainly rely on actor 3 (prefecture of Oruro). To make use of the instruments I6, I5 and I2 (highest overall priorities), different actors should be taken into account: A3 (prefecture of Oruro) may be assumed to be the main actor for the application of I6 (implementation of education and training programs; highest priority $w_{A3} = 0.495$; see Table 7). Only A2, (Bolivian Operating Unit, ALT) and A7 (organizations such as NGOs, universities, etc.) are seen to be of moderate importance concerning education and training; all other authorities are below $w_{Ii} < 0.1$, which is an unmistakable signal of their relative unimportance for I6. For both, I5 (formation of WMLO) and I2 (base line with stakeholder involvement) the most important actors are A5 (local organizations) and A6 (basin coordination for defense of the BIOTA), respectively.

Independent of the instruments considered above, actor A3 (regional government – prefecture of Oruro; total $w_{A3} = 0.282$; see Table 8) seems to be the actor with the highest "authority" with respect to IWRM, followed by A5 (local organizations) and A6 (basin coordination for defense of the BIOTA). This result confirms findings by Phumpiu and Gustafsson (2009): "WSS [water and sanitation service] partnerships at local level have demonstrated to be efficient and to bring the best of abilities at very high levels of equity". However, from our experience, the lack of sustainable financial support, capacity building and implementation ability could be permanent obstacles for A5 to really play an important role within the implementation process. Furthermore, A4 (regional municipalities) are of significant importance, and all other actors are considered to be significantly inferior when concerning IRWM.

Table 8 Absolute priorities of MCDA (actors, instruments)

	w_{Ii}	w_{A1}	w_{A2}	w_{A3}	w_{A4}	w_{A5}	w_{A6}	w_{A7}	w_{A8}
I1	0.119	0.010	0.011	0.049	0.022	0.008	0.008	0.010	0.002
I2	0.166	0.003	0.009	0.015	0.027	0.047	0.051	0.009	0.005
I3	0.137	0.006	0.009	0.013	0.027	0.052	0.019	0.011	0.002
I4	0.107	0.016	0.012	0.040	0.022	0.003	0.005	0.007	0.002
I5	0.181	0.006	0.006	0.024	0.023	0.054	0.054	0.012	0.003
I6	0.214	0.010	0.029	0.106	0.015	0.007	0.006	0.024	0.017
I7	0.075	0.005	0.010	0.034	0.006	0.003	0.007	0.004	0.005
Total weight		0.057	0.086	0.282	0.141	0.172	0.149	0.077	0.037
Rank		7	5	1	4	2	3	6	8

5.6 Sensitivity and Consistency Analysis

Finally, one must consider that MCDAs are usually connected to some methodological problems. Therefore, it is necessary to finally analyze the stability of these results (sensitivity analysis) and the consistency of the subjective judgments (connected with pairwise comparisons and the transitivity of the ranking of the analysis). These problems are broadly discussed in relevant literature (e.g. Linares 2009); examinations in this regard help us to assure that analytical results are not generated on the basis of random decisions.

Concerning the sensitivity analysis, it might be concluded that the generated results are robust and stable. Even if we shift the weighting of the first level of the hierarchy significantly, the final ranking of instruments and actors would not change. This is a reliable signal for stability.

Concerning consistency, the results are much more problematic. To prove the consistency of the pairwise comparisons, we used Saaty's standard solution for evaluating consistency of AHP decision matrixes (Saaty 1980), following Perron's Theorem that any positive matrix has a maximum, real and positive eigenvalue λ_{max} (Stein and Mizzi 2007). If $\lambda_{max} = n$ (number of elements of the relevant pairwise comparison) a consistent matrix is available. If $\lambda_{max} > n$ then the matrix is not consistent. The referring Consistency Index (CI) is defined by (Saaty 1980)

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

However, the metric amount of CI depends on the size of the matrix; therefore, CI is not useful for evaluating the consistency of a matrix but the *ratio* of CI divided by CI of a random matrix should be used (i.e. Consistency Ratio CR). We took the random consistency from Saaty (1995), as shown in Table 9.

Confirming Saaty's (1980) suggestions, CR should not exceed the level of 0.1. This might also be interpreted that a small proportion of inconsistent judgments is not harmful, but a typical concept of human behavior. However, if this proportion exceeds a relevant level (0.1 for Saaty's CR) one should rethink the whole decision process. Unfortunately, we calculated a CR far beyond 0.1 for some of the pairwise comparison matrixes analyzed above. The reasons for the inconsistencies of the decision are likely to be due to high complexity and cultural aspects. Therefore, we had to find ways of evaluating the results with respect to the criteria "consistency".

For this purpose, we transformed each inconsistent pairwise comparison matrix with $CR > 0.1$ step by step, by reducing or augmenting the most inconsistent value to the next evaluation point (as long as it did not exceed the maximum scale value of 9 and $^1/_9$, respectively; when it did, we took the second most inconsistent evaluation) until we reached the required level of $CR \leq 0.1$. For the first matrix (pairwise comparisons of C1, C2, C3) the original matrix shifted from

$$M_1 = \begin{pmatrix} 1 & 3 & 7 \\ 1/3 & 1 & 9 \\ 1/7 & 1/9 & 1 \end{pmatrix} \text{ to } M_1' = \begin{pmatrix} 1 & 2 & 7 \\ 1/2 & 1 & 9 \\ 1/7 & 1/9 & 1 \end{pmatrix}.$$

Table 9 Random consistency

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 10 Consistency ratio (original matrixes and modified)

	Original matrix M_i CR	Modified matrix M'_i CR ≤ 0.1
Criteria		
M_1, M'_1	0.198	0.096
Conflicts		
$M_{2.1}$, $M'_{2.1}$	0.256	0.097
$M_{2.2}$, $M'_{2.2}$	0.138	0.098
$M_{2.3}$, $M'_{2.3}$	0.284	0.096
Instruments		
$M_{3.1}$, $M'_{3.1}$	0.244	0.094
$M_{3.2}$, $M'_{3.2}$	0.148	0.097
$M_{3.3}$, $M'_{3.3}$	0.112	0.097
$M_{3.4}$, $M'_{3.4}$	0.105	0.085
$M_{3.5}$, $M'_{3.5}$	0.195	0.099
$M_{3.6}$, $M'_{3.6}$	0.088	0.088
$M_{3.7}$, $M'_{3.7}$	0.138	0.098
$M_{3.8}$, $M'_{3.8}$	0.351	0.094
$M_{3.9}$, $M'_{3.9}$	0.087	0.087
$M_{3.10}$, $M'_{3.10}$	0.141	0.099
Actors		
$M_{4.1}$, $M'_{4.1}$	0.196	0.097
$M_{4.2}$, $M'_{4.2}$	0.113	0.097
$M_{4.3}$, $M'_{4.3}$	0.268	0.098
$M_{4.4}$, $M'_{4.4}$	0.177	0.099
$M_{4.5}$, $M'_{4.5}$	0.067	0.067
$M_{4.6}$, $M'_{4.6}$	0.110	0.091
$M_{4.7}$, $M'_{4.7}$	0.184	0.095

In this case, only one change in one cell was necessary in order to reach a consistency level of CR $\leq$ 0.1 (CR = 0.096). To get all matrixes (Table 10) to a sufficient consistency level, we had to make more iteration in many cases.

Subsequently, we recalculated the final results and asserted, via this approach, that the shift of the total weighting of instruments and actors can be neglected. The maximum deviation between the original weighting and the weighting calculated with matrixes fulfilling the condition CR $\leq$ 0.1 was much lower than $\pm$0.01 (for instruments; see Table 11) and even beyond that level for the actors' priorities (Table 12).

Table 11 Consistency analysis—instruments

	w_{I1}	w_{I2}	w_{I3}	w_{I4}	w_{I5}	w_{I6}	w_{I7}
Original	0.119	0.166	0.137	0.107	0.181	0.214	0.075
CR < 0.1	0.121	0.167	0.131	0.108	0.181	0.222	0.069
Deviation	−0.002	−0.001	0.006	−0.001	0.000	−0.008	0.006

Table 12 Consistency analysis—actors

	w_{A1}	w_{A2}	w_{A3}	w_{A4}	w_{A5}	w_{A6}	w_{A7}	w_{A8}
Original	0.057	0.086	0.282	0.141	0.172	0.149	0.077	0.037
CR < 0.1	0.056	0.085	0.283	0.143	0.172	0.146	0.077	0.038
Deviation	0.001	0.001	−0.001	−0.002	0.000	0.003	0.000	−0.001

On the basis of these results, we may conclude that the evaluation within this analysis fulfills both conditions:

1. The results are stable (sensitivity analysis). The results do not change even if we change part of the weightings of higher hierarchy levels.
2. The inconsistencies are not harmful. The inconsistent matrixes within this evaluation process, which are rather high for part of our PC matrixes and probably connected to the complexity of the decision problem and to a cultural approach, do not damage the explanatory power of the evaluation via the AHP presented herein. No intransitivity was found, a pre-condition for rational decision making, or—in other words—"cornerstone of rational preference" (Linares 2009). One have to consider that the strict paradigm of a completely rational decision maker is not valid—and should be even less valid if we include the relevant culture of a decision maker. Confirming Lewis (2007) Latin Americans are extremely relationship oriented which implies dialogue orientation, the preference of first-hand, qualitative (oral) information over quantitative data and a higher relevance of emotions in DM (Gesteland 2005). This might lead to higher inconsistencies in DM but, as we could clearly show, needs not to harm the validity of the evaluation.

6 Concluding Remarks

The values obtained through application of the MCDA model, represent the critical line to follow in order to confront the sustainability of water resources in the Lake Poopo basin. The results acquired from the MCDA allow water resources managers to search for efficient instruments, which take into account ecological, social and economic criteria. These instruments were evaluated according to the preferences of decision makers, based on the active participation and validation of stakeholders. In this case, the most effective instruments should be education and training programs (I6), formation of WMLO (I5), and base line with stakeholder involvement (I2), or a combination of these (Fig. 3).

Concerning the implementing actors identified in the first section of this paper, the local government (A3) seems to be the most appropriate to implement the instruments (Fig. 4). However, it should be discussed to what extent a co-operation between several or all actors could bring even better results concerning IWRM. This point cannot be solved via this evaluation process, as the methodological basis of the MCDA (the pairwise comparisons) does not consider combinations of hierarchy elements (which would be an interesting question). However, we may assume that

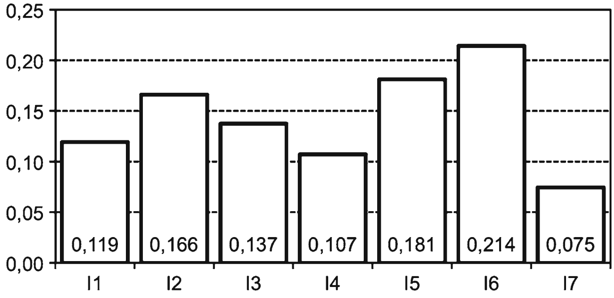

Fig. 3 Priorities of instruments

co-operations are unconditionally necessary in order to introduce IWRM principles in the Lake Poopo basin.

There is a clear need for methodologies and tools to put IWRM principles into practice. This is required in an application context in which decisions and choices are assessed in terms of their sustainability, not only over the long term, but also with regards to their day-to-day contribution to the perspective of sustainable development. Applying the MCDA to the Lake Poopo basin proved to be a practicable and effective way to start a real master plan towards the IWRM strategy. This first approach forms a basis for all further developments and should be empowered and consolidated by the active intervention of stakeholders at all levels, especially in the conformation of the water management local organization (WMLO) in each sub basin.

Finally, an important latent point is, if the MCDA is the best way to serve the decision making process for our purpose. The analysis can be framed in different ways, in some instances directly supporting the eventual decision, and in some less. Therefore, the MCDA might be structured, according to Dodgson et al. (2000), into:

(a) Showing the decision maker the best way forward
(b) Identifying the areas of greater and lesser opportunity
(c) Prioritizing the options
(d) Clarifying the differences between the options
(e) Helping the stakeholders to understand the situation better
(f) Indicating the best allocation of water resources
(g) Any combination of the above

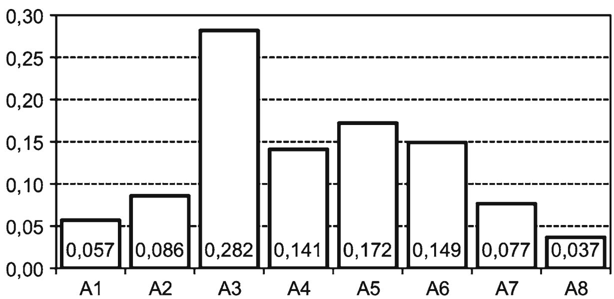

Fig. 4 Priorities of actors

Following this, the results of the research indicate a good direction for the introduction of IWRM principles in the Lake Poopo basin; all of the points a) to g) were included in the above analytical approach. Of course, some problems occurred, mainly connected to consistency of PCs. However we were able to show that these problems are not necessarily influencing the explanatory power of the conclusions. These results are comparable to Linares (2009) when he concludes, "improving consistency is not really significantly improving the validity of the preference weights". By using a stepwise process to reduce inconsistency to a tolerable level ($CR \leq 0.1$) we could show that priorities did not change significantly. Of course, this is no methodological prove of the overall tolerability of inconsistencies. It should be understood that the avoidance of inconsistencies is an important task in DM, but is not always of primary importance. It is likely that inconsistent DM is connected to cultural aspects and should therefore not be overrated. Inconsistent DM might harm the evaluation results and ranking of alternatives; in our case, it did not.

Concerning IWRM, it should be mentioned that the results have already been widely spread throughout the Lake Poopo basin, obtaining positive response and identification of the stakeholders with these results. This should facilitate involvement of all affected institutions and organizations (even if they have opposed points of view), which is probably the key factor for successfully introducing the principles of integrated water resources management.

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