Addressing Socioeconomic Objectives through Enhanced Decision Support Systems for Water Resources Management: Vision, Gaps, and Challenges in South Africa

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ABSTRACT

Water resources management has become a field where computer-aided analytical techniques are expected to facilitate a complex process of decision making which involves several stakeholders with varied interests and various socioeconomic objectives of the natural resource development and management strategies. In many ways, the decision-making related to water resource management exhibits a political process that requires water resources engineering expertise combined with suitable use of informatics. This paper investigates the case of South Africa to assess the extent to which various computer-based decision support systems have succeeded in terms of addressing the socioeconomic objectives encompassed under the new vision for water resources management. Prevailing gaps have been identified through an exhaustive review of relevant initiatives in the country and abroad. A conceptual recommendation has been made to address the identified gaps while highlighting the challenges that lie ahead.

Keywords: Decision support, water resource management, and socioeconomic objective.

GENERAL WATER SITUATION IN SOUTH AFRICA

Recently proposed National Water Resources Strategy for South Africa notes that, in an average year, South Africa gets only about half (450 mm) the world's average rainfall (860 mm per year). In addition, temporal and spatial variations in runoffs across the country considerably constrain the availability of water in terms of adequate, reliable, and timely supplies of water at the required places for various uses [1, 2]. Such variations also influence the extremities such as droughts and floods. Besides these limitations, the competition for water within a sector and across sectors is expected to increase due to:

- Growing water demands resulting from increasing economic activities,
- National commitment to fulfill basic human needs, and
- Reduced water availability for natural ecosystems, including wetlands and forests, in a context of growing ecological consciousness.

Nearly 11 out of the 19 Water Management Areas (WMAs) already have deficit water supplies though the country as a whole has a surplus [2]. The deficits are generally projected to increase and surpluses to diminish considering the future demands for water over the coming years.

THE NEW VISION FOR WATER RESOURCES MANAGEMENT

Over the last decade, the vision for water resource management in the country has been refined and broadened to address a wide range of purposes [1, 2]:

- Meeting basic human needs of present and future generations;
- Ensuring equitable access to water while also redressing past racial and gender discrimination which discriminatory laws and practices of the past have caused in relation to the use of water resources;
- Promoting efficient, productive, beneficial, and sustainable water use;
- Facilitating social and economic development through integrated water resources management,
- Fulfilling growing demands for water;
- Protecting biodiversity and ecology;
- Preventing pollution and degradation of water resources;
- Meeting international obligations in relation to water sharing;
- Enhancing safety of water infrastructures;
- Managing extremities - floods and droughts;
- Institutional development of various stakeholders; etc.

The overall goal is to maximize economic and social well-being in an equitable manner without compromising the sustainability of vital ecosystems. The primary focus is on incorporating the following key objectives into the decision making process related to water resources management in the prevailing hydrological, ecological, and socioeconomic context of South Africa [1]:

1) Achieving efficiency, productivity, equity, and sustainability;
2) Addressing past inequities in access to water;
3) Securing environmental water needs; and

4) Meeting basic human water needs.

Besides being diverse, several of these purposes and objectives are cross-sectoral and not limited to just the water sector and relate to, in addition to water, the natural and human systems. This also indicates a need for a more intensive and integrated management of the water resources while keeping the new principles in mind. In relation to scale, the emphasis now is on river basins compared to individual water systems in the past. Procedurally, a sharper focus is on stakeholders' involvement in decision-making; the delegation of responsibilities of water resources management to the stakeholders; stakeholders' empowerment; and compatibility among the national, provincial, and local spheres of water governance structures [1].

Thus, this new vision for the water resources management in South Africa not only implies the diversity of the issues to be taken into account while undertaking water-related planning, implementation, evaluation activities but also make the decision making process more complex and challenging.

This new water management vision, to facilitate its effective implementation, has been enforced mainly by promulgation of the National Water Act, 1998. Directed by this Act, the ongoing reforms in the water sector of South Africa involve several institutional measures, taken and being taken, both in terms of rules and tools. For examples:

- Formulation of new policies, strategies, rules, regulations, and guidelines;
- Creation of various stakeholders' organizations such as Water Users Associations (WUAs) and Catchment Management Agencies (CMAs) in various WMAs;
- Promotion of stakeholders' participation at various stages of decision-making process;
- Power devolution to stakeholders and their empowerment via WUAs and CMAs;
- Control of water uses through Compulsory licensing, Water pricing, Reserve determination, etc;
- Invocation of the concept of cooperative governance,
- Agencies' role change – from implementer to facilitator/regulator;
- Promoting involvement of community-based organizations and non-governmental organizations; etc.

DECISION SUPPORT SYSTEMS FOR WATER RESOURCES MANAGEMENT

Internationally and in South Africa, water resource managers have access to various computer-based tools for decision-making. These are Information Systems such as databases and Geographical Information Systems (GIS), computational frameworks like expert systems and simulation modeling techniques. Though there have been variations in interpreting what a Decision Support System (DSS) means, there seems to be some consensus as to the purpose of the DSS, i.e. to support decision making in more or less complex (i.e. multi objective or semi structured) situations [3]. The DSSs are computer-based systems that integrate the following three components into a single software implementation [3]:

1) State information - data which represent the water resource system's state at any point in time;
2) Dynamic and process information – first principles governing the resource behavior over time; and
3) Plan evaluation tools - utility software for transforming raw system data into information relevant for decision making.

Thus, a DSS may assist the decision makers in taking the right decisions on the basis of a good comparison of different strategies under various scenarios, and combine the benefits of GIS, expert systems, and simulation models. Such decision-making can relate to any of the three tiers: strategic planning, management control, and operation control [3]. Modern visualization techniques, that are often integral part of the recent DSSs, enable the decision makers to get a quick insight into the various options and tradeoffs. In that respect, a DSS is considered quite useful for priority rankings in a river basin.

There exist six types of DSSs in the field of water resources management [3]:

1) Watershed models,
2) Surface-water quantity models,
3) Surface-water quality models,
4) Ground water models,
5) Economic models, and
6) Social models.

However, most recent efforts to develop models and DSSs extend over more than any one of the above types, for instance, combining ground water and surface water, water quantity and quality, surface water and economic aspects, etc. This is mainly due to the widely expressed need for adopting an integrated approach for water resources management and to address the intensified necessity for integrated science for effective evaluation of tradeoffs in the choices that face society [4].

Use of a DSS for integrated water resource management is very common in several successfully managed river basins around the world, e.g. Murray-Darling river basin in Australia, Komering River basin in Indonesia, Colorado River in the USA, and so forth. It is increasingly being given attention also in South Africa. There can be a range of feasible water management alternatives (longer-term strategic choices for managing water resources) depending upon the development stage of a river basin and corresponding important concerns perceived by the stakeholders [5]. In order to adopt the best favorable alternative, one needs to assess and compare the implications of these alternatives on several sets of criteria depending upon the goals and objectives set forth by the stakeholders and/or as guided by the national strategy for water resources management in a given setting.

THE NEED FOR AN ENHANCED DECISION SUPPORT SYSTEM IN SOUTH AFRICA

The plurality of concerns ensuing from: (1) water scarcity, both temporal and spatial; increasing competition for water, (2) diversified purposes and objectives; (3) integrated approach for managing water which also embraces human systems, and (4) related institutional measures; establishes a pressing need for improved and more comprehensive water resource planning and management. Such management needs to consider all the three dimensions: hydrological, ecological, and socioeconomic - as against the biophysically biased business as usual. This is particularly important in a country like South Africa where approximately 70% of the gross domestic product depends upon the water resources [2].

In order to assist such a comprehensive water resources planning and management, it is imperative that a relevant DSS also encompasses a comprehensive set of criteria against which various water resource management alternatives can mutually be compared. These would include the socioeconomic criteria pertaining to socioeconomic objectives. The need to include socioeconomic component in the decision support tools are particularly important from at least two viewpoints: 1) to facilitate integrated approach of water resources management and 2) to pursue socioeconomic development goals through water resources management such as poverty alleviation, equity in water entitlements and access, addressing past inequity, meeting basic human needs, etc.

Several recent legislative initiatives clearly highlight the need to also take account of socioeconomic indicators in such decision support tools. This need is also in accordance with the Promotions of the Administration Justice Act (Act 3 of 2000, Section 3), which requires that decisions related to the National Water Act (1998) consider all relevant information including the rights of affected parties.

Including all these hydrological, ecological, and socioeconomic dimensions into a DSS has two-fold implications. Firstly, it modifies the larger paradigm in which water resources management options are perceived, assessed, developed, adopted, and managed. Secondly, it influences the criteria set (value tree) against which various water resource management alternatives are assessed and compared.

SOCIOECONOMIC OBJECTIVES OF WATER RESOURCES MANAGEMENT IN SOUTH AFRICA

"Objective" can be defined as 'an aim, goal, or end of action toward which an effort is directed'[1]. "Socioeconomic" usually means 'of or relating to social and economic status of human society'[2]. In general, all activities related to IWRM have something to do with the human society and has direct impact on the socioeconomic status of the society in the form of monitory gain, food security, social cohesion, employment, etc. Besides, the water management activities can also have impacts on hydrologic and ecological conditions of the river basin, which in turn, may influence the socioeconomic status of the stakeholders in the basin. For instance, promoting groundwater use (within the annually rechargeable limit) in a river basin may decrease the need for run-off-the-river diversions leaving more water to flow through the river network affecting the hydrologic conditions of the basin. Such a change in hydrological conditions may increase the hydropower generation potentials improving the socioeconomic conditions of the basin. In addition, the availability of more water in the river could affect the ecological conditions in the surrounding area increasing the opportunities for recreational activities and hence, the employment. Thus, a water management related activity could have direct or indirect effects on several fronts though it might not have considered all of them at the inception stage. Many of these effects can be interdependent. Accordingly, water resources management can have many interdependent sets of objectives covering many fields, such as hydrological, ecological, socioeconomic, etc. Their interdependency makes it challenging to categorize objectives uniquely, such as socioeconomic objectives. Nevertheless, for a more systematic assessment, these effects need to be grouped in most closely related categories. Such a categorization can facilitate the assessment of objectives with the help of variables which are more relevant and meaningful.

Based on the document review, information gathered through interviews with the government officials and water users, various socioeconomic objectives in South Africa can be outlined as follows:

1) Equity - in entitlements, physical and economic accessibility
2) Beneficiation (beneficial to all users, contributing to socioeconomic development, addressing peoples' needs)
3) Public Participation (stakeholders' involvement, use of local knowledge, transparency, fairness, protection of basic rights)
4) Poverty alleviation (employment generation, boosting income, improving water use by resource poor, reducing vulnerability)
5) Institutional Development (organization, accountability, financial viability)
6) Stakeholders' Empowerment (authority delegation, subsidiarity, representivity, capacity building)
7) Basic human need fulfillment
8) Social sustenance (taking account of population change in future)
9) Addressing past inequalities (accounting for Previously Disadvantaged Individuals/Historically Disadvantaged Individuals, corrective actions to reduce social and economic power gaps)
10) Fostering cooperative governance (shared responsibilities)

These objectives imply that any water management alternative must contribute, possibly with varying effects, towards fulfillment of these objectives. Alternatively, consequent effects of any alternative need to be assessed against these objectives.

CONSIDERATION TO SOCIOECONOMIC OBJECTIVES IN EXISTING DECISION SUPPORT SYSTEMS

In South Africa and abroad, numerous efforts have been made and still being made to develop various DSS for water resources management [5, 6, 7, 8, 9, 10]. Several of them are currently in use by various water management entities. To assess the extent to which various socioeconomic objectives have been addressed in the DSS - and thus to identify the gaps - more than 100 relevant DSS were appraised.

An appraisal of in-country efforts indicate that the nature of such initiatives has been diverse and meant for varied purposes [9, 10, 11, 12, 13, 14, 15, 16, www.capetown.gov.za/water/wsdp]:

1. Relative assessment of various scenarios under particular water management alternatives, such as:
    - comparing and identifying best land use scenario for the alternative of changing land use,
    - prioritizing licensing options under the alternative regulating water use through licensing/allocation plans,
    - comparing and identifying best option for augmenting supplies for the alternative of increasing water supplies,

[1] http://m-w.com/dictionary/objective
[2] http://www.defenselink.mil/prhome/poprep99/html/chapter7/c7-def_ses.htm

- identifying the best way to influence the water demand under the alternative of demand management, etc.

2. Evaluating impacts of specific tasks of CMA, which it is expected to undertake under the prevailing legislations and acts, such as reserve determination for human and ecological needs, resource classification, resource-directed measures, assessing individual license applications, etc.
3. Monitoring the process of CMA development to ensure its sustainability using sustainability indicators for catchment management.
4. Developing a tool to support the process of dispersed decision-making by the CMAs for developing catchment management strategy and to carry out envisioned water management tasks.
5. Developing a methodology using multi criteria decision analysis (MCDA) that could facilitate stakeholder participation water resource management.
6. In-stream flow assessments considering flow reduction activities for improved understanding the water situation in a catchment and developmental constraints.
7. Social impact assessment of a particular water-related project.

Despite having different visions and purposes, many of these decision support tools intend to address several socioeconomic objectives. However, an assessment of the extent to which these initiatives ensure fulfillment of the previously identified socioeconomic objectives while being used for the intended purposes indicate that though partial efforts are evidenced under many examples, no single decision support tool covers appreciable extent of the previously identified socioeconomic objectives. The close ones are the efforts made under Social Assessment Framework, Multi-criteria Decision Support for Reserve Determination and Other Catchment Management Activities, and Strategic Environmental Assessment.

Among initiatives made abroad, only a few initiatives have made some efforts towards incorporating socioeconomic objectives, namely GIS-Based Decision Support System (GDSS), Egyptian Water Resources Socio-economic and Environmental System (EWRSES), Rio Grande Decision Support System (RGDSS), SEWSYS, Watershed and River System Management Program (WaRSMP), and System Dynamics Model of the Walker River Basin (WBSM) [17]. The RGDSS aims at evaluating alternative water development and administration strategies against the related policies and laws. However, this also is under development and focuses on regional water allocation considering the only objective of maximizing economic returns. EWRSES is also under development though it plans to accommodate social, economic, and environmental impacts in water resources planning. The conceptual model has tried to take a multi-dimensional and integrated approach to assess the effects of policy makers' different actions on water resources and environmental systems, socioeconomic system, and microeconomic system, to investigate eventual effects on the quality of life. SEWSYS is primarily a decision support tool for urban water management and it is still under testing. In the name of socioeconomic variables, its deals with only operation and maintenance cost in quantified terms. The rest of the variables; such as institutional capacity, socio-culture, and equity; are dealt in form of linguistic variables with qualitative categories such as: very good, good, bad, etc; based on participant's opinion. WaRMSP facilitates decision-making to ensure an equitable balance among competing water uses. Nevertheless, it takes account of only one socioeconomic objective, i.e. equity. WBSM, which also is under development, is aimed at comparing ecological and economic impacts of stream flow restoration alternatives mainly to assess environmental impacts. This general equilibrium model has been developed and is currently being tested to derive regional economic impacts of surface water allocation, which has been considered as the only water management alternative. EIADSS addresses some useful socioeconomic attributes but focuses on environmental impact assessment and does not regard predefined socioeconomic objectives.

CONCLUSIONS

Several decision support systems have been developed and still being developed in South Africa and abroad. Most of them aim to facilitate integrated and comprehensive decision-making with regard to water resources management at various scales. The review of initiatives related to the development of various DSS substantiates that a substantial amount of works has been done and progress made with regard to hydrological and ecological components and related criteria sets. The initiatives made so far with regard to socioeconomic component have been fragmented and insufficient to develop an appropriate and confidently usable socioeconomic module for the decision support [18]. Efforts made to date in South Africa, in which mainly South African universities and local consultants were involved, have been geared toward the specific needs of the respective sections in the Department of Water Affairs and Forestry without sufficiently encompassing the socioeconomic objectives. Similarly, among the completed efforts made abroad, GDSS looks into the singleton objective of maximizing economic returns for regional water allocation, whereas, WaRSMP considers only one socioeconomic objective of equity to help achieve a balance among competing demands. EIADSS is meant for environmental impact assessment and does not address predefined socioeconomic objectives.

These important but partial and fragmented efforts can be very useful for developing a general and more comprehensive methodology for establishing links between water management indicators and socioeconomic objectives, and eventually for relative assessments of various water management alternatives. Use of this socioeconomic module can identify better suitable alternatives from socioeconomic objectives in combination of others: hydrological and ecological; and hence help make better-informed decisions. Besides enriching the decision-making capacity by incorporating the socioeconomic component for improved and more comprehensive water resources development and management, it will help in adopting more acceptable project planning, catchment management strategy formulation, and implementation processes at various hydrological scales [19]. In addition to fostering transparency and communication among the stakeholders, the socioeconomic module and its conceptual framework will also be useful for comprehensive impact assessments.

A NOTE FOR WAY FORWARD

Alternative longer-term strategic choices for managing water resources at the scale of interest can be interpreted as water management alternatives. The main goal of the most water management alternatives is to satisfy water demands of the aspirant water users. Such alternatives may include: dam construction; improving water distributional efficiency; water reallocation; water pricing; groundwater development, etc. Often, such a goal is associated with detailed tasks such as ensuring the availability of water in right quantity, at right time, of right quality at the needed points and locations. Further added conditions may include, accomplishing such tasks in an efficient, reliable, safe, and sustainable manner[3].

How well a task is performed is tracked and assessed by means of appropriate water management indicators, such as water availability, adequacy, efficiency, reliability, etc, depending upon what were the expected immediate outcomes from the task. In other words, the immediate outcomes of a water management alternative first need to be assessed with the help of water management indicators, on which various water management alternatives have immediate effects. These outcomes, in turn, generate several implications on socioeconomic conditions of the basin (This explanation also holds in relation to hydrological and ecological fronts). These implications are expected to contribute towards fulfillment of larger socioeconomic objectives of water resource management (poverty alleviation, equity in water entitlements, access to water services, addressing past inequity, meeting basic human needs, etc).

In sum, all identified water management alternatives, depending on their technical viabilities including hydrological, biophysical, and financial limitations, will have immediate and more visible and direct effects on water management indicators. These effects eventually will have various implications on the socioeconomic conditions of the basin in a given socio-institutional context, which eventually need to contribute toward fulfillment of the longer-term socioeconomic objectives of integrated water resource management. A structured illustration of this interrelationship among the socioeconomic objectives, water management alternatives, water management indicators, and socioeconomic implications is portrayed in Figure 1.

Obviously, this assertion is based on an assumption that it is possible to quantify the ranking of criteria, which has intricate implications from the viewpoints of rational choice theories. This can be addressed by using MCDA techniques in a suitably enhanced DSS [6]. Thus, the approach will help in aggregated prioritization of different water management alternatives by investigating and taking account of the tradeoffs on hydrological, ecological, and socioeconomic fronts altogether. The suggested overarching framework for the use of MCDA in an enhanced DSS is shown in Figure 2.

Nevertheless, in order to rank-order different water management alternatives against the socioeconomic objectives, all the indicators identified for specific socioeconomic objectives will need to be quantitatively aggregated based on a scoring system as agreed upon by the stakeholders themselves. In other words, stakeholders will themselves define how much one socioeconomic objective is more important that the other. It is may also include qualitative grouping. MCDA techniques have been proved very useful for such analyses and the analyses will need to be based on ante-facto approach. The challenges on the way forward can be outlined as follows:

1. Finding appropriate indices for the identified indicators;
2. Defining scales for quantification of indicators;
3. Identifying suitable weight assigning principles; and
4. Developing a perpetually aggregating quantitative and qualitative scoring system for the use of MCDA for rank-ordering the water management alternatives.

[3] http://sofia.usgs.gov/sfrsf/entdisplays/restudy/gettingright.pdf, http://epw.senate.gov/107th/str_0920.htm, http://www.icid.org/v_uk.pdf, http://www.waterinbeeld.nl, http://wa.water.usgs.gov/outreach/hydrology.primer.htm

REFERENCES

[1] NWA, 1998. National Water Act, Act No 36 of 1998. Republic of South Africa.

[2] NWRS, July 2002. National Water Resource Strategy of South Africa (proposed). Republic of South Africa.

[3] Reitsma, R., Zagona, E., Chapra, S., Strzepek, K. 1996. Decision Support Systems for Water Resources Management; in: Mays, L. (Ed.) Handbook of Water Resources Management; Mc-GrawHill.

[4] Turner, C. and Karl, H., 2001. Scientific and social landscapes – new framework and forums for water management and sustainability. In proceedings of "Two Decades of Water Law and Policy Reform: A Retrospective and Agenda for the Future". June 13-15, 2001. Natural Resources Law Center Conference, University of Colorado, Boulder, CO, USA.

[5] Molden, D., Turral, H., Amerasinghe, F., Drechsel, P., van Koppen, B., Wester, F., Tharme, R., Raschid, L., Samad, M., Murray Rust, H., Shah, T., Acreman, M., Smakthin, V., Peden, D., Burton, M., Albergel, J., Meinzen-Dick, R., Dunkhorst, B., Merrey, D., Mustafa, M., Brown, D. and James Dalton, 2002. Integrating research in water, food and environment. Paper No. 5. Challenge Programme on Water and Food. International Water Management Institute. Colombo, Sri Lanka.

[6] Stewart, T.J., Joubert, A.R. and Liu, D. April 2001. Group Decision Support Methods to Facilitate Participative Water Resource Management. WRC Report No. K5/863/0/1, Water Research Commission. South Africa.

[7] DWAF 2002a. Using Water Wisely: A National Water Resource Strategy for South Africa. Information document. August 2002. DWAF, Republic of South Africa.

[8] DWAF 2002. Guidelines for Models to be used for Water Resources Evaluation. Version 1. Prepared by A. Gorgens, A. Tanner, J. Viljoen, K. Sami, I. Dennis, and J. Nel. DWAF Report no. P.RSA/002/2707. June 2002.

[9] DWAF 2002 b. August 2002. The design, management and development of a programming application, which spatially links hydrological, economic, social and environmental information in a decision support system: User Requirements Survey and Conceptual Design of Application. Discussion document. DWAF South Africa.

[10] DWAF 2002c. Progress report: Multicriteria decision support for reserve determination and other catchment management activities. October 2001 - November 2002. WRC Project K5 / 1186 and K5/1298. DWAF, Republic of South Africa.

[11] CPH 2002. Hydrology and Economic in the Usutu-Mhlathuze Water Management Area (Draft). CPH Water, South Africa.

[12] DWAF 2001a. ToR: Social Assessment Framework within the Water Resources Management Programme of the Department of Water Affairs and Forestry (DWAF). South Africa.

[13] USDC. 1994. Guidelines and Principles For Social Impact Assessment. Prepared by The Inter-organizational Committee on Guidelines and Principles for Social Impact Assessment. May 1994, U.S. Department of Commerce, NOAA. National Marine Fisheries Service.

[14] Walmsley JJ, Carden M, Revenaga C, Sagona F & Smith M. 2001. Indicators of sustainable development for catchment management in South Africa – Review of indicators from around the world. Water SA 27(4): 539-550.

[15] Walmsely, J., 2002. Overview: Sustainability Indicators for Catchment Management in South Africa. Water Research Commission, South Africa.

[16] Abdin, A. and Kheireldin, K. A., 2001. Schematization of the Egyptian Water Resources Socio-economic and Environment System for a Planning DSS. In Hayes, D. and Mac McKee (Eds.), 2001. AWRA Summer Specialty Conference and UCOWR Annual Conference Proceedings. " Decision Support Systems for Water Resources Management." American Water Resource Association, Virginia, TPS-01-2, 430 pp.

[17] Prasad, K. 2004. Socioeconomic module for decision support for water resource management in South Africa. PhD dissertation. University of Colorado, USA.

[18] DWAF 2000. Strategic Environmental Assessment for Water Use. Mhlathuze Catchment – KZN. I. Steyl, D.B. Versfeld, and PJ Nelson, Department of Water Affairs and Forestry. Report Number: SEA-01/2000.

[19] WRC 2003. A synthesis and encapsulation of hydrological research findings into a DSS for application at operational/planning level. Terms of Reference for Solicited (Non-targeted) Research Projects. Water Research Commission, South Africa.

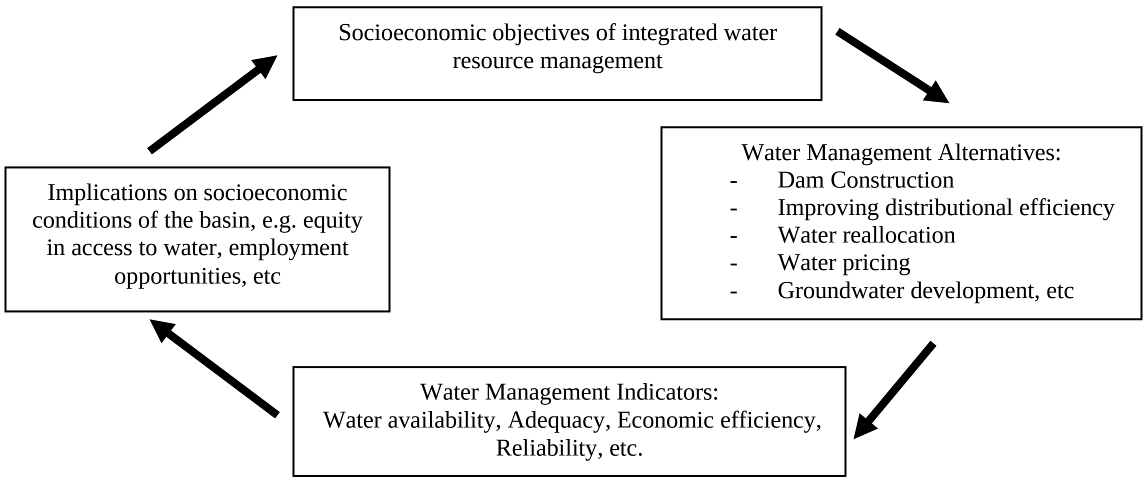

Figure 1: Linkage among socioeconomic objectives, water management alternatives, indicators, and socioeconomic implications

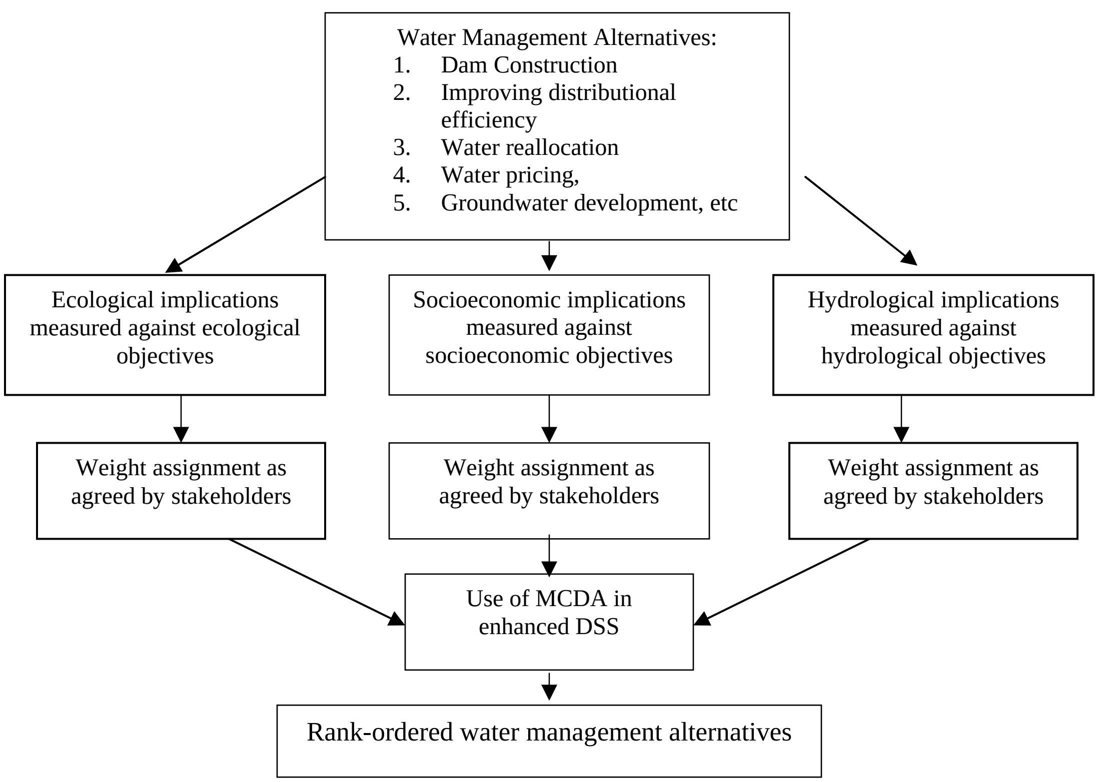

Figure 2: Suggested framework for prioritizing water management alternatives using MCDA