# A DECISION-AID FOR RESOLVING ENVIRONMENT-AGRICULTURE WATER CONFLICTS IN THE GREAT RUAHA RIVER BASIN, TANZANIA

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**Abstract.**
The Great Ruaha River Basin is one of Tanzania's most important river basins. The basin includes one of the major rice producing areas in Tanzania; it embraces the Usangu plains and wetland; the river serves the Ruaha National Park and supplies water to two national hydroelectric power stations (Mtera and Kidatu). The basin is characterized by increasing competition over water resources and conflicts among users. Managers in the area face the challenge of devising effective measures to ensure efficient and equitable allocation of water resources. The conventional ways of allocating water resources in the basin have proved to be inefficient largely due to lack of integrated and strategic approaches to natural resource management. In addition, water allocation decisions have been reached without having a comprehensive understanding of the river basin characteristics and the inter-linkages between the different components, and are undermined by a lack of supportive tools for decision makers. This paper discusses the current water management framework in the Great Ruaha River Basin, the need for having a river basin Decision-Aid (DA), and a description of the DA, which is currently being developed by the RIPARWIN project (Raising Irrigation Productivity And Releasing Water for Intersectoral Needs). The DA is designed with the involvement of key stakeholders in the basin and will help assessing, among other things, the hydrological and socio-economic impacts of different allocation decisions.

**Key words:** Decision-Aid, Great Ruaha River Basin, Integrated water management, Water allocation, Water productivity

## INTRODUCTION

A Decision-Aid (DA) can be defined as an interactive system consisting of data, information, expertise or activities that aid or contribute to options selection. This can be paper based, physical or computer based; and is intended to assist decision makers in their decision making process ([please provide reference here].

Over the past 50 years, cross-sectoral water utilization in Tanzania has grown considerably due to rising human populations, and increasing food demands and economic activities that require water in their production. At the same time, agriculture has remained the engine of development in the country, employing more than 80% of the total population. Recognizing this, the government of Tanzania has attached great importance to the development of this sector with irrigated agriculture being one of the options for achieving this. Yet, irrigated agriculture is globally the major consumer of water resource denying other sectors access to adequate water, including the environment and downstream users. In Usangu plains (upper part of the Great Ruaha River Basin), for example, irrigated paddy alone consumes about 576 $Mm^3$ of water, about one third of the annual outflow (Kadigi *et al.*, 2003). Irrigation activities in this area have increased significantly over the past 30 years and have been implicated as one cause of the drying up of the Great Ruaha River (GRR) in the Ruaha National Park (RNP).

The Great Ruaha River Basin comprises multi-sectoral water uses that have different but important impacts on the livelihoods of the local people and on the national economy as a whole. Most of the population in the basin depend on irrigation and other water-related activities (such as fishing and livestock keeping) to sustain their livelihoods. Irrigated paddy is the main water user in the basin, mainly practiced during the wet season in the alluvial plains upstream of the western wetland. Dry season irrigation (for high value crops such as vegetables) only occurs in very localized areas in the upper courses of the rivers, but irrigation schemes have their canals

abstracting water to meet other needs (e.g., domestic uses and dry season activities such as brick making). Due to these abstractions, downstream, most rivers that supply the wetlands have zero or very minimal flows in the dry season. This has resulted in transforming the western wetland from permanent to seasonal wetland and diminishing the amount of water supplied to the *Ihefu* wetland. Below the *Ihefu* wetland, the GRR has been drying up completely during the dry season for the last ten years. As the GRR is the major source of water for the park, supplying about 80% of the total water, this has caused significant ecological change of both aquatic ecosystems and wildlife in the park. In 2003, for example, about 5,000 fishes and 49 hippopotami died when the GRR dried up. Downstream of the RNP is the Mtera Reservoir, which generates about 80 MW and acts as a regulating reservoir for the large Kidatu hydropower scheme, which generates some 204 MW.

There has been a recognition that the conventional ways of allocating water resources among these competing sectors have proved to be inefficient largely due to a lack of integrated approaches to natural resource management. The decisions to allocate water resources judiciously are recent but in the past such decisions were made without a comprehensive understanding of the river basin characteristics, inter-linkages between the components, or tools to support decision making processes. As stated in the National Water Policy (2002 page ???[***quote the page number***]) "integrated planning…and river basin management" are compulsory "in order to sustain the desired pattern of growth and consumption, and to ensure that all the socio-economic activities maximize their capacities." I can't find this quote though sorry

The above arguments suggest a need for developing tools that will inform water managers and decision makers of the consequences of various decisions about water resources allocation and utilization. With this in mind, this paper reviews the current water management framework in the Great Ruaha River Basin, the need for a river basin Decision-Aid (DA) and presents a description of a computer-based DA, which is being developed by a research project 'RIPARWIN' (Raising Irrigation Productivity And Releasing Water for Intersectoral Needs). The paper also discusses the objectives of such a DA, called the 'RUaha Basin Decision Aid' (RUBDA).

## THE FRAMEWORK FOR WATER MANAGEMENT IN TANZANIA

Natural resources in Tanzania were governed by informal rules until the early 1900's when the German colonial government first started efforts to curb water problems as a response to an increase of water demand. The first Statutory Water Law (1923 Water Ordinance) as well as by-laws concerning water management were created in the 1920's. These state policies remained until the 1960's when Tanzania adopted a more socialistic economy and launched the creation of a policy framework incorporating natural resource management into the broader national framework of sustainable social and economic development and insisting on the collective ownership of natural resources. In the early 1980's, the government through the then Ministry of Water started the management of water under a river basin approach.

Recently Tanzania has formulated a new water policy but its implementation is limited, as the Water Regulation Act has not yet been amended. According to Sokile et al. (2002), the water management initiatives in Tanzania are characterized by an institutional gap and the institutions involved are loosely connected and lack basic coordination. Over a period of time, these initiatives lead to a divorce between customary arrangements for land and more formal water management (Sokile et al., 2002). Institutions involved in water management are listed as follow:

- Which Ministry?? Regional water engineers in charge of water supply;
- Ministry of Agriculture and Food Security responsible for irrigation;
- Hydropower under the Tanzania Electric Supply Company (TANESCO) in the Ministry of Energy and Minerals;
- Ministry of Natural Resources and Tourism is responsible for conservation of biodiversity in water bodies;
- Planning Authorities oversee construction of resort facilities and hotels along the shorelines of lakes; rivers, islands and oceans; and
- The Ministry of Industry and Commerce is responsible for industrial discharge to water.

The National Water Policy emphasizes maximizing economic and social well-being generated by the development and use of water resources and ecosystems in such a way as to ensure that the present and future generations enjoy the benefits of this vital resource. Yet, the present institutional framework ignores informal institutions, especially traditional by-laws, norms and restrictions (Sokile et al., 2002). According to Kaize-Boshe et al. (1994), the predominance of isolated institutions locked into narrowly defined activities with no

interactive learning is likely to continue to hamper national aspirations to manage water. The expectations are diverse and relate to, besides water, other natural and human systems. The goal of the National Water Policy (2002) is to incorporate the following objectives into water resources development and management:

- A minimum water requirement is guaranteed to all humans to maintain human health, and sufficient water is guaranteed to restore and maintain the health, services and functions of ecosystems.
- Water for food security, energy production and other economic activities is readily available.
- Water quality is maintained to meet agreed objectives and standards and that human actions do not impair the long term availability of freshwater stocks; ensure that water resources management is financed and raw water priced to promote efficiency, sustainability and equity.
- Integrated water resources management is instituted.
- Effective and sustainable strategies are in place to address natural and man-made water resources problems.
- Water resources planning and decision-making are participatory. involving all users and stakeholders.
- Water resources data are available and easily accessible to all and an effective infrastructure and information system is in place and operational.
- Institutional mechanisms exist to resolve conflicts over water resources.
- Adequate number of motivated and highly skilled professionals is available.

Procedurally, emphasis is on delegating responsibilities to stakeholders (through water users entities), local governments and Basin Water Offices in order to have the river basin or sub-basin as the planning unit.

**Water management in the Great Ruaha Basin**

The main water management institutions in the basin are the River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP); the Zonal Irrigation Unit – Mbeya; the Rufiji Basin Development Agency (RUBADA); the River Basin Water Office of the Rufiji Basin (RBWO); the Ministry of Agriculture and Food Security through its extension agents and other activities; and NGOs, community-based organizations, and grassroots organizations. Water management institutions in the basin reflect the wider framework of the national level explained above. Several government organizations and formal institutions are dominant, although in the actual sense such institutions do not guide day-to-day human interactions with water. Most of these institutions, especially the governmental ones, are normally backed by formal rules and constraints. The village-based, local informal institutions are inconspicuous and are often ignored. NGOs, although they are very influential in water management and service delivery (Suleiman 2002 [***quote but reference***]), they are not fully involved in national or regional strategic management.

Several initiatives have been introduced, often in an uncoordinated fashion, some of which are described here. The Water Utilization Act No.42 of 1974 (Control and Regulation) created Water Users' Associations (WUAs), which are now viewed as important conflict resolution tools and seek to reduce the number of water right holders for effective purpose of coordination of water use. WUAs are a potential organ to take over all water rights now held by government departments, public corporations, local government authorities, etc Not sure what is meant by this last statement, can you check with Charles. Currently, unregistered users abstracting water in accordance with customary law are being encouraged to regularise their water abstraction by forming WUAs. Previously, the conventional more individual way of allocating water resources via rights has proved to be inefficient. In addition, in the last 10 years, several initiatives were taken in the basin, such the gazettement of the *Ihefu* wetland as a Game Reserve in 1998 by the Ministry of Natural Resources. People that were depending on the wetlands through livestock-keeping, agriculture, fishing and bee keeping are no longer allowed to utilize the resources in the reserve. The gazettement, which has left a large population without real alternatives is one of the initiatives taken by decision-makers without reference to other Ministries or intiatives. This gazettement lacked initial coordination between managing organisations and appears to be having little success on restoring downstream flows. It is possible, that such ill-attuned interventions partly arise from a lack of adaptive tools able to provide a comprehensive view of the basin and the linkages between different water users. The reminder of this paper presents the rationale for having a DA to assist decision-making concerning water resource management in the basin, its objectives and structure.

## RATIONALE AND OBJECTIVES OF RUBDA

The development of a DA was initiated under the former technical co-operation project SMUWC (Sustainable Management of the Usangu Wetland and its Catchment). It was first developed as a hydrological model

(SMUWC, 2000) but for different reasons the software was only partly finished. One reason was its interface, programmed in Fortran 77, which had a "poor" interface in terms of ease of use. Following the SMUWC project, a new version of the model was developed **by whom??** using visual basic interfaces but this version was not completed too and never delivered to decision-makers. One achievement of SMUWC and of other projects and initiatives has been to show that Integrated Water Resource Management (IWRM) helps avoid water conflicts between different uses and users. The Ministry of Water and Livestock Development and most of the institutions in Tanzania now hold this view, implying that a multi-disciplinary understanding and approach is required. The National Water Act ([***quote year and page for this quotation and reference accordingly***]) describes "water resources models and decision support systems" is an instrument for the implementation of water policy and a means of getting an integrated multi-sectoral approach. The Basin Office has also raised the need for such a DA for the management of natural resources, in general, and water resources, in particular.

As a follow up to SMUWC, the RIPARWIN Project initiated further development of a DA through enhanced stakeholder involvement/participation. The actual structure of this DA, called RUBDA, was first adopted during the project steering workshop in September 2002 where key policy stakeholders from the ministries and representatives of most of Great Ruaha River Basin's stakeholders were present. Since then, the RUBDA has evolved in accordance to discussion held during various seminars, workshops and interviews that were held with stakeholders. The main objective of RUBDA is to support RBWO and Districts Councils (especially Mbarali and Mbeya Rural) in making decision concerning water resource management and allocation. For the last 10 years, these institutions have seen their role increase progressively, a role that will grow yet more with the coming Water Regulation Act.

RUBDA is rightly described as a "decision incubator". In other words, the spirit of this DA is not to deliver "ready-to-use" answers for water allocation but instead to generate discussions between decision-makers that could lead to decisions being taken further down the line. This tool will allow the user to go beyond the existing hydrological model (UBM) to involve economic, environmental and social implications in the various scenarios created. It aims to support the implementation of the national water policy and enhancing users' understanding on various issues concerning water management. It is also fundamental to highlight the decision-making mechanisms that stakeholders are using and will use when managing water and land resources in the Great Ruaha River Basin in order to deliver appropriate "answers and solutions" supporting these mechanisms. We will not give in this paper a description of how RUBDA was developed using stakeholder participation, but instead concentrate on its architecture and main "outputs", offered as follows:

- Act as a database;
- Offer GIS "facilities" for providing spatial and technical information related to mapped objects;
- Assess the available water resources;
- Assess the basin characteristics, climatic and allocation means, risks and typologies;
- Delivering water rights that reflect water availability at the sub-basin scale;
- Assist the formulation of water allocation plans and strategies at the sub-basin level;
- Assess the amount of water available for environmental needs as well as basic human needs; and
- Assess the economical impacts of these water allocation strategies especially focusing on potential and impacts of transferring water between sectors on the basis of improved irrigation management and productivity.

Up to now, RBWO has been allocating water without elaborating an overall allocation strategy or a priority plan concerning the allocation of water. In other words, it is "giving water to whoever asks" considering only the water available without giving weight to the use of water. This then ignores environmental needs, even though the latter is now of prominent significance in the new Water Policy. When dry years occur the RBWO ask users to restrict their abstraction of water, without having a priority plan of whom to restrict first or any means of monitoring whether users are following instructions. It has been revealed that when issuing water rights in a particular location, basin authorities notionally use the "10 or 20 year minimal flow" in the river at this location to estimate the water available and then assess the effect of the new water abstraction on downstream users by consulting various actors, including Districts Councils. RBWO is in charge of assessing the effect of new water uses at the basin level, but does not have access to any tools or efficient means of quantitatively estimating these inter-relationships or effects. If correctly designed, RUBDA could be a tool to help meet these needs for a strategic approach by providing a holistic description of the basin and the effects of allocation strategies.

## DESCRIPTION OF RUBDA

Several models constitute RUBDA; it is based on an upgraded hydrological model (the Usangu Basin Model or UBM), is supported by an Outcome Model and Water Management Modules (WMM) and is accompanied by a 'Geographical Information System' (GIS) viewer. Except for the hydrological model, programmed in Fortran 90, the other modules and users interfaces are developed in VISUAL BASIC. This language provides a means of developing interactive "windows" type interfaces that are an added advantage when trying to develop an "easy-to-use" software. Structurally, RUBDA can be divided in three parts as shown in Figure 1.

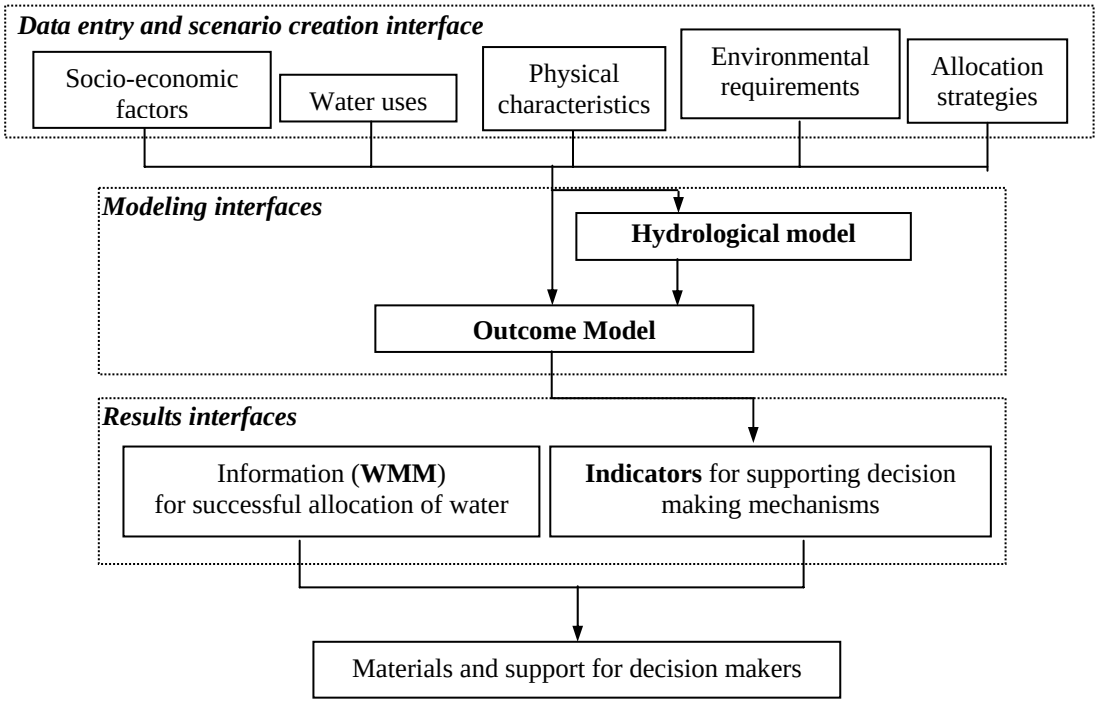


**Figure 1: Structure of RUBDA**

**Data entry and scenario creation interfaces**

The user is, here, given a description of the basin and is offered the opportunity to create scenarios. The description of the basin section is important for situating the policy-maker in recognising that the characteristics of the basin greatly affect the types of water management strategies that must initially be considered. RIPARWIN is trying to build a comprehensive database by collecting all the data scattered in the different institutions that are involved in the basin, including the project data originating from field surveys under RIPARWIN. The description interface uses a GIS viewer developed using a facility called MapObjects™. This GIS viewer allows the user to examine, extract and print the comprehensive database using tables or dynamics maps. The data required to run RUBDA are numerous and cover a wide range of domains. These inputs are processed and used to run scenarios. In default mode, RUBDA runs by using actual data. This means that the "baseline" is the basin information as at 2002/2003 and that scenarios are generated by modifying this default data. These scenarios can be policy-driven scenarios, physical changes scenarios and water demand scenarios and may include the following:

1. Rainfall data: the user can here define a sequence of years. In other words, historical flow data have been classified from very wet, wet, normal, dry to very dry allowing the user to define the type of year;
2. Input from the rainfall stations: new rainfall data. This utility can be used if the user has new rainfall data;
3. Input from the gauging stations: new flow data. This utility can be used if the user has new flow data;
4. Irrigated area. This is a major driver of irrigation demand, it can be adjusted up or down;
5. Irrigation efficiency is another factor affecting water demand and can be adjusted;
6. Water abstracted for irrigation, related to the previous two, the total abstraction volume can be adjusted;
7. Environmental flow requirements. This establishes various instream and downstream demands that then need to be provided;
8. Western floodplain threshold value. This defines the size of the wetland, and is another measure of environmental conservation;

9. Ifushiro wetland area and flow routing characteristics. This establishes the manner in which water is released to the Ruaha National Park;
10. Policy-driven scenarios can assess the impact of policies that would be implemented to reach these objectives. In the Great Ruaha River Basin case, it is mainly the concerns of water allocation planning or land planning, but might also address 'what-if' adjustments to the price or import of rice in defining changes in rice area.

The physical scenarios (i.e., 1 to 3 above) will allow the user to estimate the water that is available in the basin in different climatic situations, while the demand and policy-driven scenarios (i.e., 4 to 10) will directly assess the needs of the decision-makers. Indeed, the decision-makers have socio-economic objectives to reach and need to assess the effects of trying to reach those objectives. After defining the policies and water allocation plans that could be used to reach those objectives, RUBDA will evaluate their socio-economic impacts.

**Modelling interfaces**

Part of the data entered in the scenario interfaces is processed through the hydrological model and other part is directly used in the Outcome Model. The hydrological model (UBM) basically addresses hydrological issues without giving due consideration to the economic and social issues as a comprehensive decision tool. The UBM has six components that tend to capture the main hydrological features of the basin. The components are; (i) the high-catchment rainfall-runoff pattern; (ii) the impact of irrigation activities on the runoff (main user of the Usangu waters); (iii) losses that occur on the alluvial fans (i.e. plains); (iv) flows through the western floodplain; (v) the routing through the eastern swamp; and (vi) the hydrological routing from the swamp through the Ruaha National Park to the Mtera Reservoir.

The development of the UBM was based on a hydrological understanding of the basin using historical data of more than 40 years. The data include rainfall, climatological parameters such as temperature, wind speed, relative humidity and sunshine hours, river runoff, land use and land cover. The inputs into the UBM are rainfall and/or stream flow at the high catchment with an optional evaporation as well as rainfall and optional evaporation on the plains including the wetlands (the floodplain and the swamp). The model runs on a daily basis and so its outputs can easily be aggregated into decadal format that is useful for agricultural planning or into monthly format for water balance that is needed for managerial decisions.

Once the hydrological model has run, the user has access to a large set of flows at different critical points in the basin. These points can be water available for irrigation and after irrigation, flows entering the swamps and wetlands or at the outlet of the basin. These flows are then combined with data acquired directly from the scenario interfaces to form the input to the Outcome Model. The aim of this module is to use the water available as an indicator to help addressing issues as livelihood, economic or environmental issues. The Outcome Model is developed using work undertaken by the RIPARWIN project on Water Productivity Indicators (WPIs). "Water productivity indicators can be defined in terms of physical, economical or social values. Physical indicators normally show the physical output such as ton or kilogram of crop biomass produced, the number of catches of fish from a given water resources/ecological system. The economic indicators derive from the physical ones in the sense that they represent the equivalent value in monetary terms ($) of the output from water given the market conditions. While some social indicators may fall into economic indicators they include benefits such as; the number of jobs created from the presence of the natural resource; livelihood sustenance directly from the natural resources; and the social value (aesthetic) attached to the presence of water by rural communities. It is important to note that most social benefits are generally difficulty to value (Mdemu et al., 2003; p 2). By using WPIs, the DA intends to capture both intended and unintended benefits of water uses. The outcome model, in particular, intends to analyse tradeoffs and present that information in sectoral terms summed for the total volume of water allocated to each sector to allow comparison between sectors and in turn support decision-making over the re-allocation of water.

**Results outputs and interfaces**

Results generated when running scenarios use indicators. These indicators were defined during workshops and interviews with stakeholders and represent the type of results needed to meet the different users' needs. The indicators assess the outcomes of the different scenarios and are of three types. The first set is physical, while the other two (economic and social) explain the tradeoffs of the new allocation patterns. The following is the list of indicators that were defined - this list is not exhaustive and still needs to be expanded:

- Water available at the basin level;

- Water available per capita;
- Sectoral water uses at the basin level;
- Environmental Flows Requirements (EFRs) in five key sites upstream of the Ruaha National Park and the *Ifushiro* and *Ihefu* (Usangu) wetlands. Some of the EFRs are not yet quantitatively defined but work on-going under RIPARWIN project should help evaluate the flow required for the environment;
- Subsistence Flow Requirements (SFRs). SFRs are flows required to meet basic human needs of the population (could be 25 liters/person/day or more if needs for micro-enterprises water uses are included) depending on rivers for domestic water supply;
- River flows in key locations;
- Irrigation flow requirements;
- Wet and dry season size of the wetlands;
- Area under different land-uses;
- Costs/benefits of rice production;
- Costs/benefits of water used for the hydroelectric power generation;
- Costs/benefits of water utilization in other sectors;
- Percentage area under different land uses;
- Population benefiting of each water use.

The indicators are presented as graphs, tables and maps using the GIS viewer (except for graphs) that can be printed or saved. The stakeholders themselves, through interviews, have determined the degree of support, the units and the "scale" in which the results are to be presented.

The Water Management Module (WMM) will contain the indicators. They constitute a set of sub-modules; here the user is prompted on critical issues that have appeared in the results. These modules give information about institutional issues, demography, water and environmental laws or any other subject the user must keep in mind when running scenarios on water allocation. WMM could also contain information on real cases in other basins or impacts of decision on water management that have been made in the past. In doing so, this WMM briefly explains how inter-sectoral water allocation might be effected successfully and sustainably.

The indicators and the outputs of the WMM are then combined as a "package". This package enables the user to print and keep a record of his scenarios, choices and results obtained. The report obtained in this interface can be used as a dissemination tool.

## CONCLUSION

Resolving current conflicts over water utilisation in the Great Ruaha River Basin requires that managers are equipped with tools that will assist in making appropriate and well-informed water allocation decisions. RUBDA, being developed under RIPARWIN, intends to serve as one of these tools. RUBDA will also act as a potential database and will help assessing the available water resources and hence the sectoral water demands at the sub-basin level. This DA is expected to assist the River Basin Authority in its task of reviewing and delivering water rights by matching it to the available water resources. By using the hydrological and socio-economic information, the DA users will be able to assess the impact of each water allocation decision. In order to make the DA useful, there are some prerequisites that need to be observed. These include, among others, the need to collect and enter reliable data. In addition, involving all the key stakeholders in the on-going design and operation of the DA, as well as in other decision-making institutions is very necessary if RUBDA is to be successful in helping resolving the current water management problems in the basin.

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