A DECISION-AID FOR THE MANAGEMENT OF WATER RESOURCES IN THE 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 and it embraces the Usangu plains and wetlands. The Great Ruaha 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

Decision support, and therefore Decision-Aid (DA) can be defined as an interactive system consisting of ``any and all data, information, expertise or activities that contribute to option selection' [1]. This can be paper based, physical or computer based; and is intended to assist decision makers in their decision making process.

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 [3]. 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 [7]. 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. According to the National Water Policy [6, p.13] 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.

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 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 effective in communicating findings it generated. R&D institutions have also fail to account how and to what extent investment in research has had impact especially on the poor and uptake by a wider section of beneficiaries (Bopp, 2002; Hazzell and Haddad, 2001; Gundel, *et al.*; 2001).

The problem is partly caused by the way research projects are designed, whereby most GUIDELINES FOR research projects do not demand a plan of how the research project and its outputs will contribute to impact on the livelihoods of the poor and ways in which research findings would be communicated to ensure that this happens. Because of this shortfall often there is an attribution gap between impacts and the contribution of research, thus making assessment of the impact of NRM research projects difficult (Douthwaite *et al.*, 2003). The other stakeholders are necessary for creating enabling environmental to allow uptake of research products such as manufacturing and distribution, policies, institutions and processes that would promote use of the products. Uptake of research products need more players other than research, extension and farmers as suggested in the Agricultural and Knowledge Information Systems (AKIS) knowledge triangle (FAO/World Bank, 2000). Furthermore, R&D failed to address institutional and policy issues in order to support broader integrated strategy that addresses NRM and poverty. Ashby (2003) argued that researchers should recognize that outcomes and impact on NRM research depends on relationships with other stakeholders, who may have more power to visualize and to realize the desired outcomes of interventions than the researchers do.

This posing a new challenge to researchers to manage "the complex science-policy interface" an important feature of integrated water resource management' (Lankford, *et al*; 2004). Managing this interface call for a change in the way research projects are designed and communicated to end users at all stages of research projects implementation. This would create better understanding of the research findings across a range of stakeholders in the R&D sectors, and use of information from research findings to a wider scale would increase research outcomes and impact on farming household's livelihoods and the watershed development.

Methodology

A number of policy and strategy documents were reviewed to get the insight of policy aspects about issues of NRM management and research guidelines and pathways through which policy are received, implemented and reviewed based on scientific evidence of their performance. Consultation with Policy makers, Research managers in the Directorate of Research and Development and Extension services managers in the Ministry of Agriculture and Director for Forestry Research Institute, Director of Postgraduate studies, Dean of University Faculties and NRM researchers was carried out at national level to collect information about policy and guidelines for research designs and how communication activities are funded and implemented. Two semi-structured questionnaire were designed to soliciting in-depth information. One questionnaire was administered to potential policy makers and research managers and the second questionnaire to researchers. Fifty researchers were interviewed; out of these 9 were women scientists (that is 19 percent) of the total respondents.

Information at village level was also gathered to evaluate the current sources of information to farmers regarding NRM technologies with reference to rainwater harvesting in Maswa and Pare lowlands. Focus group discussions with farmers were conducted in twelve villages in Maswa. Mwanga and Same districts. Among other things research was to establish the efficacy of various communication methods and media in reaching a cross section of stakeholders.

Hypotheses tested include:

i) The role of research systems, institutions and researchers in uptake promotion is rarely recognised or promoted in policies and strategies that guide research on soil and water management.

ii) The mind-set of most of research planners, managers and researchers in soil and water management are still fixated in linear dissemination approach of reaching the ultimate beneficiaries through extension services.

iii) Research programmes and projects rarely include promotion and uptake plans.

iv) Research programmes and projects are rarely evaluated for communication, knowledge sharing, uptake and utilisation of knowledge and technologies produced.

v) A very small proportion of programmes and project budgets and activities are committed or used in the communication and uptake promotion of research results.

vi) Research outputs rarely include specific advise to farmers, input suppliers (e.g. fertilizer suppliers, manufacturers, extension services, policy makers and other clients.

vii) Researchers are not adequately trained for communication and uptake promotion

viii) The rewards and incentives systems like salaries, promotion, prizes to researchers do not demand evidence of utilisation and impact of research.

Results and Discussion

Awareness of the Policy and Strategies in NRM by Scientists

There are policies that guide NRM in all relevant sectors that include agriculture, forestry, land and water policies. Analysis shows that only small proportion of scientists was aware of the existence of national policies and strategies. Policy documents that were mentioned by researchers include Poverty Reduction Strategy papers, Agro-forestry Strategy, Agricultural Mechanisation Strategy, Agricultural Sector Development Strategy (ASDS) and Agricultural Sector Development Programme (ASDP) and Soil and Water Conservation strategy. In the University about 50% of the respondents were aware of policy documents guiding soil and water conservation. In the ARIs on average only 37% are aware of these documents despite the fact that they are the makers and custodians of most of these documents. Scientists from other research institutions such as TAFORI are slightly aware of these documents. One of the reasons is limited accessibility to these documents, particularly in the ARIs. The source of information on policies and strategies to researchers are mentioned as being MAFS headquarters (2%), institute libraries (8%), government website (7%) and friend/colleagues (2%).

Table 1: Awareness of policy documents (% of respondents: n=50)

Documents	Institutions/Organisations			
	ARIs	University	TAFORI	DRD/DLRT
Soil Fertility Initiatives	100	-	-	-
Irrigation Master Plan	41.4	41.4	7	10.3
Soil Water Conservation Strategy	25.0	50.0	-	25.0
Land Use Policy	28.6	42.9	14.3	14.3
Poverty Reduction Policy	100	-	-	-
Agricultural Sector Development Programme	66.7	16.7	-	16.7
Water Policy	44.4	44.4	-	11.2
Agriculture and Livestock Policy	37.5	62.5	-	-
Agro-forestry Strategy	100	-	-	-
National Forestry Research Master Plan	-	-	100	-
National Forestry Policy	-	40.0	40.0	20.0
Agricultural Mechanisation Strategy	100	-	-	-

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" [4]. 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:

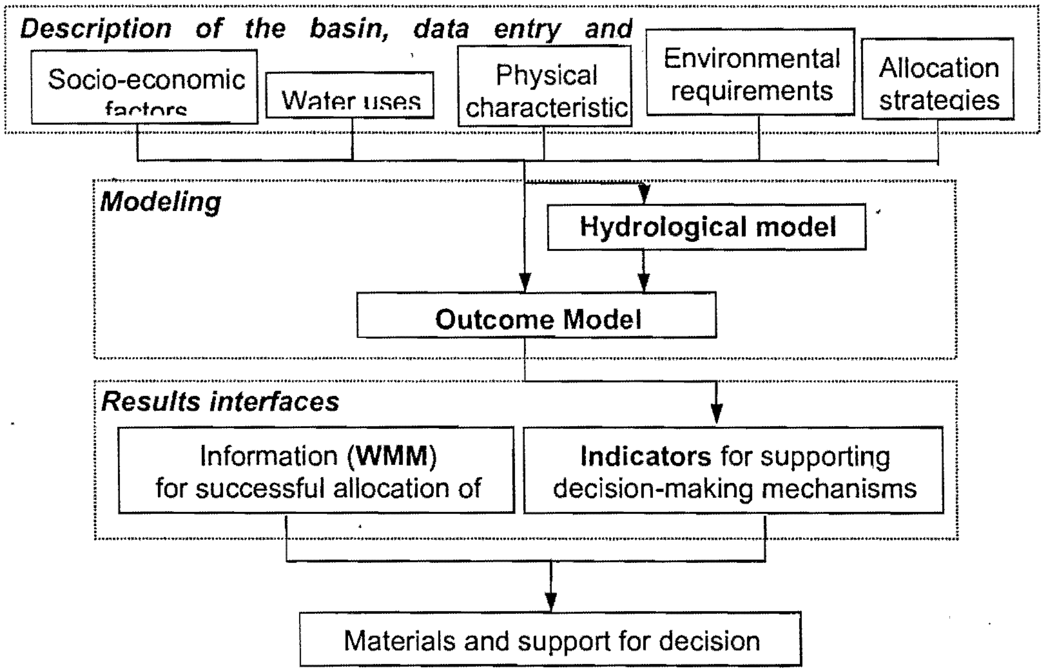
- Act as a database;
- Offer GIS "facilities" for providing spatial and technical information related to mapped objects;
- Assess the available water resources;
- Assess the basin characteristics, climatic and allocation means, risks and typologies;
- Delivering water rights that reflect water availability 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 2004, the 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 ignored environmental needs, even though the latter is of prominent significance in the new Water Policy. When dry years occurred the RBWO asked users to restrict their abstraction of water, without having a priority plan of whom to restrict first or any means of monitoring whether users were following instructions. However, recently RBWO started developing water allocation strategies where water rights are not a strategy on there own anymore but a tool, among others, to achieve the allocation plans. It has been observed 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. The RBWO is in charge of assessing the effect of new water uses at the basin level, but it 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 programming language provides a means of developing interactive "windows-type" interfaces that are an added advantage when trying to develop "easy-to-use" software. Structurally, RUBDA can be divided in three parts as shown in Figure 1.

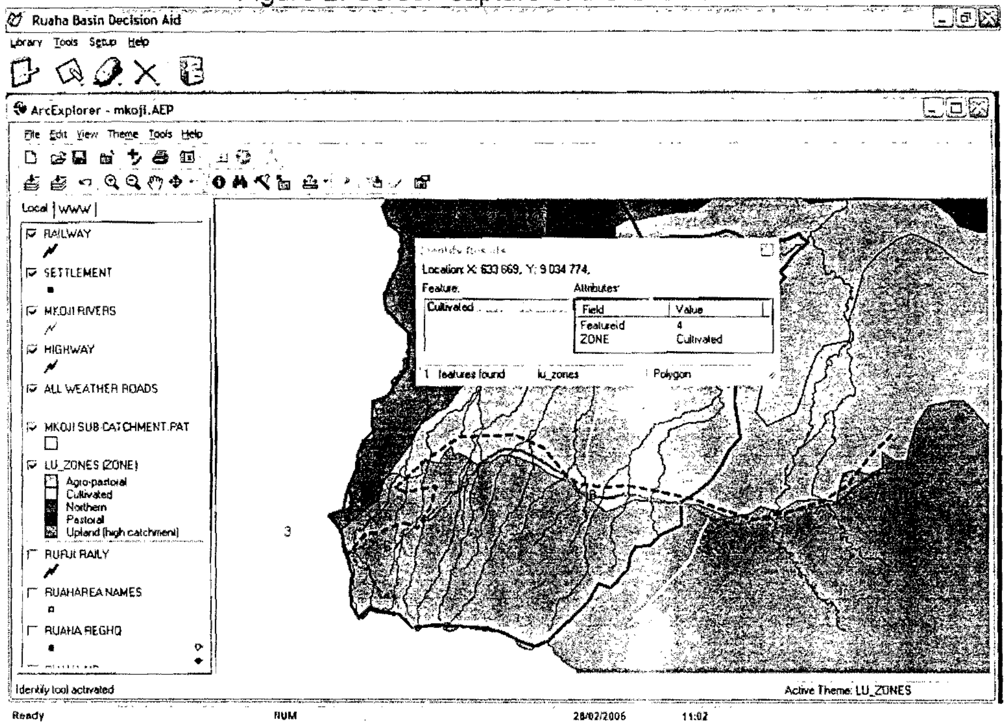
Figure 1. Structure of RUBDA



Description of the basin, 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 RIPARWIN project data originating from field surveys. The description interface uses a GIS viewer (Figure 2) developed using a facility called MapObjects™ technologies. This GIS viewer allows the user to examine, extract and print the comprehensive database using tables or dynamics maps.

Figure 2. Screen capture of the GIS Viewer

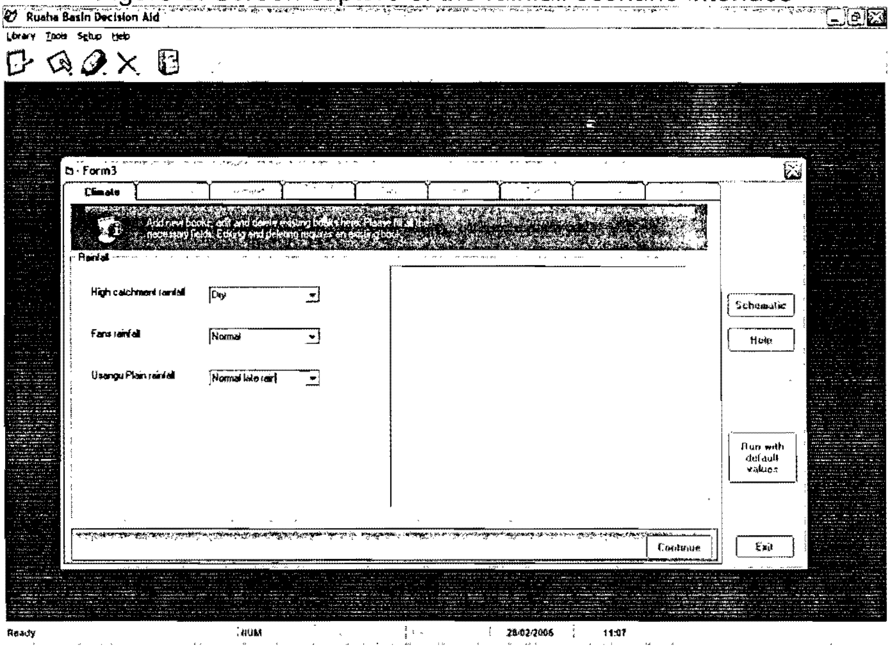


The data required to run RUBDA are numerous and cover a wide range of domains. These inputs are processed and used to run scenarios. In default mode, RUBDA runs by using actual data. This means that the "baseline" is the basin information as of 2003/2004 and that modifying this default data generates scenarios. These scenarios can be pre-defined scenarios, physical changes scenarios and water demand scenarios and may include the following:

- 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 (Figure3):
- Input from the rainfall stations: new rainfall data. This utility can be used if the user has new rainfall data;
- Irrigated area. This is a major driver of irrigation demand, it can be adjusted up or down;
- Irrigation efficiency is another factor affecting water demand and can be adjusted;
- Water abstracted for irrigation, related to the previous two, the total abstraction volume can be adjusted;
- Environmental flow requirements. This establishes various instream and downstream demands that then need to be provided;
- Western floodplain threshold value. This defines the size of the wetland, and is another measure of environmental conservation;
- Ifushiro wetland area and flow routing characteristics. This establishes the manner in which water is released to the Ruaha National Park;
- Pre-defined scenarios such as "balanced" (optimal share of water between sectors; ensuring year round flow through the Ruaha National Park, but also allowing water for rice and hydropower), "hydropower" (priority given to hydropower generation through the Mtera/kidatu dams system - downstream of the catchment) and "irrigation" (priority given to agriculture water uses - upstream of the catchment).

The physical scenarios (i.e., 1 to 2 above) will allow the user to estimate the water that is available in the basin in different climatic situations, while the demand and pre-defined scenarios (i.e., 3 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. The pre-defined scenarios will be sort of "teaching scenarios" for training DA users, but will be the basis of more nuanced scenarios in the future. After defining the hydrological impacts of the various scenarios, RUBDA will evaluate their socio-economic impacts.

Figure 3: Screen capture of the rainfall scenario interface



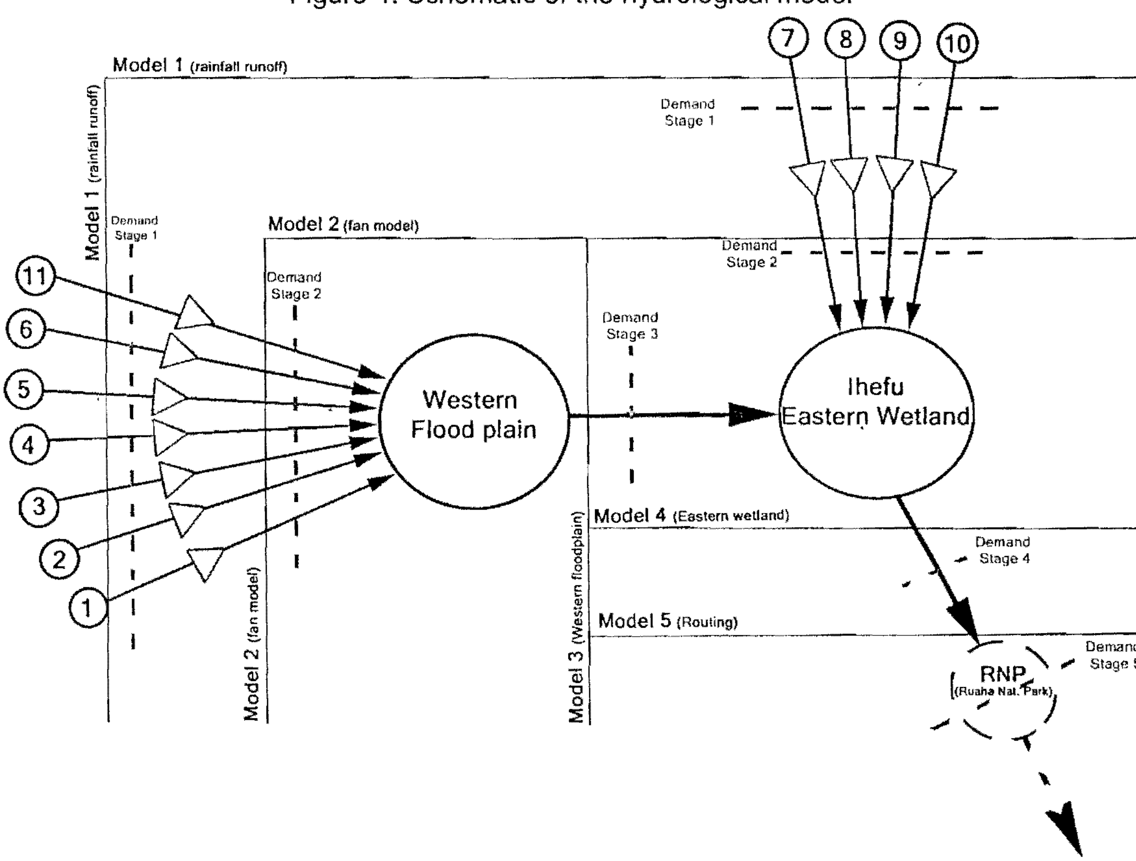
Modelling interfaces

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 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 human activities on the runoff (water demand); (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, climatologic 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 attached to the presence of water by rural communities. It is important to note that most social benefits are generally difficulty to value [5, 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.

Figure 4. Schematic of the hydrological model



Results outputs and interfaces

Results generated when running scenarios are named indicators. These indicators were defined during workshops and interviews with stakeholders and represent the type of results needed to meet the various 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 litres/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;
- 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 constitute a set of sub-modules; here the user is prompted on critical issues that might 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/her 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 processes is very necessary if RUBDA is to be successful in helping resolving the current water management problems in the basin.

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