GLOWA VOLTA PROJECT (GVP)

Report of the training workshop on

The Use and Application of the M³ WATER Model

organised by

UNITED NATIONS UNIVERSITY (UNU)
INSTITUTE FOR NATURAL RESOURCES IN AFRICA (INRA)
CENTRE FOR DEVELOPMENT RESEARCH (ZEF), UNI-BONN.

ICT Centre, University of Ghana, Legon
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Introduction

One objective of the GLOWA Volta Project (GVP) is to develop a Decision Support System (DSS) that is scientifically sound and relevant to the needs and interests of diverse water sector stakeholders in the Volta Basin. For the past years, researchers working on the GVP have developed an integrated hydrologic-economic model coded in GAMS and MIKE Basin at catchment and basin scales. Preliminary output demonstrates the value of integrated analysis in evaluating water-energy sector interactions. Such scientific information system integrates knowledge and provides decision support for planning, management and use of water resources in the Volta Basin. As part of developing close collaboration with partners in the basin and sharing with them knowledge produced out of the project, GVP and UNU-INRA, organized a workshop to introduce participants to a coupled hydrologic-economic model, M^3 WATER, for the Volta River Basin.

The two-day workshop was held at the ICT Centre, University of Ghana, on 16-17 March 2009. The workshop started at 10 a.m. with Prof. Karl Harmsen (Director, UNU-INRA), chairing it. The highlights of his opening speech are:

- The workshop is to present M^3 WATER allocation model developed by GVP.
- To discuss the pros and cons of the water allocation model, and
- To seek views of stakeholders about the model and help in its improvement.

The workshop was attended by 33 participants from GLOWA-Volta partner institutions from the water sector like the Volta Basin Authority, Water Resources Commission, Hydrological Service Department, and the research community from Water Research Institute, School of Allied and Nuclear Sciences, University of Ghana, University of Science and Technology. Resource persons for the workshop included Dr. Nicos Perez, Dr. Barnabas Amisigo and Dr. Anik Bhaduri, with Dr. Wolfram Laube and Dr. Eva Youkhana as moderators.

Workshop Process

During the workshop session, participants who were also the potential *user community*, were introduced to the M^3 WATER Model, and engaged into discussions on policy scenarios, climate change scenarios and trans-boundary water allocation for the Volta Basin. They were also given hands-on training on the use of the M^3 WATER Model. The resource persons then discussed the possible institutional arrangement for the implementation, data requirements, user friendliness and the available policy options and result/output selections of the M^3 WATER model.
The activities for the two days entailed, registration, introduction of participants, presentation, and hands-on application and discussion of the model.

On the first day, Dr. Wolfram Laube, gave an introductory talk about the workshop. The GLOWA-Volta project research activities focused mainly on integrating the field of climate, hydrology and socio-economic factors. Dr Wolfram touched on the impact of climate change in the White Volta Basin, local adaptation via different types of irrigation, socio-economic and environmental consequences of such adaptation. Research within the basin has shown that as a measure of the local farmers to adapt to climate change, more households are engaged in shallow groundwater irrigation in the White Volta Basin. The workshops were to present research on how people specifically farmers, as major water users, living in the White Volta basin adapt to climate change by engaging in irrigation activities as a means of adaptation.

Dr. Amisigo presentation was on the Hydrological Model and Climate Scenarios. The sub-topics expatiated on were on the following:

- The climate generator
- The water allocation model for the Volta basin
- Structure of the M^3 WATER Model

Dr. Amisigo, explained the structure of M^3 WATER. M3 WATER uses two main models MIKE Basin and GAMS. MIKE Basin (with data generated from MM5/WASIM-ETH) calculates water supply per catchment, whilst the economic model (GAMS) calculates water demand per catchment for every water user.

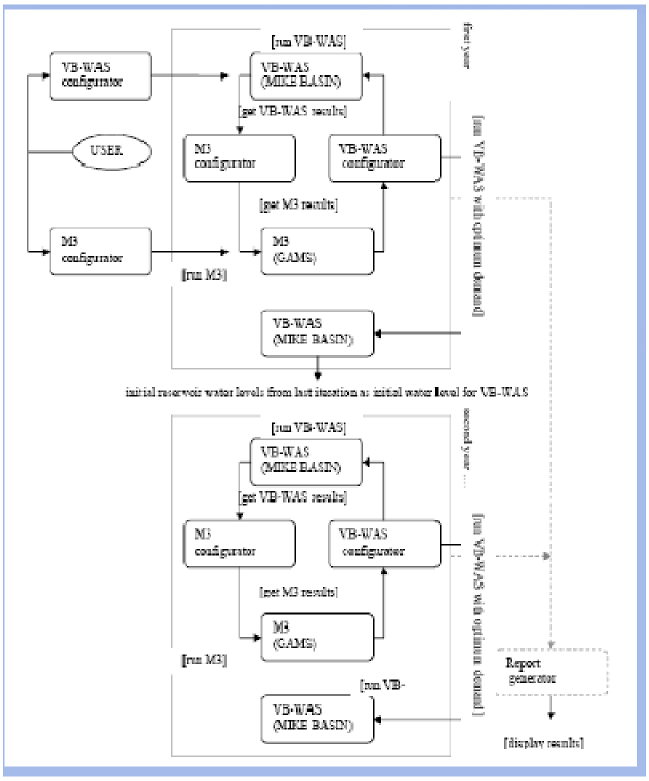

Figure 1. Normal workflow of the integrated simulation

Dr. Amisigo explained why M^3 WATER uses the simulation results of the MM5/WASIM-ETH model as input data for water supply. MM5/WASIM-ETH is a climate-hydrological model which provides spatially distributed simulation results with a 1-day temporal resolution. The climate model MM5 simulates global climate change scenario. MIKE Basin is a network model and provides fast simulation runs, its use is necessary because, coupled with an optimisation model (economic model), it needs a number of model runs to generate an output.

Importantly, MIKE Basin allows integrating technical infrastructure like large reservoir operation and water users. It was mentioned that due to the expensive nature of MIKE Basin software, the project team is trying to couple the economic model (GAMS) with WEAP model (Water Evaluation and Planning System). WEAP model has the same structure and options like Mike Basin. Notably, it was concluded that M^3 WATER model is a powerful tool for watershed management considering the impact of climate variability. It is a coupled dynamic hydrologic-economic model for water policy scenario analysis. The model accounts for national water management strategies that can be used as a supportive tool for trans-boundary water management. Lastly, it allows generating user defined climate scenarios.

Dr. Nicos D. Perez introduced participants to *economic modelling* and the M^3WATER- Decision Support System, which consisted of 3-phase training and transfer of M^3 WATER. The 3-phase consists of:

- Introduction to Policy Modeling (hydrologic-economic models): he discussed methods of water allocation, structure of M^3, policy scenarios;
- Economic modelling and Mathematical Programming: under this theme he introduced participants to basic economics and economic modelling and;
- The possibility of organizing in-house training for institutions that will use M^3WATER model consisting of policy scenario-building and analysis, how to modifying GAMS and Mike Basin/WEAP codes and validation to selected base-year.

M^3WATER Model is considered to be an *optimization* model imbedded in a *simulation* model. It simulates the *supply of water* and the *existing markets*, including: agricultural commodities market (domestic and foreign trade), agricultural input market, labour and land markets, and energy market.

The optimization is done after the simulation of existing hydrologic and economic processes. Therefore, the optimization model prescribes how the economic processes (and to a certain degree, the hydrologic processes) could be modified to achieve a preferred economic condition. With optimization a form of value judgment is involved. The model optimizes the allocation of water resources among competing countries, sectors, and uses.

The Model's objective function (the criterion for optimum water allocation) is to

Maximize

$$SB = ES_{Agriculture} + T_{Agriculture} + NB_{Domestic} + NB_{Industry} + CS_{Hydropower}$$

subject to resource constraints such as:

- land, labour and material inputs for agriculture
- water utility infrastructure for domestic and industry sectors, and
- generation capacity of for hydropower plants
- and the water resources available for all sectors

where

SB = society's total benefits,
$ES_{Agriculture}$ = total economic surplus (sum of consumer and producer surpluses) from agriculture,
$T_{Agriculture}$ = value of net agricultural trade,
$NB_{Domestic}$ = net benefits from domestic water use,
$NB_{Industry}$ = net benefits from industrial water use, and
$CS_{Hydropower}$ = cost-savings derived from using water energy instead of alternative fossil fuels

Based on the simulated water flow data from MIKE Basin, the water-allocation mechanism of the economic model, coded in GAMS, effectively the social welfare, *SB* (total economic benefits to society) of water use, and helps evaluate the effectiveness of the policies of the countries in the Basin with respect to social benefit and opportunity cost. In economic terms, the marginal or additional unit of supply of water is allocated to the sector or user the gives the highest additional benefits to society. Alternatively, any increase (decrease) in the supply of water would be allocated to (deducted from) the sector that maximizes (minimizes) the benefits (loss) to the entire society.

This criterion for optimal allocation of water runs parallel with the *Guiding Principle* of water allocation included in the National Water Policy of Ghana (2007) which states: *'The principle of the greatest common good to society in prioritizing conflicting uses of water'*.

M^3WATER that is made up of 4 different sectors: agriculture, hydropower, domestic, and industry.

The Agriculture sector is modelled with:

- 11 Crop groups
- 3 Fertilizer-based production technology
    - No Fertilizer, Lo- Fertilizer, Hi-Fertilizer application
- 7 Types of inputs
    - Land, Labour, Irrigation, Seed, Fertilizer, Chemicals, Other inputs
- 2 labour productivity-enhancing technology
    - Animal traction and machine traction
- 4 Sources of irrigation
    - Rainfall, Small-scale, Large-scale, Pumped (river and shallow groundwater)
- 4 Land types
    - Irrigated (small-scale), Irrigated (large-scale), irrigated (pump), Rainfed

The domestic sector is classified into urban and rural, while the industrial and hydropower sectors comprise the total located in the basin.

General applications of the Model include:

- Policy Evaluation and Analysis

- Policies affecting the agricultural markets (production and consumption of crop commodities)
    - trade policies, population policies, commodity-specific policy (like self-sufficiency in rice), labour employment policy, input-pricing policy, etc
- Investment Planning
  - Investment in irrigation (small-scale and large-scale irrigation systems), increasing hydropower generation capacity
- Short- and Medium-Term Projections
  - 5 , 10, 20, 30 years - multi-period optimization
- Impact analyses of exogenous shocks
  - Global warming scenario, impact of prolonged drought years, bio-fuel production, technological improvement in agriculture and energy sectors, increase in world prices of food and energy
- Trans-boundary water management and energy trade issues
  - Bilateral and multilateral water and power trade agreements
- Water valuation
  - Scarcity value of water
  - Agriculture-Hydropower trade-off

Discussion on the operational M³ WATER model

In order to ensure that the M^3 model addresses issues relevant to the intended research institutions, participants were divided into groups to discuss the model and try to use the beta version in policy analyses.

Figure 2. Participants in discussion groups.

Emerging Questions and Issues

There were several issues discussed and brought into attention during the workshop which would help in the effective implementation of the model.

Host institution(s) for M³ WATER

M³ WATER can be a valuable tool for policy, research, academic, and advocacy institutions. The initial plan is for the Volta Basin Authority (VBA) to host the model and share it with selected satellite agencies, both in Ghana and Burkina Faso, and other interested *member* countries.

VBA and participating agencies would be responsible for the maintenance of the model, update of its data inputs, and relevant modifications to make the model current and relevant to the needs of policymakers.

In-depth training for the use of the model would be undertaken within and by VBA and participating agencies.

Technical Improvement of the Model

Technical enhancement of the model includes both the software (MIKE Bain and WEAP) and the scale of analysis (national and sub-basin).

At present MIKE Basin is the software used to simulate the hydrologic aspects of M³ WATER. MIKE Basin, however, is an expensive commercial software whose cost can be prohibitive to some institutions. An alternative option is to use WEAP instead. WEAP is a semi-public domain software and very cost-effective. Another advantage is that WEAP is already widely used in basin by agencies involved with hydrologic modelling, including in the VBA and some of its satellite agencies. It would then be more cost-effective and would require less training and shorter period to learn the version of M³ WATER with coupled WEAP-GAMS. (Note that the GVP is already considering both hydrologic software – MIKE Basin and WEAP as part of versions of M³ WATER)

Another technical issue is on the scale of analysis. Currently, M³ WATER is a national policy model, although the scale of hydrological and some of economic inputs is sub-watershed. There was a suggestion that since development investments are planned and implemented on sub-basin scale (three major river systems – Black Volta, White Volta, and Oti), M³ WATER can be more effective if both the national and sub-basin policies can be analysed by it. (This improvement and modification of M³ WATER can be initiated and undertaken by VBA and host agencies with assistance from GVP and other project after it).

Schedule:

1st day (17.03.2009):

Morning session:	**technical requirements: conference room + beamer**
09:00 – 12:00	Opening ceremony Introduction of the workshop (Wolfram Laube or Eva Youkhana) Hydrological model and climate scenarios (Constanze Leemhuis) Economic model (Nicos Perez) Questions, discussion, feedback
12:00 – 14:00	lunch
Afternoon session:	
14:00 – 17:00	Online introduction of the coupled hydrological-economic model M³ WATER (Interface, policy and climate scenarios, results) Moderated discussion on scenarios + relevant policy equity + subsistence

2nd day (18.03.2009):

Morning session:	**technical requirements: training room equipped with 10-20 computers**
09:00 – 12:00	Guided hands on training of the M³ WATER Model (Constanze Leemhuis, Nicos Perez): Application of climate scenarios, irrigation investment, food self sufficiency and trans-boundary water allocation
12:00 – 14:00	lunch
Afternoon session:	
14:00 – 17:00	Moderated discussion on the operational M³ WATER model (user friendliness of the interface, data updating, documentation results etc)

	Training on the use and application of the M³ WATER Model		
	17-18 March 2009		
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