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CAWAT – A CATCHMENT WATER ALLOCATION TOOL FOR INTEGRATED IRRIGATION AND AQUACULTURE DEVELOPMENT IN SMALL WATERSHEDS

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Water resources development has seen little development in the vast rural areas of Sub-Sahara Africa (SSA) due to lack of investment, means of access and poor policy environment. In search of sustainable and efficient water resources development, participatory approach is widely accepted as a key strategy for water resources development and conservations in many SSA countries. To encourage bottom-up solutions for local water resources development, a Catchment Water Allocation Tool (CaWAT) was developed to aid rural water resources planning for agriculture in small watersheds. The tool is based on water balance accounting to examine water allocations among different users. It builds on the FAO AquaCrop plugin to simulate irrigation water requirement and crop productivity. It has a storage simulation module that models not only water balance but also fish production. Multiple catchment and on-farm management options are built in to enable comparisons of alternate scenarios. The model water tested in a small watershed in Southern Malawi. And the results provide interesting insight for integrated irrigation and aquaculture development using the available water and local water infrastructure investment options.

INTRODUCTION

Integrated Water Resources Management (IWRM) has long been promoted yet with limited success in Africa. Actively promoted by international and donor agencies, IWRM has been adopted in various forms by most, if not all, sub-Sahara African countries. However, the advanced framework seems to have difficulty finding its way of integrating governance structure, planning and operations at country or basin level [1,2]. The greatest challenge lies in the implementation in an environment where knowledge, capacity, infrastructure, and communications are all lacking, all of which drawing critical review of IWRM for water resources development in Africa.

Bottom-up participatory approach was another point of entry favored by many researchers and practitioners. Such approach encourages end users' own initiatives through collaborations with other players. It promotes ownership of water resources development among the beneficiaries which in turn stimulates greater efforts of sustained engagement and improved management [3].

Water however as a finite resources in many regions are becoming increasingly scarce as results of population growth and development, and often worsen by climate change. Bottom-up approach focuses on local development and tend to ignore upstream-downstream effects, potentially introducing conflicts should success is secured in one place. This success might alter hydrological regimes of flows to downstream, or be impacted by upstream induced changes in the in-flows. Water resources therefore requires innovative solutions at both local level and beyond.

This paper explores a small watershed approach to integrated water resources development. The assumption is if coordination of planning and operations are not possible at large scale, then small watersheds where users are responsible for their own development who could easily negotiate with each other have a better chance of adopting integrated approach. To test this hypothesis the Catchment Water Allocation Tool (CaWAT) was developed and applied in a small watershed in southern Malawi with field experiments and stakeholders consultations.

THE CAWAT MODEL

CaWAT model is a decision support tool to aid water allocations for agriculture and domestic uses in small watersheds of rural areas. It provides options for agricultural planning, irrigation and aquaculture development representing a range of demands. It also incorporates rainfall-runoff simulation, storages and diversions infrastructure development representing supply side. It then allows users to intervene the water balance processes through storing, diverting, and allocating water among upstream and downstream units. The model also simulates crop yields and fish production based on the management scenarios as feedbacks to help assess user interventions. The overall framework of the model is illustrated in Figure 1.

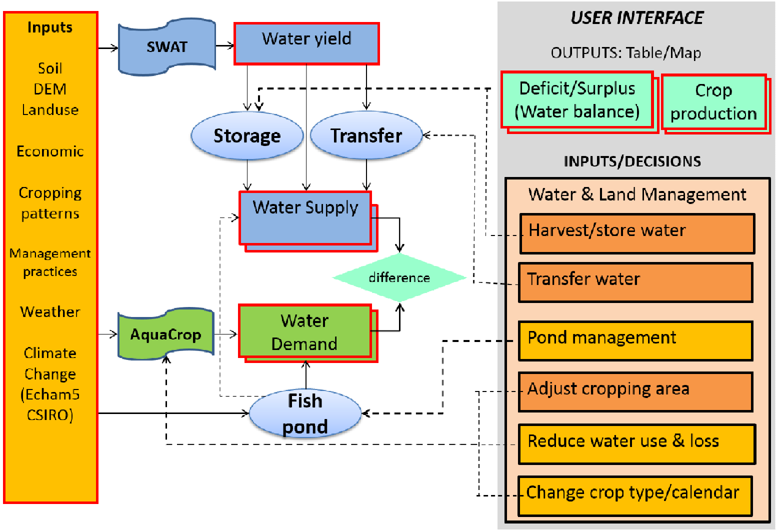

Figure 1. The modeling framework and modules of the CaWAT tool.

CaWAT integrates two external models in its model structure, the SWAT as a rainfall-runoff model and the AquaCrop to simulate crop yield-water response. While SWAT run is executed independent of the model, the AquaCrop version 4 [4] plug-in was built into the model to calculate crop yield, irrigation water requirement, as well as yield reduction in water stress scenarios. The model also has a fish pond management module which allows options for pond water allocations to either fish or crops. A fish growth module modified from Omizo et al., [5] is used to estimate fish production. Market prices of fish and crops are used to estimate total production in monetary terms. This function allows users to explore optimal water allocation strategies at times of stress based on maximum economic return criteria. The model was developed in MS Excel environment using Visual Basic Applications which presents users with traditional MS Windows interfaces for operations and outputs viewing in tables and GIS maps format.

APPLYING THE CAWAT MODEL TO A SMALL WATERSHED IN MALAWI

The model was tested in a small watershed in the Chingale area, Zomba District of southern Malawi. The watershed has a drainage area of 188 km^2. Average annual rainfall is 940 mm. the area is dominated with subsistence agriculture with land holding of about 1.3 ha per house hold, of which 24 percent is irrigated. Major crops include maize, sweet potato, vegetables, cassava, and peanuts. A land use map was delineated using high resolution satellite images (one time acquisition for 15 September 2010) from GeoEYE (Figure 2). It can be observed from the map that the irrigation forms a belt along the valley in parallel to the main river stream. A total of 741 ponds were identified in the watershed. These ponds are mostly fish ponds with some also used for irrigation. The average surface area of the ponds are 223 m^2.

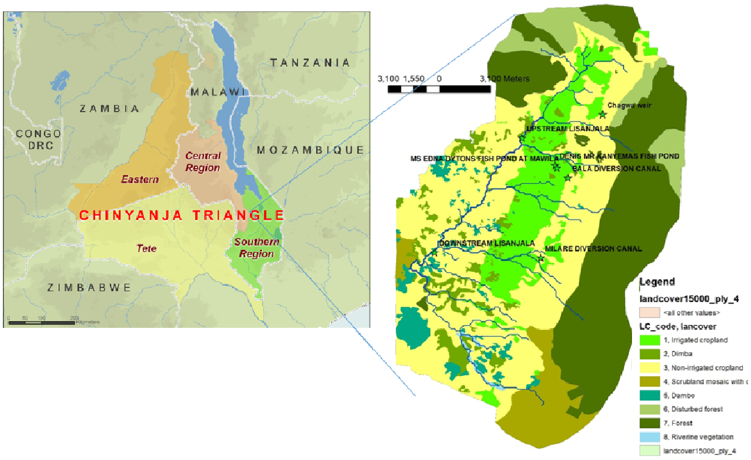

Figure 2. The land use and hydrometric measuring points in the Chingale study site in southern Malawi.

A number of field measurements were set up in the catchment including two river staff gauge meters, constructed cross sections (V-notch) at the inlets and outlets of a fish pond (also used for irrigation), staff gauge meters at two selected ponds, and evaporation pans and rain gauges at two primary schools in the catchment (Figure 2). Crop yields and fish production was obtained from farmers' survey. The river flow is estimated using the observed flow depth with a rating curve developed for the specific cross section. The model is then set up, calibrated and validated using the collected data from November 2010 to April 2013. It is noted that the

AquaCrop and SWAT model is calibrated and validated separately outside CaWAT environment for the ease of operations.

A number of surveys and interactive sections with farmers' representatives were conducted to gain information on farmers' agriculture and water management practices and their possible interventions for wet, normal and dry weather conditions. The responses were then fed into the tool to simulate expected water balances and agricultural productions.

RESULTS AND DISCUSSIONS

The catchment water balance is shown in Table 1. It shows that about 23 percent of annual rainfall turns into discharge in the river system, while some 59 percent is depleted through evapotranspiration. The overall water availability is in excess of demand. However, the rainfall has a high variability which causes periodic shortage of supply in the dry season from June to August and at the beginning of wet season in October to November. In fact weekly water balances show that some sub-catchments encounter shortages of water for up to 5 weeks in the normal years.

Table 1. Catchment water balance for year 2010.

Precipitation	Evapotranspiration	Water Yield	Shallow Aquifer Recharge	Deep Aquifer Recharge	Domestic Demand
881.3	520.2	205.73	76.53	35.69	0.91

The model also allows possibility to adjust cropping patterns and assess the subsequent water use situations. Figure 3 shows that when crop sowing dates are adjusted with different rainfall scenarios, the crop yields, beneficial (T) /non-beneficial (E) consumptions, and crop water productivity respond in different ways. For example early planting of irrigated pulses in a normal year have much less irrigation water requirement because of reduced T and significantly reduced E, while crop yields maintain similar levels.

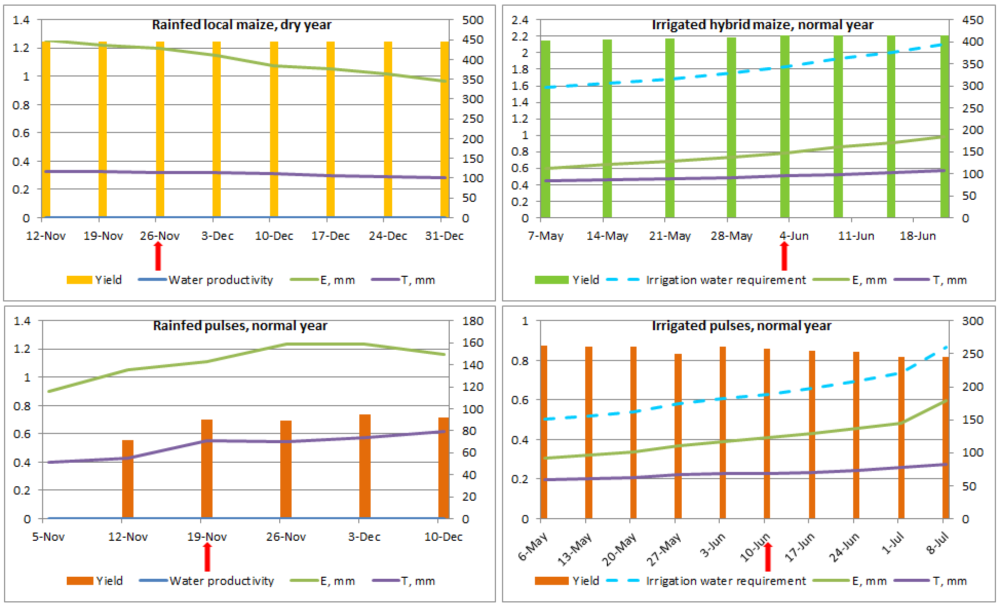

Figure 3. Crop yields, water productivity, evaporation, transpiration and irrigation water requirement of rainfed and irrigated crops in different years.

Small storages have significant contribution in storing water for fish and crop production. These small storages are usually constructed and managed by farmers themselves. Good management practices lead to increased water availability. However, the small storages also have high percentage of losses through evaporation and seepage/percolation. Figure 4 shows that during March 2011 to February 2012, the pond lost a total of 2590 mm depth of water, among which the seepage and percolation is about 511 mm and evaporation 2079mm respectively. The effects of such high losses especially to evaporation poses serious challenges in efficient water uses and maintaining pond water levels.

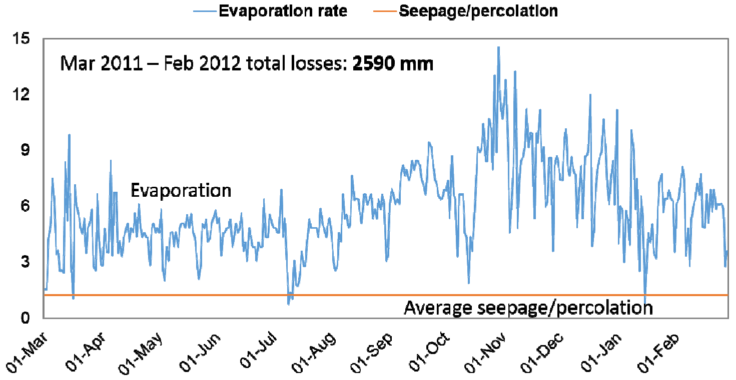

Figure 4. Pond water losses to evaporation, seepage, and percolation.

CONCLUSIONS

Water resources development is becoming an increasing need and priority in many African countries. Small watershed approach takes the principle of IWRM and applies it at a much more workable scale. At this scale the inputs to water resources management are dominated with small scale interventions such as small storages development, local diversions, on-farm management practices which are much easier for famers to adopt. Small watershed including fewer villages is also a scale they are more familiar with which enable better negotiations and collaborations among upstream and downstream users.

CaWAT as an integrated DSS tool provides the opportunity for diagnosis and negotiations among local communities. The tool connects several models to link hydrology with rural water management which is largely dominated by agricultural uses. It helps users not only with quantitative outputs based on interventions, but also the processes to help users better understand the dynamics of water and agricultural systems.

REFERENCES

[1] Biswas A., "Integrated Water Resources Management: Is It Working?", *International Journal of Water Resources Development*, Vol 24, No. 1, (2008), pp 5-22.

[2] Giordano M., Shah T., "From IWRM back to integrated water resources management", *International Journal of Water Resources Development*, (2013), Pp 1-13.

[3] Cleaver F., "Paradoxes of participation: questioning participatory approaches to development", *Journal of International Development*, Vol. 11, No. 4, (1999), pp 597-612.

[4] Steduto P., Hsiao T.C., Raes D., and Fereres E., "AquaCrop—The FAO Crop Model to Simulate Yield Response to Water: I. Concepts and Underlying Principles", *Agron J*, (2009), Vol (101), pp 426–437.

[5] Omizo H., Mkandawire R., Mtegha S., Suzuki H., Eda H., "Water depth and productivity in smallholder ponds in the southern region of Malawi", *JICA Technical Report*, 2005, pp 1-6.