Evaluation of Water Allocation Models Case Study: Menik Ganga River Basin, Sri Lanka

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INTRODUCTION

Many mathematical simulation and optimization models for water allocation have been developed and are playing an important role in the analysis of the behavior of complex water resources systems.These tools are very useful for water managers to take decisions on water allocation among competitive users in the basin following three water allocation principles: equity, efficiency and ecological integrity. It is very important to select the most appropriate model which can address the exact problems in the basin. Therefore the objective of this study was to develop a framework that provides water managers with a comprehensive guide to select the most appropriate model for water allocation in a river basin and at the same time look into the performance of two different models;Waflex and WEAP in the Menik Ganga river basin in Sri Lanka.

HIGHLIGHTS

- Criteria and a framework were developed to select the most appropriate model
- The available software for water allocation were analyzed using the framework
- Most appropriate model can be selected using the criteria in the framework
- Waflex and WEAP are not giving similar results for satisfaction of water users
- Presently there are no considerable shortages for users in the Menik Ganga river basin

METODOLOGY

Criteria and a supporting framework were developed to select the most appropriate water allocation model that suits the local conditions of a river basin. Model category, appropriate use, input data, output, user friendliness, technical support and cost are the criteria used in the framework of model selection. An overview of the available software for water allocation was made using the criteria in the framework of model selection. Literature review identified the following existing water allocation software packages: Waflex, RIBASIM, REALM, Mike Basin, WARGI-SIM, WBalMo, WRAP, HEC-3, MODSIM-DSS, WRYM, WEAP, AQUARIUS and EPIC.

Two water allocation models were selected;Waflex and WEAP for which the developed framework was filled completely. The present water allocation situation in the Menik Ganga basin was simulated (business as usual scenario). Additionally, a set of scenarios, including maximum inter-basin transfer, future developments, giving first priority for non-consumptive water users and giving equal priority for all the users, were simulated and analyzed using the satisfaction of the different users as an indicator.

RESULTS

Both models show that at present there are no considerable shortages for the users in Menik Ganga river basin.The recently constructed reservoir has resolved the existing water shortages and at present the basin is capable to cater the existing annual water demand including an inter-basin transfer. The majority of the users experience a satisfaction of 100% and the minimum satisfaction is with 89%, which is still very high. In all other scenarios the users achieve less satisfaction due to the future developments and maximum inter-basin transfer. The satisfaction decreases to 60% for some users in some of the scenarios. Kataragama religious festival water demand and minimum flow requirements experience the most water shortages in the basin as they are further downstream and require large amounts of water. The result confirms that the amount of water available in the river is not adequate to cater for the proposed development water requirement in the basin and the maximum transfer to the Kirindi Oya basin. Further studies are needed to study how to overcome the shortages in future development scenarios.

The evaluation of the two models with the criteria of the framework of model selection shows that they are very similar in application. Waflex can be identified as a simulation model where WEAP is a combined simulation and optimization model. WEAP uses a linear programming technique for the water allocation aiming to maximize the satisfaction among the users. Both Waflex and WEAP can be used to simulate both prior appropriation and proportional allocation systems in water allocation. There is no difference on the criteria appropriate use and input data, but the model development and simulation are different. Both models are able to address the three key principles in water allocation: equity, efficiency and ecological integrity with the output of the models. Equity can be expressed through the indicator of satisfaction.

The results of this study show that Waflex and WEAP are not giving similar results in terms of satisfaction of different water users in the basin. Although all the input data are the same for both models the different approaches for calculating the water allocation results in differences in outputs. The obtained levels of satisfaction vary depending on the model used. These differences are created by a different reservoir operation calculation in the models. The case of the Menik Ganga river basin shows that when the basin doesn't have a reservoir, there are no differences in the satisfaction of the users. When reservoir becomes more empty the possibility exists to ration the demand. In water allocation models this is usually modeled through identifying zones and rationing percentages. However the results of this study show that WEAP does not strictly follow its rationing percentage, called buffer coefficient, to control downstream releases from the reservoir where Waflex exactly release according to the rationing percentage. Therefore, the reservoir releases are different in both models creating different satisfaction for the users.

CONCLUSION

It can be concluded that the most appropriate model can be selected using the evaluation criteria in the framework for model selection. Furthermore, it is advised to simulate the water allocation in a river basin with different models as they can give different results. By analyzing these results the most appropriate allocation system for the particular river basin can be obtained.

Figure 1 shows the Menik Ganga river basin and the locations of meteorological and discharge gauging stations.

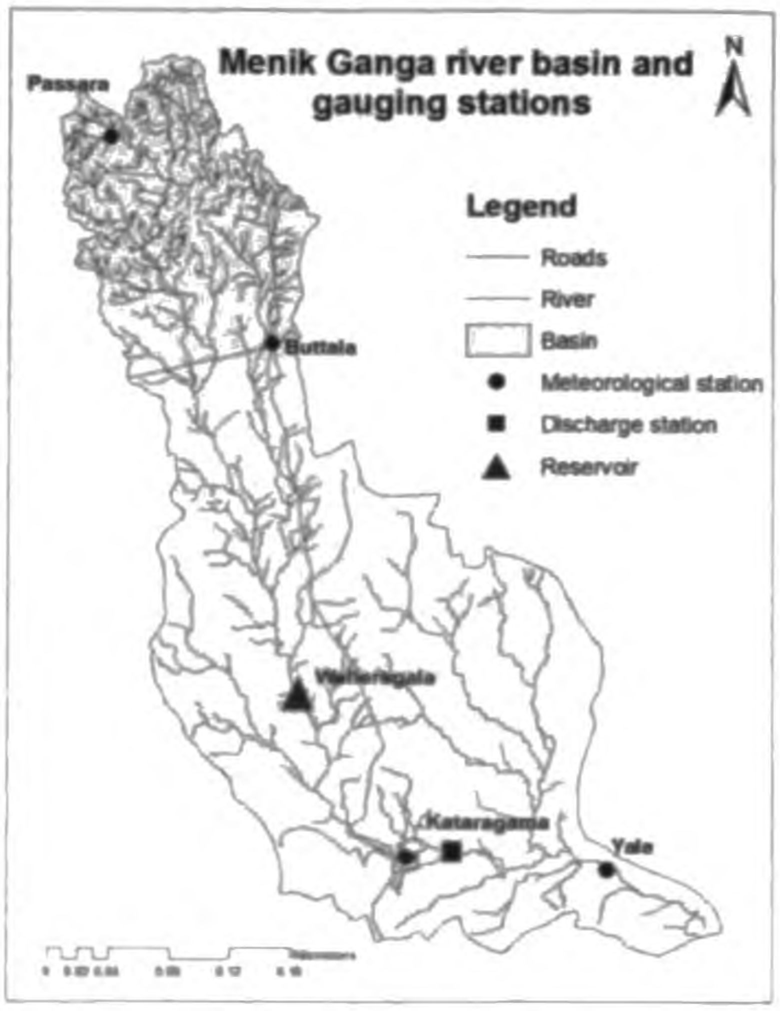

Figure 1: Location of gauging stations in the basin

Table 1 shows the framework can be used for the selection of the most appropriate water allocation models.

Criteria	Evaluation factors
Model category	• Simulation • Optimization • Simulation + Optimization
Appropriate use	• Allocation system • Spatial and temporal resolution • Infrastructure planning • Demand analysis • Literature on application with published year
Input data	• User demands • Hydrological data • Meteorological data • Reservoir characteristics and other infrastructure works • Operating policies of infrastructure works
Output	• Equity • Economic efficiency • Ecological integrity • Relate to management task • Verifiable results
User friendliness	• Graphical interface • Flexibility for improvements
Technical support	• Comprehensive user manual and tutorials • Availability of "Help" function • Special training requirements
Cost	• Open source software • Commercial software

Table 1: Framework of model selection

Figure 2 shows a difference in satisfaction levels of the users between the two models. All the users, except for the Kataragama religious festival water demand and minimum flow requirement, have a higher satisfaction with Waflex than WEAP. This is caused by the lower storages occurring in WEAP. WEAP release more water in the buffer zone and therefore the reservoir experiences less storage. This creates shortages for the most prioritized users. Waflex is more conservative and release less water to downstream in times of low storage in the reservoir. This small release may be adequate to cater to the upstream small demand users. Then they will get higher satisfaction in Waflex. But this small release is not adequate to cater the downstream high demand users. That creates low satisfaction in Waflex for Kataragama religious festival demand and minimum flow requirement.

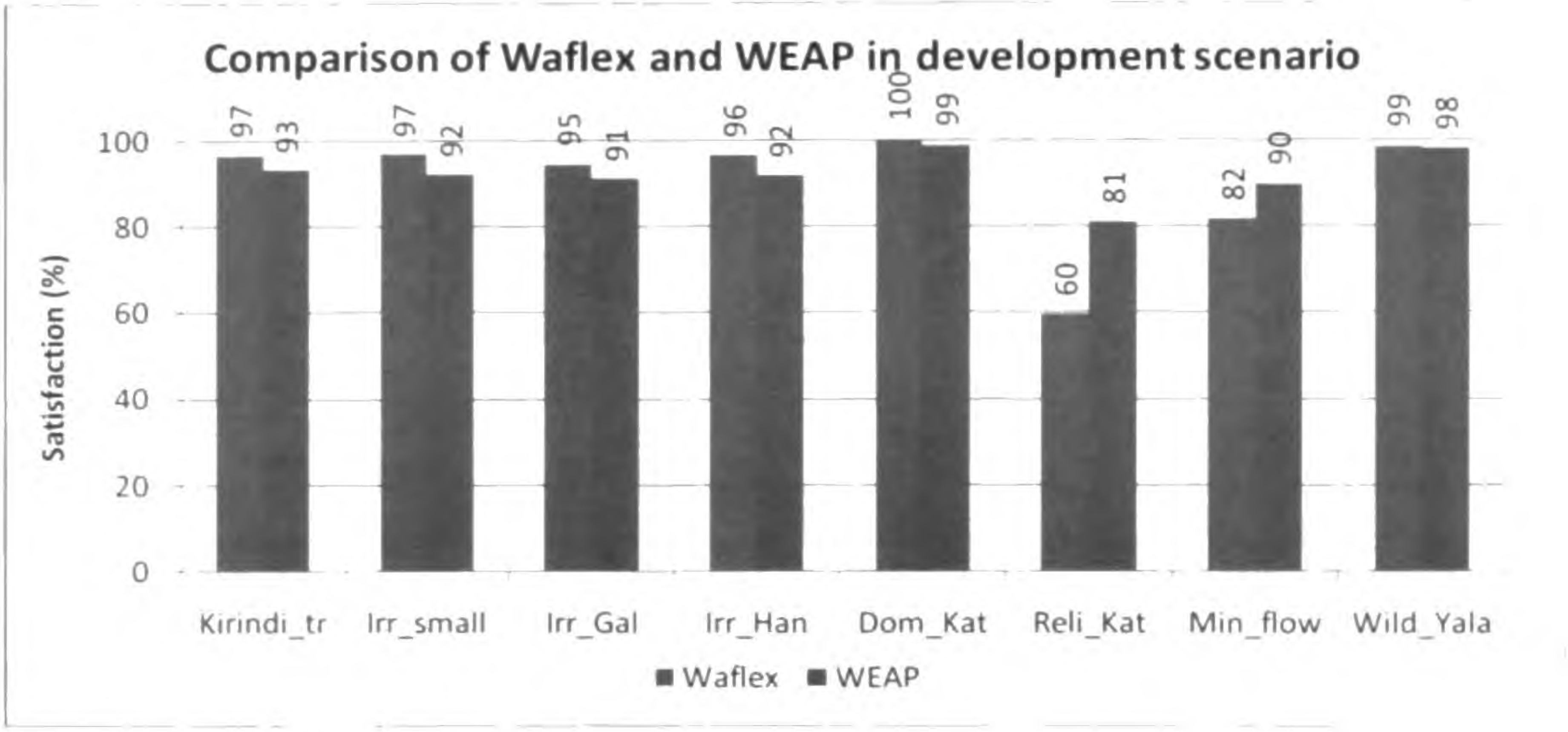

Figure 2: Waflex and WEAP model results

Figure 3 shows the differences in reservoir storage in both models. Most of the times, the pattern of reservoir storage is similar for both models. WEAP allows less storage in the reservoir at times than Waflex. Both models do not allow the reservoir storage to go beyond the dead storage level of the reservoir.

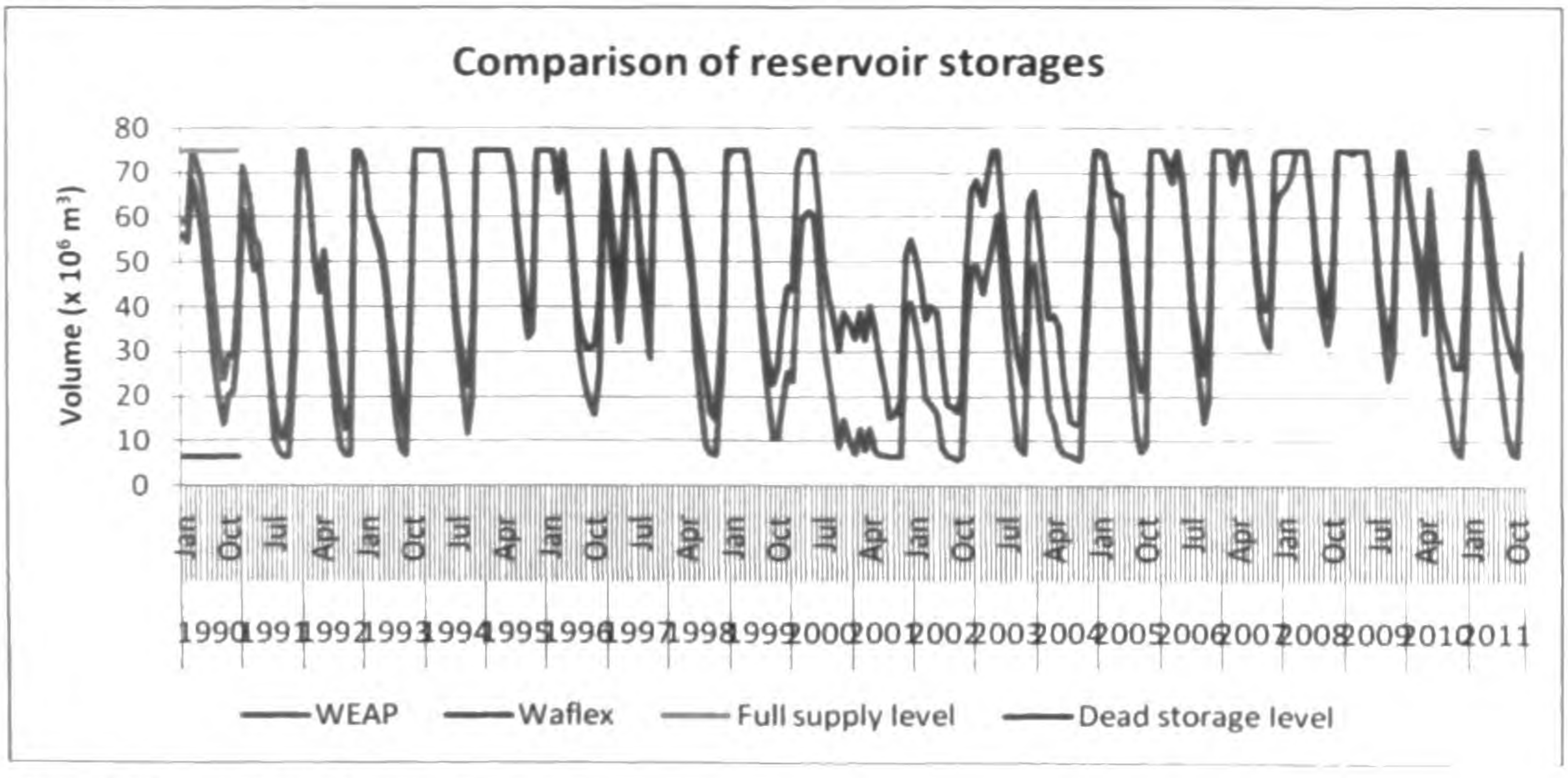

Figure 3: Comparison of reservoir storages

THEME 6

Table 2 shows the comparison of both models for the different criteria of the framework evaluation for model selection.7

Criteria	Evaluation factor	Waflex	WEAP
Model category	Simulation	Simulation model	Simulation+Optimization (With the use of linear programming)
	Optimization		
	Simulation+Optimization		
Appropriate use	Allocation system	Basically prior appropriation. Can develop for proportional allocation	Both prior appropriation and proportional allocation
	Spatial and temporal resolution	River basins. Any time step from daily to annually.	River basins. Any time step from daily to annually.
	Infrastructure planning	Possible	Possible
	Demand analysis	Possible	Possible
	Literature on application	Available	Available
Input data	User demands	Required	Required
	Hydrological data	Required	Required
	Meteorological data	Required	Required
	Reservoir characteristics and operating policies	Required	Required
	Water quality	Depend on requirement	Depend on requirement
	Cost	Depend on requirement	Depend on requirement
Output	Equity	Presents	Presents
	Economic efficiency	Presents	Presents
	Ecological integrity	Presents	Presents
User friendliness	Graphical interface	Need to develop	Well developed
	Flexibility for adjusting to specific conditions	High	Low
Technical support	Comprehensive user manual and tutorials	Not available	Available
	"Help" function	Not available	Available
	Special training requirements	Required	Can do self learning
Cost	Cost	Low	Depends on user