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Development of Reservoir Simulation Model for Effective Irrigation Water Management of Magalla Reservoir at Nikaweratiya, Sri Lanka

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Abstract: Magalla is a reservoir which is located at Nikaweratiya area in Deduru Oya river basin. Deduru Oya river basin which is in dry zone of Sri Lanka has severe flood during rainy season and lean flow during dry season. Magalla is one of the ancient tanks in the basin and major source of water is receiving through Ridi Bendi Ela canal. There is a diversion scheme just downstream of the Deduru Oya reservoir which is named as Ridi Bendi Ela weir. Water is diverted to the Ridi Bendi Ela canal from the weir and length of the canal is 21 km. Runoff water which is coming from Magalla reservoir catchment also significant, other than Ridi Bendi Ela canal inflow. There is a proposal to augment water to Magalla through Deduru Oya multipurpose reservoir development project. Objective of the study was to develop reservoir simulation model for effective irrigation water management of Magalla reservoir. Nikaweratiya, Wariyapola and Ridi Bendi Ela rain gauge stations are selected for the study and daily rainfall data from 1991 – 2012 was statically analysed. Crop water requirement calculated using CROPWAT 8.0 software. HEC-HMS 4.0.1 software selected to model rainfall runoff and reservoir simulations. Magalla model was developed while using initial and constant loss method, Clark unit hydrograph method, recession base flow method and Muskingum routing method. Model was calibrated and validated for continuous and event based simulations. Simulated and observed values of the model were statistically verified and results revealed that the calibrated model is capable of capturing the seasonal characteristics of stream flow and storages satisfactorily. The calibrated model with the parameters of respective sub-catchments can be used to find water diversion requirements from Deduru Oya river to achieve 100 % cropping intensity in Magalla scheme.

Keywords: Deduru Oya, HEC-HMS model, Magalla tank, Ridi Bendi Ela, Reservoir Simulation, Statistical test

1. Introduction

Deduru Oya river basin is 6th largest river basin in Sri Lanka and Magalla reservoir is one of the major reservoirs in the basin. Magalla reservoir which is located at Nikaweratiya, North-Western Province of Sri Lanka is one of the intra basin diversion irrigation systems and Magalla reservoir and Ridi Bendi Ela canal which were built by King Mahasen during Anuradhapura era, and later renovated, are very important irrigation systems in the Deduru Oya river basin. Ridi Bendi Ela weir constructed across the Deduru Oya river diverts water to an unlined canal (Ridi Bendi Ela canal) of 21 km length and 4.25 m^3/s capacity to Magalla reservoir.

The Magalla reservoir with a capacity of 9 MCM and basin area of 32 km^2 stores the water for the irrigation requirements in downstream areas. It has three irrigation canals; Right Bank canal, Left Bank canal and Centre Canal to distribute water to the downstream irrigable areas. Magalla reservoir receives inflow from its own basin and from the Ridi Bendi Ela canal. Today, approximately 2400 hectares of paddy fields are irrigated under Magalla reservoir irrigation scheme [2].

Hydrological modeling is a commonly used tool to estimate the basin's hydrological

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response due to precipitation. Various types of hydrological models from black box models which require less basin data to physically based models which require large amount of basin data have been developed [1]. The selection of the model depends on the basin and the objective of the hydrological prediction in the basin. The HEC–HMS, developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers is a hydrological model that supports both lumped parameter based modeling as well as distributed parameter based modeling [5]. HEC-HMS has been successfully applied to many basins to assess water resources including river basins in Sri Lanka [3] [4].

In this paper the HEC HMS Model is applied to Magalla reservoir irrigation system and developed reservoir simulation model for effective water management to Magalla reservoir irrigation system.

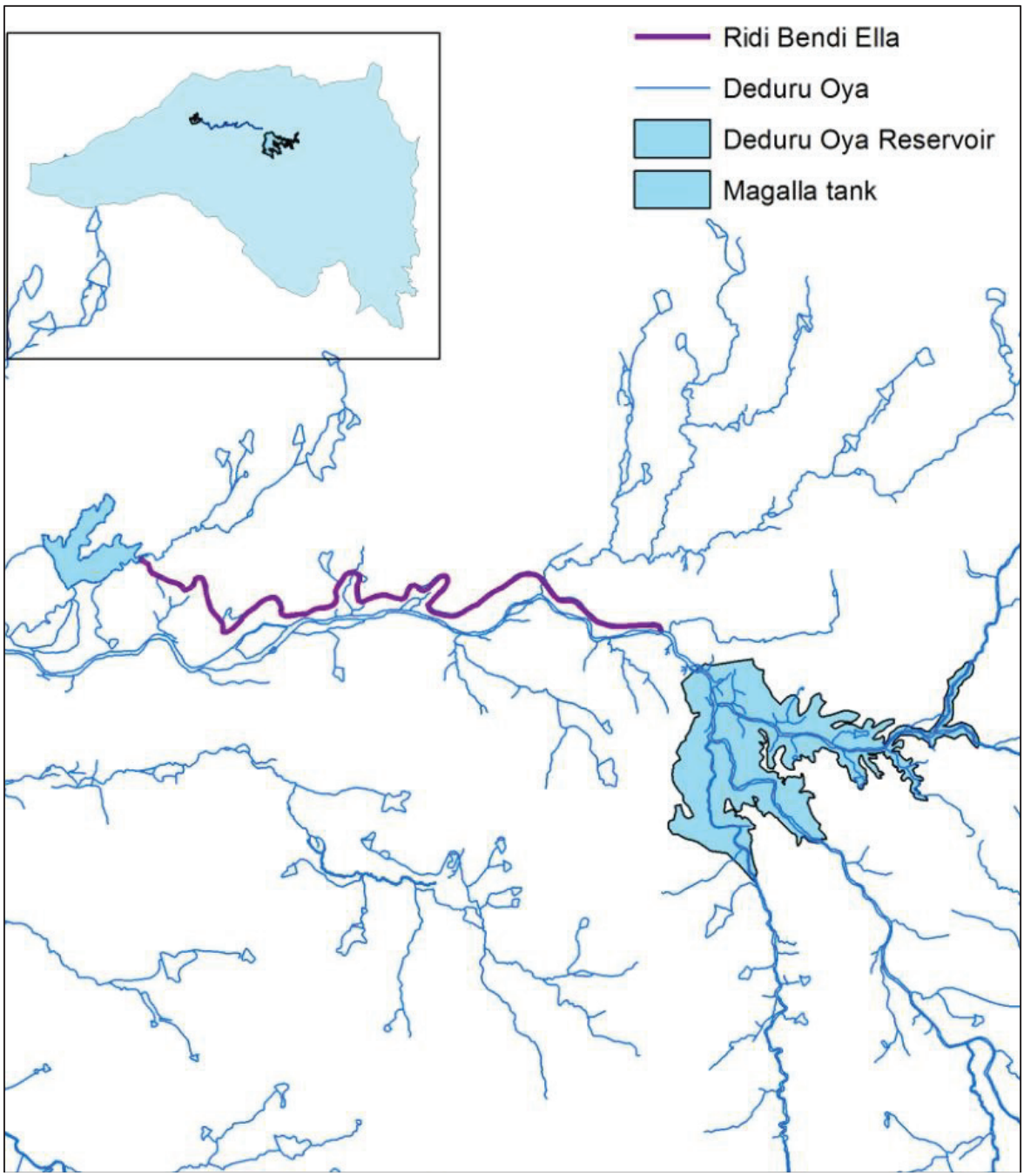

Figure 1- Magalla reservoir and Ridi Bendi Ela canal in Deduru Oya basin

2. Material and Methodology

Methodology of the study is shown in the Figure 2.

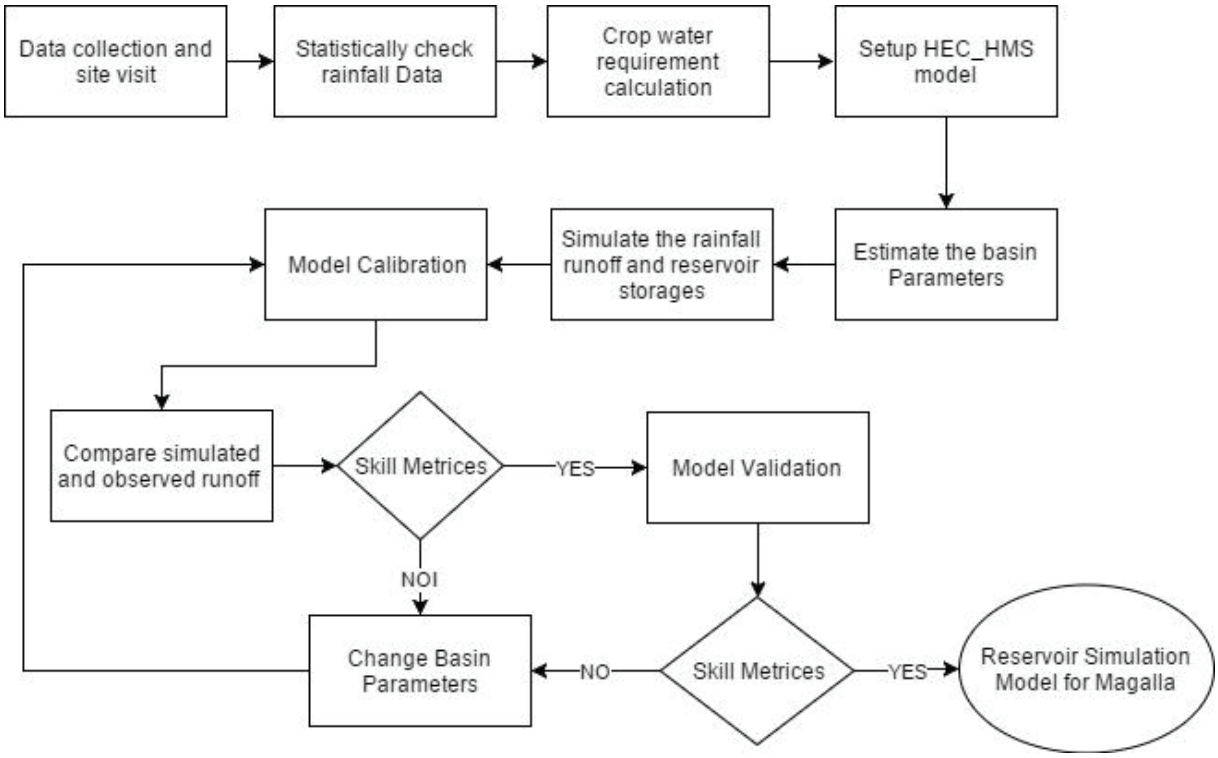

Figure 2- Methodology

Numbers of rain gauge stations are available at Deduru Oya river basin and Nikaweratiya, Wariyapola and Ridi Bendi Ela rain gauge stations were selected for the study based on their geographical distribution. Selected period was 1991 to 2012. Polonthalawa and Kurunegala rain gauge stations also used during missing data estimation based on data availability and distance between stations.

The basic procedure begins with an initial and rough screening of the data. Missing data were estimated. Rainfall data were statistically verified and found that data are suitable for further analysis.

Crop water requirements calculated by CROPWAT 8.0 model for Magalla Scheme. Crop type is assumed as low land paddy is cultivating 100% and command area is 3000 ha. Mahailuppallama reference crop (green grass) evapo-transpiration rates and crop factors for each growth stage were used for crop water requirement computations. Effective rainfall was taken as 60% from the mean monthly rainfall (FAO empirical formula for worldwide applications). Application efficiency was taken as 60% and conveyance efficiency was taken as 75% [6]. Land soaking and tilling requirement was taken as 175 mm per 14 days [6].

The HEC - HMS 4.0.1 was selected to the develop reservoir simulation model. Features of Magalla scheme modelled using different elements of HEC-HMS software. Ridi Bendi Ela modeled as reach element, Magalla tank modeled as reservoir element, Center, LB and RB channels of Magalla tank modeled as reach element, Magalla catchment and Ridi Bendi Ela catchment modeled as sub basins and inflow from Deduru Oya river modeled as source element. Figure 3 shows the graphical user interface of the HEC-HMS model.

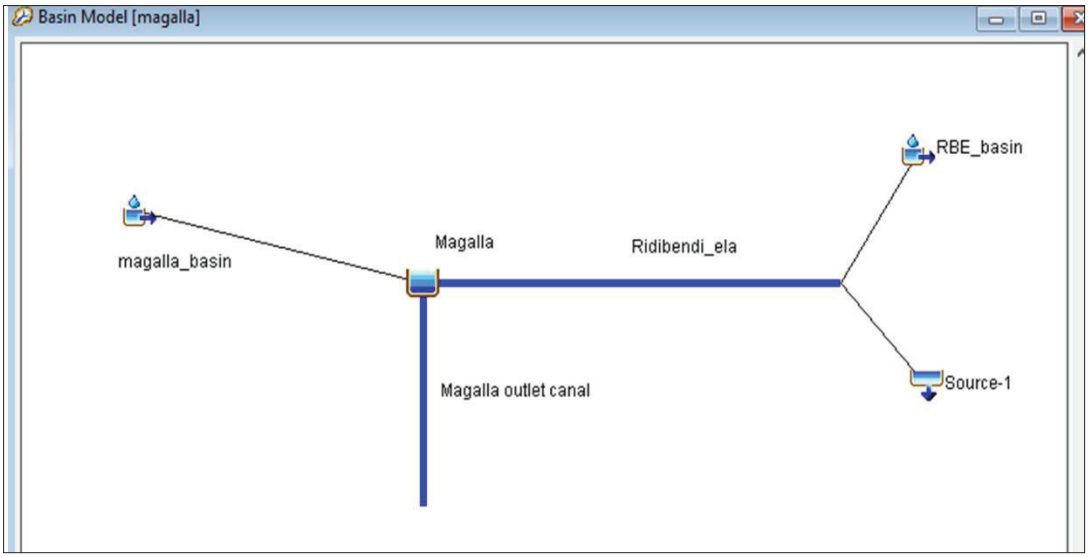

Figure 3- HEC-HMS model setup

HEC-DSSVUe software was used to store and manage data sets of HEC- HMS model. Magalla model was developed by using basin parameters, storage data of Magalla, flow data of Ridi Bendi Ela canal and precipitation data of the basin. Initial and constant loss method, Clark unit hydrograph method, recession base flow methods and Muskingum routing method selected for the model simulations.

Simulated and observed storages of Magalla were compared both graphically and statistically. Statically comparison was done using skill matrices.

Calibration and validation of the model was done using both event based and continuous simulation methods. 6th Jan- 23rd Jan 2010 extreme peak event was selected for event based calibration. 8th May – 18th May 2011 event and 4th Feb – 26th Feb 2011 were selected for the validation of the model.

1st June – 1st Aug 2011 (2 months) period was selected for continuous calibration of the model. 1st Jun – 25th July 2011 (1.5 months), 1st Aug – 31st Dec 2012 (5 months) period and 1st Jan – 31st Dec 2012 (1 year) were used to validation of the continuous simulation of the model.

Normalized Objective Function, Nash Sutcliffe efficiency and Percentage bias values were calculated for each event based and continuous simulations of the rainfall events.

Results and Discussion

Results of event based calibration of HEC-HMS model is shown in Figure 4. 7 days (Jan 6 - Jan 22, 2010) period was considered. Graphs show the goodness of fit between simulated and observed storages of Magalla reservoir.

Results of event based validation of HEC-HMS model is shown in Figure 5. 10 days (May 08 – May 18, 2011)period was considered.

Results of continuous based calibration of HEC-HMS model is shown in Figure 6. 1 month 25 days (Jun 01 – Aug 1, 2011)period was considered. Graphs show the goodness of fit between simulated and observed storages of Magalla Reservoir.

Results of continuous validation of HEC-HMS model is shown in Figure 7. 5 month (Aug 01 - Dec 31, 2012)period was considered.

The values of skill matrices are shown in Table 1. The NOF, δ_b, R^2_{NS}, values are close to the reference values that's represent the goodness of fit and matching of the observed and simulated storages of Magalla tank.

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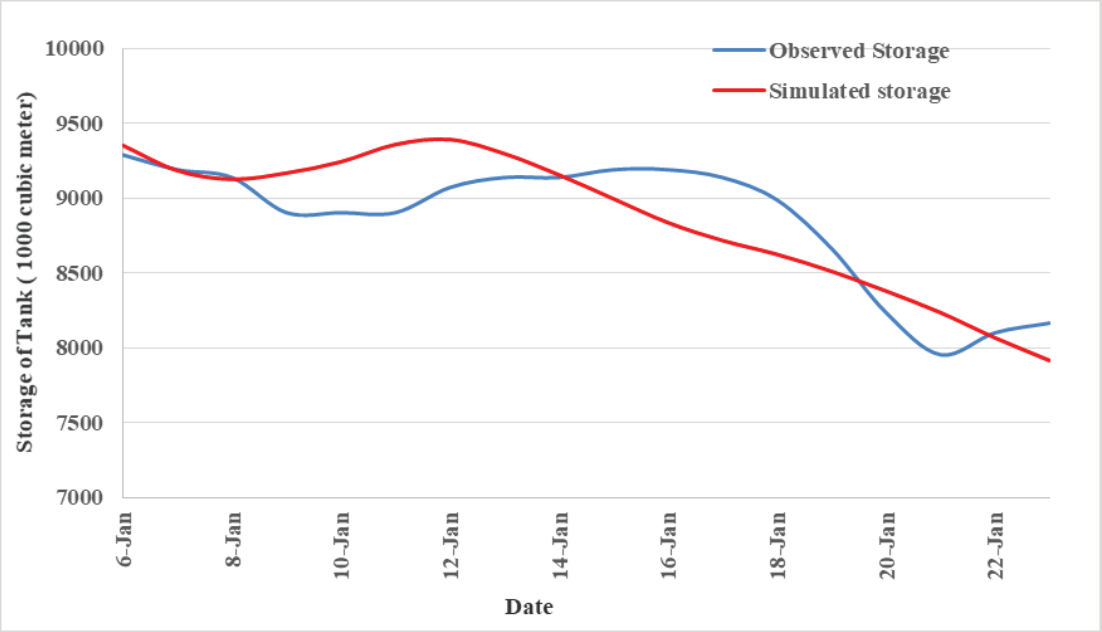

Figure 4- Event based calibration

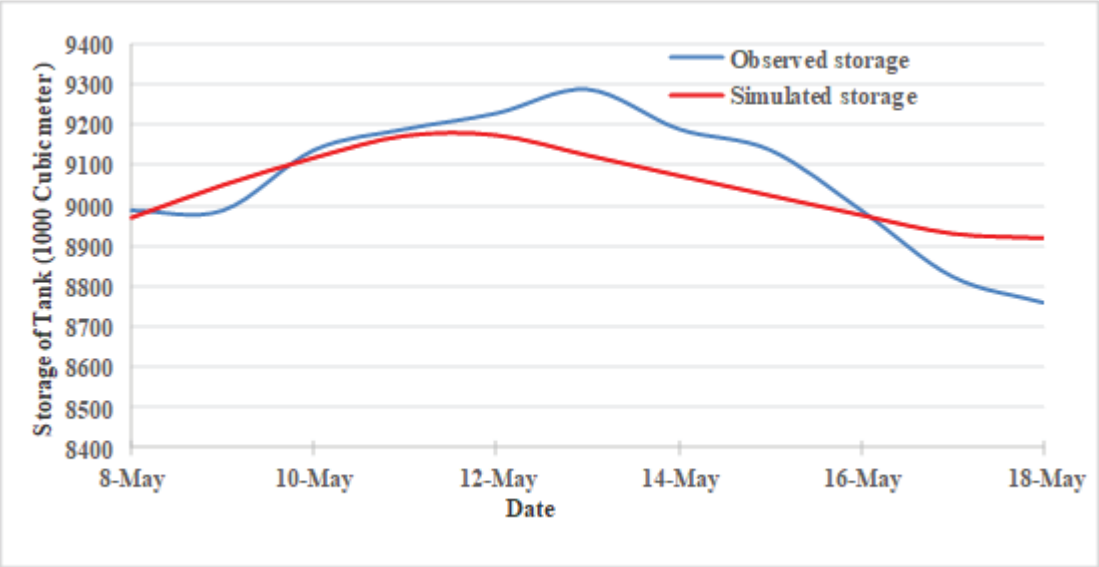

Figure 5- Event based validation

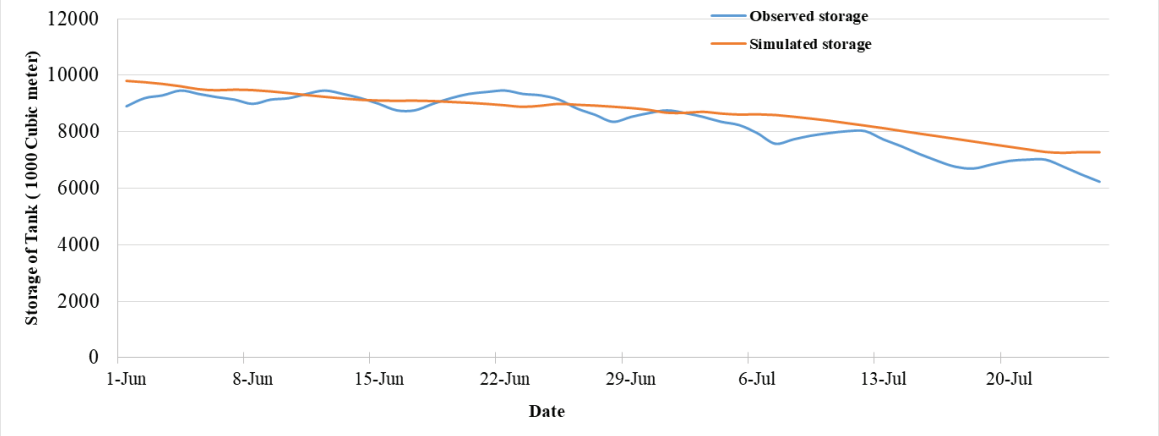

Figure 6- Continuous based calibration

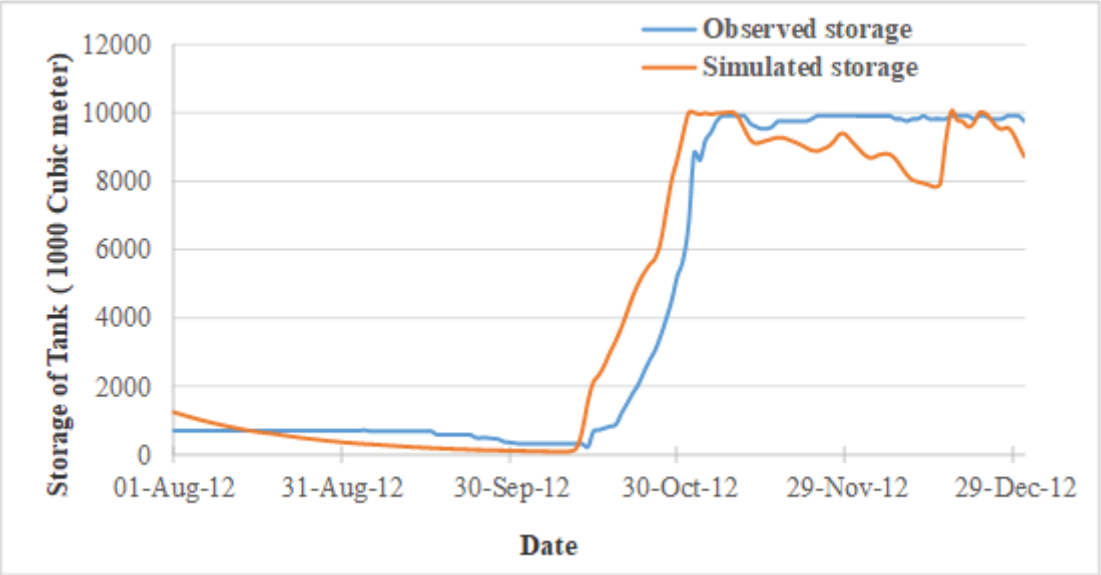

Figure 7- Continuous based validation

Table 1- Skill Matrices

	Time period	NOF	R^2_{NS}	δ_b
Event based	2010 Jan 6 – 23	0.029	0.63	0.16
	2011 Mar 8 – 18	0.01	0.66	-0.18
	2011 Feb 04 – 26	0.028	0.67	-0.30
Continuous based	2011 Jun 01 - Aug 01	0.11	0.60	6.24
	2012 Jan 01 -Dec 31	0.47	0.62	-3.64
	2012 Jul 01-Dec 31	0.288	0.93	4.03
	2011 Jun 01 - July 25	0.059	0.73	3.61

Results of continuous simulations and event based simulation of HEC-HMS model show that the calibrated models are capable of capturing the seasonal characteristics of stream flow and storages satisfactorily.

Reservoir simulation model was developed by coupling HEC-HMS model and CROPWAT model results. The calibrated model with the parameters of respective sub-catchments together with CROPWAT model can be used to find water diversion requirements from Deduru Oya river to achieve 100 % cropping intensity in Magalla scheme.

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