Integrated Water Resources analysis of the Deduru Oya Left Bank considering traditional and modern systems

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Abstract

The Deduru Oya reservoir which was commissioned in 2014 is primarily planned to improve the livelihood of farmers in parts of the North-Western Province of Sri Lanka by increasing the productivity of its land and water resources by regulating and diverting water to irrigation systems through two main canals in both river banks. . The left bank (LB) canal supplement water needs for paddy cultivations LB irrigation area from existing traditional rainfed small reservoir based irrigation systems. The right bank canal is a transbasin canal conveying excess water from the reservoir to adjacent Mee oya basin. The Deduru Oya irrigation project is an example of integration of modern irrigation systems and traditional irrigation systems to improve cropping intensity and resilience.

This study develops a model for water management in LB canal development area to study the resilience of Deduru Oya LB canal irrigation system. Hydrological Engineering Center-Hydrological Modeling System (HEC-HMS) is used for runoff estimations and CROPWAT model is used to estimate crop water requirements. The analysis estimates the water resources available for paddy cultivation from ancient irrigation systems through a detailed analysis of inflow to individual tanks and clarifies the water resources improvement from the Deduru Oya reservoir.

The simulation carried out for past ten years reveals that the Deduru Oya reservoir project which has planned to operate LB canal irrigation management incorporating the existing traditional rain fed small reservoirs will be able to supply the water demand for LB irrigation area for paddy cultivation without failure.

1 Introduction

Deduru Oya basin located between Northern latitude 7^0 19’ 00” to 7^0 52’ 00” and Eastern longitude 79^0 47’ 0” to 80^0 35’ 0” has an area of 2620 km^2 with elevation ranging from 0 m to 1280 m MSL. It is the sixth largest river basin in Sri Lanka extending from Chilaw in the west coast to the central hills as shown in Figure 1. The basin boundaries are Mee Oya basin to the North, central hills to the East, Maha Oya basin to the South and coast to the West. The basin could be categorized into three regions according to geographical features, viz. Coastal and alluvial areas: in the most downstream area in the western end of the basin, Mountainous region in the eastern boundary of the basin, Moderately sloping region in the western peneplain.

The rainfall in the basin has a significant temporal and spatial variation. Annual rainfall ranges from 2600 mm in the upper basin to 1100 mm in the lower basin. The average annual rainfall in the basin is about 1600 mm, ranging from 50 mm in a dry month to 280 mm in a wet month (Jinapala et al, 2003). From the annual rainfall about 50% is received during inter monsoon months (March, April, October & November), about 35% during Southwest monsoon months (May to September), while remaining 15% during Northeast monsoon months (December to February). Representative rainfall in the basin is depicted by the records of the rain gauge at Kurunegala (Fig. 2). The average daily mean temperature varies between 28 and 32 ^{0}C.

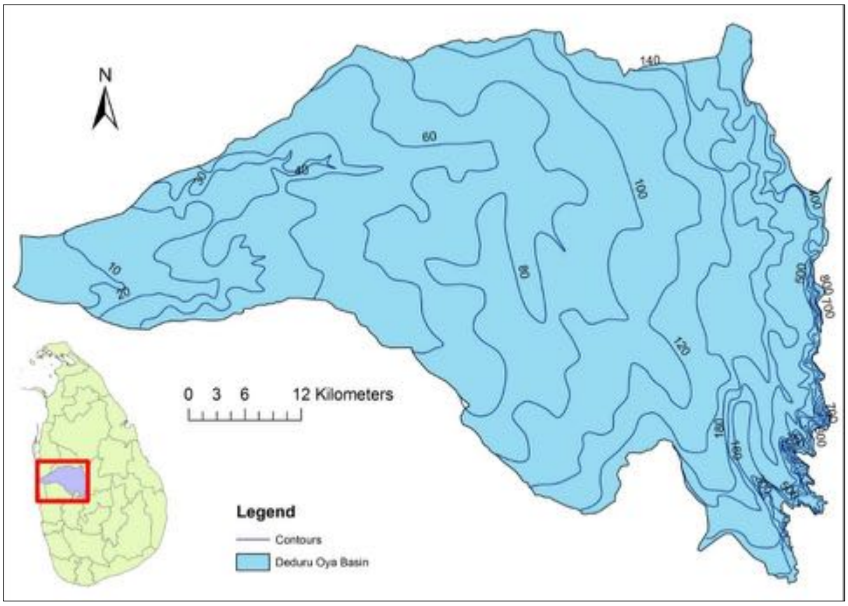

Figure 1: Topography of the Deduru Oya basin

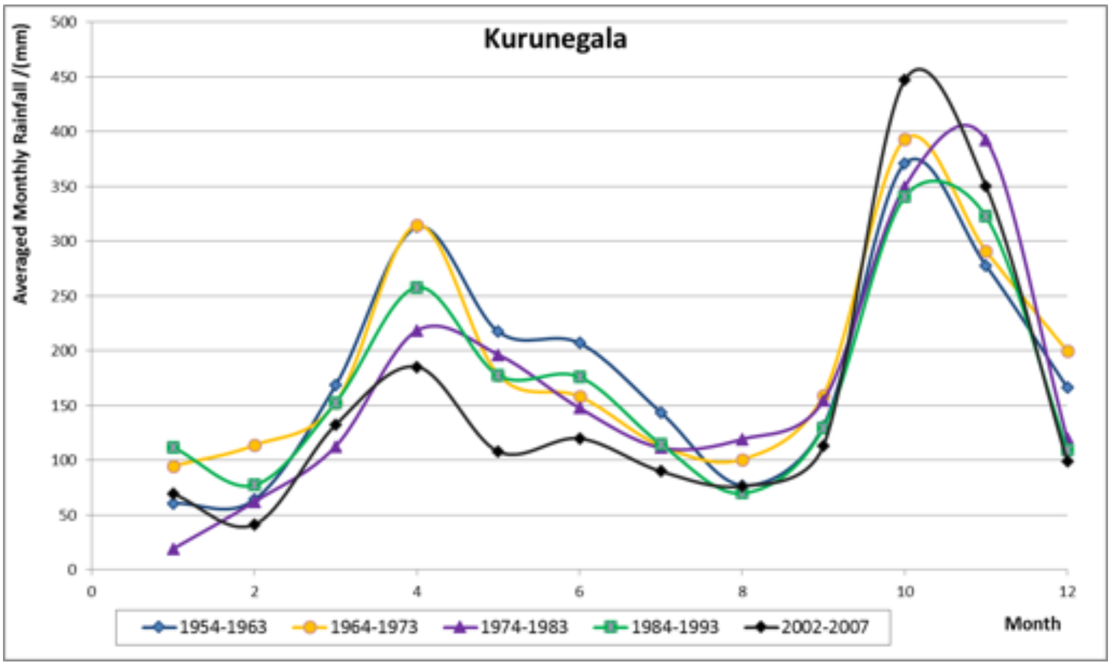

Figure 2: Mean annual rainfall at Kurunegala gauging station

Upper catchment of the river is nourished by water springs around Galagedara, in Kandy district which receives about 2000 to 2250 mm of annual rainfall. The upper reaches of the main river has a high gradient, where the most upstream 16 km segment of the river has elevation ranging 200m to 1000 m. The Deduru Oya releases about 1600 MCM of water to the sea annually without being much used in the basin (National Atlas, 2007). Deduru Oya carries flash floods during rainy season and very low flows during the dry season owing to the significant temporal variation of its basin rainfall. The single reservoir intercepting the Deduru Oya is the recently constructed reservoir in 2014 though there are several weirs across it to divert water for irrigation schemes.

2 Irrigation systems in Deduru oya basin

Paddy cultivation is done under the tropical climate conditions in Sri Lanka in two seasons per year: wet (*Maha*) season from October to March and dry (*Yala*) season from April to September. Deduru Oya basin is one of the major paddy cultivation basins in the country. A prominent feature in the Deduru Oya basin is that it contains approximately 3000 small reservoirs called tanks and cascade irrigation systems (Fig. 3). These irrigation systems are operated from ancient times, tank construction records dating back to the period of King Mahesen in 270 A.D. and the period of King Parakramabahu in 1153-1186 A.D. (Parker H. 1889, Mahāvaṃsa 1912, Cūlavaṃsa, 1929, Brohier, 1935, Attygala, 1948, Nicholas, 1954) are used to irrigate approximately 50,000 hectares of paddy lands in the basin which is about 18% of the basin area. The surface water storage capacity of the reservoirs in the Deduru Oya basin is about 400 MCM (Weerakoon et. al, 2001). Despite the existence of over 3000 small reservoirs scattered all over the Deduru Oya basin, the basin still suffers considerable scarcity of water at present. Changes of rainfall pattern and the long dry season are the main reasons for this water scarciy. Cultivation of the total area under these irrigation schemes is possible only during *Maha* season. In *Yala*, lands under 60 percent of small reservoirs are not cultivated due to water scarcity (Somaratne et al, 2003). The Deduru Oya reservoir project which was recently commisioned in 2014 is expected to increase the cropping intensity of paddy cultivation in the Deduru Oya basin.

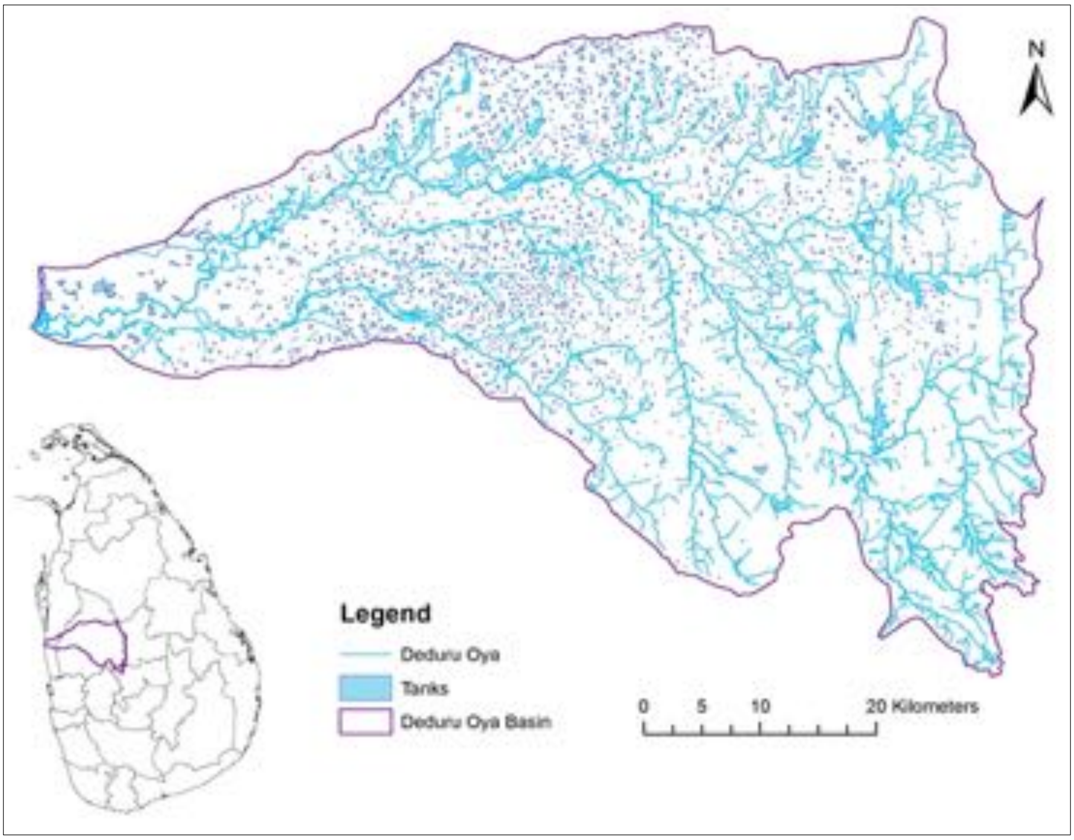

Figure 3: Irrigation reservoirs and stream network in the Deduru Oya basin (Source: adapted from Survey Department)

3 Deduru Oya reservoir project

Deduru Oya reservoir project (Fig. 4) is a multi-purpose water resource development project implemented by the Irrigation Department of Sri Lanka primarily to improve the livelihood of farmers in part of the North Western province by increasing the productivity of land through irrigated agriculture. Block diagram of Deduru Oya reservoir project is shown in Fig. 5. The project includes construction of a dam across Deduru Oya at Thunmodara which is 66.7 km along the Deduru Oya from the sea mouth to impound stream flow in a reservoir with a capacity of 75 MCM, construction of two diversion canals at the left bank (LB Canal) and right bank (RB Canal) to provide irrigation for 11415 ha of cultivated land and installation of a 1.5 MW hydropower plant at the downstream of the dam. Other purposes of the project include enhancement of reliable sources for domestic and industrial water supply schemes, control downstream floods and regulation of the flow to enhance existing diversion at 300 m downstream to Ridi Bendi Ela irrigation scheme.

The unique feature of the Deduru Oya reservoir is the design of LB Canal where this contour canal supplements water to a large number of traditional tanks and cascade systems to form a combination of traditional tanks and modern reservoir irrigation system.

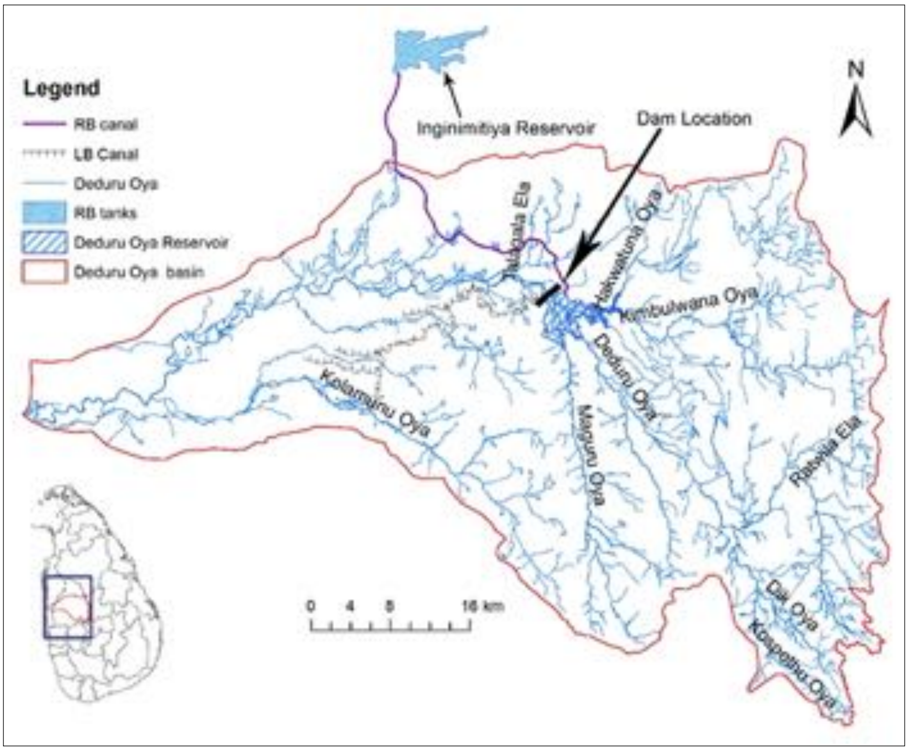

Figure 4: Deduru Oya reservoir project

RB Canal is a transbasin canal to supply water to Iginimitiya reservoir which is located in the adjacent Mee Oya basin. It is proposed to develop 1000 ha along the transbasin canal and 4115 ha in the Mee Oya basin. Furthermore, 3000 ha in Ridi Bendi Ela scheme will be benefited by regulated water supply from the Deduru Oya reservoir (Table 1).

Release from the reservoir to the downstream of Deduru Oya is 7 m^3/s of which 5.65 m^3/s is for the diversion to Ridi Bendi Ela at 300 m downstream from the dam and the balance is for environmental flow at the downstream of the diversion (Pre-feasibility Report, 2001).

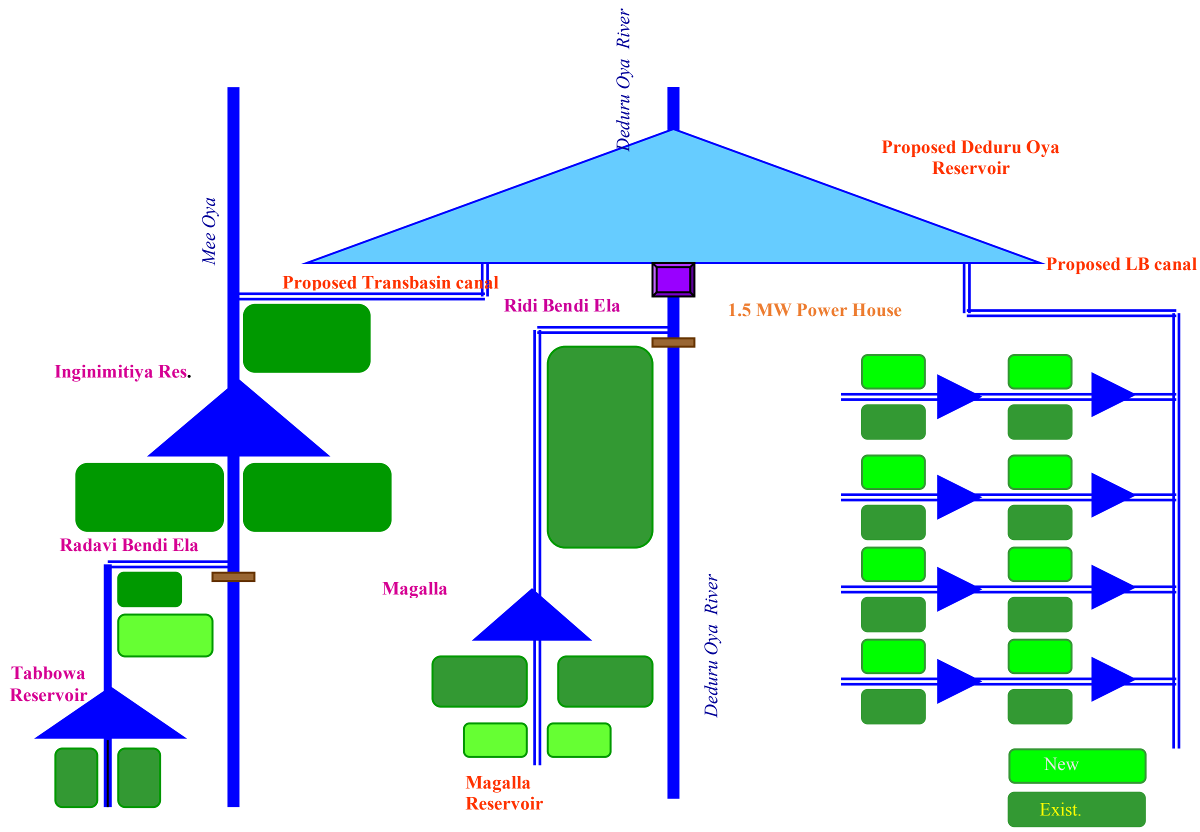

Figure 5: Block diagram of Deduru Oya project

Table 3: Summary of proposed and existing irrigation areas

Canal	Existing area (ha)	Proposed area (ha)
LB canal	2400	600
RB canal	4715	700
Ridi Bendi Ella	2400	600
Total	9515	1900

4 Deduru Oya LB canal irrigation system

The Deduru Oya LB canal is 44.1 km long, and supplies water to augment 136 existing storage-based ancient irrigation systems in the left bank of the Deduru Oya (Fig. 6). The canal which begins from the reservoir with a capacity of about 7.1 m^3/s forms 17 level-crossings with small tanks and also supplies water to four branch canals (Fig. 6). Control Outlets (CPO) along the canals release water to distribution canals and 136 existing tanks (Table 2).

Table 2: Number of tanks supplied by main canal and branch canals

Canal Name	Number of tanks	Capacity of the canal (m^3/s)
Main Canal	77	7.08
Branch Canal 1	15	4.25
Branch Canal 2	16	2.83
Branch Canal 3	27	1.42
Branch Canal 4	1	1.42

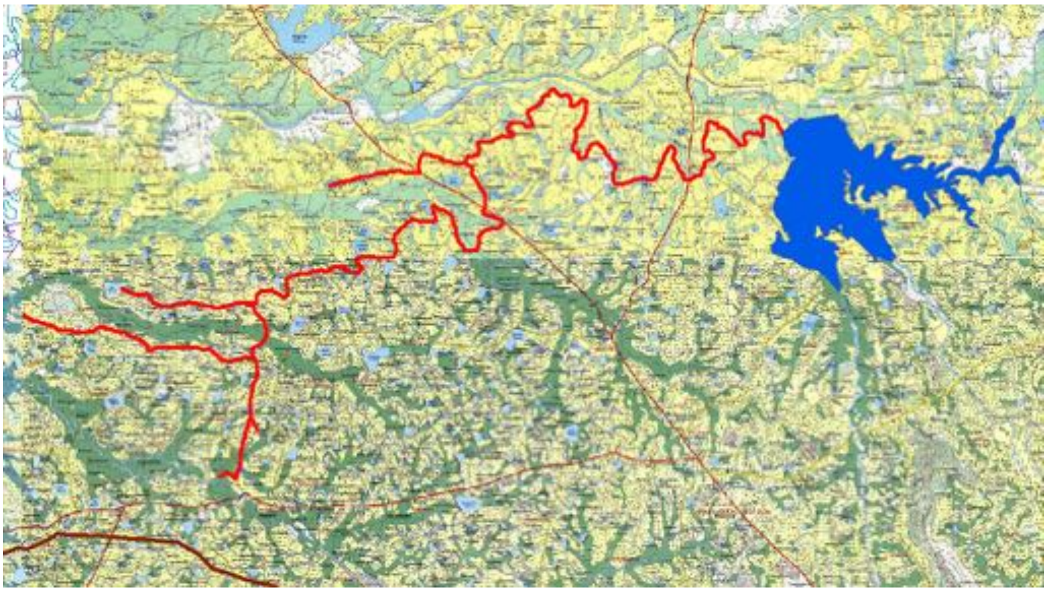

Figure 6: DeduruOya reservoir and LB canal

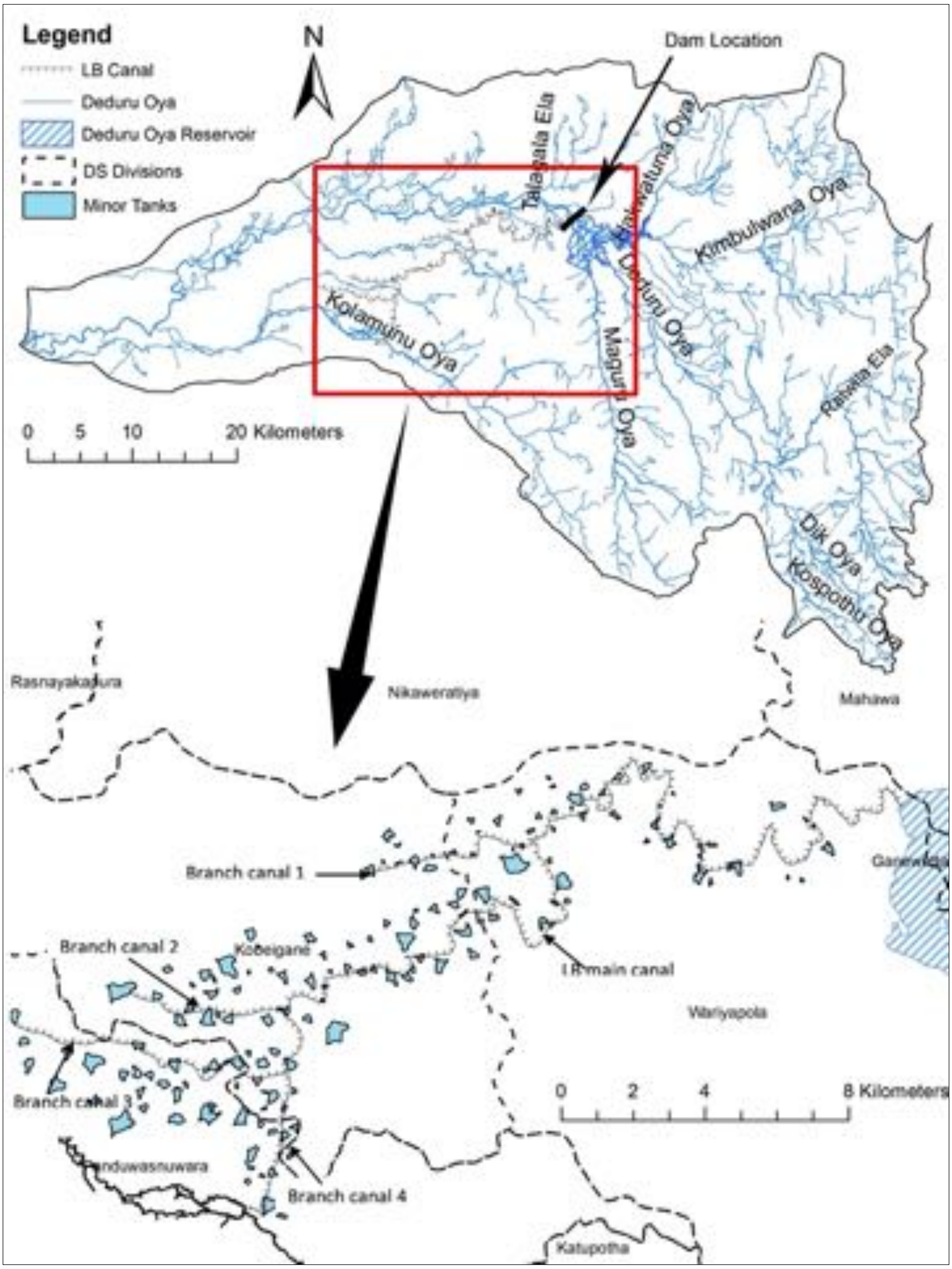

Figure 7: Deduru Oya reservoir and LB canal

4.1 LB Canal Irrigaton system - Combined system of traditional tanks and modern reservoir irrigation system

Irrigation systems consisting of modern and traditional systems are expected to improve overall resilience of the system and improve livelihoods of farmers through the increases in productivity (Herath et al, 2013). With the extreme weather events experienced in recent times attributed to climate change, more attention is given today on the sustainability and resilience of ancient irrigation systems based on distributed small storages. In order to improve sustainability and resilience of modern irrigated agricultural systems, it is imperative that resilient features of ancient irrigation systems are incorporated to modern irrigation systems. These combined system of traditional tanks and modern reservoir systems with the features of modern and ancient systems are expected to improve livelihood of farmers through sustainable and increased productivity. The Deduru Oya irrigation project in North-Western Province of Sri Lanka is one such combined system of traditional tanks and modern reservoir irrigation project developed incorporating features of modern and ancient irrigation systems.

The LB canal irrigation system is shown in Figs. 7 & 8. Each tank has its own catchment area to receive and store water drived from seasonal rains in order to irrigate the command area under the tank. With the operation of the LB canal, these tanks will aslo receive water from the Deduru Oya reservoir to supplement the irrigation demands from tanks to

Figure 8. Distribution of ancient tanks in the LB canal

increase the cropping intensity of existing cultivations and also to increase the cuiltivation area under each tank.

While there have been a number of hydrological modeling studies on irrigation tanks and small cascade systems a systematic study of the irrigation potential of ancient irrigation systmes has not been done before. In this study, the availability of water resources for the LB development area in the traditional sytem and in the combined system after the project is analysed. Major components of water accounting for the new reservoir are shown in Fig. 9.

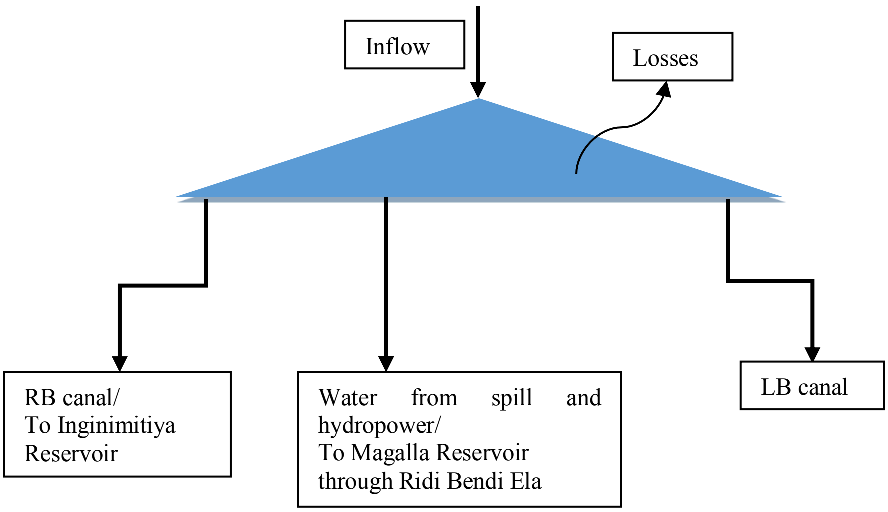

Figure 9: Water accounting in the reservoir

4.2 Estimation of wateravailability from the traditional system for irrigation in the LB development area

Inflows to the irrigation reservoirs in LB development are not readily available and therefore, a rainfall - runoff model was developed to estimate the direct inflows to the reservoirs from their own catchments. Rainfall-runoff model developed to Tittawella reservoir is used to set up and calibrate the inflows to ancient tanks in the LB development area. Tittawella reservoir is located about 10 km away from LB canal development area in the same agro-climatic region and its catahcmnet is hydrologically similar to the reservoir catchments in Deduru LB canal development area. Daily observed rainfall, runoff and evaporation data of Tittawella catchment are available for the period of May 1995 to March 1997 (Dept. of Irrigation, 1998). The catchment area of Tittawella reservoir is 2.95 km^2 and the reservoir has a capacity of 0.31 MCM. Major soil group is reddish brown earth and soil depth is more than 120 cm. Longest water course is 1800 m long and catchment slope is 0.82%. The land use pattern in the basin is identified as homesteads 55%, paddy 25%, coconut 7.5%, and forest cover.

Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) version 3.0.1 developed by US Army Corps of Engineers in USA was used as the rainfall runoff model to estimate inflows to the tanks (Scharffenberg et al, 2006). The HEC–HMS supports both lumped parameter based modeling as well as distributed parameter based modeling and has been tested for tropical catchments (Agrawal et al, 2005). HEC HMS has been successfully applied to many basins to assess water resources including river basins in Sri Lanka (De Silva et al, 2014, Halwatura et al, 2013).

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4.2.1 HEC-HMS application to Tittawella reservoir

HEC-HMS model was calibrated and validated for Tittawella reservoir using the observed daily rainfall and catchment runoff from selected storm events during Oct-Nov 1995, Oct 1996 and May 1995 and also using observed data of the continuous periods of Sept-Nov 1995, Sept-Nov 1996, Sep 1995-Aug 1996 and May 1995-Mar 1997 are shown in Figs. 10 to 16 respectively. Figs. 13 to 16 depict graphical comparisons of the calibration and validation results respectively for continuous simulation. The study used the computed skill metrics of simulated stream flow against observation as a criterion to calibrate model parameters. Table 3 shows that the skill of simulations of calibrated model NOF, R_{NS}^2 and $\delta_{b,}$agree reasonably well against observed discharges during both calibration and validation periods in event based and continuous simulation.

4.2.2 Calibration

HEC–HMS model was calibrated for isolated rainfall events and also for continuous rainfall. Observed daily rainfall and discharge during Oct-Nov 1995 was used for event based model calibration. Skill metrics for simulated river discharge were computed and the best fit with observed was obtained by adjusting model parameter values for moisture loss, runoff transform method and baseflow processes of the HEC-HMS model. The rainfall and discharge in Oct 1996 and May 1995 were used to validate the calibrated event based model. Rainfall and discharge data during Sept to Nov 1995 period was used to calibrate the continuous simulation of the model while 3 months, 1 year and 23 months, time series during Sept to Nov 1996, Sept 1995 to Aug 1996 and May 1995 to Mar 1997 were used to validate the continuous model simulations.

The event based simulations employed the initial and constant loss method to compute infiltration loss while continuous simulations used the 5–layer soil moisture accounting loss method. The initial and constant loss rate model requires the constant loss rate and initial loss to be specified. The soil moisture accounting loss method uses five layers to represent the dynamics of water movement in and above the soil. The layers include canopy interception, surface depression storage, soil, upper groundwater and lower groundwater. The soil layer is subdivided into tension storage and gravity storage (Scharffenberg et al, 2006), (US Army Corps of Engineers, 2000). Implementation of both loss methods requires the soil properties of the sub basin. According to soil type and catchment properties in the basin, an initial loss of 30 mm, and a constant loss rate of 1.0 mm/hr and catchment imperviousness of 10% were used in initial and constant loss method. Above parameters were able to produce the best fit against observations. Parameters used for soil moisture accounting loss method are shown in Table 4.

Table 4: Summary of parameters used in soil moisture accounting loss method

Parameter	Value
Canopy (%)	0
Surface (%)	0
Soil (%)	70
Groundwater 1 (%)	31
Groundwater 2 (%)	82
Canopy storage (mm)	23

Surface storage (mm)	5
Max infiltration (mm/hr)	15
Imperviousness%	22
Soil storage (mm)	124
Tension storage (mm)	25
Soil percolation (mm/hr)	31
Groundwater 1 storage (mm)	44
Groundwater 1 percolation (mm/hr)	0.05
Groundwater 1 coefficient (hr)	66
Groundwater 2 storage (mm)	201
Groundwater 2 percolation (mm/hr)	0.42

Groundwater 2 coefficient (hr)	30

Clark unit hydrograph was selected as transformation method where time of concentration and storage coefficient were selected as 3 hr and 2 hr respectively for the Clark unit hydrograph. The storage coefficient is used in the linear reservoir that accounts for storage effects (Scharffenberg et al, 2006).

Recession baseflow method was employed for both event based and continuous simulations. The recession constant was set to 0.76 and ratio to peak was set to 0.5 while the initial discharge was set to 0.05 m^3/s after simulating several trials.

Table 3: Computed skill metrics for event based and continuous simulation

	Period	NOF	R_{NS}^2	$\delta_{b,}$
Event based simulation	Oct-Nov 95	0.20	0.95	0.20
	Oct-96	0.26	0.86	1.64
	May-95	0.28	0.92	12.0

Continuous simulation	Sept-Nov 95	0.83	0.85	3.00
	Sept–Nov 96	0.77	0.84	18.0
	Sept 95-Aug 96	1.69	0.73	33.0
	May 95- Mar 97	1.60	0.72	20.0

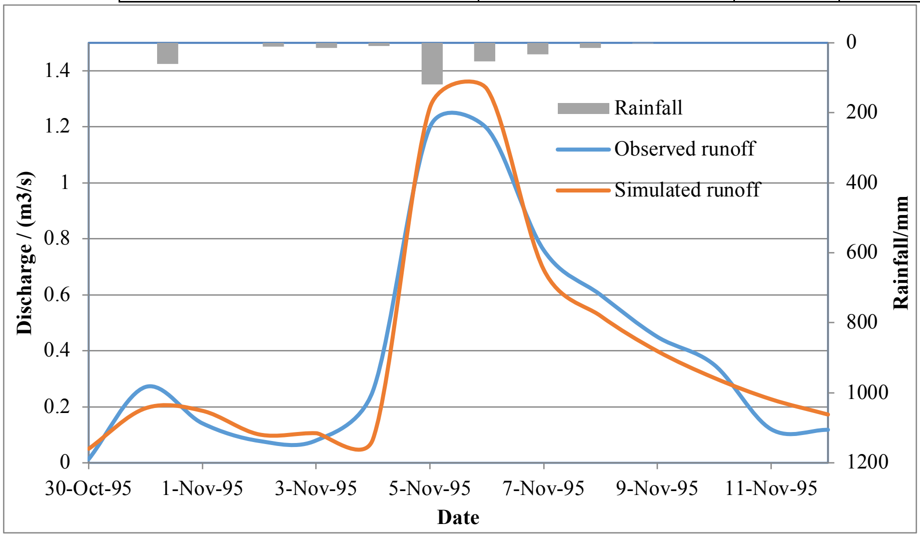

Figure 10 : Calibration of event based simulation

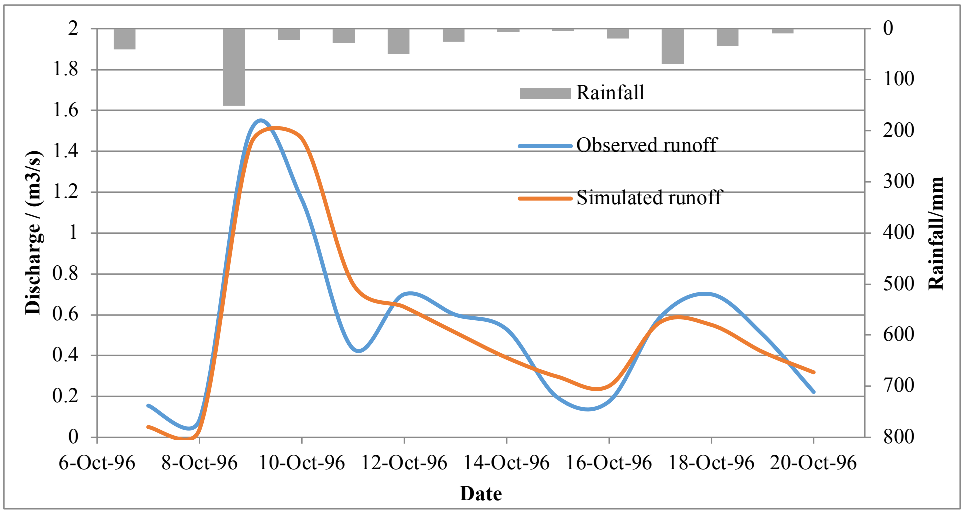

Figure 11: Validation of event based simulation

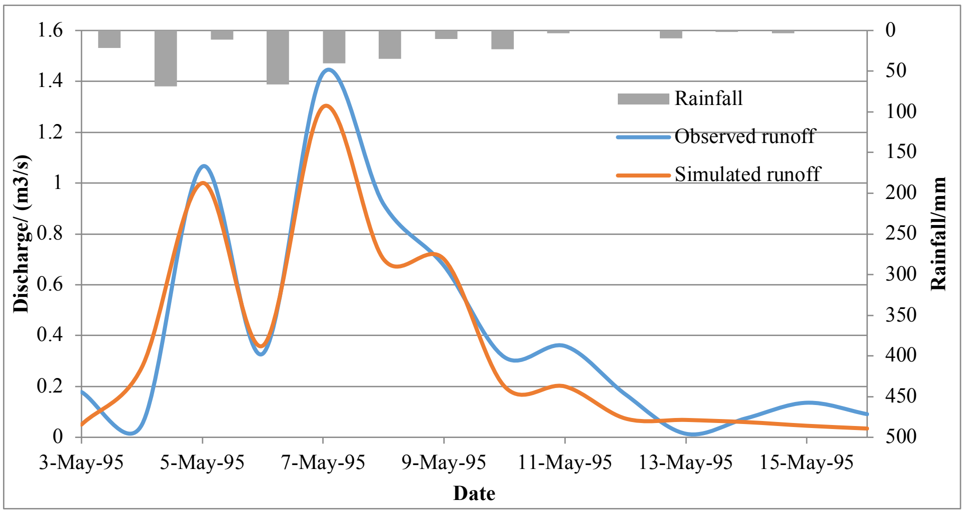

Figure 12: Validation of event based simulation

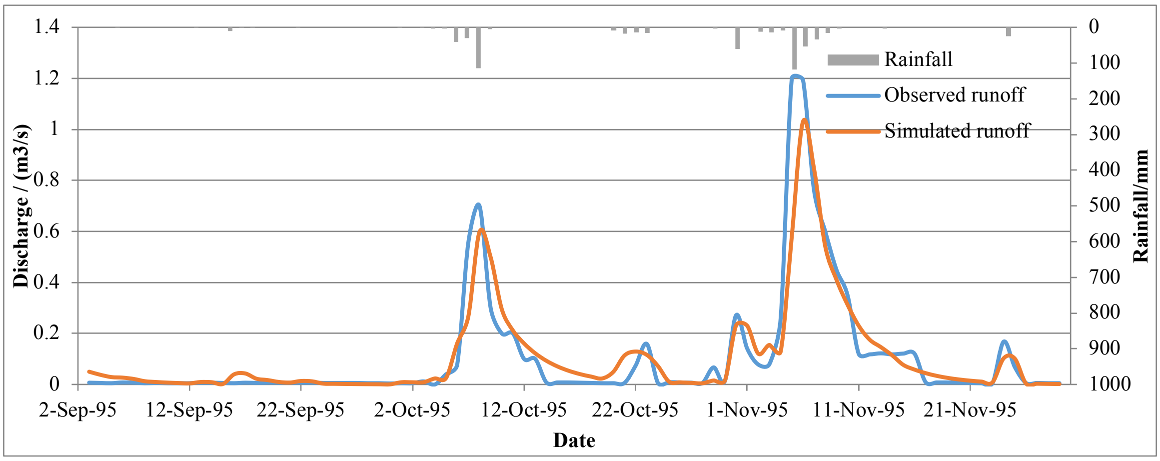

Figure 13: Calibration of continuous simulation

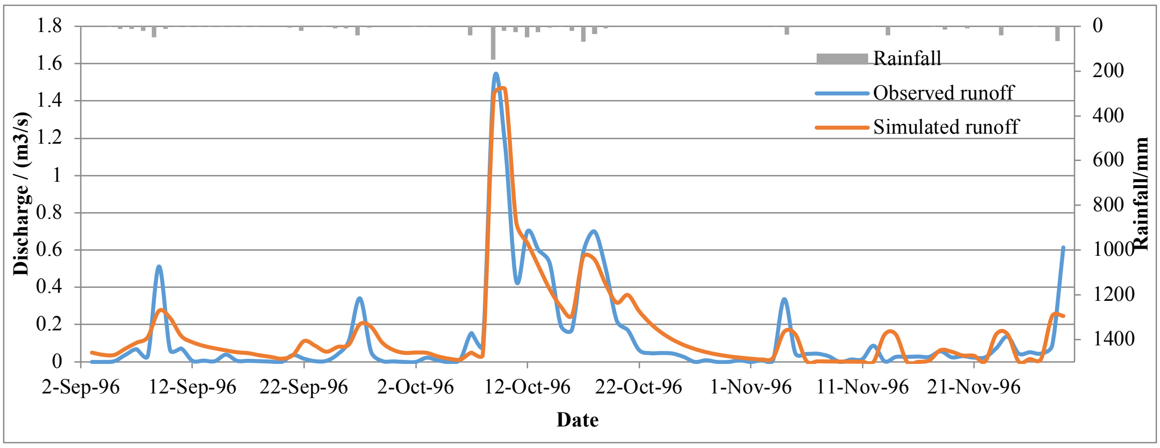

Figure 14: Validation of continuous simulation

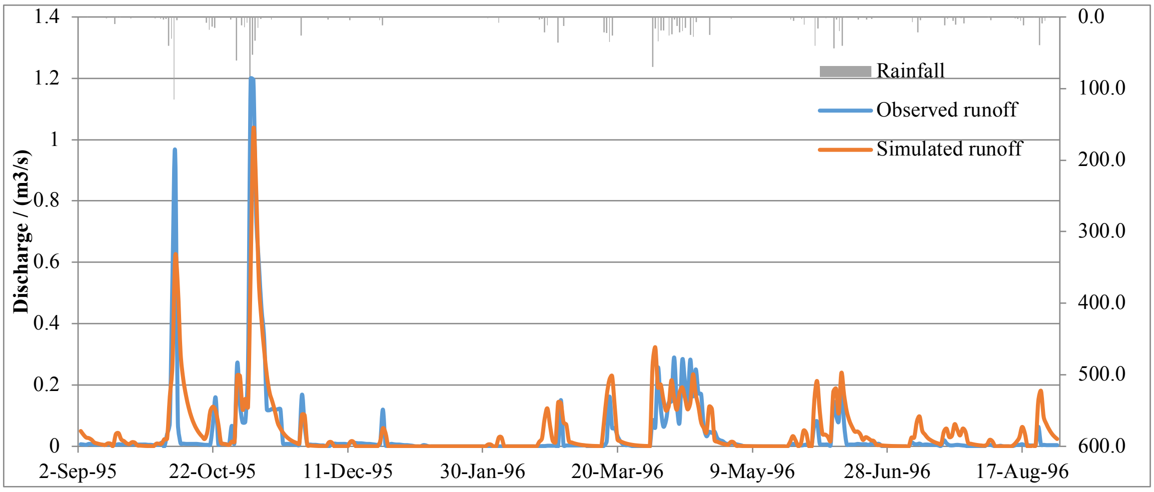

Figure 15: Validation of continuous simulation

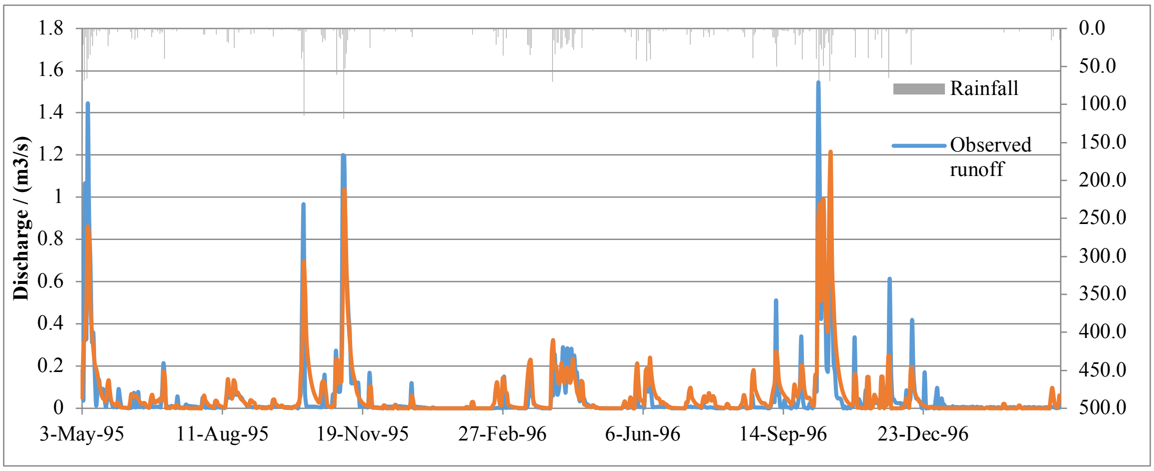

Figure 16: Validation of continuous simulation

Calibrated and validated HEC-HMS model was applied to generate daily inflows to 136 small tanks in LB development area from their respective catchments. .

Catchment areas, land use patterns storage capacities, command areas, natural streams, geological features and cascades were identified by using relevant GIS data and digitizing techniques for all minor reservoirs augmented by the LB canal. Topographic, geologic and land use data were collected from the digital data of the Survey Department of Sri Lanka. ArcGIS 9.3 was used for spatial analysis of the Deduru Oya LB region.

Fig. 17 shows the calculated monthly inflow values for Mellapoththa reservoir. Fig. 18 shows calculated monthly inflow values for Amunukole reservoir.

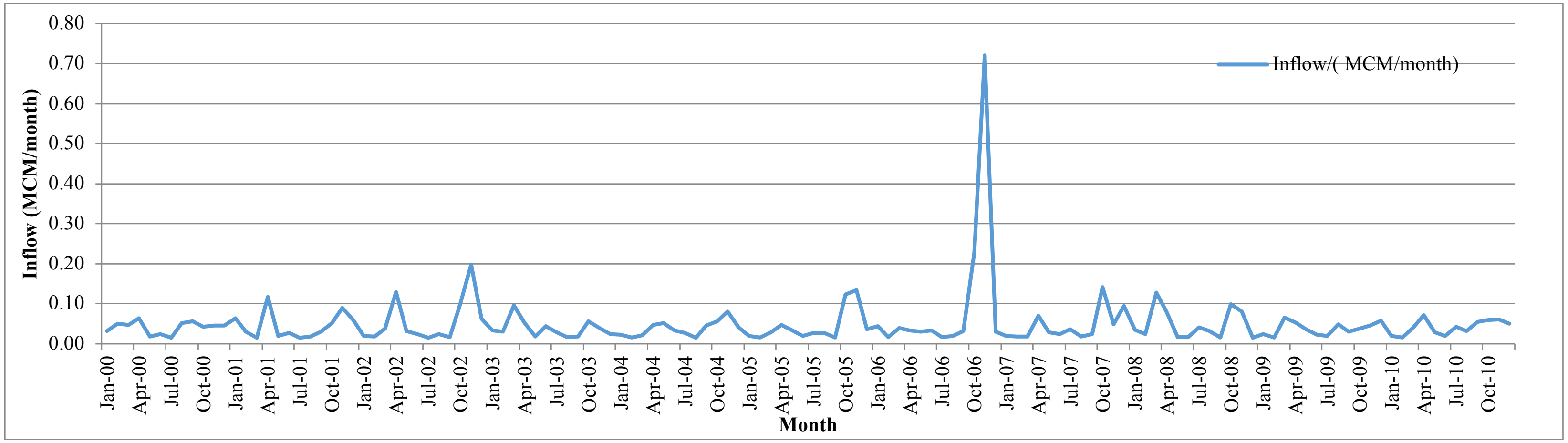

Figure 17: Monthly inflows to Mellapoththa reservoir

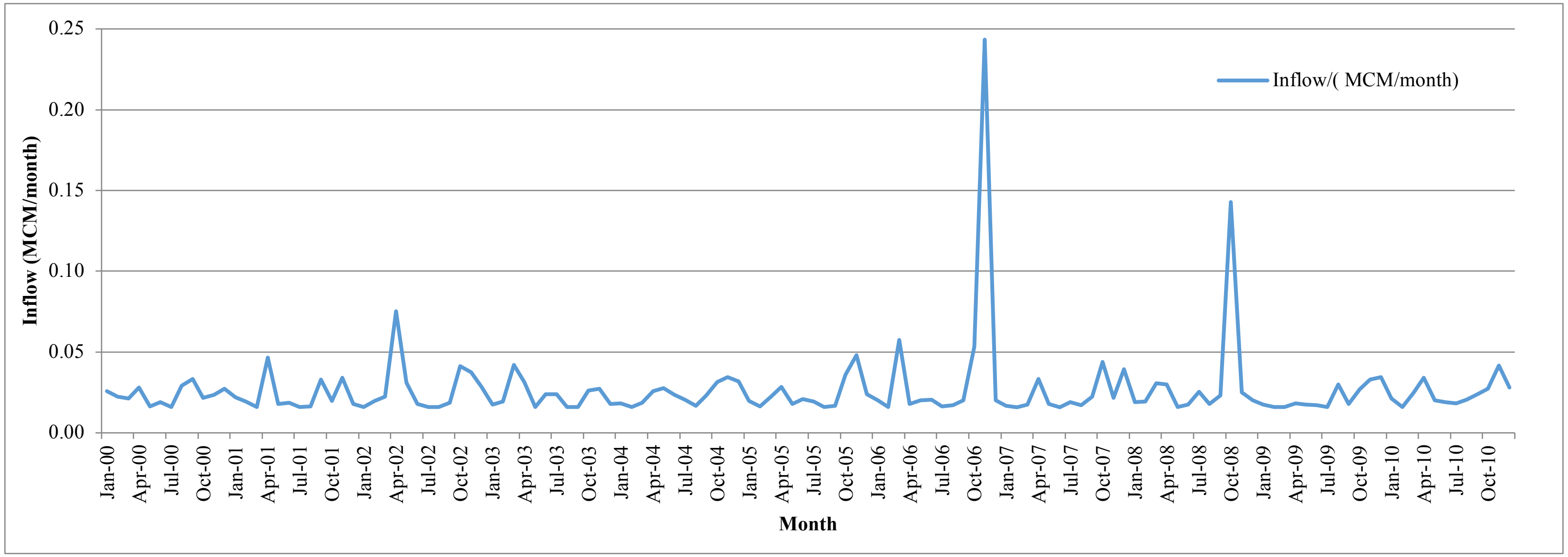

Figure 18: Monthly inflows to Amunukole reservoir

4.2.3 Modeling of flow into Deduru Oya reservoir

Rainfall data at stations in the basin including Ridi Bendi Ela, Wariyapoala, Millawa, Delwita, Batalagoda, Nikaweratiya and Kurunegala stations were compiled for the analysis. Evaporation data from Batalagoda and Mahawa, which are the closest stations to the proposed reservoir site, were obtained from Department of Meteorology, Colombo. Daily stream flow data available at Moragaswewa gauging station and was obtained from Department of Irrigation, Colombo. Also, stream flow data is availble at Ridi Bendi Ella station in the report of Hunting Survey Corporation Ltd and Survey General (1963).

Stream flow data is available only at Moragaswewa from 1981 to 1989. Therefore, HEC HMS model was applied to Deduru Oya basin above Moragaswewa (79.990^0 E, 7.700^0 N) which is located 32 km downstream to the Ridi Bendi Ela. Hereafter referred as DMW sub basin. DMW sub basin which is an upper basin of the Deduru Oya has an area of 1950 km^2 ranging from 30 m to 1280 m MSL extending from Moragaswewa to the central hills of Sri Lanka (Fig. 19). DMW sub basin of Deduru Oya basin covers 74% of whole Deduru Oya basin. DMW sub basin located between 7.320^0 N and 7.860^0 N latitudes, and 79.990^0 E and 80.580^0 E longitudes is one of the major rice production basins in the country. The Deduru Oya of DMW sub basin flows through Matale and Kurunegala districts.

There are intra-basin diversions for irrigation systems in the basin Irrigation systems release part of irrigated water as drainage flow to the downstream of them and these drainage flows enters into the basin drainage network and contributes to the flow at the downstream reach of the Deduru Oya in the DMW sub basin.

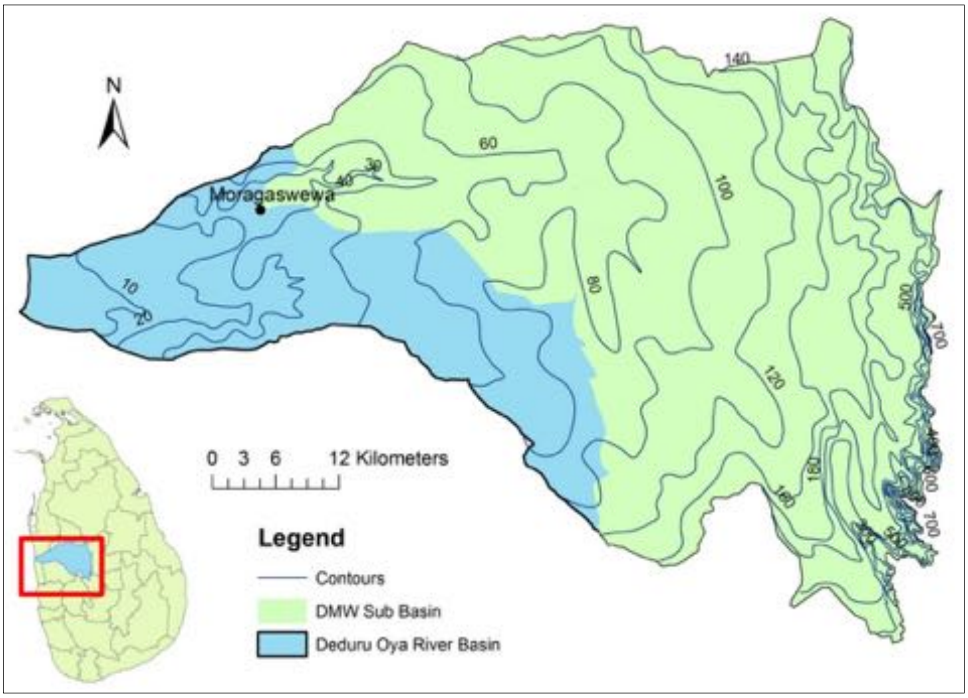

Figure 19: Location and topography of the basin

4.2.3.1 Intra-basin diversion to Magalla reservoir

There is an intra–basin diversion from the Deduru Oya river flow for irrigated paddy cultivation to the right bank at its middle reach. A weir constructed across the river diverts water to unlined Ridi Bendi Ela canalof 21 km length and capacity of 4.25 m^3/s to Magalla reservoir at Nikaweratiya (Fig. 20). The weir diverts all most all flow of the Deduru Oya to the Magalla reservoir during low river flow months. The Magalla reservoir with a capacity of 9 MCM stores water for the irrigation requirements in downstream areas. There are 2224 ha of paddy lands cultivated presently under the Magalla reservoir irrigation system. The Magalla reservoir has its own catchment area of is 32 km^2.

The Magalla reservoir has three irrigation canals; RB canal, LB canal and Centre canal to distribute water. Capacities of the canals and the irrigable areas under each canal are shown in Table 5. The drainage water from the paddy fields at Magalla reservoir irrigation systems flows into the Deduru Oya at the upstream of Moragaswewa (Fig. 20).

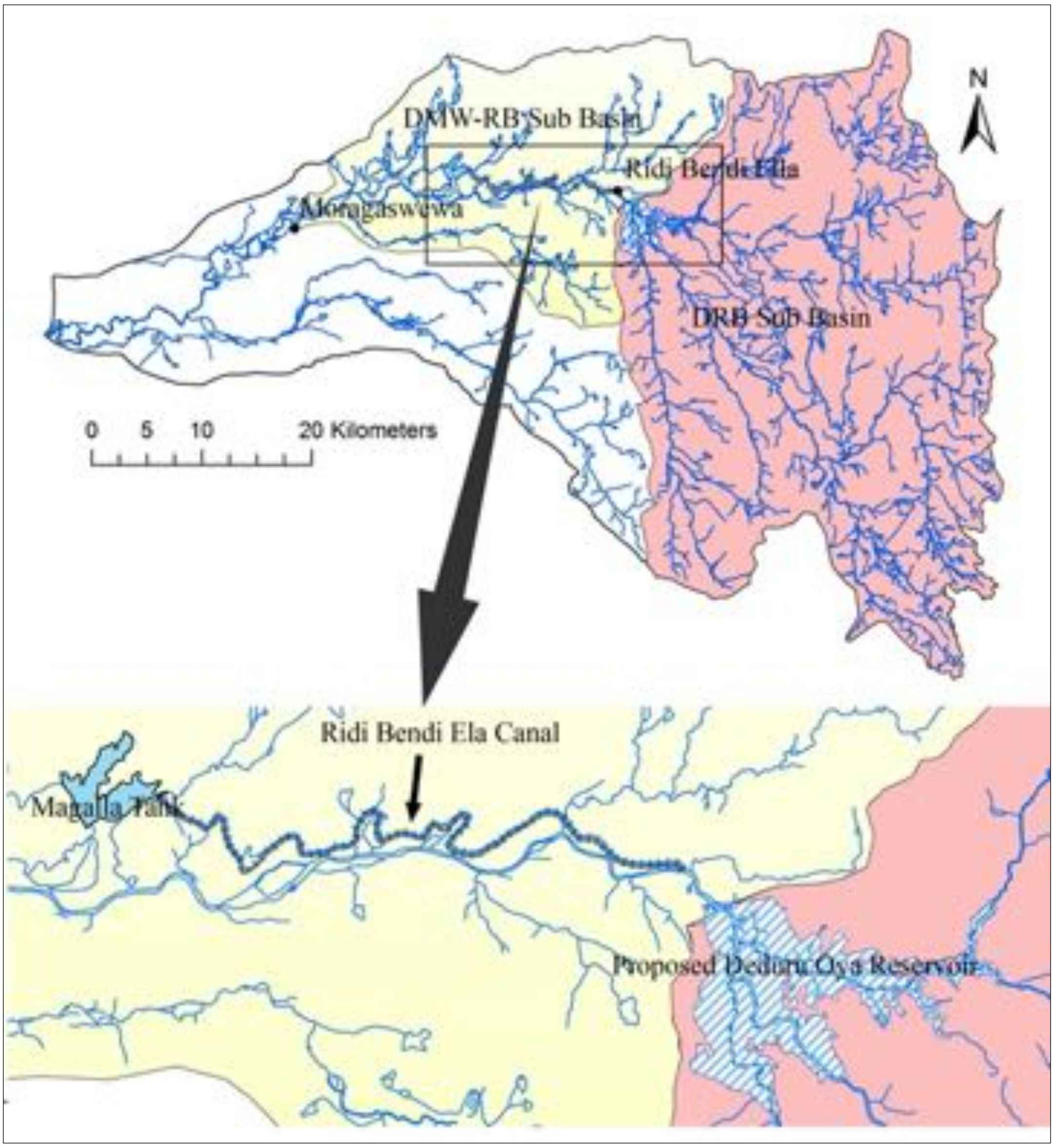

Figure 20: Magalla reservoir and sub basins in the study area

Table 5: Capacities of Magalla reservoir outlet canals and irrigation area

Canal	Capacity	Irrigation areas
RB Canal	3.4 m^3/s	1792 ha
LB Canal	1.13 m^3/s	312 ha
Center Canal	0.43 m^3/s	120 ha

For the application of HEC-HMS, the DMW sub basin which has an area of 1950 km^2 was divided into two sub-basins; DRB sub basin of an area of 1400 km^2 above the irrigation diversion at Ridi Bendi Ela and rest of the DMW basin (referred to as DMW-RB sub basin) of an area of 550 km^2 (Fig. 20). The schematic diagram of the HEC-HMS model setup is given in Fig. 21.

Ridi Bendi Ela canal was modeled as a diversion element and Magalla reservoir was modeled as a reservoir element. The drainage flow from the irrigation systems under Magalla reservoir is modeled as a reach element.

Daily stream flow at the DRB basin outlet was estimated by HEC-HMS model application to the DRB basin. Diversion to Magalla reservoir from DRB basin outlet through Ridi

Bendi Ela canal is 4.25 m^3/s or maximum available at the DRB basin outlet. The flow excess of 4.25 m^3/s is an inflow to the DMW-RB basin through Deduru Oya.

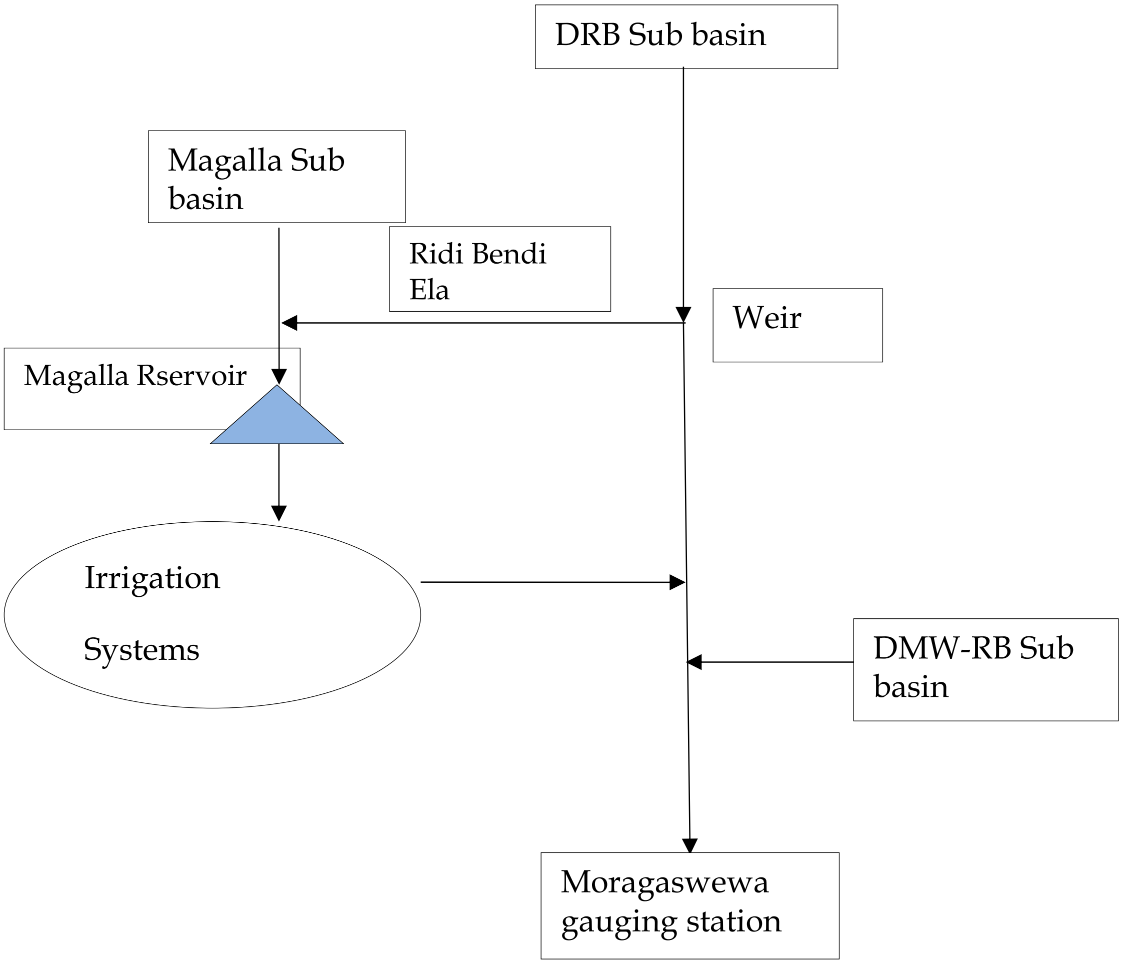

Figure 21: Schematic diagram for modeling DMW sub basin

Magalla reservoir receives inflow from its own basin and from the Ridi Bendi Ela canal. Daily releases from Magalla reservoir for irrigation systems through the three canals depends on the irrigation requirements and available storage. Reservoir simulation was carried out to estimate the actual daily releases.

Irrigation requirements in the irrigation systems were estimated by CROPWAT model. Drainage flow from the irrigation systems was taken as 40 % of the total release of Magalla reservoir through the three canals according to loss calculation and water balance study.

GIS data was used to identify stream paths, catchments, natural streams, land use patterns, geology and soil types in the basin. Topographic, geology and land use details were obtained in digital format from the Survey Department of Sri Lanka. The major portion of the soil in river basin was identified as reddish brown earth (HWSD, 2013), (Mapa et al, 2005).

Daily rainfall was collected from seven stations in the basin (Fig. 22), viz. Kurunegala, Delwita, Wariyapola, Millawa, Ridi Bendi Ela, Batalagoda and Nikaweratiya, for twenty years from 1980 to 2000. Monthly evaporation data for the same years for the agro-meteorological station Mahawa was used in the study. The rainfall data and the evaporation data were obtained from the Department of Meteorology, Colombo. Discharge rating curves for Ridi Bendi Ella, LB, RB and center canals of Magalla reservoir, discharge curve for Ridi Bendi Ela and area-capacity-elevation curve for the Magalla reservoir were available from the Department of Irrigation. The only stream flow data available for the Deduru Oya is from 1980 to 1989 at Moragswewa gauging station. Daily flow data at Moragswewa for the latest three years was used for model calibration and validation, viz. 3 months for calibration and 3 years for validation. Normalized Objective Function (NOF), Nash Sutcliffe efficiency (R^2_{NS}), Percentage bias (δ_b) and Root Mean Square Error ($RMSE$) values were used as quantitative measures for the skill of simulations.

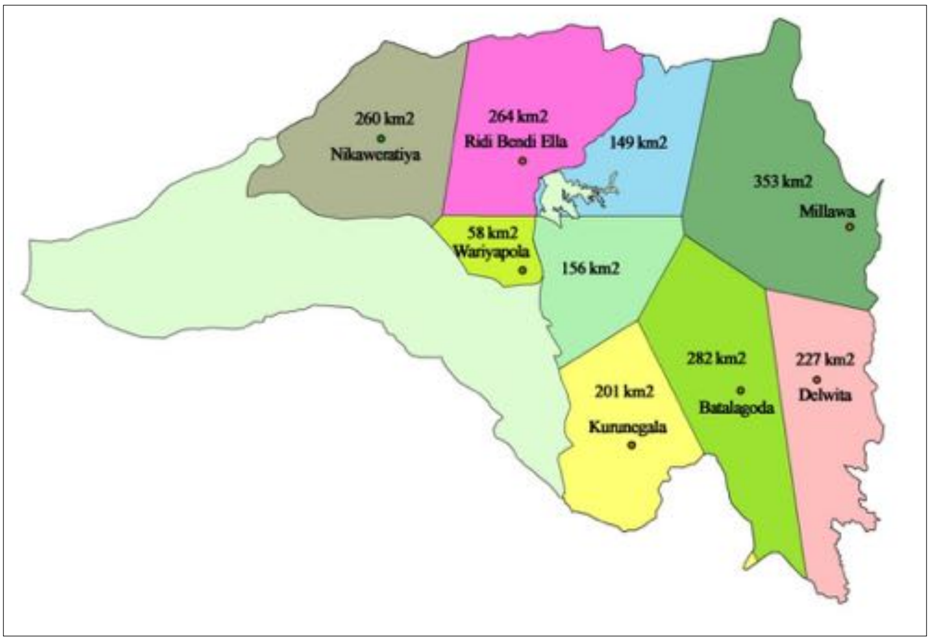

Figure 22: Rain gauge stations and Thiesson polygon areas

4.2.4 Model calibration

Calibration for continuous modeling was carried out by using daily rainfall from Oct 1985 to Dec 1985. Soil moisture accounting loss method, Clark unit hydrograph transformation method, and recession base flow method were utilized for continuous simulations. Muskingum routing method was used to route the flow through the canal.

Table 6 shows the values used for the parameters related to soil moisture accounting loss method for the sub basins. Tables 7 to 9 shows parameters related to Clark method, recession, surface flow routing respectively.

Table 6: Summary of parameters used in soil moisture accounting loss method

Parameter	Value		
	Deduru Upper Basin	Magalla reservoir catchment	Moragaswewa sub-catchment
Canopy (%)	0	0	0
Surface (%)	0	0	0
Soil (%)	70	70	70
Ground water 1 (%)	46	46	46
Ground water 2 (%)	82	82	82
Canopy Storage (mm)	10	10	10

Surface Storage (mm)	0	0	0
Max Infiltration (mm/hr)	7	7	7
Imperviousness	50	45	42
Soil Storage (mm)	123	123	123
Tension Storage (mm)	60	60	60
Soil Percolation (mm/hr)	1.3	1.3	1.3
Ground water 1 Storage (mm)	200	200	200
Ground water 1 Percolation (mm/hr)	1.4	1.4	1.4
Ground water 1 Coefficient (hr)	80	80	80
Ground water 2 Storage	200	200	200

(mm)			
Ground water 2 Percolation (mm/hr)	1.3	1.3	1.3
Ground water 2 Coefficient (hr)	1.5	1.5	1.5

Table 7: Time of concentration and storage coefficient for Clark method

Parameter	Value		
	Deduru Upper Basin	Magalla reservoir catchment	Moragaswewa sub-catchment
Time of Concentration	24	7	35
Storage Coefficient	33	12	40

Table 8: Recession baseflow parameters

Parameter	Value		
	Deduru Upper Basin	Magalla reservoir catchment	Moragaswewa sub-catchment
Initial discharge / m^3/s.	51	8	10
Recession constant	0.77	0.65	0.7
Ratio to peak	0.65	0.5	0.5

Table 9: Muskingum routing parameters

Parameter	Value		
	Deduru Upper Basin	Magalla reservoir catchment	Moragaswewa sub-catchment

Muskingum K/(hr).	10	2	4
Muskingum X	0.2	0.2	0.2
Sub reaches	2	1	2

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For the calibration period, which is from Oct –Dec 1985, simulated daily discharge values were compared with observed daily discharge values. .Fig. 23 shows the graphical distribution of simulated discharge against observed discharge. The values of NOF, R_{NS}^2, δ_b and $RMSE$ are equal to 0.30, 0.96, 4.88% and 22 respectively.

4.2.5 Validation

The time series data from Oct 1984 to 30 Sept 1985 (1 year) and Oct 1987 to Sept 1989 (2 years) were used for validation of continuous simulation. Validation results indicate that there is a good agreement between the observed and simulated flows. Table 10 shows the goodness of fitting between simulated and observed flow for validation periods, and the parameters fall within acceptable ranges. The observed and simulated discharge hydrographs are shown in Figs. 24 and 25 respectively.

Table10. Goodness of fit for stream flow simulation

Event	NOF	R_{NS}^2	δ_b	$RMSE$
Oct 1984 to Sept 1985	1.00	0.76	18%	25
Oct 1987 to Sept 1989	1.00	0.7	17%	34

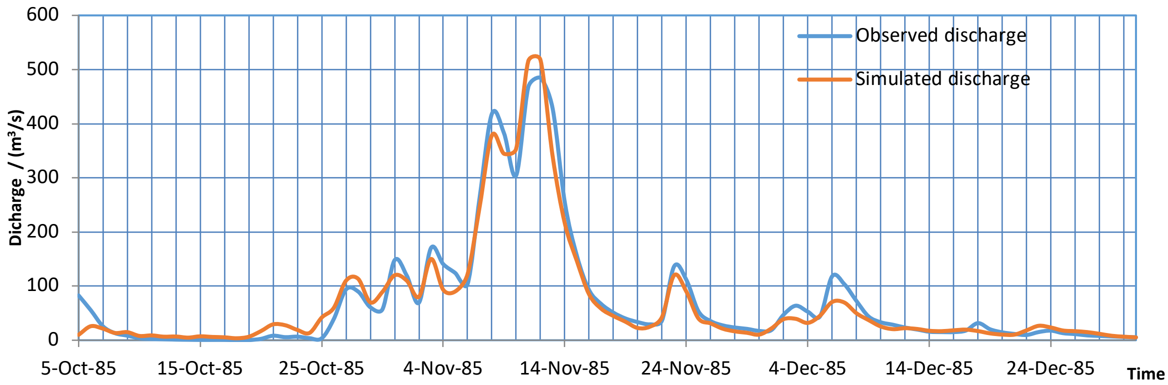

Figure 23: Observed and simulated discharges at Moragaswewa for Oct - Dec 1985

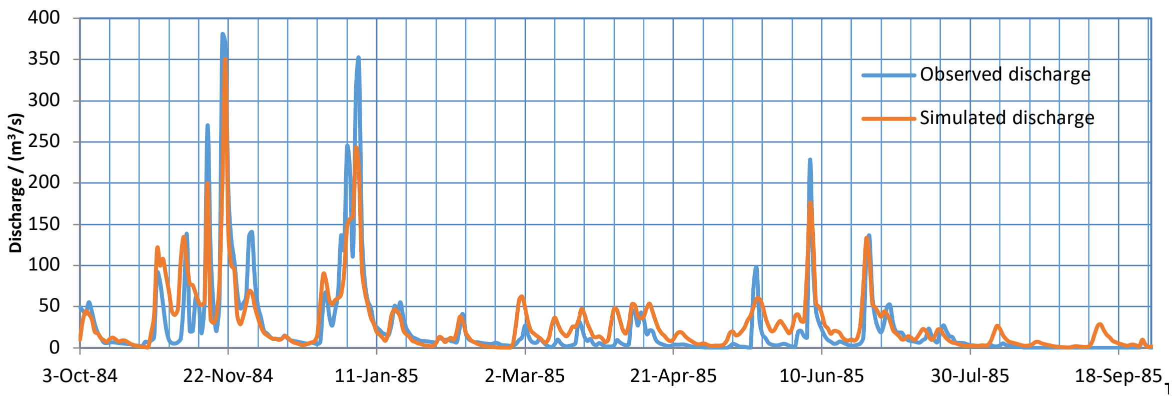

Figure24: Observed and simulated discharges at Moragaswewa for Oct 1984 - Sept 1985

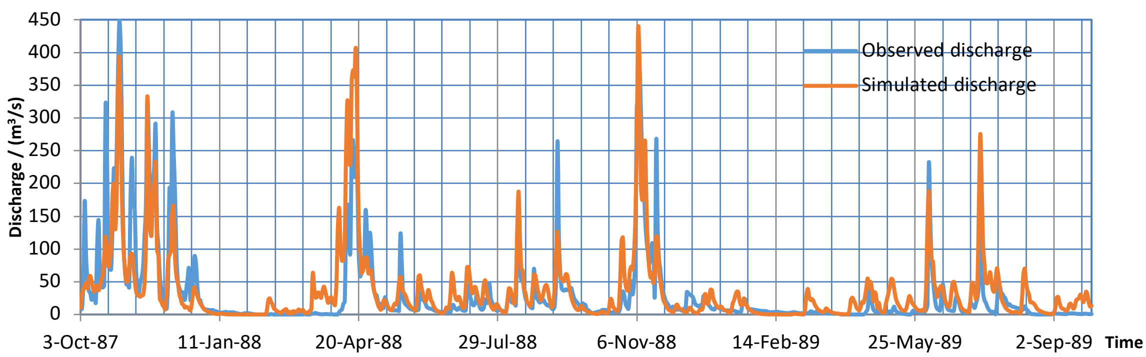

Figure 25: Observed and simulated discharges at Moragaswewa for Oct 1987- Sept 1989

5 Results summary

Based on the hydrological models set up for the ancient tank catchments and Deduru Oya new reservoir basin, it is possible to estimate the total inflows to both modern and ancient irrigation systems. Fig. 26 shows the maximum, average and minimum monthly inflows to new Deduru Oya reservoir estimated from the 2000-2010 raifall records. The inflow values show a large intra-annual variability of inflows as shown by inflow value changes

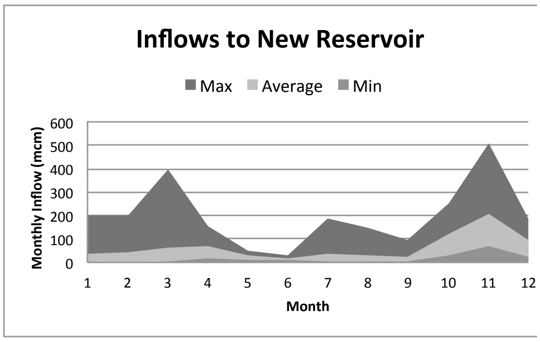

Figure 26 Inflow to Deduru Oya reservoir

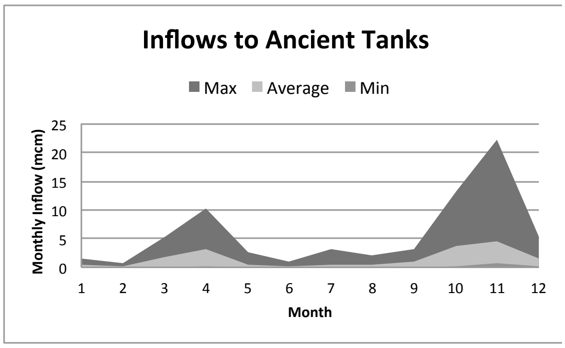

Figure 27 Inflow to ancient irrigation tanks

from January to December. A large inter-annual variation is also observed as shown by the large differences among maximum, average and minimum stream flows for the 2000-2010 period records. A similar trend is also observed in the inflows to ancient tanks as shown in Fig 27.

A comparison of annual inflow shows a very high inter-annual variability as shown in Figure 28 by the contrast among maximum, minimum and average flows. The most striking feature however, is the large difference of inflows to the new reservoir compared

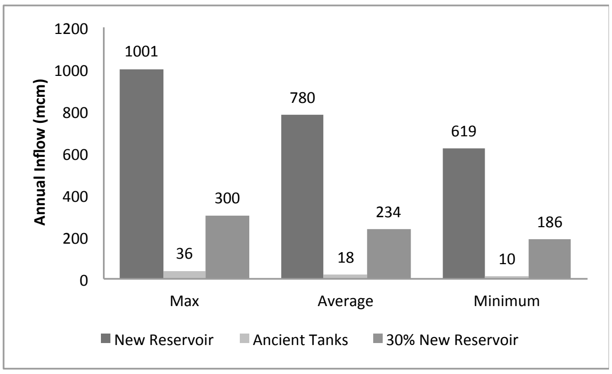

Figure 28 Annual inflow into new reservoir and the ancient irrigation system.

to the ancient irrigation system. Assuming about 30% of inflow to the reservoir may be available for LB canal, the potential contribution from the new reservoir would be more than 10 times that entering ancient irrigation tanks. From these inflow estimates we may expect that new reservoir alone would be supplying most of the irrigation water requirements in an average year and the role of ancient irrigation system could function more for building social harmony and to absorb unexpected shocks associated with climate change to form a resilent system.

6 Summary

Water availability for the Deduru Oya LB canal development region from the traditional tanks and from the Deduruoya reservoir was investigated.

HEC-HMS, rainfall runoff model was set up for modelling event–based and continuous stream flow in to the Tittawella reservoir. Predictions were compared with observations and skill of simulations is satisfactory, as depicted by NOF, R_{NS}^2 and $\delta_{b,}$ for both calibration and validation periods in event based and continuous simulations. Moreover, the results of continuous simulations show that the calibrated model is capable of capturing the seasonal characteristics of stream flow satisfactorily. Run off from LB reservoir sub basins were calculated by using corresponding parameters of Tittawella reservoir model.

HEC-HMS rainfall runoff model was developed for part of Deduru Oya basin with intra-basin diversion and storages. Simulation results agree reasonably well with observed discharges as described by NOF, R_{NS}^2 , δ_b and $RMSE$. The results show that the calibrated model is capable of capturing the seasonal characteristics of Deduru Oya flow satisfactorily. By using long term daily rainfall forecast, the model with the calibrated parameters can be used for estimating inflow to the Deduru Oya reservoir as well flow at the Deduru Oya basin outlet. The study demonstrates potential HEC–HMS application in flow estimation from tropical catchments with intra-basin diversions and irrigation storages. The model developed is a useful tool for water management in the Deduru Oya basin.

The hyrological models are very useful tools that can be used for water resources development and irrigation water management under changing climate in the LB development area of the Deduru Oya Project.

Through the hydrological modeling of the entire LB canal area it was possible to clarify the water resources available for irrigation from both ancient irrigation system and the new Deduru Oya project. The simulation carried out for past ten years reveal that the Deduru Oya reservoir project which has planned to operate LB canal irrigation management incorporating the existing small irrigation reservoirs will be able to supply the water demand for LB development area for paddy cultivation with a high degree of reliability.

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