

DEVELOPMENT OF HYDROLOGICAL MODEL TO EVALUATE SPATIAL VARIABILITY AND TEMPORAL CHANGE OF SURFACE WATER FLOW IN SRI LANKA

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INTRODUCTION

Water needs to be protected and used in a sustainable way as the world is facing rapidly growing demand for better quality water resources due to the increasing population and industrial demand more water while, availability remains constant. Although Sri Lanka is blessed with rich water resources emanating from the central highlands that receive rain during the monsoon, its spatial variability and temporal changes need to be asses for proper water resources management since water availability significantly varies across the river basins and seasons.

Remote sensing and Geographic Information Systems (GIS), in combination with appropriate distributed rainfall runoff models, provide ideal tools for the estimation of the direct runoff volume, peak discharge and hydrographs under spatial variability and temporal changes of rainfall. The present study evaluates the spatial variability and temporal changes of surface runoff on seasonal rainfall over the country using distributed hydrological model.

STUDY AREA AND DATA

Sri Lanka is an island off the southeast coast of India in the Indian Ocean, occupies an area of 65,610 km². Annual average rainfall extremely varies over the country (900mm in South Eastern and North Western and more than 2500mm in western slope of the highland) and it comes by two major monsoons (South Western and North Eastern) while two inter monsoon gets active on transition periods. There are 103 small and medium rivers radial flow starting from the central highland (Fig.1), collecting about 44 billion cubic meters (bcm) of annual surface runoff.

Shuttle Radar Topography Mission (SRTM) Digital Elevation Model and Landsat 7 ETM+ remote sensing data were resample to 1000m and used respectively for elevation and land use data derivation. 17 meteorological stations' (Fig: 1) data from the Global summary of the daily climatic data from NOAA's National Climatic Data Center (NCDC) were used as precipitation and temperature data. Based on the data available, a period from 2009 to 2011 was selected for this study.

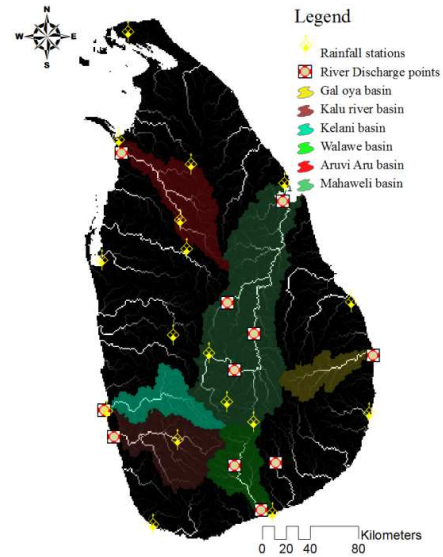


Fig. 1: Selected river basins with rainfall and river discharge stations

METHODOLOGY

A distributed runoff model was developed by Kashiwa et al. (2010) under the structure proposed by Kazama et al. (2004) was modified to estimate the surface runoff in Sri Lanka. In this model considered three reservoirs: Subsurface reservoir, groundwater reservoir, and a third one to account for the snowmelt contribution (not consider in this study). Flow estimation is calculated by a combination of direct flow and base flow models.

Direct flow is calculated with the kinematic wave method and base flow is calculated with the storage function method. River flow is also calculated by the kinematic wave method. Governing equations of the model are as follows:

Kinematic Wave;

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = (R - R_{in} - ET)B \quad (1)$$

$$Q = \frac{1}{n} B h^{5/3} I^{1/2} \quad (2)$$

Table 1: Average seasonal runoff volume and percentage for unit area in selected river basins

River Basins	Average Runoff Volume							
	1st Inter Monsoon (March - April)		South West Monsoon (May - September)		2nd Inter Monsoon (October - November)		North East Monsoon (December - February)	
	Volume (km ³) *10 ⁻⁶	Percentage	Volume (km ³) *10 ⁻⁶	Percentage	Volume (km ³) *10 ⁻⁶	Percentage	Volume (km ³) *10 ⁻⁶	Percentage
Mahaweli	62.75	5.92	117.70	11.11	248.57	23.46	630.54	59.51
Walawe	97.24	10.08	189.44	19.64	200.07	20.74	478.02	49.55
Kalu	329.18	21.20	686.28	44.19	199.02	12.82	338.46	21.79
Kelani	171.03	14.65	420.98	36.06	219.65	18.82	355.71	30.47
Gal Oya	36.75	5.99	25.38	4.14	134.89	22.00	416.05	67.86
Aruvi Aru	105.50	9.35	75.64	6.70	325.32	28.83	621.96	55.12

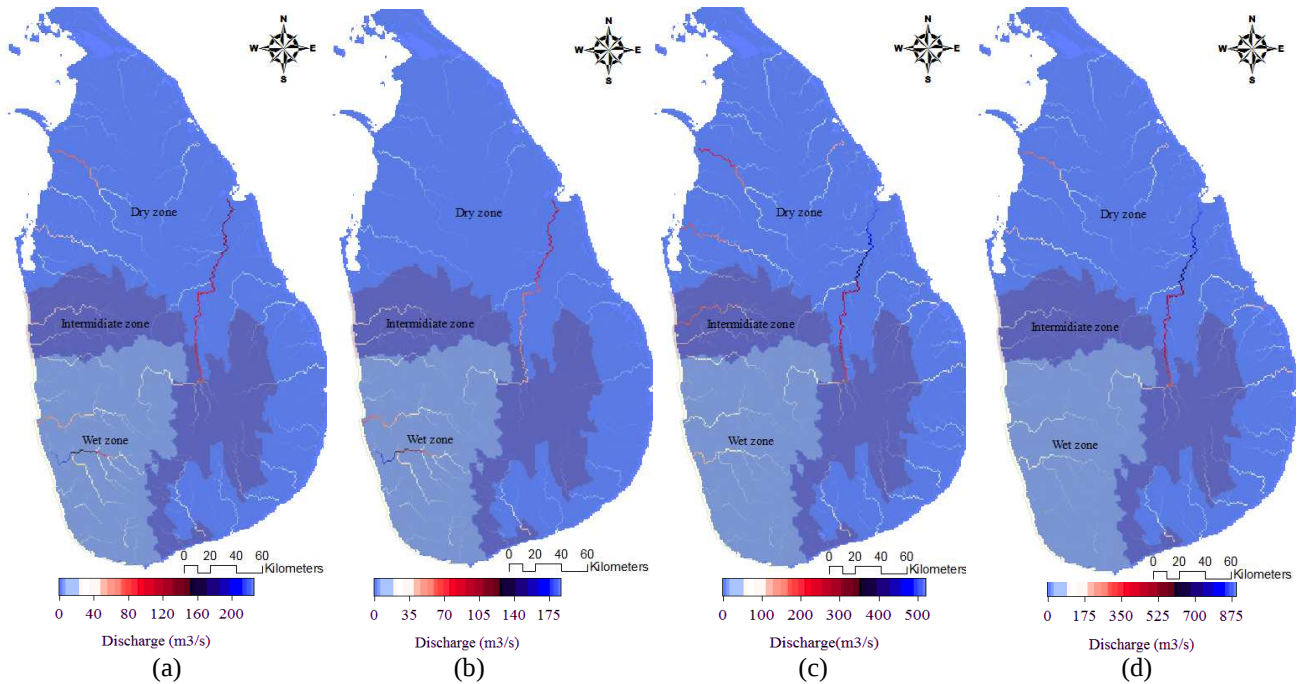


Fig. 2: Spatial variability of surface runoff over different monsoons (a) 1st Inter monsoon (March-April) (b) Southwest monsoon (May-September) (c) 2nd Inter monsoon (October–November) (d) Northeast monsoon (December–February)

Here, A is the cross section of water (m^2), Q is the flow rate (m^3/s), B is a mesh width (m), R is rainfall (m/s), R_{in} is the amount of infiltration (m/s), t time (s), x is the distance between the flow direction (m), h is water depth (m), I is the gradient flow, n is the Manning roughness coefficient. ET is the evapotranspiration (mm/day) and it was calculated by Hargreaves method.

Storage function method;

$$\frac{ds}{dt} = R_{in} - q \quad (3)$$

$$S = kq^p \quad (4)$$

Here, S is the apparent high retention (m), q is a high base flow discharge (m/s) and k , p is the model constant ($k = 120.0$, $p = 0.5$).

RESULTS AND DISCUSSION

The time series map of rainfall, temperature and evapotranspiration were made using 17 meteorological stations' data and used as an input file for runoff model. Surface runoff was simulated under different rainfall seasons for the whole country. River discharge was derived for selected river basin to represent different climatic zones and used to assess quantitative spatial variability and temporal changes of surface water flow. Average runoff volume and percentage generated by unit area ($1km^2$) of every basin for different monsoon was calculated for cross comparison over basins in different climatic zones.

Mahaweli, Walawe, Gal 'Oya' and Aruvi 'Aru' river basins generate more than 50 percent of its annual surface runoff during the Northeast Monsoon while, Kalu and Kelani basins generate their bulk during the Southwest monsoon (Table 1). Spatial variability of surface water flow under different monsoon is shown in FIG. 2 and it shows less spatial variability of water in 2nd inter monsoon (October–November) as whole country gets some rainfall. Highest surface runoff variability can be seen during the

Southwest monsoon (May – September) since most of the river basin in the dry zone gets dry while Southwest part of the country gets their maximum runoff (Kalu and Kelani river basins).

Surface runoff in the Southwest part (Kalu and Kelani basins) of the country show less temporal changes since the area is entirely located in the wet zone (Table 1). River basins located in dry zone are under higher temporal variability of surface water as a shortage of rainfall during the 1st Inter and south western monsoon.

CONCLUSIONS

The monsoon rainfall pattern has a major influence on water availability within the country and highest spatial variability can be seen during the South West monsoon. Highest temporal changes of surface water flow can be seen in river basin located in dry zone but Mahaweli and Walawe river basins are located in wet and dry zone both and facilitate water availability for dry zone during south western monsoon.

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