SUITABILITY OF A SELECTED HYDROLOGICAL MODEL AND OBJECTIVE FUNCTION FOR RURAL WATERSHED MANAGEMENT IN SRI LANKA

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Degree of Master of Science

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in text.

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ABSTRACT

In a period where water resources are becoming scarce due to increased population and human activities, it is very important to have appropriate models and objective functions for water resources management especially in rural contexts. Therefore, the selection of appropriate model and objective function and to ascertain their suitability on a rural watershed is necessary. Preliminary screening of hydrological models was carried out based on the application availabilities and modelling purpose. Five models namely HEC-HMS, SWAT, TOPMODEL, MIKE SHE and SWMM were shortlisted. The shortlisted models were reviewed under several criteria such temporal scale, spatial scale, hydrological processes, documentation, resources requirement, user interface and model acquisition cost. Similarly, objective functions recommended on 'Guide for hydro-meteorological practices' by WMO namely NSE, RMSE, RAEM and MRAE were reviewed. Review of the objective functions was based on criteria such as mathematical implications, flow regimes and modelling purpose. The review of hydrological models and objective function suggested the Storm Water Management Model (SWMM) and Mean Ratio of Absolute Error (MRAE) as an appropriate model and objective function respectively for water resources modelling in rural watersheds. Accordingly, the SWMM was applied to the Ellagawa (1342 km^2) and Ratnapura (653 km^2) watersheds in the Kalu river basin of Sri Lanka using observed rainfall and streamflow from 2006-2014. In the present work, the SWMM model was calibrated and validated while investigating the effect of layout modifications to carry out continuous simulation of streamflow. Initially, two lumped models were developed for Ellagawa and Ratnapura watershed. Then a semi-distributed model with three sub-watersheds was developed for Ellagawa watershed. Model calibration was done for 2006-2010, and verification was carried out for the period 2011-2014. High, medium and low flow in the flow duration curve and the annual water balance were also observed during the calibration and validation. Ellagawa and Ratnapura lumped were calibrated with MRAE 0.3634 and 0.4531 respectively and validated with MRAE 0.5865 and 0.7843 respectively. Annual water balance errors of Ellagawa and Ratnapura lumped model were 38% and 31% respectively during calibration and 10.25% and 11% respectively during validation. Ellagawa and Ratnapura lumped models calibrated intermediate flow with MRAE 0.40 and 0.37 respectively. Manning's roughness coefficient for pervious layer, depression storage for pervious layer, saturated hydraulic conductivity and initial defect, lateral discharge coefficient and deep percolation coefficient were the main parameters to be calibrated. Manning's roughness coefficient of pervious layer (n-pervious) was optimized in the range (0.02-0.028), depression storage of pervious layer (d-store pervious) was optimized in the range of (1.2mm-2.5mm). Similarly, saturated hydraulic conductivity (K_{sat}) was optimized in the range of (0.3mm/hr.-0.67mm/hr.). Furthermore, the initial moisture deficit (Θ) was optimized in the range of (0.2-0.5). Ellagawa semi-distributed model showed some improvement in overall and intermediate flow compared to Ellagawa lumped model. MRAE for overall hydrograph was reduced by 19% and MRAE for intermediate flow was reduced by 24%. However, Ellagawa semi-distributed model showed a poor estimation of annual, seasonal and monthly streamflow compared to Ellagawa lumped model. Hence, the semi-distributed model with single gauging cannot be considered as a better and meaningful modelling option in SWMM with certainty. This study recommends more application of SWMM for continuous modelling of streamflow in monsoon regions and more research on automatic optimization, objective function and groundwater.

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