Fayoum University
Faculty of Engineering
Department of Civil Engineering

# Mean Annual Runoff Modeling within the Budyko Framework for Climate Impact Studies: Case Study in the Eastern Nile River

**By**

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A thesis submitted in partial fulfillment
of
the requirements for the degree of

***Master of Science***
in
***Civil Engineering***

***(Irrigation and Hydraulics Engineering)***
Department of Civil Engineering
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**2018**

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## Abstract

The water balance concept provides a framework that aims to increase our knowledge of the catchment characteristics. This framework is summarized in studying the hydrological cycle of the catchment. Actual evapotranspiration, which is one of the main important components in the water balance framework, can be estimated directly using the weighting lysimeter in a difficult and expensive way. Consequently, the Budyko framework is used to estimate the actual evapotranspiration by investigating the balance process between the energy and the water availability.

In this study, we first investigate eight Budyko framework equations on the Nile tributary catchments of Blue-Nile and Atbara Riversto estimate the annual water balance. None of the eight versions of the Budyko framework produces satisfactory results. Then, the Du et al. (2016), the latest Budyko framework equation, is applied on a finer timescale (monthly timescale). Although the monthly model was found to fit the observed data better than the annual model, the errors between the simulated and observed values show a clear seasonality and at least a one lag autocorrelation. To overcome such deficiencies, we propose a time series SARIMA model, to fit the error term of the best performing Budyko equation. Furthermore, the physical understanding of large basins may suggest that the simulated monthly runoff would depend not only on the concurrent values of precipitation and evapotranspiration, but also on these variables of the previous months as well.

The investigated performance criteria are the Nash-Sutcliffe and Kling-Gupta efficiency indices, root mean square error, bias, mean absolute percent error and the Akaike Information Criterion. The novel hybrid SARIMAX-Budyko model exhibits high performance to simulate both basins. The proposed model outperforms the previously published Budyko equations, in almost all performance

criteria and especially on the annual time scale. The SARIMAX-Budyko framework model is compared with the best Budyko framework equation; and the NSE is increased by 75% and 90% for monthly and annual timescales, respectively. The findings of this research are used in climate change impact assessment for the Eastern Nile Basin tributaries using CORDEX data.