Using a hydrological model calibrated with satellite based evapotranspiration to simulate stream flow in a data sparse tropical catchment

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Abolanle E. Odusanya[1], Bano Mehdi[1], Christoph Schürz[1], and Karsten Schulz[1]

[1]Institute of Water Management, Hydrology and Hydraulic Engineering, University of Natural Resources and Life Sciences, Vienna (BOKU)

Contact info: abolanle.odusanya@boku.ac.at

I. Introduction and Objective

The general lack and scarcity of up to date stream flow information has made water resources management challenging and difficult in the tropical regions, even in catchment areas that are of high strategic importance for state and national water development plans. This is the main limitation for setting up hydrological models for watershed simulations. Recent advancements in remote sensing have enabled the calibration of hydrological models with satellite based products.

The main objective of this study was to use an innovative approach to simulate stream flow for individual subbasins using Soil and Water Assessment Tool (SWAT) that was calibrated and validated at the monthly time step with actual evapotranspiration derived from the Global Land Evaporation Amsterdam Model (GLEAM_v3.0a) and Moderate Resolution Imaging Spectroradiometer Global Evaporation (MOD16) for the Ogun River Basin of 20,292 km^2 .

II. Study Area and Data

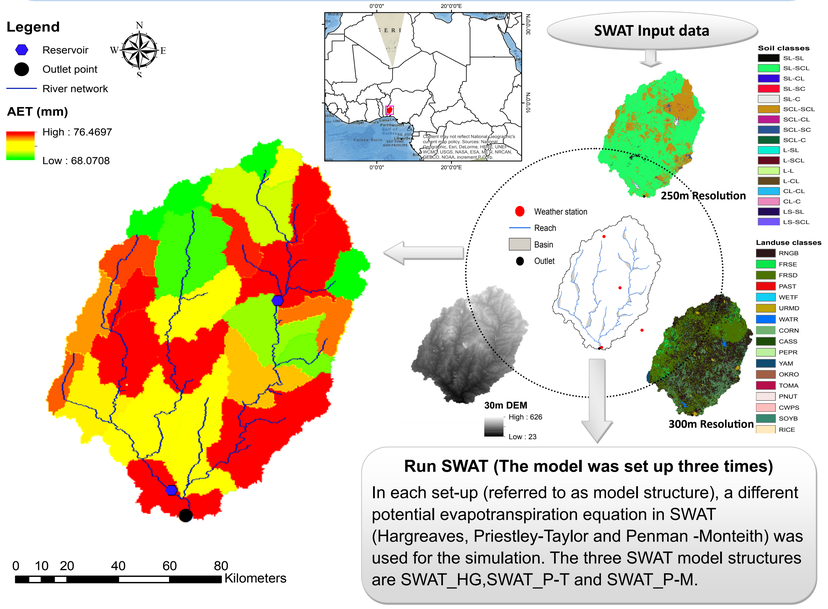

Fig. 1. The Ogun River Basin location in Nigeria, West Africa showing the river network and GLEAM_v3.0a mean monthly (1989 - 2012) actual evapotranspiration (AET) values of each of the SWAT-delineated subbasins.

Run SWAT (The model was set up three times)

In each set-up (referred to as model structure), a different potential evapotranspiration equation in SWAT (Hargreaves, Priestley-Taylor and Penman -Monteith) was used for the simulation. The three SWAT model structures are SWAT_HG,SWAT_P-T and SWAT_P-M.

Fig. 2. The SWAT input: Soil classes, landuse classes, digital elevation model (DEM) and the daily precipitation and minimum and maximum temperature obtained from four weather station.

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III. Methodology

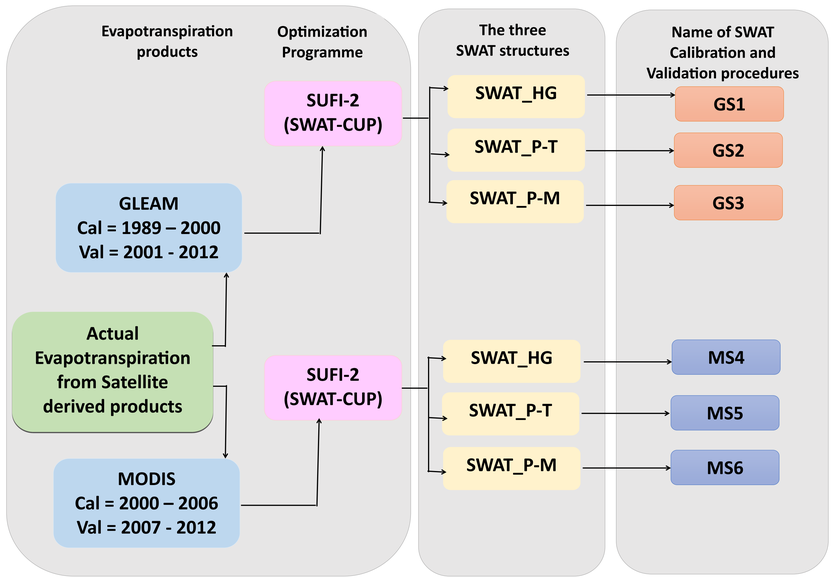

Fig. 3. Schematic diagram showing the three structures of the SWAT model, the two global AET products, and the resulting six calibration and validation procedures for the Ogun River Basin.

IV. Result 1 : Calibration and validation (GS1 to MS6)

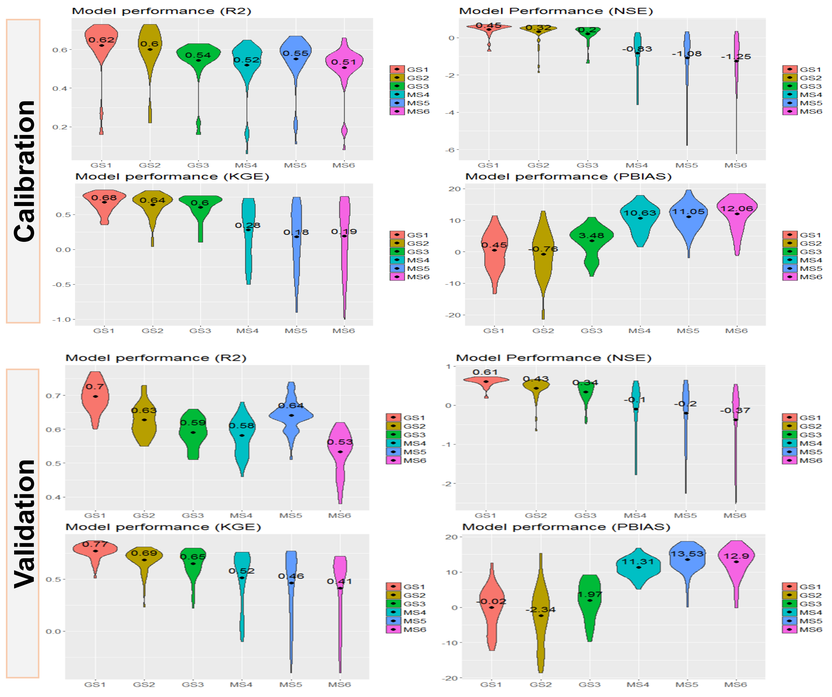

Fig. 4. The plots of the performance result of SWAT in simulating actual evapotranspiration. The values and the black symbol (“ . ”) depicts the average values of the objective function obtained.

V. Result 2: Uncertainty analysis (GS1)

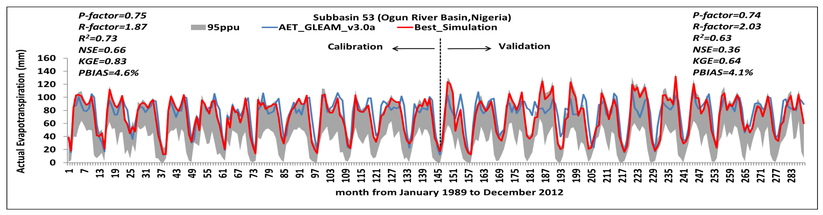

Fig. 5. Extracts of the monthly calibration and validation result (GS1) showing the 95% prediction uncertainty interval along with the SWAT simulated AET and the satellite based AET (GLEAM_V3.0a).

VI. Result 3: Model verification (GS1)

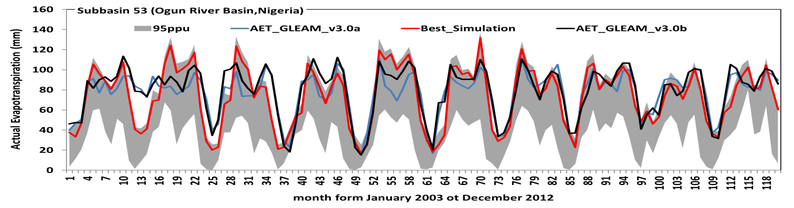

Fig. 6. Extracts of the SWAT model verification results showing the satellite based AET GLEAM_V3.0a used for the model calibration/validation, the SWAT simulated AET, and an independent GLEAM_v3.0b time series bracketed by 95% predictive uncertainty.

VII. Result 4: Stream flow simulation (GS1)

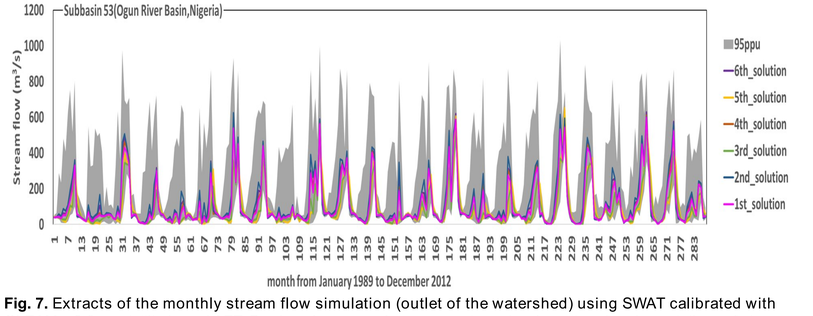

Fig. 7. Extracts of the monthly stream flow simulation (outlet of the watershed) using SWAT calibrated with GLEAM_v3.0a satellite based AET. By choosing non-unique parameter sets, six well-performing solutions of stream flow estimates bracketed by their 95% prediction uncertainty were obtained when Nash-Sutcliffe efficiency (NSE) was selected as the main objective function with a threshold value of 0.59.

VIII. Conclusion

- The use of globally available AET from GLEAM results in an alternative approach to calibrating SWAT. Our results showed a higher model performance (NSE,R^2,KGE and PBIAS) in simulating monthly AET. The resulting stream flow simulations in the Ogun River Basin had a predictive uncertainty within the 95PPU.
- Our analysis shows that the Hargreaves potential evapotranspiration (PET) equation proved to be the most efficient when used in SWAT to estimate AET and led to the highest SWAT performance when compared with the satellite based AET from GLEAM.
- Our findings suggest that the SWAT model using the Hargreaves (PET) equation can be used as a potential decision support tool in tropical regions for further studies and predictions on basin hydrology.

Future work will examine predictions on nutrient loading in the study area