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SEMI DISTRIBUTED HYDRO CLIMATE MODEL; THE Xls2NCascii PROGRAM APPROACH FOR WEATHER GENERATOR

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ABSTRACT

Modelling a hydro climate model can be tedious and time consuming due to many factors. This paper presents a new advanced approach for automatisation of weather generator data processing of soil and water assessment tool (SWAT) model in reducing the hardship of a hydro climate model. This approach is based on integrating multiple climate data programs in MATLAB environment and allowing the modification of Providing Regional Climates for Impacts Studies (PRECIS) output to suit the hydrological model needs. This is achieved by linking NCO, net CDF and CDO with each other and correcting the program by comparing the results using manual approach.This project is undertaken in the West part of Malaysia. The selected research area for this project is the upper part of Langat River Basin. This choice was made considering the importance of the Langat River basin to the Selangor state, one of the most important states in Malaysia. The current state of historical data for model setup, calibration and validation of the model includes future hydro-climate changes using PRECIS A1B data projection that is simulated for this project to see the quality of Xls2Ncascii in preparing soil and water assessment tool for weather generator.The hydrological changes due to climate change are investigated.

Keywords: climate change, hydro climate, PRECIS, SWAT, Xls2Ncascii.

INTRODUCTION

The climate change impacts on hydrological regimes have become a priority area, both for research development as well as for water and watershed management strategies (Xu *et al*., 2005). It is important to understand how a change in global warming could affect the availability and variability of water resources (Jha *et al*., 2006). Using the Providing Regional Climates for Impacts Studies (PRECIS) regional climate modelling system, this study analyses the changes in stream flow trends of West Malaysia in the recent past (1981–2010) and in the projected future (2011–2197) climate under the IPCC SRES A1B emissions scenario. Operations of PRECIS model is based on 360-day calendar with each month having 30 days. However, for most of the hydrological model, the simulations are run based on a 365day normal calendar. This paper uses the Xls2Ncascii program to modify the PRECIS output to suit SWAT model input and simplifies the weather generator input processes. The paper is organized as follows where methodologies for developing architecture of the hydro climate model are presented in section 2, followed by the results and discussion of the model outcome in section 3 and finally the conclusions are presented in section 4.

Developing architecture of hydro- climate model

The Soil and Water Assessment Tool (SWAT) model was established by the US Department of Agriculture Research Service (USDA-ARS). It is a theoretical model that functions on a continuous time step. Model mechanisms include erosion/sedimentation, plant growth, nutrients, pesticides, weather, hydrology, agricultural management, channel routing, and pond/reservoir routing resources (Jha *et al*., 2006), (Gassman *et al*., 2007).

The Langat River basin, located in West Malaysia area is one of the most important river basins in Malaysian as shown in Figure-1. The role of the Langat River basin is to provide raw water supply to approximately 1.3 million people in the area. The area was chosen based on historical data availability and the current state of the river that triggers the need of further research on climate change impact on hydrology (Ali *et al*., 2014a). This paper addresses the application of Soil and Water Assessment Tool (SWAT) model to evaluate its ability to simulate changes on hydrology due to climate change.

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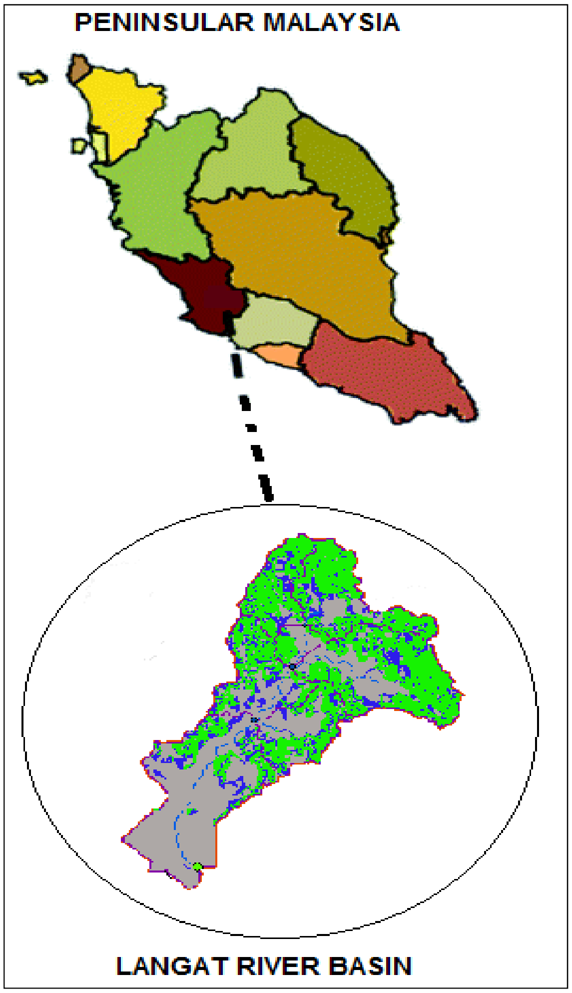

Figure-1. Location of study area.

The model was simulated for 31 years, from 1976 - 2006 for the past-present climate. Model setup was from 1976 to 1979. The 2012 version of SWAT (SWAT2012) was calibrated and verified using hydrological data available from the river basin. Data of meteorological and hydrological such as rainfall, ground water and evaporation were obtained from the Department of Irrigation and Drainage Malaysia (DID) which are the stations scattered in the upper part of the catchment area (Ali *et al*., 2014b). The Department of Agriculture supplied a Soil map for Peninsular Malaysia. Land use map and Digital Elevation Model were attained from the Department of Survey and Mapping Malaysia (JUPEM) (Khalid *et al*, 2015)

Providing Regional Climates for Impacts Studies, also known as PRECIS is a regional climate modeling system developed by the Hadley Centre. PRECIS was chosen for climate-change data to investigate the hydro climate effect in the research area. PRECIS allows the RCM it incorporates, HadRM3P (HadRM3P is a regional model based on UK MET office) so it can be run over any area on the globe. The detail on HadRM3P is discussed by Jones *et al*., 2004.

In order to properly simulate PRECIS output in SWAT, it is important to have the same period of simulation. The easiest approach is conversion of 360 days simulation to 365 simulations by using the Xls2Ncascii program. This program will take into account the months with 30 days and 31 days. Plus, it will also consider the leap year in processing the modified output. A normal year has 365 days, 5 days with no data will be placed as -99 as SWAT input requirement and the missing data will be calculated using the embedded weather generator (WGN) in SWAT. Current approach of preparing the WGN is by manual calculation using Microsoft Excel, station by station, individually. It is a tedious and time consuming process. One of the advantages of this program is that some of the parameters required by SWAT WGN can be calculated all at once no matter how many weather stations are involved. The program was written in MATLAB language, integrating Netcdf operator (NCO), Netcdf (Network Common Data form) and Climate Data Operator in the program. A generalized box diagram of hydro climate model is shown in Figure-2.

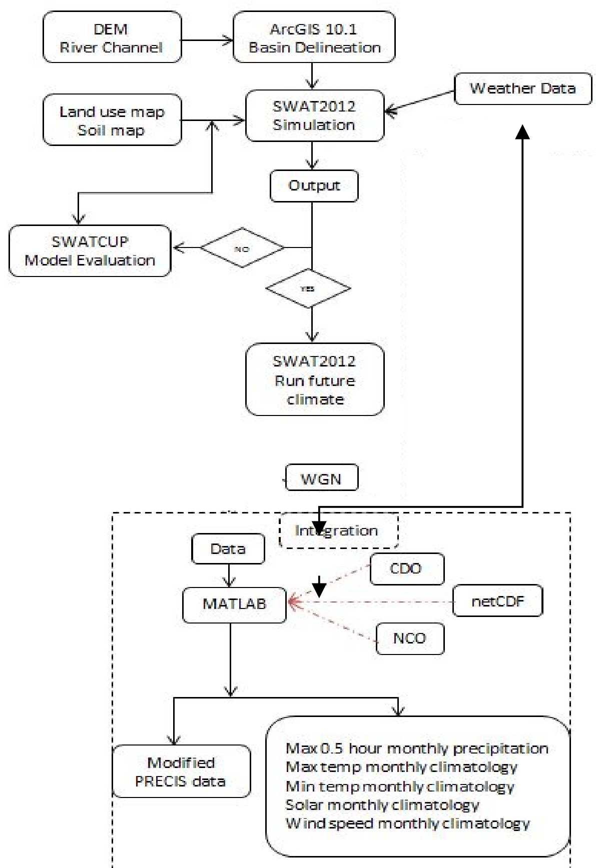

Figure-2. A generalized box diagram of hydro climate model.

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RESULTS AND DISCUSSIONS

The coefficient of determination (R^2) was used to evaluate the performance of theXls2Ncasciiprogram. R^2 value ranges from 0-1 and shows the correlation between the values. If the R^2 is less than or very close to zero, the model performance is considered unacceptable or poor (Rahman *et al*., 2014). In contrast, if the values are equal to one, then the model prediction is considered perfect. The R^2 values for all the parameters calculated using the program as shown in Table-1.

Table-1. Selected parameters for SWAT WGN evaluation.

No.	WGN parameter	Coefficient of determination, R^2
1	Average maximum air temperature for month	1
2	Average minimum air temperature for month	1
3	Maximum 0.5 hour rainfall in entire period of record for month	1
4	Average daily solar radiation in month	1
5	Average wind speed in month	1

Once the wgn was calculated, the SWAT model is simulated for the historical period of 1976 to 2006 for calibration and validation before the model was tested on a climate change scenario. Calibration of SWAT model is important in tuning the odel to reflect the study area condition. Average monthly stream flow was simulated well with (0.65< NSE<0.75[good]) based on the Nash-Sutcliffe efficiency (NSE) value. The simulated values were significantly fit with the obseved values. The model then was run using the future PRECIS A1B conditions and the result of the hydrologic response to climate change is as shown in Figure-3.

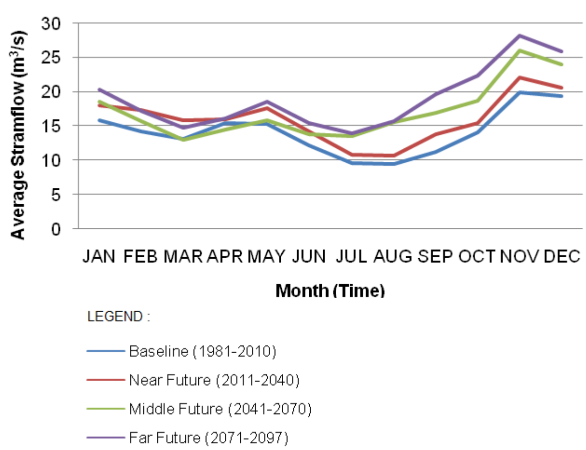

Figure-3. Seasonal hydrologic response for three future PRECIS A1B conditions.

The results show that for the present climate, the model simulates well. In the entire future climate condition, all would experience significant increase in average monthly stream flow. The future climate projected a small increment during the dry season and higher increment in rainy season at the upper part of Langat River basin. The stream flow future trend is projected to increase especially towards the end of the century particularly in the month of September to December. Additionally, no significant decreasing trend is found except a minor decreasing trend in the months of March and April. The percentage of the changes is represented well in Figure-4. One possible reason for the increasing trends is the increase in temperature that results in an increase in the amount of precipitation that fall to earth in the future.

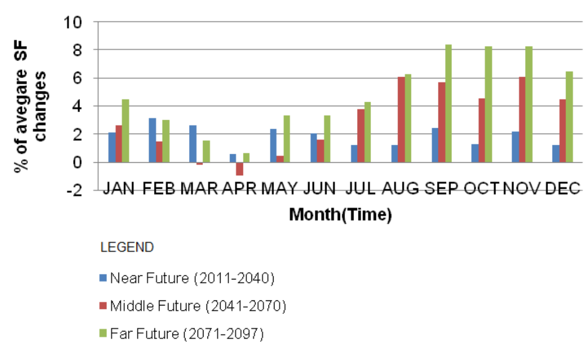

Figure-4. Percentage of streamflow changes for three future PRECIS A1B conditions.

The results show that for near future (2011-2040), the changes in average monthly stream flow throughout the year are small. April shows to be the least affected month with results ranging from 1-3% with. For middle future (2041-2070), the changes show a decrease in monthly average streamflow for March and April, and show significant rises especially during the rainy season (July-Dec). The far future (2071-2097), shows a greater increase with the highest percentages of changes compared to the baseline. By understanding and taking the global warming into consideration, a well-established physical law (the Clausius-Clapeyron relation) defines that the water-holding ability of the atmosphere rises by about 7%

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for every 1°C rise in temperature. Thus, warmer climate will increase water vapour and caused more intense precipitation events that lead to a higher percentage of changes in average monthly stream flows (Trenberth *et al*., 2007). Hence, the warmer climate may increase risk of both drought and flood at different time and places. By understanding the increasing or decreasing trends in streamflow, proper remedial action can be taken when the values approach the thresholds.

CONCLUSIONS

The new approach for automatisation of processing SWAT weather generator using Xls2Ncascii program successfully calculated the input needed with $R^2 = 1$ by integrating NCO, netCDF and CDO in a MATLAB environment. This is a huge help in handling the data preparation for semi distributed hydrological model. The SWAT2012 coupled with PRECIS A1B data has a successful modelled future hydrology response due to climate. However, it is understandable that due to many uncertainties in climate scenario, future flow conditions cannot be projected precisely. Apart from that, for the integration output of hydro climate models, in this case are SWAT and PRECIS, one should understand that these model simulate based on simplified assumptions. Thus, the uncertainties will keep on accumulating toward the final output. This research projects future hydrology conditions based on changes on climate only; assuming there will be no modification on land use scenario, soil management and other climate variables that may contribute some impact on water availability. Based on the projection results, this research demonstrates the rigor need to simulate the model for various climate input sources to see the spread of hydrological changes within the watershed in the future.

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