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Drought Forecasting using SPI and EDI under RCP-8.5 Climate Change Scenarios for Langat River Basin, Malaysia

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Abstract

In Malaysia, droughts often lead to water deficit and overcoming a lack of fresh water has become one of the important challenges in the country. Climate change have brought about a big environmental impact globally, such as the rise in sea levels, unavailability of fresh portal water and more extreme drought and flood events occurring and Malaysia is no different and not spared all this calamities. The Langat River Basin is located in a fast growing region in Peninsular Malaysia, the Greater Kuala Lumpur Valley and hence the implementation of the drought index in this basin is vital important and necessary. Normally drought characteristics can be determined or identified using the drought indices. The two drought indices were used in this study, namely the SPI (Standardized Precipitation Index) and the EDI (Effective Drought Index) to assess the severity, duration and extend of drought event. The CanESM2 outputs under Representative Concentration Pathway (RCP) 8.5 emission scenario of IPCC Fifth Assessment Report (AR5) were utilized to produce regionalized precipitation and temperature data. The GCM outputs were statistically downscaled using the Statistical Downscaling Model (SDSM) version 4.2.9. Next, the SPI for time scale period of 1-month, 6-months and 12-months (SPI-1, SPI-6 and SPI-12) and EDI were calculated for both the observed and statistically downscaled climate data to investigate and analyze the severity and extent of drought. Both indices were compared to get a more operational index between SPI-1, SPI-6, SPI-12 and EDI outlook for representing Malaysia drought events.

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1. Introduction

Droughts have become a frequent occurrence in many parts of the earth surface and are a calamity of big magnitude that needs global intervention. The reasons of drought occurrence are a deficiency of rainfall and prolonged periods of warmer temperatures. Recurring and permanent droughts will inevitably lead to desertification of sizeable areas of our planet. Since there is no single definition for droughts, a wide range of drought identification and assessment indexes had been introduced to monitor drought: the Standardized Precipitation Index (SPI) [1], Standardized Precipitation Evapotranspiration Index (SPEI) [2] and Effective Drought Index (EDI) are the commonly used for gauging droughts. This study focuses on the Langat River Basin, a fast growing urbanized region in Malaysia. In this study, the SPI and EDI will be analysed and used to identify the severity of potential future drought events. The main objective of this study is as follows: (i) to develop a future rainfall scenario for the 21st century, (ii) to investigate and analyse the severity and extent of drought events, and (iii) to develop a framework for operational drought indices outlook for the Langat River Basin.

2. Methodology

Rainfall observations from a specific station were used to establish SPI and EDI time series baseline and identify drought during 1976 to 2011. This observed rainfall is further used along with other large scale data such as NCEP and GCM data to downscale future rainfall event. Future rainfall generated based on the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) scenario are then examined for future drought events using the SPI and EDI. The methods and data used here are described below.

2.1. Location of study and precipitation

The Langat River Basin in the state of Selangor, Malaysia has a total catchment area of about 1815 km^2, formed by 15 sub-basins which lie within latitudes 2˚40’15” N to 3˚16’15” N and longitudes 101˚19’20” E to 102˚1’10” E. This basin is a fast growing region in this country in terms of rapid urbanization, new build-up areas, modern road network, industrialization and agricultural expansion. Unavoidably, the basin is subject to dire consequences of land use and land cover changes, pollution stress, forest fragmentation, depletion of ecosystem. These posed numerous challenges to sustainable development. Under such circumstances, the implementation of a best suited drought index on future climate outlook was deemed necessary. The rainfall data from station 3818110 at Sekolah Kebangsaan Kampung Sungai Lui (3°10'25"N, 101°52'20"E, 91.0m above sea level), was use to represent Langat River Basin. One of the reasons of this selection was due to its close proximity to the Langat reservoir. The 36 years (1976-2011) data available had been subjected to homogeneity tests before perusal.

2.2. General Circulation Model and downscaled data

The Canadian Earth System Model, CanESM2 Model from Canadian Centre for Climate Modeling and Analysis (CCCma) was chosen as a sole GCM output used for generating future rainfall in Langat River Basin. This model employed T63 triangular truncation with spatial resolution of 128x64 and 35 vertical layers [3]. In this study, Representative Concentration Pathway - 8.5 W/ m2 (RCP 8.5) scenario was employed rather than the ‘peak-and-decline’ scenario (RCP 2.6) or ‘stabilization’ scenario (RCP 4.5 and RCP 6.0). This decision was made because of the assumption that the GHG emissions will continue to rise according to current trends. Our goal was to project future drought based on the continuity of the present level of CO2 emissions which more likely to happen as no significant strategies of GHG reduction has come into play yet. Besides the GCM data, the NCEP/NCAR Reanalysis data was another set of large scale data used in the downscaling model to establish the statistical relationship with observed station data. This Global Reanalysis Model has a resolution of about 210 km horizontally and 28 levels vertically [4].