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Simulating future climate projection under HadCM3 GCM scenarios on a tropical karst island using SDSM: A case study of tropical karst catchment in Rote Island, Indonesia

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Abstract. A robust assessment on the impact of climate change at regional atmospheric condition is crucial to ensure the sustainability of groundwater resource for tropical karst island, where water is considered relatively scarce and thus important for the community. In this study, future long-term climate projection under HadCM3 global model climate (GCM) scenarios for a period of 2020-2090 is validated and simulated, using input data of weather variables downscaled by Statistical Downscaling Model (SDSM). The simulation indicated that the climate variables, i.e. temperature and rainfall, are expected to be affected by climate change and generally vary over the period under the scenarios. The rainfall is estimated to slightly raise by 0.14% and 0.09% under H3A2a and H3B2a scenarios, respectively. Steady temperature increases by 1.89-2.16% (Tmax) and 1.05-1.59 % (Tavg) and a decrease of 0.73-0.76% were predictable for all scenarios.

1. Introduction

Rote Island, geologically characterized by karst landforms of carbonate formations, is under high stress of increased population and land use modification as a result of power devolve policy in Indonesia [1-4], resulting in corresponding rapid land use change for settlement in the expense of about 4% of the total area of bush, grass, forest and plantation in the recharge area of the Oemau spring [5-6]. Data of over 31 years (1982-2015) recorded in Lekunik station indicates an increasing trend of temperature (0.06%) and rainfall (0.15%). Change on climatic condition can potentially modify the hydrological system related to recharge regime of the Oemau spring, which may result in a change of the amount of spring discharge in the future. Therefore, examining the current situation and taking into account the aforementioned remarks, the aim of this study was to generate a dataset of climate variables (rainfall and temperature) using the downscaling technique (SDSM) of the projected period of 2010-2020 as an input data for simulating groundwater model for the projected period of 2020-2090.

2. Materials and methodology

2.1. Study area

The study area is the recharge area of Oemau spring (RAOS), located between latitudes 10º46’42.17” - 10º43’36.91”S and longitudes 123º3’14.84” - 123º9’17.64”E. With a recharge area of 20.11 km^2, the topography is typified by highly rippled terrain with surface elevation ranges from around 98 to 340 m above sea level [7-9]. Governed by a monsoonal climate with two distinct seasons namely dry (May-November) and wet (December-April), the area experiences mean annual precipitation of 1000-2300 mm and humidity of 75-92% [10-12].

2.2. Downscaling input data and method

Data series of four meteorological elements, i.e: daily precipitation; minimum, average and maximum air temperatures, referred to as weather model variables (WMVs), were obtained from Lekunik Station. The first 10 years (1982-1991) data series were used as predictands to calibrate the SDSM model and the subsequent 10 years (1992-2001) to validate the model. Figure 1 shows the hydro-meteorological data used as predictands in SDSM for period 1982-2015. The atmospheric variables (predictors) input were extracted from the Canadian Climate Change Scenarios Network (CCCSN). Reanalysis of large-scale dataset from the National Center for Environmental Prediction (NCEP) was derived for the calibration and validation steps of the SDSM model. For climate scenario periods, the modelled predictor input was obtained from the HadCM3 (Hadley Centre Coupled Model, ver.3). To simulate future climate projection for period 2020-2090, two scenarios, i.e. H3A2a and H3AB2a [13] were selected. The SDSM ver.4.2 [14] was employed to assess the suitability of the downscaled dataset for climate scenario purpose. In the calibration and validation steps, a comparison between the mean of the ensemble simulations and observed values of the WMVs for the equivalent period was then performed. Having obtained a statistically acceptable calibrated and validated result, the downscaled dataset of the WMVs was modelled in the scenario generator using the HadCM3 GCM predictor variables for the H3A2a and H3B2a climate scenarios.

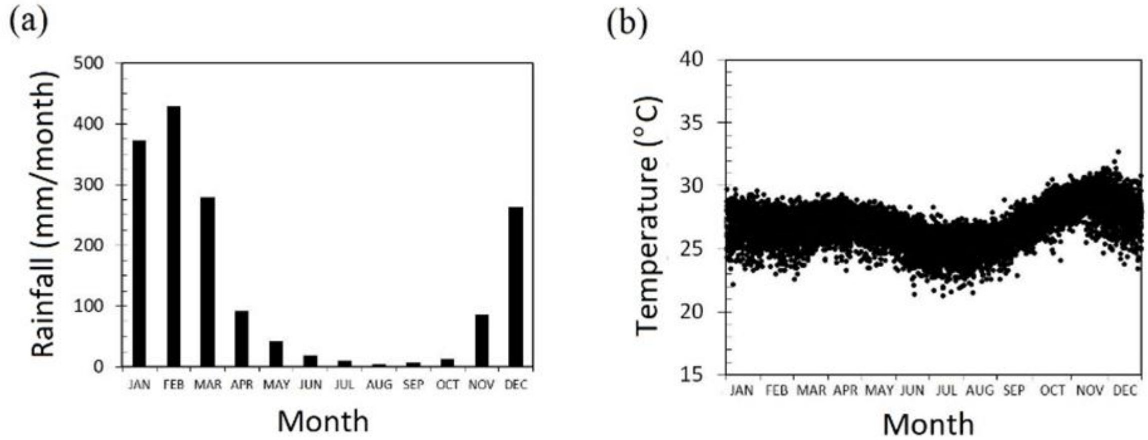

Figure 1. Climate data series (1982-2015), showing (a) monthly average rainfall; and (b) daily average temperature.

3. Results and discussion

3.1. Predictors selection, SDSM calibration, and validation

In general, the models both in calibration and validation simulation were considered statistically satisfactory with R^2 ranges from 0.57-0.91. The simulated values of the WMVs reasonably well replicated the observed values indicated with NSE varying between 0.55 and 0.84. The value range falls to satisfactory-very good categories (0.50 < NSE < 1.00), which indicates a good simulation achievement. Overall, SDSM produced a reasonably well-calibrated and validated statistical model, with the simulations closely follow the cycle of observed rainfall.

3.2. Projection of future climate scenarios
In the wet season, rainfall is projected to rise by 45.53 mm per month for H3A2a scenario and 37.59 mm per month for H3B2a scenario. Rainfall in the dry season is also predicted to increase by 9.67 mm per month and 1.19 mm per month for under H3A2a and H3B2a scenarios, respectively. The annual rainfall declines in the period of 2020-2059 and 2080-2090, while an increasing trend occurs in the period 2060-2079. In all scenarios, T max and T avg were modelled to gradually increase in all time periods. An increase of 2.16% (1.90 ºC or 0.027 ºC annually) and 1.89% (1.35 ºC or 0.019 ºC annually) of T max for H3A2a and H3B2a scenarios, respectively, is expected to occur for the period from 2020-2090. Tavg is forecasted to increase 1.05% (1.08 ºC or 0.015 ºC annually) for H3A2a scenario, and 1.59% (0.81 ºC or 0.011 ºC annually) for H3B2a scenario. In contrast, T min is foreseeable to decrease 0.73% (0.20 ºC or 0.003 ºC annually) and 0.76% (0.14 ºC or 0.002 ºC annually) for H3A2a and H3B2a scenarios, respectively.

4. Conclusions
The downscaled results of HadCM3 implied that the rainfall and air temperatures would likely to be affected by climate change. The rainfall is projected to slightly increase by 0.14% and 0.09% under H3A2a and H3B2a scenario, respectively. A gradual increase of 1.89-2.16% (T max) and 1.05-1.59% (T avg), and a decrease of 0.73-0.76% were projected for all scenarios. The generated meteorological time series can be used as input into the groundwater simulations to establish predicted discharge for period 2020-2090.

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