ESTIMATION OF THE LONG TERM DRYNESS PATTERN FOR PAHANG STATE USING INTEGRATED SDSM-SPI MODEL

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Kemarau atau musim kering yang panjang adalah satu isu global yang memberi kesan kepada seluruh dunia. Beberapa peristiwa bencana telah dilaporkan oleh Jabatan Meteorologi Malaysia (MET) sejak tahun 1900. Malaysia telah berhadapan sekurang-kurangnya 12 kali kemarau ekstrim pada tahun 1951 hingga 1998 terutama ketika perubahan musim barat daya. Walaupun pembentukan bencana ini dipengaruhi oleh perubahan musim, tetapi kekerapan berlakunya bencana ini adalah disebabkan kesan ketidaktentuan perubahan iklim global dan pembebasan gas rumah hijau (GHGs) secara drastik. Dalam kajian ini, model bersepadu iaitu gabungan Model Penurunan Skala Statistik bersama Indeks Penyeragaman Curahan (SDSM-SPI) telah digunakan untuk menganggar kebarangkalian berlakunya musim kering ekstrim di Negeri Pahang. SDSM ialah model iklim statistik yang digunakan untuk memahami perubahan iklim semasa dan jangka panjang sebagai tindak balas terhadap penyebaran jangka panjang pelepasan gas rumah hijau dan aerosol ke dalam sistem atmosfera. Pemilihan pemboleh ubah atmosfera yang bersesuai sangat penting dalam mendapatkan ramalan keadaan iklim jangka panjang yang baik. Pola unjuran hujan dan suhu pada selangan tahun Δ2020, Δ2050, dan Δ2080 digunakan sebagai input data penting untuk menganggar pola ramalan pada kawasan kajian. Oleh itu, pengenalpastian kejadian kekeringan yang berpotensi dalam jangka panjang menjadi penting untuk memantau kekerapan kejadian dan kesannya terhadap kecekapan sumber air. Berdasarkan AR5, semua RCPs bersetuju bahawa hujan tahunan diramalkan menurun sehingga akhir abad. RCP4.5 meramal penurunan yang lebih besar (-3.1%) daripada sejarah hujan tahunan berbanding RCP2.6 (-2.7%) dan RCP8.5 (-2.9%). Taburan hujan lebat diramal berlaku di kebanyakan kawasan di daerah Kuantan, Pekan dan bahagian selatan Bentong. Disebabkan corak hujan tidak seragam, hampir 42% kawasan Pahang diramal menerima taburan hujan yang rendah. Sementara itu, suhu diramal sedikit peningkatan pada bulan April hingga Jun mencapai lebih dari 33°C disebabkan pengaruh pertukaran musim. Suhu tertinggi dan terendah dianggarkan mencecah pada bulan Mei (34°C) dan pada Januari (22°C). Walaupun perubahan tidak terlalu tinggi, namun ianya menyumbang kepada masalah kekurangan air apabila berlaku dengan lebih kerap dalam tempoh yang lebih panjang. Keputusan SDSM-SPI menunjukkan peratusan kebarangkalian corak tahap normal adalah sekitar 84 - 85%. Walau bagaimanapun, sekitar 2 - 3% kebarangkalian corak tahap ekstrem dikesan pada kawasan kajian. Beberapa kawasan seperti Janda Baik dan Kg. Manchis terdedah kepada musim kering pada tahun-tahun tertentu yang memberikan bacaan SPI serendah -2. Proses penentukuran dan pengesahan dilakukan bagi memastikan kesesuaian hubungan prediktor dan peramal sepadan dengan data asal. Keputusan penentukuran menunjukan kesesuaian yang tinggi bagi stesen suhu dan hujan berdasarkan RMSE yang rendah diantara 0.01 - 0.04°C dan 5.0 - 15.0mm, masing-masing. Walau bagaimanapun, ralat sedikit meningkat di bahagian pengesahan untuk suhu dan hujan dengan julat 0.3 - 0.4°C dan 25.0 - 72.0mm, masing-masing. Oleh itu, ia mampu menjadikan maklumat ini penting kepada agensi yang bertanggungjawab dalam merancang dan mengawalselia sumber air jangka panjang.

ABSTRACT

Drought or long dry season is a global issue that adversely gives huge impact on the world. Plenty of calamities have been reported by Malaysian Meteorological Department (MET) since 1900s. Malaysia faced at least 12 times of extreme drought from 1951 to 1998, especially during southwest season changes. Although the formation of this calamity was influenced by the season changes, however frequent occurrence of this event majorly affected by the uncertainty of global climate changes and drastic emission of greenhouse gases (GHGs). In this study, the integrated model of Statistical Downscaling Model and Standardised Precipitation Index (SDSM-SPI) was applied to estimate the probability of extreme dry events in Pahang. SDSM is a statistical climate model that been used to understand the change on present or long-term future climate condition in response to the long-term dispersion of greenhouse gases and aerosols emission into the atmospheric system. The chosen of the best suitable atmospheric variables is vital in obtaining a good long-term future climate condition prediction. The projected rainfall and temperature pattern for the interval year of Δ2020, Δ2050, and Δ2080 were used as important data input to estimate the event pattern in the study region. Therefore, the identification of potential dryness event in the long-term become significant to monitor how frequent the event and how huge the impact on water resources efficiency. By AR5, all RCPs agreed the annual rainfall was predicted to decrease until end of century. RCP4.5 produced a larger decrement (−3.1 %) from the historical record compared to RCP2.6 (−2.7 %), and RCP8.5 (−2.9 %). The heaviest rainfall was predicted to occur at most regions in Kuantan, Pekan, and southern of Bentong. Due to non-uniform rainfall pattern, almost 42 % of Pahang was predicted to receive lower rainfall intensity. Meanwhile, the temperature was predicted to have small increment in April to June, reaches over 33°C which might be influenced by the season interchanges. The highest and lowest temperature was estimated to be in May (34°C) and January (22°C), respectively. Even the changes were not too high, however it will still contribute to the water scarcity problem when it frequently happens in a longer period. The SDSM-SPI result shows the probability percentage of a normal level pattern is about 84 – 85 %. However, about 2 – 3 % of probability extreme pattern were detected at this state. Several areas such as Janda Baik and Kg Manchis are exposed to the dryness in the certain year with the SPI value detected to drop to −2. The calibration and validation processes were conducted to identify the fundamental rules and the predictand-predictors relationships are suited to original data. The calibration results obtained a good agreement for temperature and rainfall stations with low RMSE ranges 0.01 - 0.04°C and 5.0 - 15.0mm, respectively. However, the error slightly increased in the validation part for temperature and rainfall intensity with ranges 0.3 - 0.4°C and 25.0 - 72.0mm, respectively. Thus, it is reliable to be significant information to the respective agencies for the long term planning and management of water resources.

TABLE OF CONTENT

REFERENCES

Amrit, K., Pandey, R. P., & Mishra, S. K. (2018). Characteristics of meteorological droughts in northwestern India. *Natural Hazards, 94*(2), 561-582.

Angelidis, P., Maris, F., Kotsovinos, N., & Hrissanthou, V. (2012). Computation of drought index SPI with alternative distribution functions. *Water resources management, 26*(9), 2453-2473.

Bates, B., Kundzewicz, Z. W., Wu, S., & Palutikof, J. (2008). Climate Change and Water. *IPCC Technical Paper of the Intergovernmental Panel on Climate Change, IPCC (VI),* 208.

Bernama. (2014, 28 February 2014). Beberapa kawasan hutan di Pulau Pinang terbakar. *Borneo Post Online*. Retrieved from https://www.theborneopost.com/2014/02/28/beberapa-kawasan-hutan-di-pulau-pinang-terbakar/

Birt, A. G., Valdez-Vivas, M., Feldman, R., Lafon, C. W., Cairns, D., Coulson, R. N., . . . Guldin, J. M. (2010). A simple stochastic weather generator for ecological modeling. *Environmental Modelling & Software, 25*(10), 1252-1255.

Blackshear, B., Crocker, T., Drucker, E., Filoon, J., Knelman, J., & Skiles, M. (2011). *Hydropower vulnerability and climate change.* Paper presented at the A Framework for Modeling the Future of Global Hydroelectric Resources, Middlebury College Environmental Studies Senior Seminar, Fall.

Bordi, I., & Sutera, A. (2007). Drought monitoring and forecasting at large scale. [Springer]. *Methods and Tools for Drought Analysis and Management, 62*, 3-27.

Chen, Y., Morton, D. C., Andela, N., Van Der Werf, G. R., Giglio, L., & Randerson, J. T. (2017). A pan-tropical cascade of fire driven by El Niño/Southern Oscillation. *Nature Climate Change, 7*(12), 906-911.

Daksiya, V., Mandapaka, P., & Lo, E. Y. (2017). A comparative frequency analysis of maximum daily rainfall for a SE Asian region under current and future climate conditions. *Advances in Meteorology, 2017*.

Deser, C., Phillips, A., Bourdette, V., & Teng, H. (2012). Uncertainty in climate change projections: the role of internal variability. *Climate dynamics, 38*(3-4), 527-546.

DOE, U. (2015). An assessment of energy technologies and research opportunities. *Quadrennial Technology Review. United States Department of Energy*.

Dorado. (2015). Kuantan, Malaysia Annual Yearly Climate Averages: Mean Temperatures, Precipitation and Sunshine Hours. Retrieved from http://www.eldoradocountyweather.com/climate/malaysia/Kuantan.html

EC. (2014). Energy Commission: Peninsular Malaysia Electricity Supply Industry Outlook 2014.

ECN. (2017). Environmental Change Network: Factors Affecting Climate.

EPA. (2017). Environmental Protection Agency: Wetland Functions.

Eum, H. I., Dibike, Y., Prowse, T., & Bonsal, B. (2014). Inter-comparison of high-resolution gridded climate data sets and their implication on hydrological model simulation over the Athabasca Watershed, Canada. *Hydrological Processes, 28*(14), 4250-4271.

Fayaed, S. S., El-Shafie, A., & Jaafar, O. (2013). Reservoir-system simulation and optimization techniques. *Stochastic environmental research and risk assessment, 27*(7), 1751-1772.

FORESTS. (2017). Environmental Impacts of Logging. *Forests Monitor Online*. Retrieved from http://www.forestsmonitor.org/en/reports/550066/550083

Gaál, L., Szolgay, J., Kohnová, S., Parajka, J., Merz, R., Viglione, A., & Blöschl, G. (2012). Flood timescales: Understanding the interplay of climate and catchment processes through comparative hydrology. *Water Resources Research, 48*(4).

Goosse, H., Barriat, P. Y., Lefebvre, W., Loutre, M. F., & Zunz, V. (2013). *Introduction to climate dynamics and climate modeling* Retrieved from http://www.climate.be/textbook

Gregoire, L. J., Valdes, P. J., Payne, A. J., & Kahana, R. (2011). Optimal tuning of a GCM using modern and glacial constraints. *Climate dynamics, 37*(3-4), 705-719.

Guttman, N. B. (1999). Accepting the standardized precipitation index: a calculation algorithm 1. *JAWRA Journal of the American Water Resources Association, 35*(2), 311-322.

Habert, G. (2014). Assessing the environmental impact of conventional and 'green'cement production *Eco-efficient Construction and Building Materials* (pp. 199-238): Elsevier.

Haslinger, K., Koffler, D., Schöner, W., & Laaha, G. (2014). Exploring the link between meteorological drought and streamflow: Effects of climate-catchment interaction. *Water Resources Research, 50*(3), 2468-2487.

Huang, B., Yan, D., Wang, H., Cheng, B., & Cui, X. (2013). Impacts of drought on the quality of surface water of the basin. *Hydrology and Earth System Sciences Discussions, 10*(11), 14463-14493.

Isha, M. T., & Wang, Z. (2008). *Transformer hotspot temperature calculation using IEEE loading guide.* Paper presented at the 2008 International Conference on Condition Monitoring and Diagnosis.

Jablonowski, C., & Williamson, D. L. (2011). The pros and cons of diffusion, filters and fixers in atmospheric general circulation models *Numerical techniques for global atmospheric models* (pp. 381-493): Springer.

Khadka, D., Babel, M. S., Shrestha, S., & Tripathi, N. K. (2014). Climate change impact on glacier and snow melt and runoff in Tamakoshi basin in the Hindu Kush Himalayan (HKH) region. *Journal of Hydrology, 511*, 49-60.

Khan, M. S., Coulibaly, P., & Dibike, Y. (2006). Uncertainty analysis of statistical downscaling methods. *Journal of Hydrology, 319*(1-4), 357-382.

Kwon, H. J., & Kim, S. J. (2006). Evaluation of semi-distributed hydrological drought using SWSI (Surface Water Supply Index). *Journal of the Korean society of Agricultural Engineers, 48*(2), 37-43.

Liu, L., Hong, Y., Looper, J., Riley, R., Yong, B., Zhang, Z., . . . Shafer, M. (2013). Climatological drought analyses and projection using SPI and PDSI: case study of the Arkansas Red River Basin. *Journal of Hydrologic Engineering, 18*(7), 809-816.

Mahmud, M. (2018). Peristiwa El Nino dan Pengaruh IOD Terhadap Hujan di Malaysia (El Nino Events and the Influence of IOD on Rainfall in Malaysia). *e-Bangi, 15*(2).

Matthews, K. (2015). New report finds human-caused climate change increased the severity of many extreme events in 2014 [Press release]. Retrieved from https://www.noaa.gov/media-release/new-report-finds-human-caused-climate-change-increased-severity-of-many-extreme-events

MET. (2015). Seasonal Forecast. *Long Range Weather Outlook.* Retrieved from http://www.met.gov.my/web/metmalaysia/climate/seasonalforecast

MET. (2016). *Laporan Tahunan 2016 Annual Report Jabatan Meteorologi Malaysia*. Retrieved from

MET. (2017). Weather Phenomena. *El Nino & La Nina.* Retrieved from http://www.met.gov.my/web/metmalaysia/education/weather/weatherphenomena/elninolanina

MET. (2020a, 13 September 2020). Fenomena Cuaca. Retrieved from http://www.met.gov.my/pendidikan/cuaca/fenomenacuaca

MET. (2020b, 13 September 2020). Iklim Malaysia. Retrieved from http://www.met.gov.my/pendidikan/iklim/iklimmalaysia

Nagarajan, R. (2009). Drought indices *Drought Assessment* (pp. 160-204): Springer.

Naresh Kumar, M., Murthy, C., Sesha Sai, M., & Roy, P. (2009). On the use of Standardized Precipitation Index (SPI) for drought intensity assessment. *Meteorological Applications: A journal of forecasting, practical applications, training techniques and modelling, 16*(3), 381-389.

NDMC. (2017). National Drought Mitigation Center: Recent and Historic U.S. Drought Impacts. Retrieved from http://drought.unl.edu/Planning/Impacts/RecentandHistoricUSDroughtImpacts.aspx

Parry, M., Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.

Peterson, T. C., Mellilo, J. M., & Karl, T. R. (2009). *Global climate change impacts in the United States*. Cambridge, MA: Cambridge University Press.

Pour, S. H., Harun, S. B., & Shahid, S. (2014). Genetic programming for the downscaling of extreme rainfall events on the East Coast of Peninsular Malaysia. *Atmosphere, 5*(4), 914-936.

Qian, J.-H., & Zubair, L. (2010). The effect of grid spacing and domain size on the quality of ensemble regional climate downscaling over South Asia during the northeasterly monsoon. *Monthly weather review, 138*(7), 2780-2802.

Rahmat, S. (2015). Methodology for development of drought severity-duration-frequency (SDF) Curves.

Rahmat, S. N., Jayasuriya, N., & Bhuiyan, M. (2015). Assessing droughts using meteorological drought indices in Victoria, Australia. *Hydrology Research, 46*(3), 463-476.

Ramli, M. M. (2016, 26 February 2016). Hutan di Batu Caves terbakar. *Berita HARIAN*. Retrieved from https://www.bharian.com.my/node/128218

Rossi, G., Vega, T., & Bonaccorso, B. (2007). *Methods and tools for drought analysis and management* (Vol. 62): Springer Science & Business Media.

Shah, R., Manekar, V., Christian, R., & Mistry, N. (2013). Estimation of reconnaissance drought index (RDI) for Bhavnagar District, Gujarat, India. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, 7*(7), 507-510.

Simon, M., & Meyer, E. L. (2010). Detection and analysis of hot-spot formation in solar cells. *Solar Energy Materials and Solar Cells, 94*(2), 106-113.

Sousa, S., Martins, F. G., Alvim-Ferraz, M., & Pereira, M. C. (2007). Multiple linear regression and artificial neural networks based on principal components to predict ozone concentrations. *Environmental Modelling & Software, 22*(1), 97-103.

Stanke, C., Kerac, M., Prudhomme, C., Medlock, J., & Murray, V. (2013). Health effects of drought: a systematic review of the evidence. *PLoS currents, 5*.

Tangang, F. T., Juneng, L., Salimun, E., Sei, K., & Halimatun, M. (2012). Climate change and variability over Malaysia: gaps in science and research information. *Sains Malaysiana, 41*(11), 1355-1366.

Tangau, M. (2016). Bersedia menghadapi musim kemarau. Retrieved from http://www.fomca.org.my/v1/index.php/fomca-di-pentas-media/fomca-di-pentas-media-2016/106-bersedia-menghadapi-musim-kemarau

Thomas, T., Jaiswal, R., Galkate, R., & Nayak, T. (2016). Reconnaissance drought index based evaluation of meteorological drought characteristics in Bundelkhand. *Procedia Technology, 24*, 23-30.

TNB. (2014). *Tenaga Nasional Berhad Annual Report 2014*. Retrieved from Jalan Pantai Baru, Kuala Lumpur:

Tsakiris, G., Pangalou, D., & Vangelis, H. (2007). Regional drought assessment based on the Reconnaissance Drought Index (RDI). *Water resources management, 21*(5), 821-833.

Tukimat, N., Syukri, N. A., & Malek, M. (2019). Projection the long-term ungauged rainfall using integrated Statistical Downscaling Model and Geographic Information System (SDSM-GIS) model. *Heliyon, 5*(9), e02456.

Tukimat, N. N. A., & Harun, S. (2014). Optimization of water supply reservoir in the framework of climate variation. *International Journal of Software Engineering and Its Applications, 8*(3), 361-378.

Türkeş, M., & Tatlı, H. (2009). Use of the standardized precipitation index (SPI) and a modified SPI for shaping the drought probabilities over Turkey. *International Journal of Climatology: A Journal of the Royal Meteorological Society, 29*(15), 2270-2282.

UCS. (2017). Cars Emissions and Global Warming. *Science For A Healthy Planet And Safer World.* Retrieved from https://www.ucsusa.org/resources/car-emissions-global-warming#.WRh6ZOuGPIU

Van Lanen, H., Wanders, N., Tallaksen, L., & Van Loon, A. (2013). Hydrological drought across the world: impact of climate and physical catchment structure. *Hydrology and Earth System Sciences, 17*, 1715-1732.

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., . . . Lamarque, J.-F. (2011). The representative concentration pathways: an overview. *Climatic change, 109*(1-2), 5.

Wang, W., Ertsen, M. W., Svoboda, M. D., & Hafeez, M. (2016). Propagation of drought: from meteorological drought to agricultural and hydrological drought. *Advances in Meteorology, 2016*.

Wilby, R. L., Dawson, C., & Barrow, E. (2007). SDSM 4.2–A decision support tool for the assessment of regional climate change impacts (User Manual). *Climate Impacts and Adaptation Research Programme*.

Wilks, D. S. (2012). Stochastic weather generators for climate-change downscaling, part II: multivariable and spatially coherent multisite downscaling. *Wiley Interdisciplinary Reviews: Climate Change, 3*(3), 267-278.

Wolfe, J. R., Goldstein, R. A., Maulbetsch, J. S., & McGowin, C. R. (2009). An electric power industry perspective on water use efficiency. *Journal of Contemporary Water Research & Education, 143*(1), 30-34.

Wu, H., Svoboda, M. D., Hayes, M. J., Wilhite, D. A., & Wen, F. (2007). Appropriate application of the standardized precipitation index in arid locations and dry seasons. *International Journal of Climatology: A Journal of the Royal Meteorological Society, 27*(1), 65-79.

Yano, T., Aydin, M., & Haraguchi, T. (2007). Impact of climate change on irrigation demand and crop growth in a Mediterranean environment of Turkey. *Sensors, 7*(10), 2297-2315.

Younggu, H., Seung-Hwan, Y., Jaepil, C., Syewoon, H., Jaehak, J., & Chounghyun, S. (2019). Uncertainty in hydrological analysis of climate change: multi-parameter vs. multi-GCM ensemble predictions. *Scientific Reports (Nature Publisher Group), 9*(1).

Zarch, M. A. A., Malekinezhad, H., Mobin, M. H., Dastorani, M. T., & Kousari, M. R. (2011). Drought monitoring by reconnaissance drought index (RDI) in Iran. *Water resources management, 25*(13), 3485.