EXTREME HEAT VULNERABILITY ASSESSMENT IN PENINSULAR MALAYSIA WITH INTEGRATION OF REMOTE SENSING AND SOCIODEMOGRAPHIC DATA

By

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The inevitable increase in temperature have attributed to the episodes of extreme heat all over the world and causes significant impacts on health, society, and economics. In the past 10 years, Malaysia has experienced more extreme heat event and yet very little research has been dedicated in exploring the heat-related vulnerability of exposed populations. In this study, the spatial and temporal pattern of extreme heat event was assessed, and the extreme heat vulnerability index (EHVI) has been evaluated based on integration of exposure, sensitivity and adaptive capacity during reference year and extreme heat year. The spatio-temporal distribution of extreme heat exposure was assessed using daytime land surface temperature (LST) Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua Earth Observation satellite from 2003 until 2018. We have applied Principal Component Analysis on 13 parameters for each 87 districts to elucidate the extreme heat vulnerability in Peninsular Malaysia. The EHVI were generated by summing up the normalized extreme heat exposure scores and factors scores from the multivariate analysis. Comparison between reference year and extreme heat year was done to evaluate the change of extreme heat exposure and vulnerability between those years. Then, the relationship between EHVI and actual heat related illness was analysed using multinomial logistic regression. The result shows that there is significant increase of LST annually and during southwest monsoon. It was found that from 2003 until 2018, El-Nino accounts about 7.8% of extreme heat event and the highest LST anomaly is 3.2°C on March 2016. The analysis reveals two major components that represents the 13 parameters: social sensitivity and adaptive capacity. EHVI in our study clarifies that the most vulnerable populations are confined in the urban and northern region of Peninsular Malaysia. The source of vulnerability varied between both regions, with urbanization and population density increase the vulnerability in urban areas while high heat exposure and sensitive population are the dominant factor of vulnerability in northern region. The result also shows that EHVI is a significant predictor for district with moderate heat related cases. A comprehensive heat vulnerable assessment will give decision-makers, planner and other stakeholders, a clear view for effective adaptation and preparedness strategies in undergo future heat-related events.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN KERENTANAN TERHADAP HABA EKSTRIM DI SEMENANJUNG MALAYSIA MENGGUNAKAN PENDERIAAN JAUH DAN DATA SOSIODEMOGRAFI

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Peningkatan suhu telah dikaitkan dengan kejadian haba ekstrim di seluruh dunia dan telah menyebabkan kesan yang signifikan terhadap kesihatan, masyarakat and ekonomi. Dalam tempoh 10 tahun yang lepas, Malaysia telah mengalami banyak ke-jadian haba ekstrim. Namun, kajian berkaitan pendedahan ekstrim haba ke atas masyarakat yang terkesan dengan kejadian tersebut kurang dibincangkan. Kajian ini menilai *Extreme Heat Vulnerability Index (EHVI)* di Semenanjung Malaysia dengan menggunakan terma pendedahan, sensitiviti dan keupayaan adaptif untuk tahun ru-jukan dan tahun yang mengalami haba ekstrim. Pendedahan terhadap ekstrim haba telah dinilai menggunakan *day-time land surface temperature (LST) Moderate Resolu-tion Imaging Spectroradiometer (MODIS) Aqua Earth Observation satellite* dari tahun 2003 sehingga tahun 2018. *Principal Component Analysis* telah dilaksanakan ke atas 13 pemboleh ubah bagi setiap 87 daerah untuk menjelaskan corak kerentanan terhadap haba ekstrim di Semenanjung Malaysia. EHVI telah dikira dengan menjumlahkan skor pendedahan terhadap haba ekstrim dan markah faktor daripada analisis multivariat tersebut. Perbandingan antara tahun rujukan dan tahun mengalami haba ekstrim telah dijalankan untuk mengenalpasti perbezaan antara kedua-dua tahun. Kemudian, hubung kait antara EHVI dan kes penyakit disebabkan oleh haba ekstrim dinilai melalui analisis *Multinomial Logistic Regression*. Berdasarkan analisis yang telah dijalankan, nilai tahunan LST dan nilai LST ketika monsun barat daya meningkat dengan kadar yang signifikan. Fenomena El-Nino telah dikenal pasti mempengaruhi 7.8% kejadian haba ekstrim sepanjang tahun 2003 sehingga 2018 dan merekodkan nilai anomali LST tertinggi iaitu 3.2ºC pada bulan Mac 2016. Analisa tersebut telah mengenal pasti dua komponen utama iaitu sensitiviti sosial dan keupayaan adaptif. EHVI telah menjelaskan bahawa masyarakat yang terdedah dengan haba ekstrim berada di kawasan bandar dan wilayah utara Semenanjung Malaysia. Sumber kerentanan haba ekstrim bagi kedua-dua kawasan tersebut berbeza. Urbanisasi dan kepadatan penduduk menyumbang kepada kerentanan haba ekstrim di kawasan bandar, manakala, pendedahan tinggi terhadap haba ekstrim dan populasi sensitif menyumbang kepada kerentanan haba ekstrim di wilayah utara. Hasilnya juga telah menunjukkan bahawa EHVI adalah ramalan yang signifikan

bagi daerah dengan kes yang mempunyai jumlah pesakit penyakit berkaitan haba yang sederhana. Kajian kerentanan terhadap haba ekstrim secara menyeluruh dapat membantu pegawai bertanggungjawab dalam menyediakan dan melaksanakan polisi, perancang bandar dan parti yang terlibat dengan memberi gambaran jelas dalam menyediakan strategi adaptasi dan mitigasi yang efektif dalam persediaan menjalani kejadian esktrim haba yang akan datang.

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私に生き方を教えてくれてありがとう。
Thank you so much and I love you all.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AR	Assessment Report
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advance Very High-Resolution Radiometer
DOE	Department of Environment
EHVI	Extreme heat vulnerability index
EMR	Electromagnetic radiation
ENSO	El-Nino Southern Oscillation
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GIS	Geographical Information System
HVI	Heat vulnerability index
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
LST	Land surface temperature
MCA	Multi-criteria analysis
MOH	Ministry of Health
MJO	Madden-Julien Oscillation
MLR	Multinomial Logistic Regression
MMD	Malaysia Meteorological Department
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NIOSH	National Institute of Occupational Safety and Health

NOAA	National Ocean and Atmospheric Administrative
ONI	Oceanic Nino Index
OWA	Ordered Weighting Averaging
PCA	Principal Component Analysis
PC	Principal component
SOVI	Social Vulnerability Index
SD	Standard deviation
TOA	Top of atmosphere
UNISDR	UN International Strategy for Disaster Reduction
WBGT	Wet bulb globe temperature
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Since 1900, the world has experienced significant increase of global average temperature mostly due to the climate change and anthropogenic activities (Stern & Kaufmann, 2014). According to IPCC Assessment Report 5, the increasing of frequency and intensity of extreme heat events has likely to increase since 1950 and there is likelihood for further changes based on the increasing of average global land and ocean temperature by roughly 0.72°C (Figure 1).

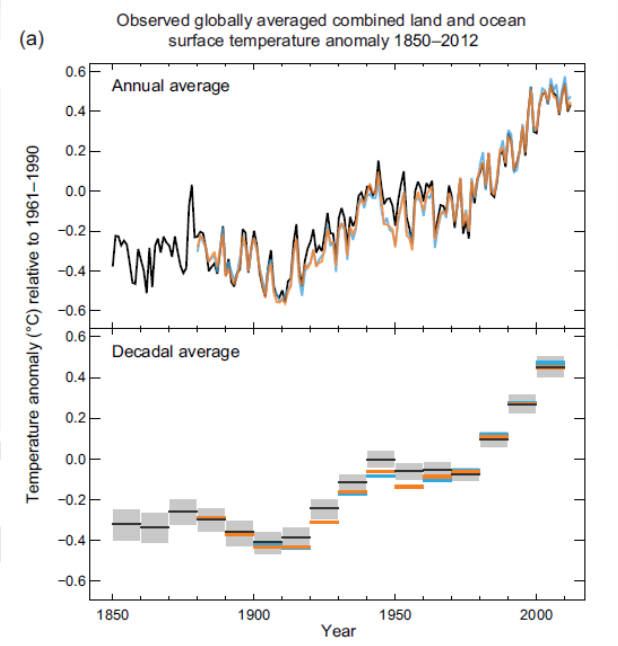

Figure 1: Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 (IPCC, 2014)

The risks posed by extreme temperature have become a significant threat that causes the increase of heat-related morbidity and mortality cases (Williams et al., 2018; Bell et al., 2019). Extreme heat overpowers the human body by affecting its normal thermoregulatory mechanism in maintaining a constant core temperature, which usually copes by perspiring and breathing (Ishimine, 2019). The rapid increase in body temperature affects mainly the central nervous system and circulatory system, which can be manifested as confusion, loss of consciousness, muscle cramps due to electrolyte

imbalance, and renal impairment due to severe dehydration (Barraclough et al., 2017). Mortality rates have been proven to increase during events of extreme heat. Paravantis et al. (2017) showed that mortality rates increased by 15% during extreme heat events. In addition, there was a significant association between extreme temperatures and mortality rates (particularly respiratory and cardiovascular mortality (Zhang et al., 2014; Kenny et al., 2017; Song et al., 2018). Heat mortality is also projected to increase due to the increase in the risk of malnutrition and the spread of infectious diseases during extreme heat events (Cukic, 2012; Bowen & Ebi, 2017).

Nevertheless, the impacts towards extreme heat are not solely driven by the high temperature. The heat vulnerability varies significantly within individual cities according to its socio-economic factors such as household incomes, population density and physical neighbourhood features such as land cover (Rosenthal et al., 2014). The sociodemographic and surroundings of the population also influence the severity of the impacts. Sociodemographic status, such as age (Li et al., 2016; Mangus & Canares, 2019), gender (Basu, 2009; Song et al., 2017), poverty (Chow, Chuang, & Gober, 2012; Christenson et al., 2017) and disability (Pincetl, Chester, & Eisenman, 2016; Macintyre et al., 2018), has been associated with the adaptability towards extreme heat. Areas with high impervious surface and less vegetation cover tend to cause 'urban heat islands' which can cause a higher increase in temperature compared to surrounding areas. Access to necessities and facilities also plays a role in an individual's adaptation towards extreme heat.

For that reason, it would be beneficial to study and identify the population's vulnerability towards extreme heat exposure by taking the sociodemographic and adaptability status into account. Identifying extreme heat vulnerability resulting from these relationships can help to identify the extreme heat prone boundaries and examine the unique relationship between vulnerability indicators. The consideration of social characteristics among specific communities is vital when examining the effects of extreme heat on communities because mortality and morbidity rates are related to extreme heat occurring in areas with poor socio-economic and health (Hu, Wilhelmi, & Uejio, 2019).

This study will focus on mapping vulnerable communities by utilizing the integration of multi-source data based on three components which is exposure, sensitivity, and adaptive capacity. A comprehensive extreme heat vulnerable assessment will give decision-makers, planner and other stakeholders, a clear view for effective adaptation and preparedness strategies in undergo future heat-related events.

1.2 Problem Statement

Extreme heat event is one of the uncommon natural hazards that present in the last decade in Malaysia. Nevertheless, it had caused significant impacts over the years as it happened frequently in longer period and higher in magnitude. The impacts of extreme heat in Malaysia are currently under-reported and it is difficult to assess information such as heat related mortality, morbidity, and economic consequences. Even though it has not

extensively investigated, there are growing number of studies focusing on significant increase in temperature and its impacts.

Ministry of Health Malaysia (MOH) reported that there were 200 cases related to hot weather which is 126 cases of heat exhaustion, 52 cases of heat cramps and 22 cases of heat stroke includes two deaths reported as a result of heat stroke. The hot and dry condition caused water rationing in several areas especially in northern region of Peninsular Malaysia such as Kedah and Perlis (The Straits Times, 2016). Northern region contributes 50% of overall 65% domestic rice production. It is reported that the rice output was decreased by 13% during the heat wave in 2016. Figure 2 shows the condition of paddy field in Kedah and grass field in Perak during the heat wave event.

Figure 2: Condition of paddy field in Kedah and grass field in Perak during heatwave event in 2016

Besides that, the high temperature caused forest and bush fire outbreak all over Malaysia. In April 2016 alone, there are 1,708 cases of forest and bush fire outbreak (Bernama, 2016). In addition, it has increased the electricity demand in Malaysia. The peak demand or the maximum electricity usage during specific period of time was recorded at 17,788 MW in 19 April 2016 which is during the heat wave event (Department of Statistics Malaysia, 2018b). Therefore, spatially explicit identification of extreme heat vulnerability is crucial to ensure appropriate development of targeted prevention and mitigation.

The development and mapping of extreme heat vulnerability index is a common approach in identifying areas and communities prone to extreme heat. The need to map vulnerability patterns at finer spatial scale is essential to reduce preventable illness and death related to extreme heat (Putnam et al., 2018; Voelkel et al., 2018) and help the

decision makers at the municipality level to allocate resources more appropriately and systematically to the affected areas (Mayrhuber et al., 2018; Nori-Sarma et al., 2019).

1.3 Significance of Study

Extreme heat vulnerability assessment has become more prevalent in recent years to develop scientific knowledge and formulation of mitigation and adaptation strategies in combating the temperature rise and frequent occurrence of extreme heat events. According to future projection of heat wave by Russo et al. (2014), more regions are going to be affected by this extreme event. Without proper disaster risk planning and management, extreme heat event is going to take a toll not just on human's health but also in economy and environment. In 2009, Malaysia has stated its commitment in finding ways to build resilience towards extreme events caused by climate change through the National Policy of Climate Change. Therefore, this study supports the policy's objective and contributes in the knowledge of constructing resilience towards extreme events. Besides that, this study is also aligned with Sustainable Development Goals 3 (good health and well-being), 11 (sustainable cities and communities) and 13 (climate action).

The application of Extreme Heat Vulnerability Index (EHVI) in this study could be used to point out population affected with high heat vulnerability and examine the unique relationship between the configuration of vulnerability and sociodemographic implications. The consideration of social characteristics among specific communities is vital when examining the effects of extreme heat on communities because mortality and morbidity rates are related to extreme heat occurs in areas with poor socio-economic and health (Hu et al., 2019). Furthermore, as EHVI includes multiple aspects, it can help in various sectors such as healthcare, agricultural, construction in managing impacts of extreme heat. The composite of several indicators provides context and perspective for the public and nontechnical groups to appreciate the diverse information through this study.

1.4 Objective of study

The incorporation of remote sensing and sociodemographic data help to provide comprehensive explanation on extreme heat attribution by using low-cost and precise data. The main goal of this research is to derive spatially detailed information on the distribution of extreme heat vulnerability in Peninsular Malaysia by integrating remote sensing with sociodemographic data. This includes examining the drivers affecting population vulnerability and identifying vulnerable districts within Peninsular Malaysia. Within this broad topic, this thesis addresses two aims:

1. To assess the spatial and temporal pattern of extreme heat event in Peninsular Malaysia.
2. To evaluate the vulnerable population based on the integration of heat exposure, population sensitivity and adaptation.

These objectives are investigated according to extreme heat vulnerability methodology, remote sensing, and geographic information system (GIS) applications within a framework to support the development that accommodates specific action and policy to reduce the risk experience by vulnerable population.

REFERENCES

Abdelmoty, A. and B. El-Geresy (2000). Assessing Spatial Similarity in Geographic Databases In: GIS and Geocomputation. P. Atkinson and D. Martin (eds.), *Taylor & Francis*: 255–269.

Aggarwal, S. (2004) Principles of remote sensing *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology* 23–38.

Acharya, P., Boggess, B., & Zhang, K. (2018). Assessing heat stress and health among construction workers in a changing climate: A review. *International Journal of Environmental Research and Public Health*, *15*(2). https://doi.org/10.3390/ijerph15020247

Aini, M. S., Fakhru'l-Razi, A., & Siew Suan, K. (2001). Water crisis management: Satisfaction level, effect and coping of the consumers. *Water Resources Management*, *15*(1), 31–39. https://doi.org/10.1023/A:1012256903509

Ainoriza, A. M., Murni, N., & Aziz, W. N. A. W. A. (2016). Housing aspirations of the elderly in Malaysia: A comparison of Urban and rural areas. *Journal of Design and Built Environment*, *16*(2), 30–43. https://doi.org/10.22452/jdbe.vol16no2.2

Al-Jazeera News. (2016). Severe heatwave grips Malaysia, 1–2. Retrieved from https://www.aljazeera.com/news/2016/04/severe-heatwave-grips-malaysia-160411102328907.html.

Amirabadizadeh, M., Huang, Y. F., & Lee, T. S. (2015). Recent Trends in Temperature and Precipitation in the Langat River Basin, Malaysia. *Advances in Meteorology*, *2015*(1), 1–16. https://doi.org/10.1155/2015/579437

As-Syakur, A. R., Osawa, T., Miura, F., Nuarsa, I. W., Ekayanti, N. W., Dharma, I. G. B. S., … Tanaka, T. (2016). Maritime Continent rainfall variability during the TRMM era: The role of monsoon, topography and El Niño Modoki. *Dynamics of Atmospheres and Oceans*, *75*, 58–77. https://doi.org/10.1016/j.dynatmoce.2016.05.004

Aubrecht, C., & Özceylan, D. (2013). Identification of heat risk patterns in the U.S. National Capital Region by integrating heat stress and related vulnerability. *Environment International*, *56*(1), 65–77. https://doi.org/10.1016/j.envint.2013.03.005

Aubrecht, C., Özceylan, D., Steinnocher, K., & Freire, S. (2013). Multi-level geospatial modeling of human exposure patterns and vulnerability indicators. *Natural Hazards*, *68*(1), 147–163. https://doi.org/10.1007/s11069-012-0389-9

Awal, M., Rashid, M., Islam, A., Imam, M., & Sarkar, M. (2016). Measuring Climate Change Vulnerability and its Adaptive Capacity: Policies and Planning for Bangladesh. *British Journal of Environment and Climate Change*, *6*(4), 279–298. https://doi.org/10.9734/BJECC/2016/27382

Azhar, G., Saha, S., Ganguly, P., Mavalankar, D., & Madrigano, J. (2017). Heat Wave Vulnerability Mapping for India. *International Journal of Environmental Research and Public Health*, *14*(4), 357. https://doi.org/10.3390/ijerph14040357

Bai, L., Woodward, A., Cirendunzhu, & Liu, Q. (2016). County-level heat vulnerability of urban and rural residents in Tibet, China. *Environmental Health*, *15*(1), 3. https://doi.org/10.1186/s12940-015-0081-0

Bao, J., Li, X., & Yu, C. (2015). The Construction and Validation of the Heat Vulnerability Index, a Review. *International Journal of Environmental Research and Public Health*, *12*(7), 7220–7234. https://doi.org/10.3390/ijerph120707220

Barraclough, K. A., Blashki, G. A., Holt, S. G., & Agar, J. W. M. (2017). Climate change and kidney disease—threats and opportunities. *Kidney International*, *92*(3), 526–530. https://doi.org/10.1016/j.kint.2017.03.047

Barron, L., Ruggieri, D., & Branas, C. (2018). Assessing Vulnerability to Heat: A Geospatial Analysis for the City of Philadelphia. *Urban Science*, *2*(2), 38. https://doi.org/10.3390/urbansci2020038

Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environmental Health*, *8*(1), 40. https://doi.org/10.1186/1476-069X-8-40

Becker, E. (2015). March 2015 ENSO discussion: El-Nino is here. Retrieved April 30, 2019, from https://www.climate.gov/news-features/blogs/enso/march-2015-enso-discussion-el-niño-here

Bell, J. E., Herring, S. C., Jantarasami, L., Adrianopoli, C., Benedict, K., Conlon, K., ... & Quattrochi, D. (2019). Key findings. In *World Population Policies 2015* (pp. 5–6). UN. https://doi.org/10.18356/b9bf1cab-en

Benali, A., Carvalho, A. C., Nunes, J. P., Carvalhais, N., & Santos, A. (2012). Estimating air surface temperature in Portugal using MODIS LST data. *Remote Sensing of Environment*, *124*(1), 108–121. https://doi.org/10.1016/j.rse.2012.04.024

Benmarhnia, T., Kihal-Talantikite, W., Ragettli, M. S., & Deguen, S. (2017). Small-area spatiotemporal analysis of heatwave impacts on elderly mortality in Paris: A cluster analysis approach. *Science of The Total Environment*, *592*(1), 288–294. https://doi.org/10.1016/j.scitotenv.2017.03.102

Bernama. (2016). Malaysia: 2,940 forest, bush fire outbreaks recorded in 10 days. Retrieved April 23, 2019, from https://www.eco-business.com/news/malaysia-2940-forest-bush-fire-outbreaks-recorded-in-10-days/

Bhattacharjee, S., Gerasimova, E., Imbert, C., Tencar, J., & Rotondo, F. (2019). Assessment of Different Methodologies for Mapping Urban Heat Vulnerability for Milan, Italy. *IOP Conference Series: Earth and Environmental Science*, *290*(1), 012162. https://doi.org/10.1088/1755-1315/290/1/012162

Bowen, K. J., & Ebi, K. L. (2017). Health risks of climate change in the World Health Organization South-East Asia Region. *WHO South-East Asia Journal of Public Health*, *6*(2), 3–8. https://doi.org/10.4103/2224-3151.213789

Bradford, K., Abrahams, L., Hegglin, M., & Klima, K. (2015). A Heat Vulnerability Index and Adaptation Solutions for Pittsburgh, Pennsylvania. *Environmental Science & Technology*, *49*(19), 11303–11311. https://doi.org/10.1021/acs.est.5b03127

Brooks, N. (2003). *A conceptual framework Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research and Centre for Social and Economic Research on the Global Environment (CSERGE)*. Geodate.

Buscail, C., Upegui, E., & Viel, J.-F. (2012). Mapping heatwave health risk at the community level for public health action. *International Journal of Health Geographics*, *11*(1), 38. https://doi.org/10.1186/1476-072X-11-38

Centers for Disease Control and Prevention. (2012). About Extreme Heat. Retrieved from https://www.cdc.gov/disasters/extremeheat/heat_guide.html

Chaudhuri, G., & Mishra, N. B. (2016). Spatio-temporal dynamics of land cover and land surface temperature in Ganges-Brahmaputra delta: A comparative analysis between India and Bangladesh. *Applied Geography*, *68*, 68–83. https://doi.org/10.1016/j.apgeog.2016.01.002

Chen, K., Bi, J., Chen, J., Chen, X., Huang, L., & Zhou, L. (2015). Influence of heat wave definitions to the added effect of heat waves on daily mortality in Nanjing, China. *Science of The Total Environment*, *506–507*(1), 18–25. https://doi.org/10.1016/j.scitotenv.2014.10.092

Chen, Q., Ding, M., Yang, X., Hu, K., & Qi, J. (2018). Spatially explicit assessment of heat health risk by using multi-sensor remote sensing images and socioeconomic data in Yangtze River Delta, China. *International Journal of Health Geographics*, *17*(1), 15. https://doi.org/10.1186/s12942-018-0135-y

Chen, S., & Zha, X. (2016). Evaluation of soil erosion vulnerability in the Zhuxi watershed, Fujian Province, China. *Natural Hazards*, *82*(3), 1589–1607. https://doi.org/10.1007/s11069-016-2258-4

Chirico, F., & Magnavita, N. (2019). The significant role of health surveillance in the occupational heat stress assessment. *International Journal of Biometeorology*, *63*(2), 193–194. https://doi.org/10.1007/s00484-018-1651-y

Chow, W. T. L., Chuang, W.-C., & Gober, P. (2012). Vulnerability to Extreme Heat in Metropolitan Phoenix: Spatial, Temporal, and Demographic Dimensions. *The Professional Geographer*, *64*(2), 286–302. https://doi.org/10.1080/00330124.2011.600225

Christenson, M., Geiger, S. D., Phillips, J., Anderson, B., Losurdo, G., & Anderson, H. A. (2017). Heat Vulnerability Index Mapping for Milwaukee and Wisconsin. *Journal of Public Health Management and Practice*, *23*(4), 396–403. https://doi.org/10.1097/PHH.0000000000000352

Chuang, W.-C., & Gober, P. (2015). Predicting Hospitalization for Heat-Related Illness at the Census-Tract Level: Accuracy of a Generic Heat Vulnerability Index in Phoenix, Arizona (USA). *Environmental Health Perspectives*, *123*(6), 606–612. https://doi.org/10.1289/ehp.1307868

Ciuha, U., Pogačar, T., Bogataj, L. K., Gliha, M., Nybo, L., Flouris, A. D., & Mekjavic, I. B. (2019). Interaction between indoor occupational heat stress and environmental temperature elevations during heat waves. *Weather, Climate, and Society*, *11*(4), 755–762. https://doi.org/10.1175/WCAS-D-19-0024.1

Ciurean, R. L., Schröter, D., & Glade, T. (2013). Conceptual frameworks of vulnerability assessments for natural disasters reduction. In Approaches to disaster management-Examining the implications of hazards, emergencies and disasters. IntechOpen. https://doi.org/10.5772/55538

Crichton, D. (1999). The risk triangle.

Cukic, V. (2012). The Influence of Climate Changes on Respiratory Allergic and Infectious Diseases. *HealthMED*, *6*(1), 319–323.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Department of Statistics Malaysia. (2017). *Population and Demographics*. *Department of Statistics* (Vol. 1). Retrieved from https://www.dosm.gov.my/v1/uploads/files/6_Newsletter/Ageing.pdf.

Department of Statistics Malaysia. (2018a). *My Local Stats: Selangor*. *Department of Statistics, Malaysia*. Retrieved from https://www.dosm.gov.my/v1/index.php?r=column/pdfPrev&id=ZzdNdXBTMG8vUUhUdDNVSUJFNE5UUT09.

Department of Statistics Malaysia. (2018b). *Overview Electricity Sector in Malaysia*. *Department of Statistics*.

EPA. (2016). What Climate Change Means for Guam. https://doi.org/EPA 430-F-16-003

Feng, Y., Gao, C., Tong, X., Chen, S., Lei, Z., & Wang, J. (2019). Spatial Patterns of Land Surface Temperature and Their Influencing Factors: A Case Study in Suzhou, China. *Remote Sensing*, *11*(2), 182. https://doi.org/10.3390/rs11020182

Fong, L. F. (2016). 200 heat-related cases this year. *The Star Online*. Retrieved from https://www.thestar.com.my/news/nation/2016/04/29/200-heatrelated-cases-this-year

Frigerio, I., Zanini, F., Mattavelli, M., & De Amicis, M. (2019). Understanding the interacting factors that influence social vulnerability: a case study of the 2016 central Italy earthquake. *Disasters*, *43*(4), 867–890. https://doi.org/10.1111/disa.12403

Fussel, H.-M. (2005). Vulnerability in Climate Change Research : A Comprehensive Conceptual Framework. *University of California International and Area Studies Breslauer Symposium*.

Füssel, H.-M. (2010). How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: A comprehensive indicator-based assessment. *Global Environmental Change*, *20*(4), 597–611. https://doi.org/10.1016/j.gloenvcha.2010.07.009

Gardoni, P., Murphy, C., & Rowell, A. (2016). Risk Analysis of Natural Hazards: Interdisciplinary Challenges and Integrated Solutions. In *Risk Analysis of Natural Hazards* (Vol. 27, pp. 1–7). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-22126-7_1

Garzon-Villalba, X. P., Mbah, A., Wu, Y., Hiles, M., Moore, H., Schwartz, S. W., & Bernard, T. E. (2016). Exertional heat illness and acute injury related to ambient wet bulb globe temperature. *American Journal of Industrial Medicine*, *59*(12), 1169–1176. https://doi.org/10.1002/ajim.22650

Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., … Armstrong, B. (2015). Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet*, *386*(9991), 369–375. https://doi.org/10.1016/S0140-6736(14)62114-0

Gebrewahid, M. G., Kasa, A. K., Gebrehiwot, K. A., & Adane, G. B. (2017). Analyzing drought conditions, interventions and mapping of vulnerable areas using NDVI and SPI indices in Eastern Ethiopia, Somali region. *Ethiopian Journal of Environmental Studies & Management*, *10*(9).

Gronlund, C. J. (2014). Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review. *Current Epidemiology Reports*, *1*(3), 165–173. https://doi.org/10.1007/s40471-014-0014-4

Gronlund, C. J., Zanobetti, A., Wellenius, G. A., Schwartz, J. D., & O'Neill, M. S. (2016). Vulnerability to renal, heat and respiratory hospitalizations during extreme heat among U.S. elderly. *Climatic Change*, *136*(3–4), 631–645. https://doi.org/10.1007/s10584-016-1638-9

Grumm, R. H. (2011). The central European and russian heat event of July-August 2010. *Bulletin of the American Meteorological Society*, *92*(10), 1285–1296. https://doi.org/10.1175/2011BAMS3174.1

Guo, Y., Gasparrini, A., Li, S., Sera, F., Vicedo-Cabrera, A. M., de Sousa Zanotti Stagliorio Coelho, M., … Tong, S. (2018). Quantifying excess deaths related to heatwaves under climate change scenarios: A multicountry time series modelling study. *PLOS Medicine*, *15*(7), e1002629. https://doi.org/10.1371/journal.pmed.1002629

Hadi, A. S., Idrus, S., Harman Shah, A. H., & Mohamed, A. F. (2010). Malaysian Urbanization Transition : From Nascent , Pseudo to Livable Mega - Urban Region. *Malaysian Journal of Environmental Management*, *11*(1), 3–13.

Hajat, S., O'Connor, M., & Kosatsky, T. (2010). Health effects of hot weather: from awareness of risk factors to effective health protection. *The Lancet*, *375*(9717), 856–863. https://doi.org/10.1016/S0140-6736(09)61711-6

He, C., Ma, L., Zhou, L., Kan, H., Zhang, Y., Ma, W., & Chen, B. (2019). Exploring the mechanisms of heat wave vulnerability at the urban scale based on the application of big data and artificial societies. *Environment International*, *127*(1), 573–583. https://doi.org/10.1016/j.envint.2019.01.057

Ho, H. C., Knudby, A., Xu, Y., Hodul, M., & Aminipouri, M. (2016). A comparison of urban heat islands mapped using skin temperature, air temperature, and apparent temperature (Humidex), for the greater Vancouver area. *Science of The Total Environment*, *544*(1), 929–938. https://doi.org/10.1016/j.scitotenv.2015.12.021

Hu, K., Guo, Y., Yang, X., Zhong, J., Fei, F., Chen, F., … Qi, J. (2019). Temperature variability and mortality in rural and urban areas in Zhejiang province, China: An application of a spatiotemporal index. *Science of The Total Environment*, *647*(1), 1044–1051. https://doi.org/10.1016/j.scitotenv.2018.08.095

Hu, L., Wilhelmi, O. V., & Uejio, C. (2019). Assessment of heat exposure in cities: Combining the dynamics of temperature and population. *Science of The Total Environment*, *655*(1), 1–12. https://doi.org/10.1016/j.scitotenv.2018.11.028

Hulley, G., Shivers, S., Wetherley, E., & Cudd, R. (2019). New ECOSTRESS and MODIS Land Surface Temperature Data Reveal Fine-Scale Heat Vulnerability in Cities: A Case Study for Los Angeles County, California. *Remote Sensing*, *11*(18), 2136. https://doi.org/10.3390/rs11182136

Ibitoye, M. O., Aderibigbe, O. G., Adegboyega, S. A., & Adebola, A. O. (2017). Spatio-temporal analysis of land surface temperature variations in the rapidly developing Akure and its environs, southwestern Nigeria using Landsat data. *Ethiopian Journal of Environmental Studies and Management*, *10*(3), 389. https://doi.org/10.4314/ejesm.v10i3.9

Im, E. S., Pal, J. S., & Eltahir, E. A. B. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. *Science Advances*, *3*(8), 1–8. https://doi.org/10.1126/sciadv.1603322

Ingole, V., Kovats, S., Schumann, B., Hajat, S., Rocklöv, J., Juvekar, S., & Armstrong, B. (2017). Socioenvironmental factors associated with heat and cold-related mortality in Vadu HDSS, western India: a population-based case-crossover study. *International Journal of Biometeorology*, *61*(10), 1797–1804. https://doi.org/10.1007/s00484-017-1363-8

Inostroza, L., Palme, M., & de la Barrera, F. (2016). A Heat Vulnerability Index: Spatial Patterns of Exposure, Sensitivity and Adaptive Capacity for Santiago de Chile. *PLOS ONE*, *11*(9), e0162464. https://doi.org/10.1371/journal.pone.0162464

Ishimine, P. (2019). Heat Stroke in children. Retrieved September 20, 2019, from https://www.uptodate.com/contents/heat-stroke-in-children

Jedlovec, G., Crane, D., & Quattrochi, D. (2017). Urban heat wave hazard and risk assessment. *Results in Physics*, *7*(1), 4294–4295. https://doi.org/10.1016/j.rinp.2017.10.056

Johnson, D. P., Stanforth, A., Lulla, V., & Luber, G. (2012). Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. *Applied Geography*, *35*(1–2), 23–31. https://doi.org/10.1016/j.apgeog.2012.04.006

Jolliffe, I. (2002). Principal Components in Regression Analysis. In *Principal Component Analysis* (Vol. 18, pp. 167–198). New York: Springer-Verlag. https://doi.org/10.1007/0-387-22440-8_8

Kang, S.-H., Oh, I.-Y., Heo, J., Lee, H., Kim, J., Lim, W.-H., … Oh, S. (2016). Heat, heat waves, and out-of-hospital cardiac arrest. *International Journal of Cardiology*, *221*, 232–237. https://doi.org/10.1016/j.ijcard.2016.07.071

Kantamaneni, K., Phillips, M., Thomas, T., & Jenkins, R. (2018). Assessing coastal vulnerability: Development of a combined physical and economic index. *Ocean & Coastal Management*, *158*(1), 164–175. https://doi.org/10.1016/j.ocecoaman.2018.03.039

Karagiorgos, K., Thaler, T., Heiser, M., Hübl, J., & Fuchs, S. (2016). Integrated flash flood vulnerability assessment: Insights from East Attica, Greece. *Journal of Hydrology*, *541*(1), 553–562. https://doi.org/10.1016/j.jhydrol.2016.02.052

Kassie, B. T., Asseng, S., Rotter, R. P., Hengsdijk, H., Ruane, A. C., & Van Ittersum, M. K. (2015). Exploring climate change impacts and adaptation options for maize production in the Central Rift Valley of Ethiopia using different climate change scenarios and crop models. *Climatic Change*, *129*(1–2), 145–158. https://doi.org/10.1007/s10584-014-1322-x

Kenny, G. P., Poirier, M. P., Metsios, G. S., Boulay, P., Dervis, S., Friesen, B. J., … Flouris, A. D. (2017). Hyperthermia and cardiovascular strain during an extreme heat exposure in young versus older adults. *Temperature*, *4*(1), 79–88. https://doi.org/10.1080/23328940.2016.1230171

Kershaw, S. E., & Millward, A. A. (2012). A spatio-temporal index for heat vulnerability assessment. *Environmental Monitoring and Assessment*, *184*(12), 7329–7342. https://doi.org/10.1007/s10661-011-2502-z

Khandelwal, S., Goyal, R., Kaul, N., & Mathew, A. (2018). Assessment of land surface temperature variation due to change in elevation of area surrounding Jaipur, India. *Egyptian Journal of Remote Sensing and Space Science*, *21*(1), 87–94. https://doi.org/10.1016/j.ejrs.2017.01.005

Kim, D. W., Deo, R. C., Lee, J.-S., & Yeom, J.-M. (2017). Mapping heatwave vulnerability in Korea. *Natural Hazards*, *89*(1), 35–55. https://doi.org/10.1007/s11069-017-2951-y

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., & Hyatt, O. (2016). Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of

Global Climate Change Impacts. *Annual Review of Public Health*, *37*(1), 97–112. https://doi.org/10.1146/annurev-publhealth-032315-021740

Kotthaus, S., & Grimmond, C. S. B. (2014). Energy exchange in a dense urban environment - Part II: Impact of spatial heterogeneity of the surface. *Urban Climate*, *10*(P2), 281–307. https://doi.org/10.1016/j.uclim.2013.10.001

Krstic, N., Yuchi, W., Ho, H. C., Walker, B. B., Knudby, A. J., & Henderson, S. B. (2017). The Heat Exposure Integrated Deprivation Index (HEIDI): A data-driven approach to quantifying neighborhood risk during extreme hot weather. *Environment International*, *109*(1), 42–52. https://doi.org/10.1016/j.envint.2017.09.011

Lemonsu, A., Viguié, V., Daniel, M., & Masson, V. (2015). Vulnerability to heat waves: Impact of urban expansion scenarios on urban heat island and heat stress in Paris (France). *Urban Climate*, *14*(1), 586–605. https://doi.org/10.1016/j.uclim.2015.10.007

Leong, T. (2016). Malaysian farmers struggle to fight damaging heatwave. Retrieved April 22, 2019, from https://www.straitstimes.com/asia/malaysian-farmers-struggle-to-fight-damaging-heatwave

Li, T., Horton, R. M., Bader, D. A., Zhou, M., Liang, X., Ban, J., … Kinney, P. L. (2016). Aging Will Amplify the Heat-related Mortality Risk under a Changing Climate: Projection for the Elderly in Beijing, China. *Scientific Reports*, *6*(October 2015), 1–9. https://doi.org/10.1038/srep28161

Li, Y., Odame, E. A., Silver, K., & Zheng, S. (2017). Comparing Urban and Rural Vulnerability to Heat-Related Mortality: A Systematic Review and Meta-analysis. *Journal of Global Epidemiology and Environmental Health*, *1*(1), 9–15. https://doi.org/10.29199/GEEH.101016

Liu, S., Su, H., Zhang, R., Tian, J., & Wang, W. (2016). Estimating the Surface Air Temperature by Remote Sensing in Northwest China Using an Improved Advection-Energy Balance for Air Temperature Model. *Advances in Meteorology*, *2016*. https://doi.org/10.1155/2016/4294219

Loh, J. Le, Tangang, F., Juneng, L., Hein, D., & Lee, D.-I. (2017). Erratum to: Projected rainfall and temperature changes over Malaysia at the end of the 21st century based on PRECIS modelling system. *Asia-Pacific Journal of Atmospheric Sciences*, *53*(1), 175–176. https://doi.org/10.1007/s13143-017-0022-7

Loughnan, M. (2014a). Living with Risk Vol. 2, *27*(1), 1–133. Retrieved from https://search.informit.com.au/documentSummary;res=IELHSS;dn=221201818411958

Loughnan, M. (2014b). Understanding the Risk: An Assessment of San Francisco's Vulnerability to Extreme Heat Events, *27*(1). Retrieved from https://search.informit.com.au/documentSummary;res=IELHSS;dn=221201818411958

Loughnan, M., Nicholls, N., & Tapper, N. J. (2012). Mapping Heat Health Risks in Urban Areas. *International Journal of Population Research*, *2012*(1), 1–12. https://doi.org/10.1155/2012/518687

Loughnan, M., Tapper, N., Phan, T., Lynch, K., & McInnes, J. (2014). *A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities Final Report* (Vol. 27). Geodate. Retrieved from https://search.informit.com.au/documentSummary;res=IELHSS;dn=221201818411958

Lucas, R. A. I., Epstein, Y., & Kjellstrom, T. (2014). Excessive occupational heat exposure: A significant ergonomic challenge and health risk for current and future workers. *Extreme Physiology and Medicine*, *3*(1), 1–8. https://doi.org/10.1186/2046-7648-3-14

Luintel, N., Ma, W., Ma, Y., Wang, B., & Subba, S. (2019). Spatial and temporal variation of daytime and nighttime MODIS land surface temperature across Nepal. *Atmospheric and Oceanic Science Letters*, *12*(5), 305–312. https://doi.org/10.1080/16742834.2019.1625701

Macintyre, H. L., Heaviside, C., Taylor, J., Picetti, R., Symonds, P., Cai, X.-M., & Vardoulakis, S. (2018). Assessing urban population vulnerability and environmental risks across an urban area during heatwaves – Implications for health protection. *Science of The Total Environment*, *610–611*, 678–690. https://doi.org/10.1016/j.scitotenv.2017.08.062

Macnee, R. G. D., & Tokai, A. (2016). Heat wave vulnerability and exposure mapping for Osaka City, Japan. *Environment Systems and Decisions*, *36*(4), 368–376. https://doi.org/10.1007/s10669-016-9607-4

Maier, G., Grundstein, A., Jang, W., Li, C., Naeher, L. P., & Shepherd, M. (2014). Assessing the Performance of a Vulnerability Index during Oppressive Heat across Georgia, United States. *Weather, Climate, and Society*, *6*(2), 253–263. https://doi.org/10.1175/WCAS-D-13-00037.1

Malaysian Meteorological Department. (2016). *Annual Report 2016*. Retrieved from http://www.met.gov.my/content/pdf/penerbitan/laporantahunan/laporantahunan2016.pdf

Mallen, E., Stone, B., & Lanza, K. (2019). A methodological assessment of extreme heat mortality modeling and heat vulnerability mapping in Dallas, Texas. *Urban Climate*, *30*(1), 100528. https://doi.org/10.1016/j.uclim.2019.100528

Manangan, A. P., Uejio, C. K., Saha, S., Schramm, P. J., Marinucci, G. D., Hess, J. J., & Luber, G. (2015). *Assessing Health Vulnerability to Climate Change: A Guide for Health Departments Climate and Health Technical Report Series Climate and Health Program, Centers for Disease Control and Prevention*. Retrieved from https://www.cdc.gov/climateandhealth/docs/AssessingHealthVulnerabilitytoClimateChange_508.pdf

Manggat, I., Zain, R., & Jamaluddin, Z. (2018). The Impact of Infrastructure Development on Rural Communities: A Literature Review. *International Journal of*

Academic Research in Business and Social Sciences, *8*(1). https://doi.org/10.6007/ijarbss/v8-i1/3837

Mangus, C. W., & Canares, T. L. (2019). Heat-related illness in children in an era of extreme temperatures. *Pediatrics in Review*, *40*(3), 97–107. https://doi.org/10.1542/pir.2017-0322

Masood, I., Majid, Z., Sohail, S., Zia, A., & Raza, S. (2015). The deadly heat wave of Pakistan, June 2015. *International Journal of Occupational and Environmental Medicine*, *6*(4), 247–248. https://doi.org/10.15171/ijoem.2015.672

Matthews, T. K. R., Wilby, R. L., & Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. *Proceedings of the National Academy of Sciences*, *114*(15), 3861–3866. https://doi.org/10.1073/pnas.1617526114

Mayrhuber, E. A.-S., Dückers, M. L. A., Wallner, P., Arnberger, A., Allex, B., Wiesböck, L., … Kutalek, R. (2018). Vulnerability to heatwaves and implications for public health interventions – A scoping review. *Environmental Research*, *166*(1), 42–54. https://doi.org/10.1016/j.envres.2018.05.021

Méndez-Lázaro, P., Muller-Karger, F. E., Otis, D., McCarthy, M. J., & Rodríguez, E. (2018). A heat vulnerability index to improve urban public health management in San Juan, Puerto Rico. *International Journal of Biometeorology*, *62*(5), 709–722. https://doi.org/10.1007/s00484-017-1319-z

Meque, A., & Abiodun, B. J. (2015). Simulating the link between ENSO and summer drought in Southern Africa using regional climate models. *Climate Dynamics*, *44*(7–8), 1881–1900. https://doi.org/10.1007/s00382-014-2143-3

MOH. (2016). Clinical Guidelines on Management of Heat Related Illness at Health Clinic and Emergency and Trauma Department, Ministry of Health , Malaysia Mac 2016.

Mortreux, C., & Barnett, J. (2017). Adaptive capacity: exploring the research frontier. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(4), e467. https://doi.org/10.1002/wcc.467

MOSTI. (2016). *Kenyataan Media Yb Datuk Seri Panglima Madius Tangau Menteri Sains, Teknologi Dan Inovasi 21 Mac 2016 Definisi ' Gelombang Haba ' Dipersetujui*. Retrieved from https://www.mestecc.gov.my/web/wp-content/uploads/2017/10/13-Oktober-2017-Majlis-Pelancaran-Portal-MCY-oleh-YB-Menteri-Sains-Teknologi-dan-Inovasi.pdf

Mushore, T. D., Mutanga, O., Odindi, J., & Dube, T. (2018). Determining extreme heat vulnerability of Harare Metropolitan City using multispectral remote sensing and socio-economic data. *Journal of Spatial Science*, *63*(1), 173–191. https://doi.org/10.1080/14498596.2017.1290558

Nayak, S. G., Shrestha, S., Kinney, P. L., Ross, Z., Sheridan, S. C., Pantea, C. I., … Hwang, S. A. (2018). Development of a heat vulnerability index for New York State. *Public Health*, *161*(1), 127–137. https://doi.org/10.1016/j.puhe.2017.09.006

Nguyen, T. T. X., Bonetti, J., Rogers, K., & Woodroffe, C. D. (2016). Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. *Ocean & Coastal Management*, *123*(1), 18–43. https://doi.org/10.1016/j.ocecoaman.2015.11.022

Nightingale, A. J. (2017). Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum*, *84*(May), 11–20. https://doi.org/10.1016/j.geoforum.2017.05.011

NIOSH. (2016). Guidelines on Heat Stress Management.

NOAA National Centers of Environmental Information. (2019). Global Climate Report - July 2019. Retrieved April 29, 2019, from https://www.ncdc.noaa.gov/sotc/global/201907

Noi, P., Kappas, M., & Degener, J. (2016). Estimating Daily Maximum and Minimum Land Air Surface Temperature Using MODIS Land Surface Temperature Data and Ground Truth Data in Northern Vietnam. *Remote Sensing*, *8*(12), 1002. https://doi.org/10.3390/rs8121002

Nori-Sarma, A., Benmarhnia, T., Rajiva, A., Azhar, G. S., Gupta, P., Pednekar, M. S., & Bell, M. L. (2019). Advancing our Understanding of Heat Wave Criteria and Associated Health Impacts to Improve Heat Wave Alerts in Developing Country Settings. *International Journal of Environmental Research and Public Health*, *16*(12), 2089. https://doi.org/10.3390/ijerph16122089

Notley, S. R., Flouris, A. D., & Kenny, G. P. (2019). Occupational heat stress management: Does one size fit all? *American Journal of Industrial Medicine*, *62*(12), 1017–1023. https://doi.org/10.1002/ajim.22961

Otto, M., Kjellstrom, T., & Lemke, B. (2019). O8B.6 Occupational heat stress due to climate change: estimating future heat wave hazards. *Occupational and Environmental Medicine*, *76*(Suppl 1), A73.2-A73. https://doi.org/10.1136/OEM-2019-EPI.197

Paravantis, J., Santamouris, M., Cartalis, C., Efthymiou, C., & Kontoulis, N. (2017). Mortality associated with high ambient temperatures, heatwaves, and the urban heat island in Athens, Greece. *Sustainability (Switzerland)*, *9*(4). https://doi.org/10.3390/su9040606

Parente, J., Pereira, M. G., Amraoui, M., & Fischer, E. M. (2018). Heat waves in Portugal: Current regime, changes in future climate and impacts on extreme wildfires. *Science of the Total Environment*, *631–632*, 534–549. https://doi.org/10.1016/j.scitotenv.2018.03.044

Patel, S., Joshi, J. P., & Bhatt, B. (2017). An assessment of spatio-temporal variability of land surface temperature using MODIS data: A study of Gujarat state, India. *Geography Compass*, *11*(4), e12312. https://doi.org/10.1111/gec3.12312

Pede, T., & Mountrakis, G. (2018). An empirical comparison of interpolation methods for MODIS 8-day land surface temperature composites across the conterminous Unites States. *ISPRS Journal of Photogrammetry and Remote Sensing*, *142*(1), 137–150. https://doi.org/10.1016/j.isprsjprs.2018.06.003

Pepin, N. C., Maeda, E. E., & Williams, R. (2016). Use of remotely sensed land surface temperature as a proxy for air temperatures at high elevations: Findings from a 5000 m elevational transect across Kilimanjaro. *Journal of Geophysical Research: Atmospheres*, *121*(17), 9998-10,015. https://doi.org/10.1002/2016JD025497

Phan, T. N., & Kappas, M. (2018). Application of MODIS land surface temperature data: a systematic literature review and analysis. *Journal of Applied Remote Sensing*, *12*(04), 1. https://doi.org/10.1117/1.JRS.12.041501

Phan, T. N., Kappas, M., & Tran, T. P. (2018). Land surface temperature variation due to changes in elevation in Northwest Vietnam. *Climate*, *6*(2), 1–19. https://doi.org/10.3390/cli6020028

Pincetl, S., Chester, M., & Eisenman, D. (2016). Urban Heat Stress Vulnerability in the U.S. Southwest: The Role of Sociotechnical Systems. *Sustainability*, *8*(9), 842. https://doi.org/10.3390/su8090842

Piya, L., Joshi, N. P., & Maharjan, K. L. (2016). Vulnerability of Chepang households to climate change and extremes in the Mid-Hills of Nepal. *Climatic Change*, *135*(3–4), 521–537. https://doi.org/10.1007/s10584-015-1572-2

Putnam, H., Hondula, D. M., Urban, A., Berisha, V., Iñiguez, P., & Roach, M. (2018). It's not the heat, it's the vulnerability: attribution of the 2016 spike in heat-associated deaths in Maricopa County, Arizona. *Environmental Research Letters*, *13*(9), 094022. https://doi.org/10.1088/1748-9326/aadb44

Ramakreshnan, L., Aghamohammadi, N., Fong, C. S., Ghaffarianhoseini, A., Ghaffarianhoseini, A., Wong, L. P., … Sulaiman, N. M. (2018). A critical review of Urban Heat Island phenomenon in the context of Greater Kuala Lumpur, Malaysia. *Sustainable Cities and Society*, *39*, 99–113. https://doi.org/10.1016/j.scs.2018.02.005

Reid, C. E., O'Neill, M. S., Gronlund, C. J., Brines, S. J., Brown, D. G., Diez-Roux, A. V., & Schwartz, J. (2009). Mapping Community Determinants of Heat Vulnerability. *Environmental Health Perspectives*, *117*(11), 1730–1736. https://doi.org/10.1289/ehp.0900683

Ribeiro, L. M., Viegas, D. X., Almeida, M., McGee, T. K., Pereira, M. G., Parente, J., … Hardin, H. (2020). Extreme wildfires and disasters around the world. *Extreme Wildfire Events and Disasters*, 31–51. https://doi.org/10.1016/b978-0-12-815721-3.00002-3

Richard, S., & Walsh, K. J. E. (2018). The influence of El Niño–Southern Oscillation on boreal winter rainfall over Peninsular Malaysia. *Theoretical and Applied Climatology*, *134*(1–2), 121–138. https://doi.org/10.1007/s00704-017-2262-y

Rinner, C., Patychuk, D., Bassil, K., Nasr, S., Gower, S., & Campbell, M. (2010). The Role of Maps in Neighborhood-level Heat Vulnerability Assessment for the City of

Toronto. *Cartography and Geographic Information Science*, *37*(1), 31–44. https://doi.org/10.1559/152304010790588089

Robine, J.-M., Cheung, S. L. K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P., & Herrmann, F. R. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus Biologies*, *331*(2), 171–178. https://doi.org/10.1016/j.crvi.2007.12.001

Rodrigues, P. C. de O., Ignotti, E., & Hacon, S. de S. (2019). Socioeconomic factors increase the adverse effects of air pollution and temperature on mortality. *Revista Brasileira de Epidemiologia*, *22*, 1–11. https://doi.org/10.1590/1980-549720190011

Romanescu, G., Hapciuc, O. E., Minea, I., & Iosub, M. (2018). Flood vulnerability assessment in the mountain-plateau transition zone: a case study of Marginea village (Romania). *Journal of Flood Risk Management*, *11*(1), S502–S513. https://doi.org/10.1111/jfr3.12249

Rosenthal, J. K., Kinney, P. L., & Metzger, K. B. (2014). Intra-urban vulnerability to heat-related mortality in New York City, 1997–2006. Health & place, 30, 45-60. https://doi.org/10.1016/j.healthplace.2014.07.014

Russo, A., Gouveia, C. M., Dutra, E., Soares, P. M. M., & Trigo, R. M. (2019). The synergy between drought and extremely hot summers in the Mediterranean. *Environmental Research Letters*, *14*(1). https://doi.org/10.1088/1748-9326/aaf09e

Russo, S., Dosio, A., Graversen, R. G., Sillmann, J., Carrao, H., Dunbar, M. B., … Vogt, J. V. (2014). Magnitude of extreme heat waves in present climate and their projection in a warming world. *Journal of Geophysical Research: Atmospheres*, *119*(22), 12,500-12,512. https://doi.org/10.1002/2014JD022098

Russo, S., Sillmann, J., & Sterl, A. (2017). Humid heat waves at different warming levels. *Scientific Reports*, *7*(1), 7477. https://doi.org/10.1038/s41598-017-07536-7

Ryan, J. (2005). Environmental Health in Emergencies and Disasters: A Practical Guide. *Emergency Medicine Journal*, *22*(8), 610–610. https://doi.org/10.1136/emj.2003.011981

Salata, F., Golasi, I., Petitti, D., de Lieto Vollaro, E., Coppi, M., & de Lieto Vollaro, A. (2017). Relating microclimate, human thermal comfort and health during heat waves: An analysis of heat island mitigation strategies through a case study in an urban outdoor environment. *Sustainable Cities and Society*, *30*(1), 79–96. https://doi.org/10.1016/j.scs.2017.01.006

Salimun, E., Tangang, F., Juneng, L., Behera, S. K., & Yu, W. (2014). Differential impacts of conventional El Niño versus El Niño Modoki on Malaysian rainfall anomaly during winter monsoon. *International Journal of Climatology*, *34*(8), 2763–2774. https://doi.org/10.1002/joc.3873

Salleh, N. H. M., Hasan, H., & Kassim, S. (2015). Trends in temperature extremes across Malaysia. Advances in Environmental Biology, 9(27), 174-181. http://www.aensiweb.net/AENSIWEB/aeb/aeb/2015/December/174-181.pdf

Salleh, S. A., Abd.Latif, Z., Mohd, W. M. N. W., & Chan, A. (2013). Factors Contributing to the Formation of an Urban Heat Island in Putrajaya, Malaysia. *Procedia - Social and Behavioral Sciences*, *105*(1), 840–850. https://doi.org/10.1016/j.sbspro.2013.11.086

Sebastian, A., Alzain, M. A., Asweto, C. O., Mahara, G., Guo, X., Song, M., … Wang, W. (2016). The Malaysian health care system: Ecology, plans, and reforms. *Family Medicine and Community Health*, *4*(3), 19–29. https://doi.org/10.15212/FMCH.2016.0101

Sekaran, R. (2019). Penang sets up climate change plan. *The Star Online*. Retrieved from https://www.thestar.com.my/news/nation/2019/04/28/penang-sets-up-climate-change-plan#:~:text=GEORGE TOWN%3A Despite managing its,rise by 1.5%25 by 2030.

Seroka, C., Kaiser, P., & Heany, J. Mapping Heat Vulnerability in Michigan (2011).

Shi, L., Liu, P., Kloog, I., Lee, M., Kosheleva, A., & Schwartz, J. (2016). Estimating daily air temperature across the Southeastern United States using high-resolution satellite data: A statistical modeling study. *Environmental Research*, *146*, 51–58. https://doi.org/10.1016/j.envres.2015.12.006

Simon, J. (2015). El Nino: The Good, Bad and the Ugly of 2015 22 September 2015.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Sohrabi, M., Farid Osman, A., & Tumin, M. (2018). Barriers in obtaining primary health care services from public clinics by non-citizen labors in Malaysia. *Malaysian Journal of Medical Research*, *2*(1), 52–60.

Song, X., Wang, S., Hu, Y., Yue, M., Zhang, T., Liu, Y., … Shang, K. (2017). Impact of ambient temperature on morbidity and mortality: An overview of reviews. *Science of the Total Environment*, *586*(222), 241–254. https://doi.org/10.1016/j.scitotenv.2017.01.212

Song, X., Wang, S., Li, T., Tian, J., Ding, G., Wang, J., … Shang, K. (2018). The impact of heat waves and cold spells on respiratory emergency department visits in Beijing, China. *Science of the Total Environment*, *615*(222), 1499–1505. https://doi.org/10.1016/j.scitotenv.2017.09.108

Stapleton, J. M., Poirier, M. P., Flouris, A. D., Boulay, P., Sigal, R. J., Malcolm, J., & Kenny, G. P. (2015). Aging impairs heat loss, but when does it matter? *Journal of Applied Physiology*, *118*(3), 299–309. https://doi.org/10.1152/japplphysiol.00722.2014

Stern, D. I., & Kaufmann, R. K. (2014). Anthropogenic and natural causes of climate change. *Climatic Change*, *122*(1–2), 257–269. https://doi.org/10.1007/s10584-013-1007-x

Suhaila, J., & Yusop, Z. (2018). Trend analysis and change point detection of annual and seasonal temperature series in Peninsular Malaysia. *Meteorology and Atmospheric Physics*, *130*(5), 565–581. https://doi.org/10.1007/s00703-017-0537-6

Suparta, W., & Yatim, A. N. M. (2019). Characterization of Heat Waves: A Case Study for Peninsular Malaysia. *Geographia Technica*, *14*(1), 146–155. https://doi.org/10.21163/GT_2019.141.11

Tabachnick, B. G. (2007). *Using Multivariate Statistics*. *Pearson Education*.

Tan, M. L., Juneng, L., Tangang, F. T., Chung, J. X., & Radin Firdaus, R. B. (2021). Changes in temperature extremes and their relationship with ENSO in Malaysia from 1985 to 2018. *International Journal of Climatology*, *41*(S1), 676–695. https://doi.org/10.1002/joc.6864

Tangang, F. T., Juneng, L., & Ahmad, S. (2007). Trend and interannual variability of temperature in Malaysia: 1961–2002. *Theoretical and Applied Climatology*, *89*(3–4), 127–141. https://doi.org/10.1007/s00704-006-0263-3

Teixeira, E. I., Fischer, G., Van Velthuizen, H., Walter, C., & Ewert, F. (2013). Global hot-spots of heat stress on agricultural crops due to climate change. *Agricultural and Forest Meteorology*, *170*, 206–215. https://doi.org/10.1016/j.agrformet.2011.09.002

The IPCC's Fifth Assessment Report (AR5) (Synthesis Report). (2014).

Thirumalai, K., DiNezio, P. N., Okumura, Y., & Deser, C. (2017). Extreme temperatures in Southeast Asia caused by El Niño and worsened by global warming. *Nature Communications*, *8*(1), 15531. https://doi.org/10.1038/ncomms15531

Thomas, K., Hardy, R. D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., … Winthrop, R. (2019). Explaining differential vulnerability to climate change: A social science review. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(2), 1–18. https://doi.org/10.1002/wcc.565

Tomlinson, C. J., Chapman, L., Thornes, J. E., & Baker, C. (2011). Remote sensing land surface temperature for meteorology and climatology: a review. *Meteorological Applications*, *18*(3), 296–306. https://doi.org/10.1002/met.287

Vanos, J., Vecellio, D. J., & Kjellstrom, T. (2019). Workplace heat exposure, health protection, and economic impacts: A case study in Canada. *American Journal of Industrial Medicine*, *62*(12), 1024–1037. https://doi.org/10.1002/ajim.22966

Vashisht, B. B., Mulla, D. J., Jalota, S. K., Kaur, S., Kaur, H., & Singh, S. (2013). Productivity of rainfed wheat as affected by climate change scenario in northeastern Punjab, India. *Regional Environmental Change*, *13*(5), 989–998. https://doi.org/10.1007/s10113-013-0412-z

Vescovi, L., Rebetez, M., & Rong, F. (2005). Assessing public health risk due to extremely high temperature events: climate and social parameters. *Climate Research*, *30*(1), 71–78. https://doi.org/10.3354/cr030071

Voelkel, J., Hellman, D., Sakuma, R., & Shandas, V. (2018). Assessing Vulnerability to Urban Heat: A Study of Disproportionate Heat Exposure and Access to Refuge by Socio-Demographic Status in Portland, Oregon. *International Journal of Environmental Research and Public Health*, *15*(4), 640. https://doi.org/10.3390/ijerph15040640

Wan, Z. (2013). Collection-6 MODIS Land Surface Temperature Products Users' Guide.

Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M., … Costello, A. (2018). The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *The Lancet*, *391*(10120), 581–630. https://doi.org/10.1016/S0140-6736(17)32464-9

Weber, S., Sadoff, N., Zell, E., & de Sherbinin, A. (2015). Policy-relevant indicators for mapping the vulnerability of urban populations to extreme heat events: A case study of Philadelphia. *Applied Geography*, *63*(1), 231–243. https://doi.org/10.1016/j.apgeog.2015.07.006

Weis, S. W. M., Agostini, V. N., Roth, L. M., Gilmer, B., Schill, S. R., Knowles, J. E., & Blyther, R. (2016). Assessing vulnerability: an integrated approach for mapping adaptive capacity, sensitivity, and exposure. *Climatic Change*, *136*(3–4), 615–629. https://doi.org/10.1007/s10584-016-1642-0

Westaway, K., Frank, O., Husband, A., McClure, A., Shute, R., Edwards, S., … Rowett, D. (2015). Medicines can affect thermoregulation and accentuate the risk of dehydration and heat-related illness during hot weather. *Journal of Clinical Pharmacy and Therapeutics*, *40*(4), 363–367. https://doi.org/10.1111/jcpt.12294

Wiesböck, L., Wanka, A., Mayrhuber, E. A.-S., Allex, B., Kolland, F., Hutter, H. P., … Kutalek, R. (2016). Heat Vulnerability, Poverty and Health Inequalities in Urban Migrant Communities: A Pilot Study from Vienna. In *Issues in Environmental Science and Technology* (Vol. 2021-Janua, pp. 389–401). https://doi.org/10.1007/978-3-319-24660-4_22

Wijayanto, T., Toramoto, S., Maeda, Y., Son, S. Y., Umezaki, S., & Tochihara, Y. (2017). Cognitive performance during passive heat exposure in Japanese males and tropical Asian males from Southeast Asian living in Japan. *Journal of Physiological Anthropology*, *36*(1), 1–11. https://doi.org/10.1186/s40101-016-0124-4

Williams, S., Venugopal, K., Nitschke, M., Nairn, J., Fawcett, R., Beattie, C., … Bi, P. (2018). Regional morbidity and mortality during heatwaves in South Australia. *International Journal of Biometeorology*, *62*(10), 1911–1926. https://doi.org/10.1007/s00484-018-1593-4

Wilson, B., & Chakraborty, A. (2019). Mapping vulnerability to extreme heat events: lessons from metropolitan Chicago. *Journal of Environmental Planning and Management*, *62*(6), 1065–1088. https://doi.org/10.1080/09640568.2018.1462475

Wolf, T., & McGregor, G. (2013). The development of a heat wave vulnerability index for London, United Kingdom. *Weather and Climate Extremes*, *1*(August 2003), 59–68. https://doi.org/10.1016/j.wace.2013.07.004

Wolf, T., McGregor, G., & Analitis, A. (2014). Performance Assessment of a Heat Wave Vulnerability Index for Greater London, United Kingdom. *Weather, Climate, and Society*, *6*(1), 32–46. https://doi.org/10.1175/WCAS-D-13-00014.1

Wong, C.-L. (2018). TREND OF DAILY RAINFALL AND TEMPERATURE IN PENINSULAR MALAYSIA BASED ON GRIDDED DATA SET. *International Journal of GEOMATE*, *14*(44), 65–72. https://doi.org/10.21660/2018.44.3707

World Meteorological Organization (2007). The Role of Climatological Normals in a Changing Climate, WCDMP-No. 61, WMO-TD/No. 1377 https://library.wmo.int/doc_num.php?explnum_id=4546

Yu, W., Vaneckova, P., Mengersen, K., Pan, X., & Tong, S. (2010). Is the association between temperature and mortality modified by age, gender and socio-economic status? *Science of the Total Environment*, *408*(17), 3513–3518. https://doi.org/10.1016/j.scitotenv.2010.04.058

Yusuf, A. A., & Francisco, H. A. (2009). Climate Change Vulnerability Mapping for Southeast Asia Vulnerability Mapping for Southeast Asia.

Zander, K. K., Cadag, J. R., Escarcha, J., & Garnett, S. T. (2018). Perceived heat stress increases with population density in urban Philippines. *Environmental Research Letters*, *13*(8). https://doi.org/10.1088/1748-9326/aad2e5

Zander, K. K., & Mathew, S. (2019). Estimating economic losses from perceived heat stress in urban Malaysia. *Ecological Economics*, *159*(June 2018), 84–90. https://doi.org/10.1016/j.ecolecon.2019.01.023

Zhang, J., Li, T. T., Tan, J. G., Huang, C. R., & Kan, H. D. (2014). Impact of temperature on mortality in three major Chinese cities. *Biomedical and Environmental Sciences*, *27*(7), 485–494. https://doi.org/10.3967/bes2014.080

Zhang, W., McManus, P., & Duncan, E. (2018). A Raster-Based Subdividing Indicator to Map Urban Heat Vulnerability: A Case Study in Sydney, Australia. *International Journal of Environmental Research and Public Health*, *15*(11), 2516. https://doi.org/10.3390/ijerph15112516

Zhao, Q., Coelho, M. S. Z. S., Li, S., Saldiva, P. H. N., Hu, K., Abramson, M. J., … Guo, Y. (2018). Spatiotemporal and demographic variation in the association between temperature variability and hospitalizations in Brazil during 2000–2015: A nationwide time-series study. *Environment International*, *120*(1), 345–353. https://doi.org/10.1016/j.envint.2018.08.021

Zheng, Y., Ren, C., Xu, Y., Wang, R., Ho, J., Lau, K., & Ng, E. (2018). GIS-based mapping of Local Climate Zone in the high-density city of Hong Kong. *Urban Climate*, *24*(1), 419–448. https://doi.org/10.1016/j.uclim.2017.05.008

Zografos, C., Anguelovski, I., & Grigorova, M. (2016). When exposure to climate change is not enough: Exploring heatwave adaptive capacity of a multi-ethnic, low-

income urban community in Australia. *Urban Climate*, *17*(1), 248–265. https://doi.org/10.1016/j.uclim.2016.06.003

Zuhra, S. S., Tabinda, A. B., & Yasar, A. (2019). Appraisal of the heat vulnerability index in Punjab: a case study of spatial pattern for exposure, sensitivity, and adaptive capacity in megacity Lahore, Pakistan. *International Journal of Biometeorology*, *63*(12), 1669–1682. https://doi.org/10.1007/s00484-019-01784-0