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Global Climate Change and Heat Wave Research from 2010 to 2019
- An Analytical Research Review -

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ABSTRACT

Purpose: This study seeks to identify major issues in heat wave vulnerability studies. As the average temperature on earth is continuously increasing, and the rate of increase is accelerating due to global warming caused by climate change, various studies have been conducted to diagnose heat wave-related vulnerabilities in cities; this is one of the phenomena that is most directly exacerbated by global warming. Among various research frameworks used to analyze heat waves, this study adopts the vulnerability evaluation framework proposed in the IPCC comprehensive report on climate change. **Method:** This study looks at an overall research trend in the field of climate change, which is vulnerability to heat waves. Using the SciVal tool, we collected and analyzed information on keywords, citation counts, and country of publication of published studies to confirm the overall trend of research in the field of climate change. Finally, this study analyzes relevant studies that investigated heat waves, vulnerability, and major issues in heat wave vulnerability. Google Academic aided in choosing studies published between 2010 and 2019. The following key words were used individually and in combination as inclusion criteria: heat wave, vulnerability, risk, climate change, heat index, multiple regression, machine learning, ANN, and deep learning. **Result:** A total of 23 papers were selected for the analysis. First, the methodological trends were categorized into four groups by purpose. The four purposes were vulnerable (hot) spot extraction, phenomenon review, analysis of heat-related indicators, and predictive model development. The studies mainly focus on developed countries rather than developing countries. Second, the material trends were categorized using the sectors of the IPCC vulnerability analysis framework, i.e. exposure, sensitivity, and adaptive capacity. The results showed that, in previous studies, many indicators were used in the sectors of exposure and sensitivity, while relatively few indicators were used in the sector of adaptive capacity.

KEYWORD

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1. Introduction

1.1. Research background and purpose

Recently, due to climate change, both the frequency and intensity of abnormal weather phenomena, such as heat waves, cold waves, extreme rain events, and droughts, has increased. Various changes in urban areas, such as rapid industrialization and urbanization, are known to be significantly accelerating the rate of increase[1]. If the average temperature of the earth continues to rise, it will become difficult to sustain everyday life in cities. In particular, abnormal urban thermal environments, such as heat waves and tropical nights, threaten the health of urban residents and cause health problems in cities around the world[2]. According to the two greenhouse gas scenarios RCP 8.5 and RCP 4.5 by the National Meteorological Research Institute[3], the average temperature on the Korean Peninsula is anticipated to rise by 6.0 and 3.4℃, respectively, at the end of the 21st century, i.e. 2070 to 2099, and the phenomena of heat waves and tropical nights will increase. Thus, it is necessary to establish a plan to minimize the impact of climate change in urban areas.

The Intergovernmental Panel on Climate Change (IPCC)[4] reports that Asian regions, including the Korean Peninsula, are more vulnerable to climate change than other regions. It is imperative that we prepare for the effects of climate change. In particular, the heat wave phenomenon, which is one of the most direct effects of global warming, causes socio-economic damage to cities and threatens the health of urban residents[1]. Establishing an appropriate heat wave response plan and a spatial planning system are important tasks for sustainable urban development.

This study seeks to identify major issues in heat wave vulnerability studies. It categorizes the major purposes, methods, and issues of relevant studies in the field of heat wave vulnerability. In addition, based on the trends that are identified

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in relevant studies, this study proposes directions for future studies with the aim of effectively responding to significant issues related to heat waves in the future.

1.2. Research method and scope

In order to analyze the trends in the latest climate change-related research, information from studies published from 2010 to 2019 was collected and analyzed, with a focus on the topics of climate change adaptation, urban climate, and adaptive capacity. Using the SciVal tool, we collected and analyzed information on keywords, citation counts, and countries of publication to confirm the overall trend of research in the field of climate change. The scope of this study was further specified using "vulnerability," "disaster," and "urban climate," which were derived as a result of keyword analysis. Depending on the scope of the identified studies, the final purpose of this study is to analyze the trend of research on vulnerability to disasters in cities due to climate change, especially heat wave vulnerability, which is the main focus of this study. This study compares and analyzes relevant studies that have investigated heat wave, vulnerability, and major issues in heat wave vulnerability. In particular, as part of the comprehensive climate change research trends analysis, we collected studies from various regions, including the five major countries listed in Table 1. (US, UK, Australia, Germany, China), and analyzed the trends of methods and materials in heatwave vulnerability-related research fields. Google Academic was used to help select studies published after 2010. The following key words were used individually and in combination as inclusion criteria: heat wave, vulnerability, risk, climate change, heat index (indices), multiple regression, machine learning, ANN, and deep learning.

After doing a keyword search for existing studies, the review process consisted of method and material analyses. When analyzing methods, we investigated the methods and approaches used in the selected studies to understand the study objectives. When analyzing materials, we also investigated the types of data used and variables that impacted vulnerability to heat waves.

2. Heat wave vulnerability concept

The IPCC is an intergovernmental consultative body on climate change whose mission is to assess the threat of climate change to human activities. The IPCC regularly publishes reports on climate change; it has published five comprehensive reports on climate change to date. The fifth and most recent report was issued in 2014; the sixth report will be published in 2022. One of the most remarkable aspects of the transition between the 4th report, issued in 2007, and the 5th report, in 2014, was that the climate change impact assessment framework was altered. It changed from a vulnerability-oriented framework[5][6] to a risk-oriented framework[7]. The vulnerability assessment framework was largely defined as a function of exposure, sensitivity, and adaptive capacity. The risk assessment framework, on the other hand, is defined as a function of hazard, exposure, and vulnerability. Table 1. shows the detailed contents of the vulnerability and risk assessment frameworks.

Although the most recent IPCC research framework is risk-based, many studies have been conducted from the point of view of climate change vulnerability. Thus, this study adopts the vulnerability assessment framework that was the content of the 4th report (2007) to analyze previous studies(see Fig. 1.).

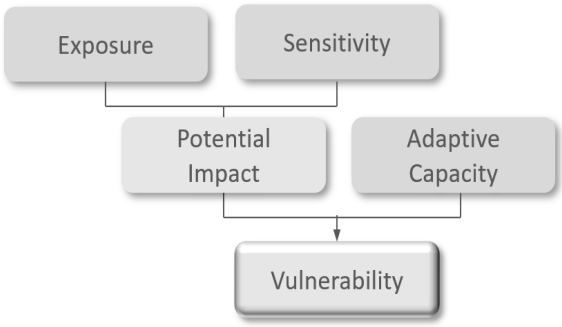

Fig. 1. Vulnerability assessment framework (IPCC, 2007)

Table 1. IPCC Framework[2,4,5,7]

Frameworks	Indicator Sector	Definition
Vulnerability Assessment	Exposure	• Contact of a person with one or more biological, psychosocial, chemical, or physical stressors, including the causes of stress
	Sensitivity	• Extent to which the community or people living in it are affected by climate change
	Adaptive capacity	• Ability for communities, institutions, and people to adapt and respond to potential damage from climate change
Risk Assessment	Hazard	• Stress that communities can experience due to climate change
	Exposure	• Extent to which property and people are physically exposed to hazard
	Vulnerability	• Degree to which a person or community is susceptible to hazard

3. Analysis of research trends in the field of climate change

In order to visualize trends in the latest climate change-related research, information from papers published between 2010 and 2019 was collected and analyzed with a focus on the areas of climate change adaptation, urban climate, and adaptive capacity. The SciVal tool and Scopus data were used for the analysis. For qualitative and quantitative analysis of research trends, information on keywords, citation counts, and countries of publication was collected.

SciVal uses the Elsevier Fingerprint Engine to identify important keywords by applying a variety of natural language processing techniques to analyze the data on publications, titles, abstracts and author keywords of documents in a subject or cluster of subjects. The method uses a text mining technique and extracts a standardized keyword list for each publication to derive important keywords based on inverse document frequency (IDF) analysis.

Fig. 2. shows the top 50 keywords related to climate change adaptation, urban climate, and adaptive capacity, which were identified based on a total of 6,112 publications. In Fig. 2., the size of the words represents their relevance and green represents an increasing trend year-over-year. Accordingly, when the contents of Fig. 2. are summarized, the overall trend of publication from 2010 – 2019 in climate change-related research fields increased, and the most influential keywords were vulnerability, climate change adaptation, and resilience.

In order to investigate trends according to a more specific research scope, an additional analysis was performed on countries/regions with the largest academic output related to the keywords vulnerability, disaster, and urban climate. The findings showed that the greatest number of papers were contributed by the US, UK, Australia, Germany, and China, in decreasing order (see Table 2.). Analyzing the number of publications by year using the same keywords confirmed that the publications were concerned with vulnerability, disaster, and urban climate. In particular, the keywords vulnerability and disaster showed a tendency to increase gradually, and all three keywords showed a tendency to increase in 2019 compared to 2018 (see Fig. 3.).

Fig. 2. Analysis of research trends in the field of climate change (2010 – 2019)

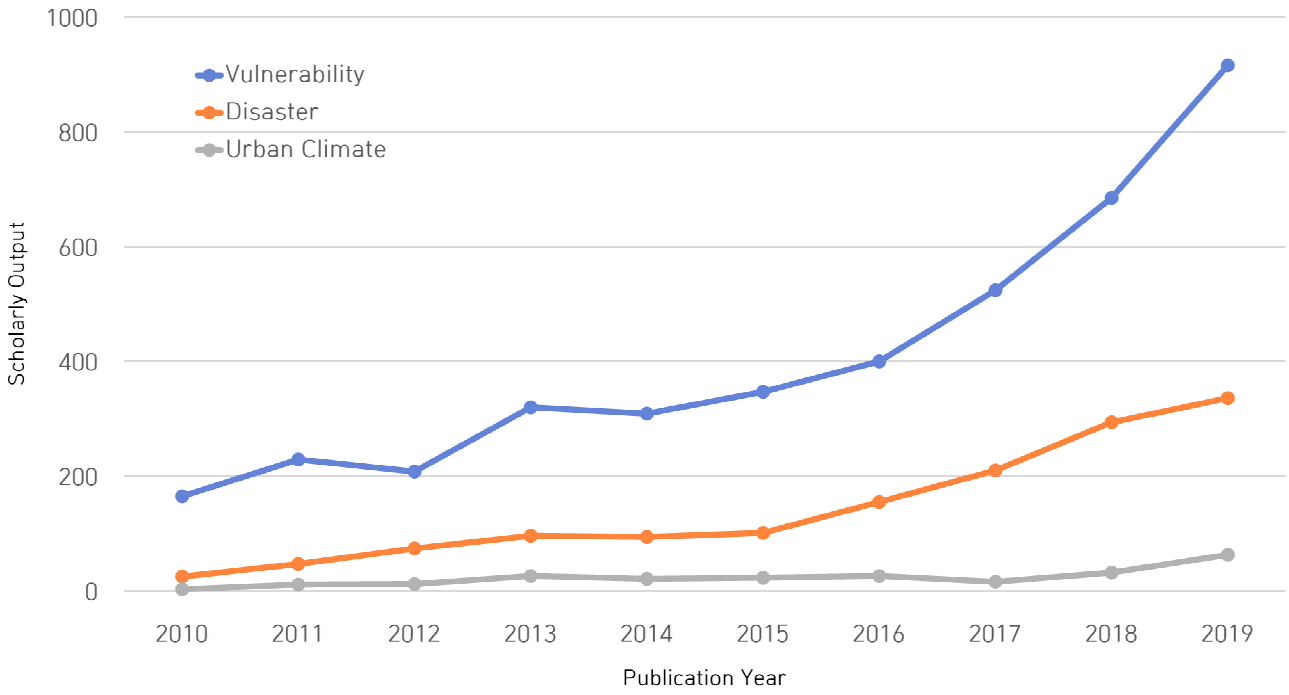

Fig. 3. Analysis of climate change research trends by year (2010 – 2019)

Table 2. Top five countries and regions by scholarly output

Countries/Regions	Scholarly Output
United States	603
United Kingdom	394
Australia	310
Germany	208
China	194

This chapter analyzes trends in urban climate change research from 2010 to 2019. Given that the number of publications containing the keywords vulnerability and disaster gradually increased over the past 10 years, we can conclude that vulnerability to disasters caused by climate change is a major global issue and an area of intense interest. This confirms the significance of the analysis of the latest trends in research in the field of heatwave vulnerability, which is the final purpose of this study.

4. Trends in Heat Wave Vulnerability Studies

This paper compares and analyzes the papers identified through Google Academic using a combination of heatwave, vulnerability, and other related keywords to examine in detail the trends in research on heatwave vulnerability. As in Chapter 3, the analysis was conducted mainly on papers published from 2010 to the present. Papers from various regions including the top five countries (USA, UK, Australia, Germany, and China) with the highest contributions were reviewed as a result of the study in Chapter 3.

20 papers were identified through the search for relevant studies. The papers were analyzed to identify major issues and topics in methods and materials.

4.1. Methodological trends in heat wave vulnerability studies

The analysis of 20 papers mainly categorized the content by research methodology into four major groups. The four categories were vulnerable (hot) spot extraction, phenomenon review, analysis of heat-related indicators, and predictive model development. Table 3. summarizes the four categories. The category of vulnerable (hot) spot extraction includes studies that identify hot spots that are vulnerable to heat waves, or areas that are extremely hot. The category of phenomenon review includes studies that review the characteristics of heat wave phenomena. The category of heat wave index analysis includes studies that extract heat-related indicators and examine correlations between those indicators.

Table 3. The four categories of heat wave-related studies

Purposes	Test bed (Site)	Year	References
Vulnerable (hot) spot extraction	London	2013	[8]
	Seoul	2016	[9]
	Seoul	2018	[10]
Phenomenon review	Germany, Australia	2018	[11]
	China, East Asia, South Asia, Sub Saharan Africa, Latin America, Europe	2019	[12]
Heat-related index analysis	Porto	2013	[13]
	A total of 63 meteorological observation points in South Korea	2014	[14]
	Seven cities in the United States (Boston, Minneapolis, Philadelphia, Phoenix, Seattle, St. Louis)	2015	[15]
	South Korea	2016	[16]
	Shanghai	2019	[17]
Prediction model development	South Korea	2016, 2019, 2011	[18-20]
	China	2015, 2019	[21, 22]
	New Zealand and Australia	2015, 2020	[23, 24]
	Montreal	2017, 2014	[25, 26]
	Pakistan	2019	[27]

Recent studies in the category of prediction model development have incorporated statistical, multiple regression (MR), machine learning (ML), and deep learning techniques and information from various fields. Accordingly, this category includes studies that aim to develop a predictive model by grafting various techniques onto heat wave and related indicator datasets. Table 4. summarizes the contents of these studies.

According to Tables 3. and 4., the test bed or sites analyzed by the relevant studies, and their corresponding methodology and focus, were mainly located in developed countries. According to the year of publication (Table 3.), most of the studies in the categories of prediction model development were published in more recent years than those in the other three categories. Additionally, according to Table 4., recent studies on heat wave prediction model development adopted relatively diverse statistical, machine learning, and deep learning-based techniques. For example, the most recently published study [27]

developed a predictive model that describes thermal phenomena by grafting one of the deep learning techniques, the long short-term memory network (LSTM) technique, onto the heat island phenomenon. Recent studies of heat waves and heat wave vulnerabilities frequently sought to combine various statistical techniques and machine learning techniques, and have expanded to deep learning techniques.

4.2. Material trends in heat wave vulnerability studies

The urban component indicators used in the 23 papers were quite varied. We extracted and classified the indicators using the sectors of the IPCC vulnerability analysis framework, i.e. exposure, sensitivity, and adaptive capacity (Fig. 1.). We also identified the trend of utilization of indicators in the field of heat wave studies(Table 5.). However, because two papers[11, 12] reviewed studies relevant to the phenomenon of heat waves, we excluded them from this classification process. Table 5. summarizes the analysis of relevant indicators in heat wave studies.

Table 4. Techniques and test sites of papers in the prediction model development category

Techniques	Test bed (Site)	Year	References
Statistical	Forty-five stations evenly distributed in South Korea	2016	[18]
	South Korea	2019	[19]
ML (Single model development, multiple model comparison)	Shanghai	2015	[21]
	Ten locations in Australia and New Zealand	2016	[23]
	Montreal	2017	[25]
	China (7 hot regions, including Shanghai)	2019	[22]
	Pakistan (one of the regions most vulnerable to heat waves; thousands of people died from heat in 2015 and 2017)	2019	[27]
MR, ML comparison	Changwon, South Korea	2011	[20]
	Montreal	2014	[26]
Deep learning	Sydney	2020	[24]

According to Table 5., studies of heat wave vulnerability most frequently use indicators related to climate exposure and sensitivity. Moreover, the exposure sector most frequently uses indicators related to external temperature, wind, and heat wave definitions. In the sensitivity sector, population (age)-related indicators are used most frequently, followed by health-related indicators. Finally, in the sector of adaptive capacity, the green areas and medical services indicators are used most frequently.

Table 5. Analysis of indicators in heat wave studies

Sector	Type	Index	References
Exposure	External temperature	max temperature, min temperature, average temperature.	[8, 10, 14, 18-27]
	Building temperature	dry-bulb temperature, location of indoor temperature measurement	[25]
	Related humidity	-	[25]
	Wind	speed, direction	[21, 22, 24, 26, 27]
	Air condition	intensity of cold air flow, Barometric pressure, Ozone density	[10]
	Solar	gain, radiation	[25, 26]
	Geopotential height	-	[27]
	Building geometry	aspect ratio, building volume	[9, 25-27]
	Housing density	building density	[8]
	Land use type	percentage of impermeable area, density of roads	[10, 17, 20, 22]
	Heat wave	intensity, duration, frequency	[9, 10, 17-19, 27]
	Tropical night	-	[10, 19]
	Heat island intensity (UHI)	-	[24]
Sensitivity	Population	age: over 65 or under 5, being elderly and isolated	[8-10, 13-15, 18, 19, 22]
		gender	[13, 19]
		ethnicity: white, black, American Indian, Asian, Pacific Islander	[15]
	Population density	-	[10, 19, 22]
	Health	morbidity, mortality	[13, 14, 16, 18, 19, [21, 22]

Sector	Type	Index	References
	Occupancy	occupants' pattern of activities, heat gain due to occupancy	[25, 26]
	Socioeconomic factors	economic ability : GDP, poor welfare dependency, Percent of residents living in poverty, Internet penetration rate, welfare recipients, basic livelihood recipient ratio, housing without central heating, Night-time-light,	[8, 9, 15-17, 19, 23]
		health condition: proportion of disabled people, percent of residents with public assistance for disability	[8, 10, 15]
		Job, Education: Laborer rate, number of micro start-up business, Proportion of non-agricultural registered permanent residence, Proportion of illiterate population, residents over age 25 without a high school diploma	[10, 15, 19, 22]
	Building condition	Buildings built before 1940, Buildings built before 1970, Building completed before 1980, housing without central heating	[8, 9, 15]
Adaptive capacity	Green areas	vegetation ratio, park areas	[9, 15, 17, 22, 25]
	Wet land	areas, distance from riparian sites	[9, 15]
	Heat shelter	number of heat shelters, distance from heat shelters	[9, 10]
	Financial independence	-	[16]
	Regional development level	-	[15]
	Sea level pressure	-	[27]
	Social welfare facilities	number of leisure facilities for the elderly	[16]
	Medical service	health center personnel, number of beds in hospitals, Availability of medical resources	[10, 16, 17]

5. Discussion and Conclusion

In order to analyze the trends in the latest climate change-related research, information from studies published from 2010 – 2019 was collected and analyzed, with a focus on the topics of climate change adaptation, urban climate, and adaptive capacity. The scope of this study was made more concrete by focusing on the keywords vulnerability, disaster, and urban climate among the keywords identified by the climate change research trend analysis. As a result, five countries that frequently publish climate change-related research were identified, and the scope of the research was specified as heatwave and vulnerability. Accordingly, 20 papers were collected from Google Academic through a combination of various keywords related to heat wave vulnerability research in major regions, including the five regions derived from the results of climate change trend analysis.

Through a review of 20 publications thus identified, this study demonstrated the most recent methodological and material trends in heat wave vulnerability. The trends in Tables 3. and 4., which examine the study sites of the 20 studies, showed that most of those studies focused on sites in developed countries. However, developing countries are more vulnerable to the negative effects of heat waves than developed countries. An insufficient amount of work has been done in developing countries. It might be more difficult to collect data in developing countries due to local conditions. Or, researchers in developed countries might not be interested in issues that are primarily relevant to developing countries.

According to the analysis of methodological trends, recent studies on predictive model development have used various machine learning and deep learning techniques. Predictive models are necessary to effectively respond to the phenomenon of heat waves. Accordingly, the accuracy of predictions should be increased, and high-performance models should continue to be developed. According to the findings in material trends, the indicators used in the chosen papers are overwhelmingly concerned with the sectors of exposure and sensitivity, and relatively less concerned with the sector of adaptive capacity. Accordingly, we suggest that it is necessary to conduct more studies on the development of indicators in the sector of adaptive capacity. Also, the indicators used in those studies vary by region. It would be helpful to establish a comprehensive list of indicators in order to develop a plan to respond to heat wave vulnerabilities. Continuously development of optimal indicators for local conditions is also important.

Climate change is accelerating worldwide. Accordingly, the damage caused by unusual heat wave phenomena is emerging. It

would be helpful to prepare locally optimized measures for each region and to develop a regional heat wave prediction model based on those locally optimized measures. A list of input indicators that could be used in heat wave prediction models and their associated vulnerabilities will be necessary to consider regional characteristics. Since it is important to understand the true extent and effects of heat waves and the regional characteristics of the phenomenon, practical response strategies and adaptation techniques for heat waves should be prepared for each region.

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Reference

[1] X. Yang et al., Environmental consequences of rapid urbanization in Zhejiang Province, East China. International journal of environmental research and public health, 2014, pp.7045-7059.
[2] J.L. Gamble et al., Ch. 9: Populations of concern, USA:US Global Change Research Program, 2016, pp.247-286.
[3] 국가기후변화적응센터, 기후변화 新시나리오(RCP)소개 - RCP 소개, 국가기후변화적응정보포털, https://kaccc.kei.re.kr/portal/climateChange/changeview/changeview_view.do?num=6, 2020.07.01. // (Korea adaptation center for climate change, climate change new scenario (RCP) introduction - RCP introduction, national climate change adaptation information portal.)
[4] IPCC, Climate Change 2007: Impacts, Adaptation and Vulnerability, contribution of working group II to the fourth assessment report of the intergovernmental pannel on climate change, Cambridge, UK:Cambridge University Press, 2007.
[5] R. Thupalli et al., An investment strategy for reducing disaster risks and coastal pollution using nature based solutions, 2018, p.153.
[6] T. Fellmann, The assessment of climate change-related vulnerability in the agricultural sector: reviewing conceptual frameworks. Building resilience for adaptation to climate change in the agriculture sector, 23, 2012, p.37.
[7] IPCC, Climate Change 2014: Mitigation of Climate Change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge UK and New York, USA:Cambridge University Press, 2014.
[8] T. Wolf, G. McGregor, The development of a heat wave vulnerability index for London, United Kingdom. Weather and Climate Extremes, 2013, 1, pp.59-68.
[9] 엄정희, 공간계획 활용을 위한 도시 열환경 취약성 연구 - 서울시를 사례로, 한국조경학회지, 2016, 제44권 제4호, pp.109-120. // (J. H. Eum, Vulnerability assessment to urban thermal environment for spatial planning - a case study of Seoul, Korea. Journal of Korean Institute of Landscape Architecture, 44(4), 2013, pp.109-120.)
[10] 최예술, 김재원, 임업. 서울시 폭염 취약지역의 공간적 패턴 및 적응능력 취약지역 분석. 국토계획, 2018, 제53권 제7호, pp.87-107. // (Y. S. Choi, J. W. Kim, U. Lim, An analysis on the spatial patterns of heat wave vulnerable areas and adaptive capacity vulnerable areas in Seoul. Journal of Korea Planning Association, 53(7), 2018, pp.87-107.)
[11] W. Leal Filho et al., Coping with the impacts of urban heat islands. A literature based study on understanding urban heat vulnerability and the need for resilience in cities in a global climate change context. Journal of Cleaner Production, 171, 2018, pp.1140-1149.
[12] H. Green et al., Impact of heat on mortality and morbidity in low and middle income countries: a review of the epidemiological evidence and considerations for future research. Environmental research, 171, 2019, pp.80-91.
[13] A. Monteiro et al., The accuracy of the heat index to explain the excess of mortality and morbidity during heat waves–a case study in a mediterranean climate. Bulletin of Geography. Socio-economic Series, 20(20), 2013, pp.71-84.
[14] 정지훈 외 4인, 우리나라 지역별 고온극한 현상에 의한 사망 취약도 비교. 대한지리학회지, 2014, 제49권 제2호, pp.245-263. // (Jung et al., Study on the vulnerability regarding high temperature related mortality in Korea. Journal of the Korean Geographical Society, 49(2), 2014, pp.245-263.)
[15] D. M. Hondula et al., Geographic dimensions of heat-related mortality in seven US cities. Environmental research, 138, 2015, pp.439-452.
[16] 김태호, 백종인, 반영운, 폭염으로 인한 건강 피해와 사회 · 경제적 요인 간 관계분석. 한국위기관리논집, 제12권 제5호, 2016, pp.67-78. // (T.H. Kim, J.I. Baek, Y.U. Ban, Analyzing the Relationship between Health Damage Caused by Heat Wave and Socioeconomic Factors. Crisisonomy, 12(5), 2016, pp.67-78.)
[17] C. He et al., Exploring the mechanisms of heat wave vulnerability at the urban scale based on the application of big data and artificial societies. Environment international, 127, 2019, pp.573-583
[18] D.W. Kim et al., Projection of heat wave mortality related to climate change in Korea. Natural Hazards, 80(1), 2016, pp.623-637.
[19] D.W. Kim et al., Weekly heat wave death prediction model using zero-inflated regression approach. Theoretical and Applied Climatology, 137, 2019, pp.823-838.
[20] 이슬기 외 4인, 인공신경망을 이용한 도시기온 예측모형 구축. 국토계획, 제46권 제1호, 2011, pp.129-142. // (Lee et al., A Predictive Model for Urban Temperature using the Artificial Neural Network. Journal of Korea Planning Association, 46(1), 2011, pp.129-142.)
[21] G. Meng et al., Meteorological factors related to emergency admission of elderly stroke patients in shanghai: analysis with a multilayer perceptron neural network. Medical science monitor: international medical journal of experimental and clinical research, 21, 2015, pp.3600-3607.
[22] Y. Wang et al., A random forest model to predict heatstroke occurrence for heatwave in China. Science of the Total Environment, 650, 2019, pp.3048-3053.
[23] S. Salcedo-Sanz, et al., Monthly prediction of air temperature in Australia and New Zealand with machine learning algorithms. Theoretical and applied climatology, 2016, 125, pp.13-25.
[24] G.Y. Yun et al., Predicting the magnitude and the characteristics of the urban heat island in coastal cities in the proximity of desert landforms. The case of Sydney. Science of The Total Environment, 709, 2020.
[25] A. Mohajerani, J. Bakaric, T. Jeffrey-Bailey, The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. Journal of Environmental Management, 197, 2017, pp.522-538.
[26] A. Ashtiani, P. Mirzaei, F. Haghighat, Indoor thermal condition in urban heat island: Comparison of the artificial neural network and regression methods prediction. Energy and buildings, 76, 2014, pp.597-604.
[27] N. Khan et al., Prediction of heat waves in Pakistan using quantile regression forests. Atmospheric Research, 221, 2019, pp.1-11.

