

Analysis on relationship between spatial characteristics and heat wave

Bong-Geun SONG , Kyung-Hun PARK, Kyeong-Ho SEO, Gyeong-Ah KIM and Chang-Hwan KIM

Abstract: This study analyzed heat wave factors using spatial and climate data from Miryang, Korea, which has been highlighted for its urban heat-island and heat waves. Results indicated that the number of heat wave days occurred the most was on average 31.4 days in 2000, and this was followed by 26.9 days in 2008, 24.2 days in 2001, and 24.0 days in 2010. Analyzing the relationship between spatial types and the heat wave index while considering topography and land cover revealed that heat waves occurred frequently in the area with larger cropland.

Keywords: Heat wave, land cover, Topographic Position Index (TPI)

1. Introduction

Occurrence frequency and scale of damage of natural disaster has been gradually increasing due to the recent global climate change. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) published in 2007, it estimated the average temperature increase by the end of 21st century was up to 6.4°C, as a consequence, occurrence frequency, intensity and duration of heat waves would be increased (IPCC, 2007). Heat waves have adverse effects on the whole society, not only by causing tropical nights which induce adverse health effects on human body such as insomnia and stress but also by bringing energy problem due to increase of electricity consumption, outbreak of forest fires and deterioration of air pollution. Frequency of heat wave occurrence has been increasing in Korea as well, hence, continuous effort to establish measures for responding to this situation is needed. Accordingly, this study discovered environmental planning measures for the continuous improvement by analyzing heat wave factors using spatial and climate data of Miryang which has been focused for its urban heat-island and heat waves in Korea.

Kyung-Hun Park

Changwon National University 20 Changwondaehak-ro

Uichang-gu Changwon-si, Gyeongsangnam-do, Korea

E-mail address : landpkh@changwon.ac.kr

2. Methodology

2.1. Study process

This study was executed as presented in Figure 1. Heat wave data have been organized by counting the days of daily average temperature of 33°C or more, which was constructed chronologically from the detailed climate data of South Korea between 2000 and 2010 with 1 km x 1 km spatial resolution, provided by the National Institute of Meteorological Sciences (NIMS). Spatial data were constructed by reclassifying types, e.g. built-up, agricultural, forest, water and pasture/bare areas, using land cover maps in 2000, 2005 and 2010. Furthermore, Topographic Position Index (TPI), which represents geological characteristics, was analyzed by introducing digital elevation model with 30 m x 30 m spatial resolution. In sequence, heat wave days, reclassified land cover map and TPI were marked within 1 km x 1 km vector grid which was same as the spatial resolution of heat wave days.

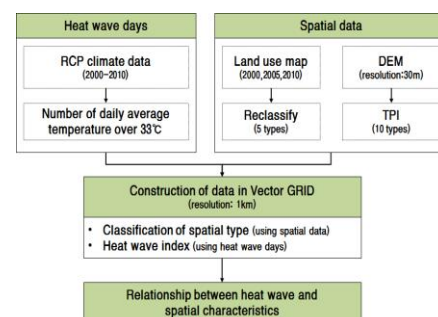


Figure 1. Study process

Heat wave days were standardized in order to provide the equivalent assessment condition for each year, while land cover map and TPI were classified through cluster analysis. Finally, constructed data were used for deriving relationship between heat wave and spatial characteristics, in addition, measures for improving heat wave were investigated.

2.2. Data collection

2.2.1 Heat wave days

South Korean detailed climate data based on the Representative Concentration Pathways (RCP) scenarios among detailed climate change forecast of Korean peninsula provided by NIMS were utilized in order to construct heat wave days data. Construction process of South Korean detailed climate data were: 1) global base climate change prediction scenario with spatial resolution of 135 km x 135 km was produced by applying artificial climate change forcing on the HadGEM2-AO (coupled Atmosphere Ocean model of Hadley Centre Global Environmental Model Version 2), a global forecast model, developed by Met Office Hadley Centre of UK; and 2) climate change scenario of Korean peninsula with spatial resolution of 12.5 km x 12.5 km was developed through regional downscaling by using HadGEM3-RA (Atmosphere Regional climate model of HadGEM3), a regional climate model. In order to construct a more detailed data, South Korean detailed climate data with 1 km x 1 km spatial resolution has been produced by; 1) correcting the deviation of a model on the seasonal climate values of grid shaped monitoring data produced by Modified Korean (MK)-Parameter Elevation Regression and Independent Slope Model (PRISM), and 2) employing PRIDE model, a statistical downscaling technique which produces high resolution climate change forecast (Park et al., 2013).

In this study, after obtaining daily temperature data from 2000 to 2010 from South Korean detailed climate data constructed by using the process stated above, the days of daily highest temperature of 33°C or more were counted followed by the construction of heat wave days data by year.

2.2.2 Land cover and TPI

Data constructed in 2000, 2005 and 2010 were utilized for the land cover maps. Land cover map data for 2000 were provided by the National Water Resources Management Information System (WAMIS) which classified the land cover properties by using Landsat 7 ETM images with 30 m x 30 m spatial resolution (<http://www.wamis.go.kr>). Land cover properties were classified into 8 types, e.g. built-up, rice paddy, dry farm, etc. Medium level land cover map with spatial resolution of 5 m x 5 m classified by the Ministry of Environment were utilized for the 2005 and 2010 data, which have been constructed based on the satellite images, aerial photographs and field surveys. Land cover properties were subdivided into 22 items, e.g. residential, industrial, orchard, etc. Land cover properties in 2000, 2005 and 2010 needed to be reclassified since they were different to a certain degree. Land cover properties of 2005 and 2010 were reclassified, on the basis of 2000 land cover properties. into 5 types, such as built-up, agricultural, forest, pasture/bare, and water areas. TPI analysis is as follows. Topographic patterns were classified through the analysis of topographic position index with using digital elevation model of 30 m grid level spatial resolution. TPI is a classification method that categorizes into 10 types, e.g. ridge, valley, steep slope, mild slope, flatland, etc. on the basis of elevation and slope, which is analyzed by overlapping based on a large neighborhood slope position classification (LN), a small neighborhood slope position classification (SN) and a gradient (Park et al., 2007; Sermin, 2008; Song and Park, 2010). This used ArcView 3.2a with TPI extension for the analysis, and discovered TPI by setting up SN as 100 m and LN as 300 m in the light of previous research and topographic characteristics.

3. Results and Discussion

3.1 Characteristics of Heat wave days

The results of heat wave days analysis are shown in Figure 2. Area of heat wave days occurred the most has varied by year, however, it was discovered that relatively high heat

wave days were occurred in the area of large cropland. Moreover, it was identified that heat wave has been frequently occurred in some valley areas of Sannae-myun compared to surrounding areas. It was revealed that the number of heat wave days occurred the most was, on average, 31.4 days in 2000, and followed by 26.9 days in 2008, 24.2 days in 2001 and 24.0 days in 2010.

3.2 Construction of land cover and TPI

As a result of scrutinizing the changes of land cover

patterns by year (Figure 3), the area of cropland increased the most by 46.59 km² and followed by built-up area increased by 25.67 km². On the other hand, it was confirmed that forest area has been decreased by 50.05 km² due to the development, which resulted the increase of built-up and agricultural areas. It was discovered from TPI that mountainous area dominated the area since there were more slope land (51.6%) than flatland (19.7%). Especially, it was identified that large valley area (12.2%) was distributed in the eastern and part of the western region of Miryang.

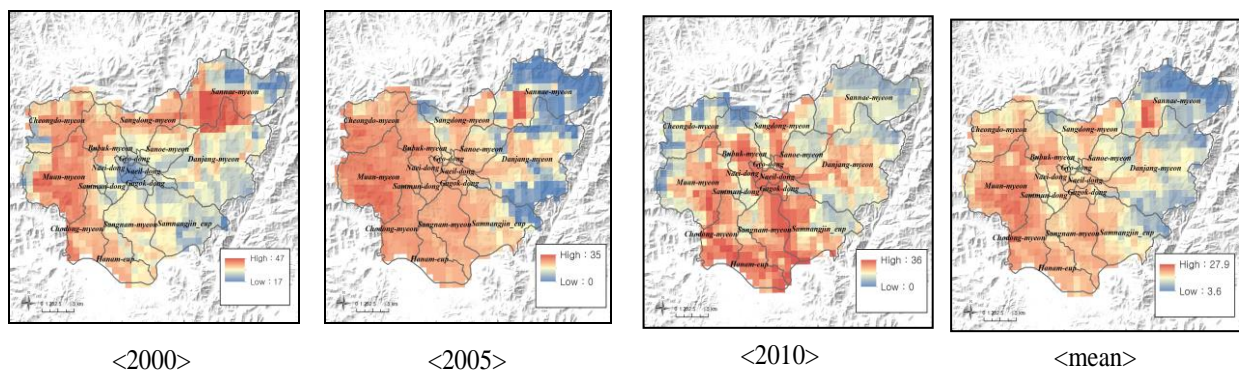


Figure 2. Distribution of heat wave days

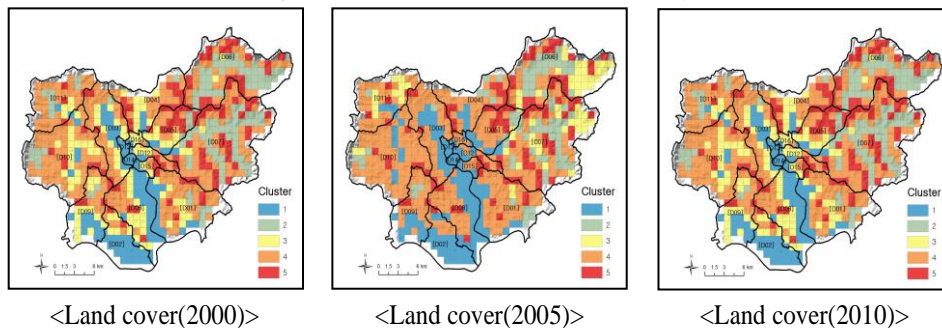


Figure 3. Distribution of spatial types

3.3 Result of spatial type classification

As a result of classifying spatial types (Figure 4), cluster 1 is mainly located in the flatland, and it has more built-up area than other cluster types. Cluster 2 is classified as a type of being distributed in valley area or in the part of slope land mostly occupying large area of forest. Cluster 3 shows diverse characteristics by year: 1) in 2000, it is a mixed land cover type located in slope land of which the cropland area is somewhat larger than the forest; 2) in 2005, it is a type of being distributed in the valley and slope land of which the forest and

cropland are mixed; and 3) in 2010, it is being distributed in the slope land and flatland of which cropland and forest are mixed. Cluster 4 is a type of being located in slope land where the large area is occupied by the forest. Cluster 5 is classified as the forest area being located in ridge and slope land.

3.4 Relationship between spatial characteristics and heat waves

In 2000, cluster 1 type, which was located in flatland with large built-up surface area, showed the lowest heat wave

index, 53.17. It seems that the influence on built-up area was not significant since the urbanization has not been progressed enough. In addition, the difference in heat wave index depending on the spatial types was not significant. Heat wave index of cluster type 1 was 74.29, which was highest compared to other spatial types, followed by the cluster type 4, 66.38, which was located in the slope land with many land cover of forest and cropland areas. Whereas, cluster type 3, which was located in the valley and slope land within the boundary of forest and cropland, showed the lowest heat wave index, 38.30. In 2010, same as 2005, cluster type 1, which was located in flatland with many built-up and cropland areas, exhibited highest heat wave index, 85.29. It was followed by the cluster type 3, which was located in flatland and slope land and also located in the boundary of forest and cropland, of which the heat wave index was 71.20. It was identified that cluster type 4 and 5, which had a large area of forest, showed the lowest heat wave index of less than 50.

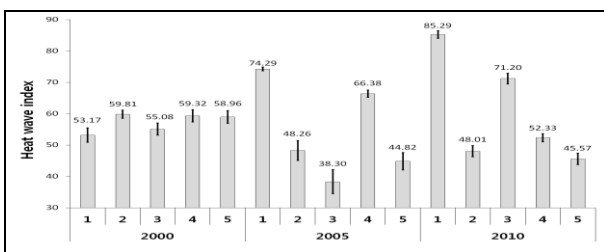


Figure 4. Characteristics of heat wave index by each clusters

From the result as stated above, it was discovered that the heat wave effect occurred frequently as more agricultural area was included. It is believed that it is caused by the anthropogenic heat radiated from green house facilities which are widely distributed on flatland. Furthermore, when comparing the heat wave index of cluster 1 in 2000, 2005 and 2010, it is revealed that heat wave effect increases due to the increase of surface area of built-up region.

4. Conclusions

This study analyzed heat wave factors using spatial

and climate data of Miryang, Korea, which has been highlighted for its urban heat-island and heat waves. As a result, heat wave has been frequently occurred in the area with widely distributed croplands, moreover, it seems that it was largely influenced by green houses, such as plastic film houses. Furthermore, it implies that it was partly influenced by the topography of nearby areas. The cause of heat wave occurrence in the light of wind flows through climate modelling analysis needs to be investigated in the future studies.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (No. NRF-2016R1A2B4015460).

References

- IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA
- Park, C.Y., Choi, Y.E., Kwon, Y.A., Kwon, J.I., and Lee, H.S. 2013. Studies on Changes and Future Projections of Subtropical Climate Zones and Extreme Temperature Events over South Korea Using High Resolution Climate Change Scenario Based on PRIDE Model. *Journal of The Korean Association of Regional Geographers* **19(4)**:600-614.
- Park, K.H., Kim, K.T., Gwak, H.G., and Lee, W.S. 2007. A Prediction of Forest Wetland Distribution using Topographic Position Index. *Journal of Korea Association Geographic Information Studies* **10(1)**:194-204.
- Sermin T. 2008. GIS-Based Automated Landforms Classification and Topographic, Landcover and Geologic Attributes of Landforms Around the Yazoren Polje, Turkey. *Journal of Applied Sciences* **8(6)**:910-921.
- Song, B.G. and Park, K.H. 2010. An Analysis of Cold Air Generation Area Considering Climate-Ecological Function. *Journal of Korea Association Geographic Information Studies* **13(1)**:114-127.