A COMPARATIVE ANALYSIS ANALYSIS OF URBAN TEMPERATURE(AIR/SURFACE) AND HEAT ISLAND INTENSITY USING S·DOT AND LANDSAT8 IN SEOUL OF SOUTH KOREA

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1. Introduction

1.1 Background and purpose of the study

More than half of the world's population lives in cities, and according to the United Nations, about 70% of the world's population will live in urban areas by 2050, given the current trajectory of urban growth. (United Nations, 2010) The growth of these cities causes climate change and aggravates abnormal weather phenomena such as heatwaves. This heatwave phenomenon causes the Urban Heat Island (UHI) phenomenon, which is one of the phenomena that occurs with the progress of urbanization, which refers to a phenomenon in which the air and surface temperature in the downtown area are higher than in the surrounding areas. (JA Voogt TR Oke, 2003) The UHI phenomenon worsens the urban environment, such as heatwaves and tropical nights, and threatens the life and health of urban residents. As a result, about 50% of the population is concentrated in the metropolitan area, which is about 10% of the national land area, and various urban problems such as an imbalance in national land development and the UHI phenomenon are occurring mainly in the metropolitan area. As a result, the average outdoor temperature was 13.5℃ in the 2019s, 1.1℃ higher than in the 1960s, and it is a continuous increase. It affects the climate change and the natural environment of downtown areas, impairs the quality of the urban environment, and threatens the health of urban residents. If the city's temperature continues to rise and climate change and destruction of the natural environment intensify, the quality of the urban environment may be compromised, which will endanger the health and life of city residents. Accordingly, from 2020, through the Smart Seoul Urban Data Sensor (S·DoT) construction project, the city of Seoul is building an industrial ecosystem using policies and city data to solve urban problems and improve citizens' lives. Therefore, this study aims to present the possibility of using urban data sensors (S·DoT) by examining the temperature of Seoul and the surface temperature data of LANDSAT8, calculating and comparing the thermal island intensity of the air temperature and the surface temperature.

1.2 Scope and Method of Study

1.2.1 Scope of the study

The spatial extent is Seoul, the capital of the Republic of Korea located in Asia. Seoul is the tallest city in Korea, 497 km long and 1-1,5.m wide, in the form of a basin crossed by the Han River. It covers an area of 605.24 and consists of 25 autonomous districts and 426 administrative dongs, with a population of 9.55 million.

The temporal range is March 30, 2021. The city data sensor used in this study was installed in March 2020 and data is provided from April 2020. In the case of Landsat 8 satellite imagery, data is provided at a cycle of 16 days The temporal range of this study were selected based on the image data of March 30, which was the lowest at 0.02% among the six days with less than 10% cloudiness among 21 years.

The content range is to figure out the difference between the heat island intensity of Seoul using city data sensor S·DoT and national meteorological observation and the heat island intensity of Seoul using LANDSAT8.

1.2.2 Method of study

First, research directions were established by investigating the characteristics and prior studies of S·DoT sensors through theories and literature related to urban heat island phenomena. Second, each heat island intensity is calculated by obtaining the surface temperature and air temperature except for the aquatic area, conservation mountain area, and natural green area through the LANDSAT8 image, S·DoT air temperature data, and national weather observation (AWS) data. Since S·DoT is installed only in Seoul and there is no data on the outside of Seoul, in this study, S·DoT in urban areas and AWS in the suburban areas were used to calculate heat island intensity. (Park Haekyung, 2021)

Finally, the temperature of Seoul is examined through the S·DoT air temperature data of administrative districts with three or more S·DoT and the land surface temperature data of LANDSAT8, and the heat island intensity of the air temperature and the heat island intensity of the surface temperature are compared.

2. Review of urban heat island phenomenon and previous research in Seoul

2.1 Definition and Characteristics of Heat Island

The urban heat island phenomenon, which is known as the most obvious cause of urban temperature rise, is a phenomenon that occurred during the rapid industrialization and urbanization since the mid-20th century. (Oh, Kyu-Shik, Hong, Jae-Joo., 2005)

The isotherm forms a closed curve because the temperature of the urban heat island is higher than that of the surrounding area. In the late 1810s, Howard discovered the urban heat island phenomenon for the first time when he discovered that the nighttime temperature in London's urban area was about 2.1°C higher than that of the surrounding suburbs. (Luke Howard, 2008)

The urban heat island phenomenon is characterized by the low albedo of the asphalt and concrete pavement surfaces constituting the urban area, which absorbs a large amount of solar radiation energy, thereby accumulating heat energy near the surface of the earth and increasing the area that reflects and absorbs sunlight. It is caused by an increase in surface temperature due to the extension of high-rise buildings. In addition, since smog generated from factory and automobile fumes stores and re-discharges atmospheric heat, a vicious cycle is repeated, which greatly affects not only environmental pollution but also global warming. In particular, forests or green areas are the most important factors for reducing the urban heat island phenomenon and have a great influence on the reduction of urban temperature. The problem with the urban heat island phenomenon is that tropical nights occur due to an increase in temperature, and the number of days and the number of people suffering from heat illness increases, resulting in a natural vicious cycle due to the heat island phenomenon.

Seoul, Korea's largest metropolis, has undergone reckless development and destruction of green areas due to rapid urbanization that began in the 1960s. has increased. In addition, as a result of analyzing the number of days of heatwaves and tropical nights in the past 48 years from 1973 to 2020 the Korea Meteorological Administration, the average number of heatwave days in the past 48 years from 1973 to 2020 was 10.1, whereas the last 10 The year was 14.0 days, which increased by 3.9 days. (Korea Meteorological Administration, 2020)

This is expected to intensify the heat wave and heat island phenomenon in Seoul. Seoul Open Data Plaza (https://data.seoul.go.kr/))

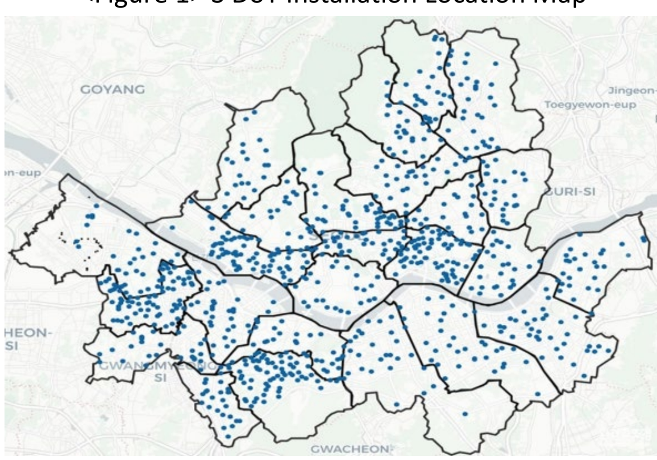
2.2 S·DoT city-data sensor and Landsat8

S·DoT city-data sensor is an abbreviation of Smart Seoul Data of Things, which means that data (Dots) are gathered to become a Smart Seoul. The purpose is to establish policies to improve citizens' lives and to build an industrial ecosystem using city city-dataset on sensors installed throughout Seoul using the Smart Seoul Network (S-NeT)'s Internet of Things (IoT) network, city city-data is a part of the project to establish a collection, distribution, and utilization system and to lay the foundation for scientific administration based on data.

The measurement items are 10 types of data on urban phenomena (fine dust, temperature, illuminance, noise, etc.) and civic behavior (floating population, vehicle movement, etc.) It is measured and provided to the general public in units of an hourly average. Data can be found at the Seoul Open Data Plaza.

Standards for installation are equal installation (424 administrative buildings), autonomous districts (residential, commercial, open space), and policy demands (construction sites, fine dust dust-generating cities, garages, visitor clusters, etc.). A total of 1,100 S-DoT installations have been completed by 2021, and a total of 2,500 S-DoTs will be installed by 2022. This is about 30 times more than the Seoul National Weather Service (AWS). <Figure 1> The installation site is installed at a height of about 3 m, such as CCTV and props, and it is close to the actual living environment of citizens. In this study, the temperature data of the S·DoT city-data sensor was used.

<Figure 1> S DoT Installation Location Map



Source: 1100 S-DoT installation areas in Seoul (provided by Seoul City)

Landsat8 is an Earth resource exploration satellite launched by the United States National Aeronautics and Space Administration (NASA) and launched in 2013. Landsat8 orbits the Earth in a cycle of 16 days, the scene size is 185 km x 180 km, and it can acquire about 740 images per day.

The Landsat 8 satellite is equipped with a measurement system of an Operational Land Imager (OLI) and a Thermal Infrared Sensor (TIS). The OLI (Operational Land Imager) multi-spectral sensor composed of 9 spectral bands has a spatial resolution of 30 m and provides a thermal infrared band. In the case of TIRS (Thermal Infrared Sensor) consisting of two thermal infrared bands, it is received with a resolution of 100 m, but the USGS provides it to users after applying a resolution matching process to 30 m. Landsat satellite data can be accessed from Earth Explorer (http://earthexplorer.usgs.gov/) with a 16-day revisit cycle. In the Republic of Korea, artificial satellites such as Arirthe and satellite (multipurpose utility satellite) and Chollian (public geostationary orbit satellite) are on missa ion, but they have not yet been stabilized enough to be used for research, so they are not disclosed to the private sector. As one of the most used artificial satellites in research using satellite images, such as Landsat in the US and Sentinel in the United States/Europe, etc.

<Table 1> LANDSAT 8 Band Information (USGS)

Instrument type	Band	µm(wave band)	Resolution
OLI	Band Coastal/Aersol	0.43 - 0.45µm	30m
	Band 2 Blue	0.450 - 0.51µm	30m
	Band 3 Green	0.53 - 0.59µm	30m
	Band 4 Red	0.64 - 0.67µm	30m
	Band 5 NIR	0.85 - 0.88µm	30m
	Band 6 SWIR 1	1.57 - 1.65µm	30m
	Band 7 SWIR 2	2.11 - 2.29µm	30m
	Band 8 Pan	0.50 to 0.68µm	15m
	Band 9 Cirrus	1.36 - 1.38µm	30m
TIRES	Band 10	10.6 - 11.19µm	100m(Resampled to 30m)
	Band 11	11.5 - 12.51µm	100m(Resampled to 30m)

2.3 Review of Prior Studies and Differentiation

The urban heat island phenomenon has a major impact on human life in general. Various studies are being conducted at home and abroad to analyze and solve these problems of the urban heat island.

First, it is a prior study related to heat island intensity (UHII). (Pingying Lin et al., 2017) derived the effect of pocket parks on UHI intensity and the relationship between UHI and five urban planning indicators by performing in-situ climate measurements and morphological analysis of 12 points in Hong Kong. (Seo, Kyeong-Ho., Park, Kyung-Hun., 2017) measured the summer temperature (LST) in 2009 through surface analysis classified into urban land and non-urban land to analyze the intensity of the urban heat island (UHI) in Korea, and MODIS It was found that the regions with the highest temperature and UHI intensity recorded from satellite images were concentrated around major cities, and correlations between the urbanization rate, UHI intensity, and tropical beasts were derived.

Second, it is a preceding study related to LST (Land Surface Temperature) using Landsat data. (PK Srivastava et al., 2009) obtained satellite data from 26 October 2001 and 2 November 2001 using visible and near-infrared(VNIR) and high-resolution thermal infrared (TIR) of Landsat-7 ETM+ for India. was utilized. The estimated LST identified the effect of surface characteristics on surface temperature. (Gordana Kaplan et al., 2018) analyzed the correlation between land surface temperature (LST), NDVI, and NDBI calculated from Landsat 8 data in the summer of 2013 and 2017 for Skopje and Macedonia. (Lee, Jong-Sin., Oh Myoung-Kwan., 2019) analyzed the feasibility of using the surface temperature using the satellite image of Landsat 8 and the temperature data measured through AWS to improve the resolution of the LST on the ground.

(Jee, Joon-Bum et al., 2014) analyzed the surface temperature calculated from MODIS, Landsat, Landsat, and Landsat 5, 7, and 8 satellites using the surface altitude, land use, and AWS temperature in some areas of the metropolitan area including Seoul. Landsat 8 revealed that the MODIS surface temperature and AWS temperature were similar to the trends, and the surface temperature calculated from the satellite showed a high correlation with the AWS temperature located in downtown rather than suburban areas.

Third, it is a preceding study related to air temperature using city sensors. (Park, Haekyung., 2021) compared the heat island intensity of Seoul by using the Seoul city sensor S・DoT (Smart Seoul Data of Things) and the national weather observation temperature (AWS). It was found that the temperature was 1.5℃ higher.

(Park se-hong, Bae woong-kyoo., 2020) analyzed the spatial and temporal structure of Seoul's urban heat island by using near-surface temperature data from regional detailed observation data (AWS) to analyze changes in the urban heat island of Seoul.

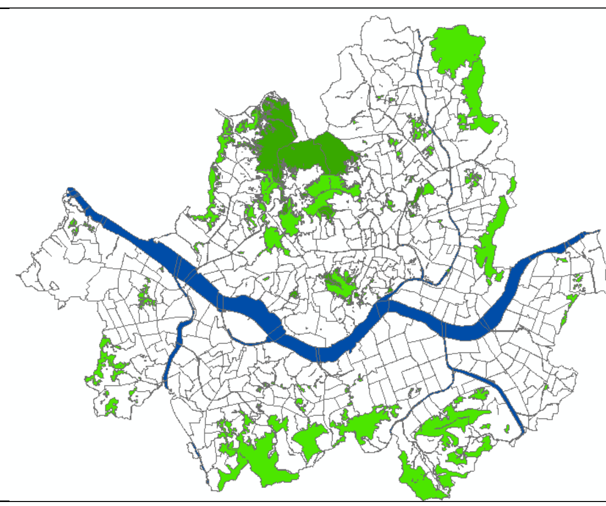
As a result of the analysis of previous studies, most of the domestic and foreign studies used Landsat data and National Weather Service (AWS) data to calculate the heat island intensity value, and there were few research cases using city data sensors. Therefore, in this study, by utilizing S·DoT (city data sensor) data for Seoul, the possibility of using S·DoT (city data sensor) by examining LANDSAT8 data and Seoul temperature, calculating and comparative analysis of heat island intensity was understood.

3.1 Analysis method

The analysis method of this study was analyzed in four stages: theory and literature review, S·DoT (atmospheric temperature)/Landsat8 (surface temperature) calculation, heat island intensity map production, temperature comparison, and heat island intensity map comparison.

First, previous studies related to the urban heat island phenomenon and S·DoT (urban data sensor)/Landsat satellite were reviewed. Second, using the temperature data of S-Dot on March 30, 2021 and the image data of the Landsat8 artificial satellite, the air temperature map and the surface temperature map of the water system and conservation mountain areas are produced. Third, a heat island intensity map of air temperature (S-DoT) and surface temperature (Landsat8) is produced using data from 17 points of the National Weather Service (AWS) in the suburbs. Fifth, Temperature(Air/Surface) data of S·DoT and Landsat8 and heat island intensity are compared. For an empirical study, in this study, in the process of calculating the surface temperature of Landsat8, the area except for the same area was considered in consideration of the fact that the conservation mountain area, natural green area, and water system may distort the average surface temperature by lowering the average value for each dong. It is used to create a map, and comparatively analyzes Temperature(Air/Surface) data and heat island intensity for administrative districts with three or more S-DoTs.

<Figure 2> Spatial range excluded from the study

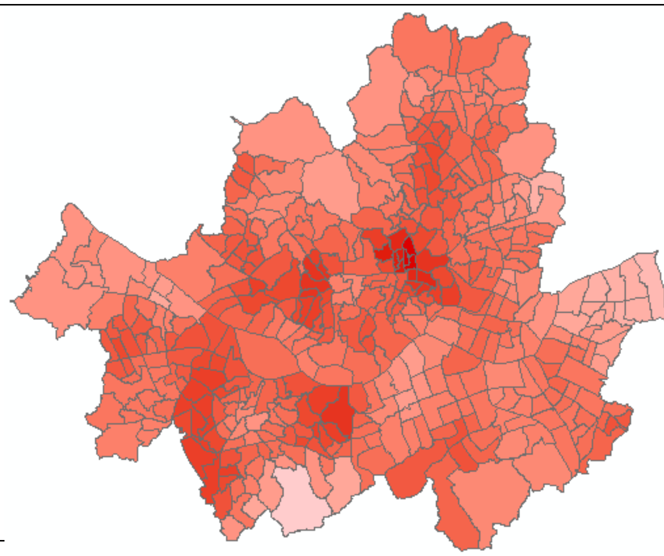
Legend	Administrative district Boundary Map of Seoul of Korea
Natural green area Conservation production area Water system area Administrative district	

3.2 S·DoT air temperature calculation

In order to produce an urban heat island map, first, data from March 30, 2,021 are collected through the Seoul Open Data

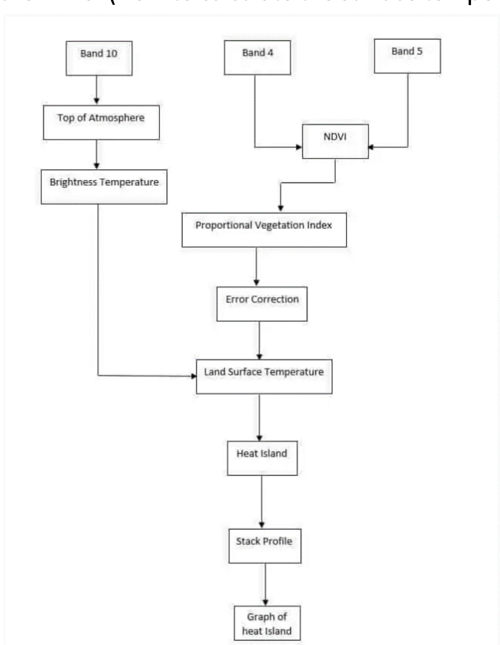
Plaza. Data processing and integration were performed using Microsoft Excel and ArcGIS programs. Second, for the reliability of the previously collected temperature data, it is corrected by deleting data showing no change in the data value for a certain period of time or showing a large difference when compared with other points. Third, ArcGIS calculates the temperature at the same time of the video data of Ladnat8 on March 30, 2021, excluding the water system and green areas, and uses the Kriging interpolation method to produce an air temperature map for each administrative building.

<Figure 3> Air Temperatiure Map Using S·DoT

Legend	March 30, 2021, Air temperature map for each Administrative Region in Seoul
12.573273 - 12.727732 12.727733 - 12.882192 12.882193 - 13.036652 13.036653 - 13.191112 13.191113 - 13.345572 13.345573 - 13.500032 13.500033 - 13.654492 13.654493 - 13.808952 13.808953 - 13.963412 13.963413 - 14.117872 14.117873 - 14.272332 14.272333 - 14.426792 14.426793 - 14.581252 14.581253 - 14.735712 14.735713 - 14.890172 14.890173 - 15.044632 15.044633 - 15.199092 15.199093 - 15.353552 15.353553 - 15.508011 15.508012 - 15.662471	

3.3 LANDSAT Surface Temperature Calculation

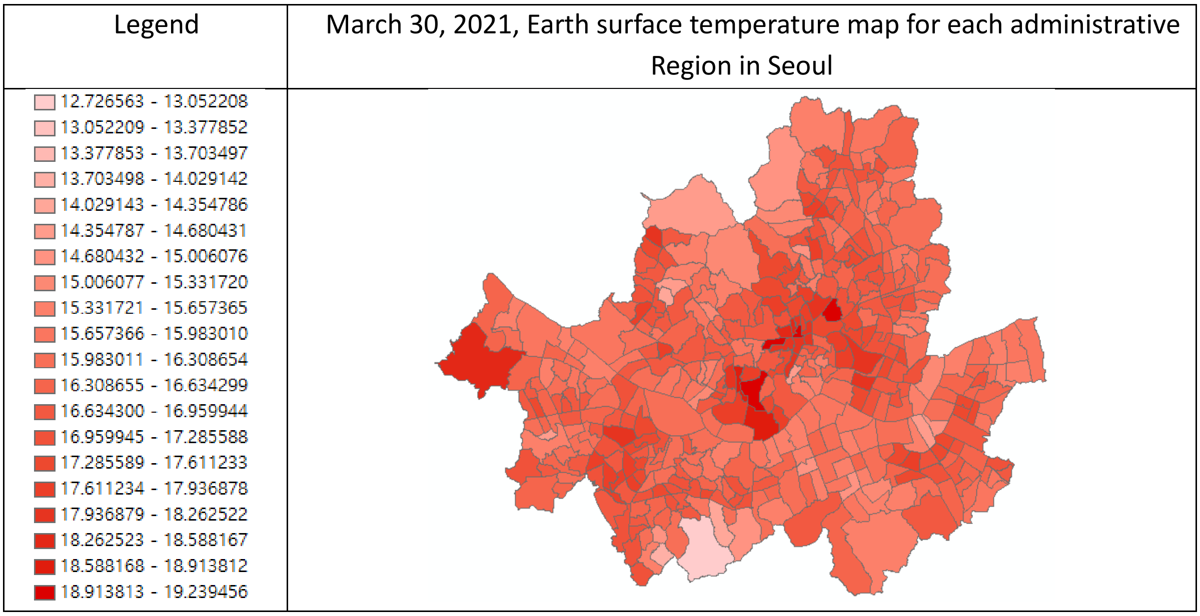
<Figure 4> LST(How to calculate the surface temperature



To extract data using satellite images, programs such as ENVI and GIS can be used. In this study, Arcgis 10.4 was used and the “Raster Calculator” Tool was used to calculate the surface temperature. In this study, we applied the automatic mapping algorithm introduced by (Avdan, Jovanovska,. 2016) because the other approach is much more time-consuming and more susceptible to false estimates to obtain surface temperature (LST) values from the Landsat-8 satellite at 30 m spatial resolution. was calculated.

In the same way as the air temperature map for each administrative dong, the surface temperature map for each administrative dong is produced using the surface temperature except for the water system and green areas.

<Figure 5> Surface Temperature Map Using Landsat 8



4. Comparison of Temperature(Air/Surface) of S·DoT and Landsat8 and comparison of heat island intensity

4.1 S·DoT heat island intensity calculation

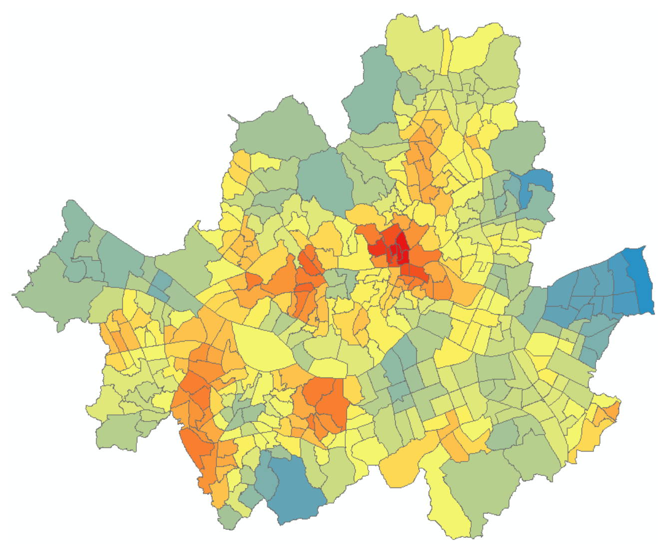
In order to calculate the heat island intensity of S·DoT in Seoul, it is first necessary to collect temperature data in the suburbs of Seoul. Since S·DoT is only operated in the Seoul area, average temperature data was collected by selecting the National Weather Service (AWS) data operated by the Korea Meteorological Administration for temperature data in suburban areas. In this study, the heat island intensity was calculated using Equation 2, which is the difference between the average temperature of each point and the suburban temperature.

Second, using the calculated heat island intensity, a heat island intensity map was produced using the Kriging interpolation method in the same way as the temperature and temperature map production method. After ArcGIS using ArcGIS Raster to point tool, the interpolated Seoul zeal intensity value the s wase a made point by cell unit. ArcGIS using the Spatial Join tool, was combined with the map of administrative dongs in Seoul to produce an average map of heat island intensity for each dong.

<Table2> Urban heat island intensity calculation equation

Division	Formula	Note
Equation 1	$\triangle$Tu-r = Tu(a)-Tr(a)	Tu(average) =Average temperature of Seoul branch Tr(average) =Suburban point average temperature
Equation 2	$\triangle$Tu-r = Tu-Tr(a)	Tu =Seoul branch temperature Tr(average) =Suburban point average temperature

< Figure 6> S·DoT heat island intensity map

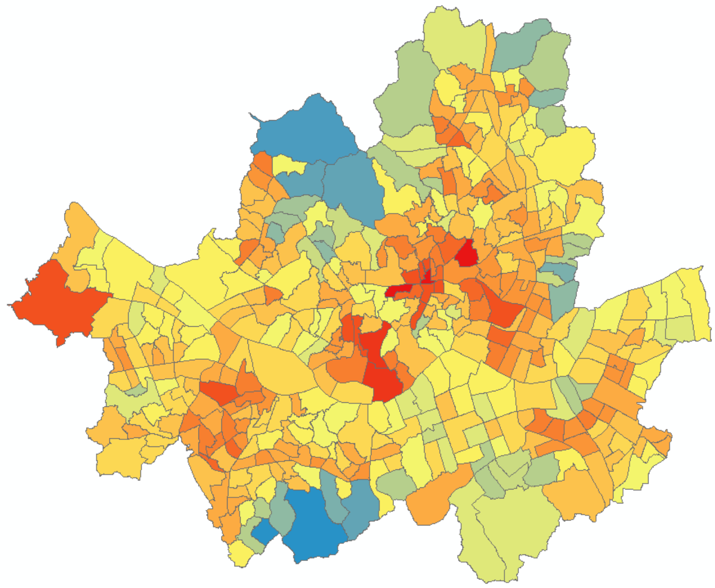
Legend	March 30, 2021, UHII map of S DoT for each administrative Region in Seoul
-0.015818 - 0.122052 0.122053 - 0.259923 0.259924 - 0.397793 0.397794 - 0.535663 0.535664 - 0.673534 0.673535 - 0.811404 0.811405 - 0.949274 0.949275 - 1.087144 1.087145 - 1.225015 1.225016 - 1.362885 1.362886 - 1.500755 1.500756 - 1.638626 1.638627 - 1.776496 1.776497 - 1.914366 1.914367 - 2.052237 2.052238 - 2.190107 2.190108 - 2.327977 2.327978 - 2.465847 2.465848 - 2.603718 2.603719 - 2.741588	

4.2 Landsat8 heat island intensity calculation

To calculate the heat island intensity of Landsat8 in Seoul, first, to collect the same suburban temperature as S·DoT, use the Arc gis Buffer tool to calculate the average distance of each AWS point from the center of Seoul to set the suburban range Suburban LST was collected. And the heat island intensity was calculated using the same urban heat island intensity calculation formula as S·DoT (Table 2). ArcGIS, using Arcgis' Raster to point tool, Seoul's heat intensity values were pointized in cell units. Third, using Arcgis' Spatial Join tool, it was combined with the map of administrative dongs in Seoul to produce an average map of heat island intensity for each dong.

In this study, green areas such as urban nature parks and bojeon mountain areas and the water system of the Han River can be distorted by lowering the average value when calculating the average surface temperature for each dong. were excluded from this study.

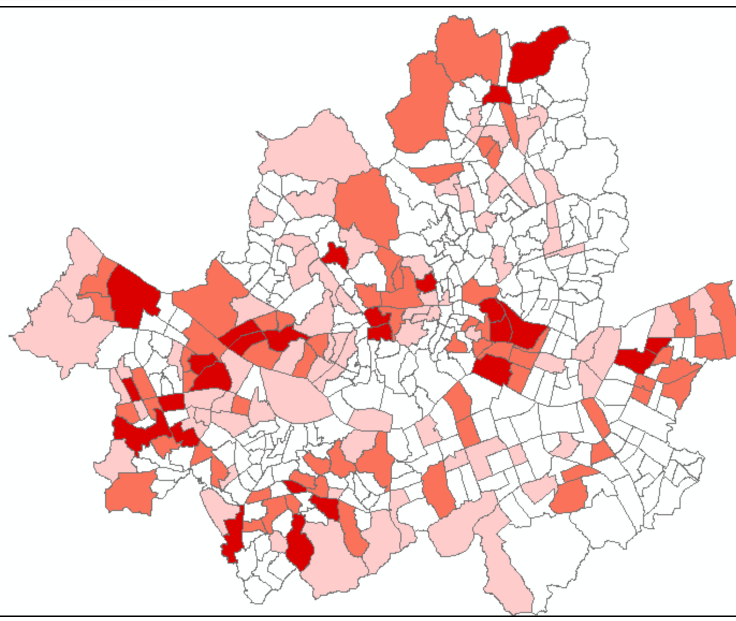
< Figure 7> Landsat8 heat island intensity map

Legend	March 30, 2021, UHII map of Landsat8 for each administrative Region in Seoul
-3.036037 - -2.704687 -2.704686 - -2.373338 -2.373337 - -2.041988 -2.041987 - -1.710638 -1.710637 - -1.379289 -1.379288 - -1.047939 -1.047938 - -0.716590 -0.716589 - -0.385240 -0.385239 - -0.053890 -0.053889 - 0.277459 0.277460 - 0.608809 0.608810 - 0.940159 0.940160 - 1.271508 1.271509 - 1.602858 1.602859 - 1.934207 1.934208 - 2.265557 2.265558 - 2.596907 2.596908 - 2.928256 2.928257 - 3.259606 3.259607 - 3.590956	

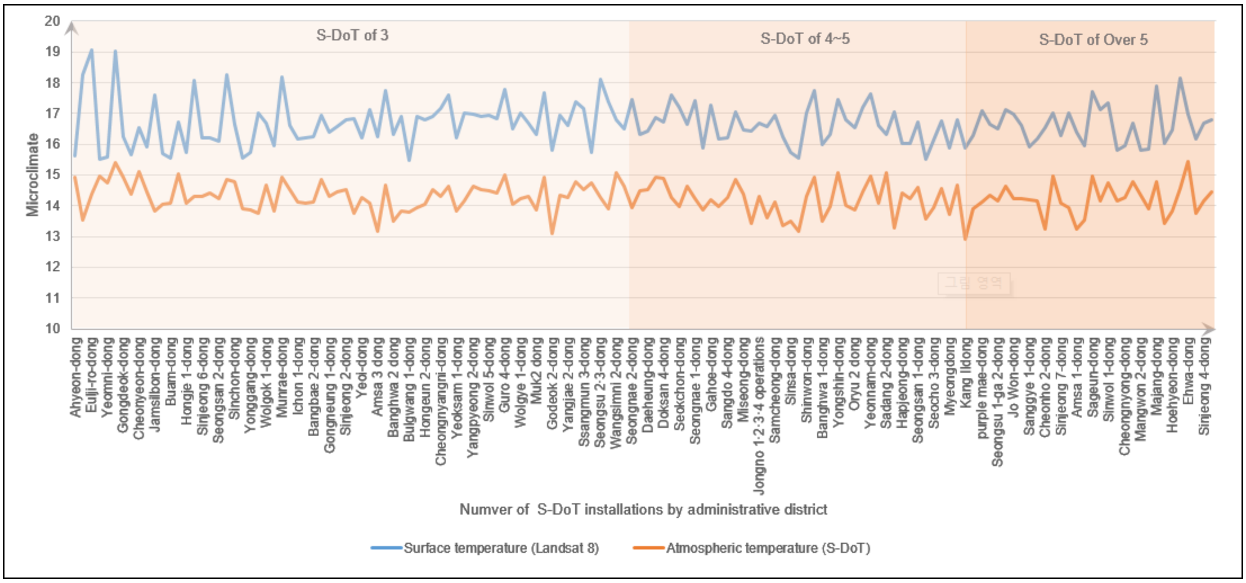
4.3 Comparison of S·DoT and Landsat8 Temperature(Air/Surface) data and heat island intensity

For an empirical and sophisticated comparative analysis, administrative districts with three or more S DoTs were used, and the temperature and heat island intensity were compared for a total of 144 administrative districts.

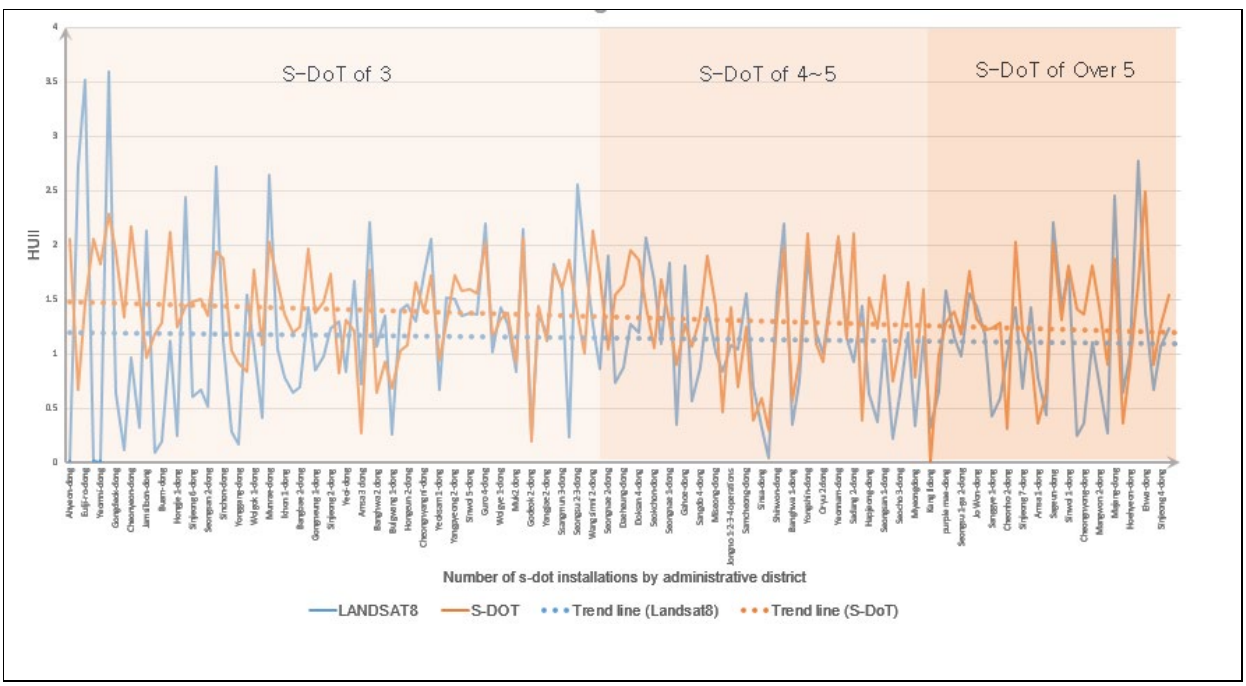
<Figure 8> Administrative district of Seoul with 3 or more s·dot

Legend	March 30, 2021 Administrative district of Seoul with 3 or more s·dot
3 4 - 5 6 - 10	

< Figure 9> Temperature(Air/Surface) Comparison by Administrative Region of Seoul



< Figure 10> UHII Comparison by administrative district of S·DoT and Landsat 8



First, Temperature(Air/Surface) data of S·DoT and Landsat8 were examined. In the case of Landsat8, the difference between the Seoul temperature and the suburban temperature was about 0.15℃, whereas in the case of S·DoT, there was a large difference of 0.87℃ or more. In addition, the air temperature (S·DoT) and the surface temperature (Landsat 8) showed a difference of about 2.4℃, and as the number of S·DoTs increased, a similar pattern was shown.

Second, the heat island intensity of S·DoT and Landsat8 was compared. The heat island intensity of S·DoT ranges from 0.08 to 2.74, while that of Landsat8 is -2.77 to 3.59, showing a large difference in heat island intensity of 0.85. Also, <Figure 10> The heat island intensity of S·DoT and Landsat8 was compared according to the number of S·DoT. The difference in thermal island strength at the point of three S·DoTs is 0.22, and the difference in thermal island strength in administrative districts of four S·DoTs is 0.17. Also, looking at the heat island intensity regions of S·DoT and Landsat8, Jongno, the center, and Yeongdeungpo Guro, where industrial areas are densely concentrated, were found to have the same high heat island intensity in S·DoT and Landsat8 as well. However, in the case of the airport building where the airport is located, S·DoT showed 0.67 and Landsat8 showed 2.72, showing a difference in heat island intensity of 2.05.

5. Conclusion

In order to specifically analyze the urban heat island phenomenon that is becoming serious with abnormal weather changes in Seoul, this study attempted to compare and analyze the Temperature(Air/Surface) and thermal island intensity of urban data sensors (S·DoT) and Landsat8. To this end, air temperature maps and surface temperature maps were produced by collecting temperature data from S-Dot and video data from Landsat 8 satellites on March 30, 2021, and heat island intensity maps were produced using national weather observation (AWS) data from suburban areas. Through this, the difference was investigated by comparing and analyzing Temperature(Air/Surface) data and thermal island intensity, and the following conclusions were obtained.

First, As a result of examining the data of LANDSAT8 and S·DoT, in the case of LANDSAT8, the temperature in Seoul and the suburbs showed a difference of about 0.15℃, whereas in the case of S·DoT, there was a large difference of 0.87℃ or more. This can be seen as the difference between the measurement environment and installation location of S·DoT and AWS. The installation location of the S·DoT is installed at a height of about 3m to measure the temperature in the area directly affected by the urban environment, while the AWS is located on the roof, so it is judged that the temperature is slightly lower than that of the S·DoT. Also, as a result of examining the Temperature(Air/Surface) data of S·DoT and Landsat8, the temperature difference was about 2.4℃. This appears to be the difference between the surface temperature and the air temperature.

Second, the result of comparing the heat island intensity of S·DoT and Landsat8 according to the number of S·DoTs, the difference in heat island intensity was 0.85. The difference was 0.22, and the difference in the heat island intensity of administrative buildings with 4 or more S·DoTs was 0.17. Through this, it could be seen that the trend of heat island intensity according to the number of installed S-DoT was getting closer, and the possibility of using S·DoT could be seen. Also, looking at the heat island intensity regions of S·DoT and Landsat8, Jongno, the center, and Yeongdeungpo Guro, where industrial areas are densely concentrated, were found to have the same high heat island intensity in S·DoT and Landsat8 as well. However, in the case of the airport building where the airport is located, S·DoT was 0.67 and Landsat8 was 2.72, showing a large difference in heat island intensity of 2.05. This is judged to be a difference according to the number of installed S·DoT.

This study is meaningful in that it presented basic data for the study by producing a heat island intensity map using high-density S·DoT to understand the degree of urban heat island and extracting more sophisticated urban heat island areas compared to Landsat8. In addition, it is significant that the feasibility of using S DoT was presented by more empirically comparative analysis of the heat island intensity of S·DoT and Ladnsat8. Even with these results, the following limitations exist. In the case of S·DoT, there are disadvantages in that data builders have to arbitrarily judge errors and because temperature interpolation is performed between points due to the limitations of the Arc GIS spatial interpolation method, it is necessary to pay attention to the selection of an appropriate interpolation method according to the target area and data distribution. In addition, there are administrative buildings with a large difference in heat island intensity even at a point where the number of S·DoT is large, which seems to be due to device errors and installation locations. Based on this study in the future, it is necessary to study concrete solutions to the urban heat island phenomenon by using S·DoT data for additional periods and regions.

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