Analysis of the Relation of Local Temperature to the Natural Environment, Land Use and Land Coverage of Neighborhoods

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Abstract
This study aims at offering effective policies for managing local temperatures and reducing the heat island effect by identifying elements that affect local temperatures. It first selected the three elements of natural environment, land use, and land coverage and then applied control factors including season, weather, and measurement unit for wind speed. In order to analyze these factors’ relation to summer temperatures, development of an integrated model, analysis of the urban heat island reduction effect of elements impacting local temperatures, nationwide Weather System (AWS) data from July and August 2007, land coverage data provided by the Ministry of Environment, and land use area data from local governments were used after being rearranged based upon their falling within a 500 meter radius (0.79km²) of respective AWS measuring points. The study results show that natural environment, land use, and land coverage all have a relation to changes in local temperatures, with natural elements bearing a greater impact than other factors and land use having less. Specific elements which were effective in the reduction of local temperatures were altitude, wind speed, broadleaf forest, inland wetland, coastal wetland, other dry land, and marine water. On the other hand, residential areas, traffic areas, and greenhouse agricultural areas all contributed to an increase in local temperatures. In the case of grassland, contrary to previous theories, its effect on the reduction of temperatures was seen to be a result of wind rather than an inherent property. Unlike its precedents, this study compared the degree of influence of each element on local temperatures. In this regard, it is meaningful in that it suggests basic data for establishing more effective policies for mitigating the heat island effect and strategies for enhancing the sustainability of cities.

Keywords: low-carbon city; local temperature; heat island; temperature management

1. Introduction
Due to the progression of urbanization, more than 80 percent of the population of developed countries is currently living in cities. This increase in the urban population has been reinforced as residential areas have been concentrated in already-developed regions. This can be observed through the expansion of high density and high-rise buildings, the decline of green spaces, and increased per capita energy consumption.
The temperatures in cities and in rural and outlying areas can differ considerably due to a range of causes. Heat islands, an urban issue, are among them. This is an effect observed only within cities that was revealed in 1820 by Luke Howard in a study on the city of London.
emissions of buildings, as this is an important element which increases the need for cooling or heating.

Therefore, the purpose of this study is to devise methods to more effectively manage local temperatures and mediate the heat island effect by statistically analyzing the correlation between local temperature, the natural environment, land use, and vegetation and land coverage. In addition, it suggests considerations for lessening the heat island effect in neighborhoods in order to utilize these results in the planning and designing of micro areas.

2. Literature Review and Hypotheses
2.1 Urban Heat Island Effect and Local Temperature

Heat island effect refers to a phenomenon in which the temperature in cities, in particular that of high-density areas, is higher than that found in rural areas. This condition is known to be impacted by time of day, season, and the characteristics of specific urban spaces (Chandler, T.J., 1968). As mentioned earlier, research on the urban heat island effect was first carried out in London in 1820; Emilienn Renou also conducted a related investigation in Paris in 1868. Furthermore, Wilhelm Schmidt began to use a device specially designed to effectively identify meteorological indicator isolines in 1927 (Landsberg, R, 1981). As many cities experienced redevelopment in the years since 1945, a number of relevant studies were implemented. Research by Chandler in 1962, 1964, and 1965 shows the results of analyses of abnormal temperatures in London. It was in 1987 when the urban heat island effect was finally established as a theory by Oke (Oke, T.R., 1987).

Even though the heat island effect does indeed increase energy consumption for cooling due to higher summer temperatures, some argue that this phenomenon can actually reduce overall energy consumption thanks to increased winter temperatures. However, most research has concluded that energy consumption due to air-conditioning is much greater than that used for heating, and that soaring urban temperatures do in fact lead to growth in the demand for cooling and increased energy supply needs (Taha, H., 1997; Landsberg, R., 1981).

In the end, the heat island effect is an urban problem that should be combatted, and management and reduction of urban temperatures are the key solutions to that end. Identifying and verifying a range of the elements that raise local temperatures could be a first step in addressing this issue. In particular, local temperatures should be studied with considerable care since they have an absolute influence on energy consumption in micro-spaces.

2.2 Literature Review

There have been a great number of studies on the elements that might drive increases in urban temperatures, with the goal of minimizing the heat island effect. Three factors which bear a close relation to urban temperatures suggested by this research can be summarized as:

- vegetation and land coverage; natural elements; and artificial heat produced depending on land use.

First, vegetation reduces temperatures by blocking the direct incidence of sunlight and solar heat, strengthening thermal resistance, preventing the intrusion of heat, and expediting the movement of latent heat. This is a well-known effect of vegetation, as proved by Barry and Chorley (1968) in a study examining various temperature changes in a temperate forest zone. Hidebrandt and Sarkovich (1998) tested the effect on cooling energy reduction by shade trees in the US city of Sacramento. Landsberg (1981) also conducted research on cooling in areas with large parks or high density, while Meier (1991) analyzed the chilling effect of green areas in hot climates.

Second, natural elements such as season, time of day, wind speed, altitude, and weather also bear a close relation to urban temperatures. These factors, not simply a cool land surface, play an important role in determining temperatures by creating absolute environmental conditions. Time and season influence changes and deviations in urban temperatures, and the urban heat island effect is found to be most prominent during the day. The intensity of this condition, however, varies by region according to differences in cooling effects due to varying wind speed, altitude, and humidity in respective areas. Chandler and Gregory (1976) identified this fundamental environmental difference through research in which they measured temperatures in London parks based on time, while Hannel (1976) discovered that a heat island effect in Quito, Ecuador was observed only during the daytime hours.

Lastly, artificial heat is an important element effecting urban temperatures. It is emitted from combustion related to various forms of land use, such as transportation or heating and cooling, as well as from consumption of electricity. This process leads to a rise in the overall urban temperature, with the flow of artificial heat in winter becoming similar to or even exceeding that of solar heat. Harrison et al. (1984) conducted research in London from 1971 to 1976 investigating the flow of heat from transportation, secondary and tertiary industrial facilities and households. Taha (1997) also analyzed increases in temperatures due to artificial heat in large cities.

The existing studies mentioned above mostly examine the relation of the average temperature in cities and respective urban elements from a macro perspective. Alternatively, they analyze individual elements affecting micro temperatures. In other words, they are limited in that they rely solely on either a macroscopic or microscopic viewpoint.

2.3 Hypotheses

Based on the review of the existing research since 1945, the following hypotheses can be drawn.

First, land use and coverage of micro spaces might influence local temperature by changing albedos and generating artificial heat.
Second, an integrated model that considers and controls various forms of land use and coverage elements would be likely to suggest results different from those of previous studies.

Third, natural factors might have an impact on local temperatures, and consideration or control of these elements would play an important role in explaining local temperature.

Fourth, elements affecting the measurement methods for temperature data, such as season, weather, and wind speed might also influence the explanatory power of an integrated model.

3. Methodology
3.1 Analysis Model & Variables

In order to verify the aforementioned hypotheses, this study devised the following research model. It focused on three elements that are known to affect local temperatures: natural environment; land use; and vegetation and land coverage. They are selected as independent variables.

First, it looked at land use, one major factor in the generation of artificial heat (Harrison, R. et al., 1984; Taha, H., 1997). In order to analyze its effect on temperatures, land use was divided into residential, commercial, entertainment, industrial, traffic, and public facility areas. The extents of these areas were selected as independent variables.

Second, elements from the natural environment, time and season, weather, wind speed, and altitude are well-known factors which have a strong influence on temperatures. Time, weather, and unit of wind speed measurement (per second/per 10 seconds) all impact temperature measurement and have been broadly identified as elements that can lead to different results depending on the standard. In order to review these elements more clearly, this study selected them as control variables. Two other basic natural environmental factors, altitude and wind speed, were set as independent variables in order to determine how much the consideration of them influences study results.

Third, vegetation and land coverage were divided into agricultural land, forest, grassland, and wetland and waterside. This study chose agricultural land, which has been the subject of little attention as a factor affecting temperatures, as an independent variable because it is also a form of vegetation. In order to specifically analyze its impact on temperature, it was categorized into rice paddy, dry field, greenhouse, orchard, and other agricultural areas. Forest has a distinct influence on temperature depending on the type of trees involved (Barry, R.G. & R.J. Chorley, 1968; Rosenfeld, A.H. et al., 1995; Akbari, H. et al., 1997). To prove this, it was categorized into broadleaf forest, coniferous forest, and mixed stand forest. Grassland's effect on temperatures also differs according to the development state (Landsberg, R., 1981; Saito et al., 1990; Jauregui, E., 1991). To take this into account, it was divided into natural grassland, golf course, and other grassland. The category of wetland and waterside is also an important element affecting temperatures, due to differing cooling and heating effects by albedo (Rosenfeld, A.H. et al., 1995; Asaeda, T.V. et al., 1997). To confirm this, the study categorized it into inland wetland, costal wetland, lighted area, other dry land, inland water, and marine water, and looked into their effect on temperatures.

This study chose 24 independent variables under the three major variables and looked at their relation to the dependent variable of local temperature. Time and season, weather, and measurement unit for wind speed were selected as control variables.

Based on the assumption that independent variables have a linear relation with a dependent variable under the control of control variables, the equation below was created:

\[ T_k = f(NE_k, LC_k, LU_k) \]

\[ T_k \] = Temperature at AWS_k
\[ NE_k \] = Natural Environment of AWS_k
\[ LU_k \] = Land Use of AWS_k
\[ LC_k \] = Vegetation and Land Coverage of AWS_k

In order to identify the meaning and explanatory power of this linear model, multiple regression analysis was used. Hierarchical regression analysis was conducted to compare each variable's step-by-step input and the explanatory power of each model. For this, the analysis program STATA 12.0 was used.

Among the 23 independent variables, commercial area, entertainment area, and orchard, where the related Variation Inflation Factors (VIF) were so high as to result in multicollinearity, were excluded.

Fig.1. Research Process
3.2 Data Collection
In order to effectively analyze the above model, the following data were collected.

First, as for local temperature data, temperatures at 2 p.m. (when temperatures peak) from July to August 2007 were used. Whether the day was sunny or cloudy was also considered, as were altitude and wind speed data at the measurement point. These data were obtained from 478 measurement points nationwide using the Automatic Weather System (AWS). These basic data used as dependent variables and some of the independent variables are from among those derived by the Meteorological Administration through the establishment and operation of AWS since 1995 as part of their efforts to generate a large-scale disaster prevention meteorological database. Precipitation, temperature, wind speed, and altitude were all observed. Land use and coverage data from 2007 provided by the Ministry of Environment were used, and gross area data from local governments were integrated into this collection. Based on this, this study selected local areas within a 500 meter radius of an AWS measurement point (0.79 km²) using ArcGIS.

Among the AWS data from the 478 measuring points, those from 36 points in island areas which do not provide coherent land use and coverage data were excluded. Only data from the remaining 442 points were analyzed.

Table 1 lists variables and their average value as utilized in this study.

Table 1. Descriptive Statistics

| Classified Area                  | Avg. | S.D. | Min. | Max. |
|----------------------------------|------|------|------|------|
| **Natural environment**          |      |      |      |      |
| Altitude                         | 150.33 | 227.0 | 2.00 | 1673.00 |
| Wind speed                       | 2.59  | 0.97 | 0.55 | 6.13 |
| **Land Use**                     |      |      |      |      |
| Residential                      | 0.41  | 0.25 | 0.11 | 1.00 |
| Industrial                       | 0.39  | 0.24 | 0.11 | 0.99 |
| Traffic                          | 0.38  | 0.24 | 0.11 | 0.99 |
| Public facility                  | 0.40  | 0.24 | 0.11 | 1.00 |
| **Vegetation & Land Coverage**   |      |      |      |      |
| Rice paddy                       | 0.35  | 0.22 | 0.11 | 1.00 |
| Field                            | 0.37  | 0.26 | 0.11 | 1.00 |
| Greenhouse area                  | 0.37  | 0.25 | 0.11 | 0.99 |
| Other agricultural area          | 0.40  | 0.25 | 0.11 | 0.97 |
| Broadleaf forest                 | 0.11  | 0.17 | 0    | 0.79 |
| Coniferous forest                | 0.12  | 0.11 | 0    | 0.60 |
| Mixed stand forest               | 0.08  | 0.09 | 0    | 0.46 |
| Natural grassland                | 0.02  | 0.04 | 0    | 0.30 |
| Golf course                      | 0.11  | 0.07 | 0.04 | 0.18 |
| Other grassland                  | 0.03  | 0.05 | 0    | 0.35 |
| Inland & coastal wetland         | 0.03  | 0.04 | 0    | 0.33 |
| Lighted area                     | 0.02  | 0.02 | 0    | 0.05 |
| Other dry land                   | 0.04  | 0.06 | 0    | 0.57 |
| Inland water                     | 0.04  | 0.05 | 0    | 0.4 |
| Marine water                     | 0.25  | 0.20 | 0    | 0.79 |
| **Dependent Variable**           |      |      |      |      |
| Micro temperature                | 23.39 | 10.36 | 2.28 | 32.75 |

4. Result
4.1 Review of Temperature, Season, Weather, and Unit of Wind Speed Measurement
As previously described, the basic natural elements affecting temperatures of season, time, weather, and measurement unit for wind speed were selected as control variables.

These control variables related to measurement methods are an important element in determining the data on dependent variables. Despite this, multiple studies have been carried out without a proper related standard, which at times results in the generation of contradictory results.

In order to reduce the possibility of error in the interpretation of results due to differences in measurement methods, this study adopted the following standards. As for season, values in July, August, and the average value of July and August were measured. For weather, values on sunny days, cloudy days, and average value of sunny and cloudy days were identified. For wind speed measurement unit, values per second and per 10 seconds were measured. Combining these values, 18 measurement models (A1-C6) were created to review explanatory power.

Table 2. Model Comparisons

| Month | Weather | MMWS, (per sec.) | Model | R²  | Adj R² |
|-------|---------|-----------------|-------|-----|--------|
| July  | Avg.    | 10              | A-1   | 0.5407 | 0.5162 |
|       | 1       | A-2             | 0.5421 | 0.5177 |
|       | Cloudy  | 10              | A-3   | 0.1724 | 0.1174 |
|       |        | 1               | A-4   | 0.1715 | 0.1164 |
|       | Sunny   | 10              | A-5   | 0.6518 | 0.6335 |
|       |        | 1               | A-6   | 0.4139 | 0.3831 |
| August| Avg.    | 10              | B-1   | 0.5941 | 0.5725 |
|       |        | 1               | B-2   | 0.5937 | 0.5741 |
|       | Cloudy  | 10              | B-3   | 0.3056 | 0.2580 |
|       |        | 1               | B-4   | 0.2775 | 0.2313 |
|       | Sunny   | 10              | B-5   | 0.6827 | 0.6660 |
|       |        | 1               | B-6   | 0.6813 | 0.6645 |
| Avg.  | 10      | C-1             | 0.6080 | 0.5871 |
|       |        | 1               | C-2   | 0.6104 | 0.5896 |
|       | Cloudy  | 10              | C-3   | 0.3234 | 0.2827 |
|       |        | 1               | C-4   | 0.3203 | 0.2797 |
|       | Sunny   | 10              | C-5   | 0.6424 | 0.6235 |
|       |        | 1               | C-6   | 0.6463 | 0.6275 |

According to the analysis results, a model using data of sunny days in August with a wind speed of 10 meters per second (mps) can best explain local temperatures. This result shows that when external factors are at their extreme, the surrounding elements have the greatest effect on local temperatures. This study analyzed the data by focusing on dependent variables measured at this point.

4.2 Analysis of Results
This study was designed to thoroughly investigate the influence on local temperatures of artificial heat
caused by vegetation and land coverage, natural elements, and land use. To do so, hierarchical regression analysis was conducted applying each variable in turn and reviewing the explanatory power of each model. Vegetation and land coverage were divided into agricultural land, forest, grassland, and wetland and waterside. As a result, six models were created.

The composition of each model is as follows: Model 1 considers simply land coverage; Model 2 adds vegetation and land coverage by agricultural land to Model 1; Model 3 adds vegetation and land coverage by forest to Model 2; Model 4 adds vegetation and land coverage by grassland to Model 3; Model 5 adds vegetation and land coverage by wetland and waterside; Model 6 adds natural elements to Model 5.

The best model could be determined by the results of an F test considering adjusted R² and degree of freedom at the same time. Accordingly, Model 6 turned out to be the most excellent model. Using this model, factors affecting local temperatures were deduced.

Model 6, which takes into account altitude and wind speed at the measurement point, has an explanatory power of 66.6 percent, a 31.15 percent improvement over Model 4 and up 31.88 percent over Model 5. This is a considerably elevated level of explanatory power, and through it we can conclude that land coverage accounts for fully half of urban temperature, while wind speed and altitude (natural environment of measuring point) make up the other half. Therefore, natural topography and wind speed should be taken into account when analyzing urban temperatures.

Coefficients in Table 3. are unstandardized regression coefficients, which show the effect of the relevant independent variable on a dependent variable when all independent variables except one are controlled. It can be considered as how much a unit of a dependent variable increases when one unit of an independent variable increases. In this study, it can be viewed as how much local temperature rises when each area of an independent variable expands one kilometer (one meter for altitude, and one meter per second for wind speed).

According to this principle, the following results can be deduced. For natural environment, altitude and wind speed have greater significance than other variables: as altitude increased by one meter, temperature dropped 0.0059°C; as wind speed rose by 1m/sec, temperature decreased 0.325°C. This shows that an increase in wind speed is effective in reducing micro temperatures.

Land use, which had been expected to show a close relation to urban temperature, actually included few variables with a significant relation to local temperature. Residential area and traffic facilities were the only variables that demonstrated meaningful relations. As for land use, when a residential area expands by one square kilometer, the local temperature rises 3.34°C, and as the traffic facility area increases by the same amount, temperature soars by 5.88°C.

With the agricultural land variables, the coefficient value for greenhouse area is the highest at 4.74. That of rice paddy and dry land field are -0.39 and -0.87°C, respectively, which indicates that the expansion of such areas lowers temperatures. Greenhouse and other agricultural areas have a coefficient value of 1.75°C, which indicates that their presence increases temperatures. In particular, as greenhouse area increases by one square kilometer, the local temperature rises 4.74°C, a relatively steep increase. This differs from the results of Model 2 and 3, with the underlying reason being that Model 6 considers natural environmental variables and controls these, which results in a difference. This shows that Model 6 is more practical than Models 2 or 3. Also, under Model 6 rice paddies and fields are seen to reduce local temperatures, while greenhouse areas raise them.

As for forest area variables, broadleaf, coniferous, and mixed stand forest all reduce temperatures. In greater detail, an expansion of one square kilometer of broadleaf forest decreases air temperature by 2.31°C, and broadleaf forest is more effective in reducing temperature than is coniferous forest.

Regarding the grassland variables, natural grassland, golf course, and other grassland areas all have little relation to temperature. The variables of natural grassland and golf course were found to increase temperature, while other grassland drops temperatures by 1.73°C. Although it is an intriguing finding that a golf course actually increases local temperatures, this result has no significance. Additional research related to this result is required.

Last, for the wetland and waterside land variables, an increase of one square kilometer in inland and coastal wetland drops temperatures by 2.18°C. The variable of other dry land also reduces temperatures by 1.96°C, and marine water lowers temperatures by a full 3.19°C. However, as area of inland water grows, temperatures go up by 0.15°C, which indicates that marine water has more relevance to temperatures than does inland water. Inland water has low relevance because it accounts for only a little area. Therefore other techniques to determine the temperature reduction effect of inland water are needed.

4.3 Results Summary

The results of this study are as follows: First, natural elements are a critical factor in changing local temperatures. In particular, wind plays a major role in the reduction of local temperatures. This reinforces the existing theory that wind path is effective in impacting not only pollution sources, but also the heat island effect. It suggests that ventilation by means of a natural wind path should be considered in the process of urban planning and design, particularly in laying out neighborhoods. In this regard, when examining the relation between local temperature and urban planning elements or urban design factors, the
effect of topography as well as of wind path should be considered.

Second, land use has less impact on local temperatures than the other two elements of the natural environment and vegetation and land coverage. In other words, artificial heat stemming from land use has a relatively minor influence on raising local temperatures compared to that of other factors. However, residential areas and traffic facilities, including roads, do affect the rising of local temperature as previous theories describe. Therefore, in urban planning, these two elements should be considered comprehensively.

Third, the vegetation and land coverage status of an agricultural area did not have a significant influence on local temperature.

Table 3. Analysis Results

| Classification          | Classified Area | Model 1      | Model 2      | Model 3      | Model 4      | Model 5      | Model 6      |
|------------------------|-----------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Natural Environment    | Altitude        | -0.0059** (0.0003) | -0.0059** (0.0003) | -0.0059** (0.0003) | -0.0059** (0.0003) | -0.0059** (0.0003) | -0.0059** (0.0003) |
|                        | Wind speed      | -0.3251** (0.0621) | -0.3251** (0.0621) | -0.3251** (0.0621) | -0.3251** (0.0621) | -0.3251** (0.0621) | -0.3251** (0.0621) |
| Land Use               | Residential area| 3.2826** (0.9692) | 4.4393** (0.8815) | 3.3467** (0.9084) | 2.8960** (0.9250) | 2.3901** (1.1703) | 3.3353** (1.6219) |
|                        | Industrial area | 2.1095 (2.0264) | 3.3272 (1.8318) | 2.2303 (1.7717) | 1.9231 (1.7550) | 1.6109 (1.8252) | 2.6373 (1.7621) |
|                        | Traffic area    | 4.8472† (2.9175) | 8.6340** (2.6921) | 5.2283† (2.6613) | 5.5790† (2.7180) | 3.1506† (2.9157) | 5.8761† (1.4920) |
|                        | Public facility area | 1.8184 (1.7581) | 5.1026 (1.6286) | 4.3978 (1.5703) | 4.2541 (1.5548) | 3.1084† (1.7023) | 2.3534 (1.7188) |
| Land Use               | Rice paddy      | 4.6289† (0.5458) | 3.4138** (0.6040) | 3.1936** (0.6060) | 2.1681† (0.8875) | -0.3889 (0.6910) | -0.8673 (0.8366) |
|                        | Field           | 3.2257† (0.8246) | 1.4704† (0.8521) | 1.2143 (0.8534) | 0.2028 (1.0169) | -0.8673 (0.8366) | -0.8673 (0.8366) |
| Vegetation & Land Coverage | Greenhouse area | 9.4070° (2.5204) | 8.4991° (2.4223) | 8.1098° (2.4040) | 7.3747° (2.4859) | 4.7403° (1.8081) | 7.3747° (2.4859) |
|                        | Other           | 4.9603† (2.6970) | 3.7522 (2.5820) | 3.6894 (2.5525) | 3.0082 (2.6269) | 1.7504 (1.8948) | 1.7504 (1.8948) |
| Forest                 | Broadleaf forest| -5.2159† (0.7674) | -5.3967† (0.7621) | -6.1686† (0.7621) | -2.3060† (0.7984) | -2.3060† (0.7984) | -2.3060† (0.7984) |
|                        | Coniferous forest| -0.1140 (0.8175) | -0.3944 (0.8165) | -1.0729 (0.8165) | -1.6989† (0.7729) | -1.6989† (0.7729) | -1.6989† (0.7729) |
|                        | Mixed stand forest| 0.5718 (1.0871) | 0.2619 (1.0817) | -0.8204 (1.0817) | -1.5845† (0.9367) | -1.5845† (0.9367) | -1.5845† (0.9367) |
| Grassland              | Natural grassland| -12.3466 (4.4901) | -14.8957 (4.5789) | -14.8957 (4.5789) | -2.0892 (3.4007) | 0.2892 (3.4007) | 0.2892 (3.4007) |
|                        | Golf course     | 13.3560 (8.6444) | 11.2965 (8.7171) | 11.2965 (8.7171) | 2.0630 (6.4215) | 2.0630 (6.4215) | 2.0630 (6.4215) |
|                        | Other grassland | -2.6576 (1.9042) | -3.3601† (1.9677) | -3.3601† (1.9677) | -1.7258 (1.4434) | -1.7258 (1.4434) | -1.7258 (1.4434) |
| Wetland & Waterside    | Inland-costal wetland| 0.1897 (2.0701) | -2.1766† (2.0701) | -2.1766† (2.0701) | -2.1766† (2.0701) | -2.1766† (2.0701) | -2.1766† (2.0701) |
|                        | Lighted area    | 18.2823 (23.6132) | -5.8069 (16.9519) | -5.8069 (16.9519) | -5.8069 (16.9519) | -5.8069 (16.9519) | -5.8069 (16.9519) |
|                        | Other arid area | -1.4677 (1.6033) | -1.9627† (1.1914) | -1.9627† (1.1914) | -1.9627† (1.1914) | -1.9627† (1.1914) | -1.9627† (1.1914) |
|                        | Inland water    | 3.8308 (1.8983) | 0.1512 (1.3805) | 0.1512 (1.3805) | 0.1512 (1.3805) | 0.1512 (1.3805) | 0.1512 (1.3805) |
|                        | Marine water    | -1.9973 (1.0046) | -3.1993† (0.7679) | -3.1993† (0.7679) | -3.1993† (0.7679) | -3.1993† (0.7679) | -3.1993† (0.7679) |
| Constant               | 28.3470° (0.1309) | 26.9049° (0.2004) | 27.7658° (0.3155) | 28.0050° (0.3267) | 28.6333° (0.6266) | 31.3889° (0.5267) |
| Adj. R²                | 0.0673 | 0.2426 | 0.3172 | 0.3545 | 0.3472 | 0.6660 |

P<0.1; †, p<0.05; *, p<0.01; **
the reduction of local temperatures. Rice paddies and fields had little impact on lowering local temperatures. However, the greenhouse area variable showed a temperature-increase effect. This is due to the fact that the average albedo of farms of 15% is not particularly high compared to that of cities at 12%, combined with the release of artificial heat from greenhouses. These results imply that agricultural areas, including greenhouse areas, should be managed in order to control local temperatures.

Fourth, the vegetation and land coverage status of forest is very effective in lowering local temperatures, which is consistent with previous studies. Considering the fact that broadleaf forest shows the greatest temperature-decrease effect, it can be concluded that planting broadleaf forest is an effective urban temperature management technique, such as through the creation of parks, tree-lined streets and afforestation.

Fifth, the vegetation and land coverage status of grassland has a low relevance to local temperatures. However, even though natural grassland showed a temperature-decrease effect in the model when not considering altitude and wind speed, it had no significance in the final model that took wind speed into account. This result shows that natural grassland has little effect on decreasing local temperatures, but that its influence has more to do with wind speed instead. In other words, natural grassland when including the wind contributes to local temperature decreases. Therefore, it can be concluded that the maintenance of wind paths using natural grassland can be employed in urban planning and would be effective in lowering urban temperatures.

Sixth, the vegetation and land coverage status of wetland and waterside reduces local temperatures overall, a result that is similar to those of existing studies. Particularly, the temperature-decreasing effects of inland wetland, costal wetland, other dry land, and marine water are greater than that of natural grassland. Previous research did not compare the temperature effect of wetland and waterside areas with that of forest. However, the results of this study show that the category of wetland and waterfront is more effective in lowering local temperature than is forest area. This suggests that consideration of wetland and waterfront areas should be an important element in local temperature management through urban planning.

5. Conclusion
This study suggests the following implications. First, even though not all forms of land use and coverage influence local temperatures, elements suggested in previous studies do indeed bear a relation to local temperatures. Among land use variables, residential area and traffic area increase local temperatures. Therefore, residential and traffic-related elements should be managed in order to temper rises in urban temperatures. In particular, appropriate policies are required for controlling the emission of artificial heat from these two factors.

Land coverage also bears a close relation to urban temperatures. Green areas, in particular forest areas, clearly have a temperature-reduction effect and broadleaf forest is more effective in this regard than is coniferous forest. Therefore, in order to moderate urban temperature rise, forest areas should be expanded and more broadleaf forest should be selected. Wetland and waterfront areas also reduce temperatures. Inland and coastal wetland, marine water and the category of other dry land all decrease air temperatures. In particular, there were new findings that the temperature-reduction effect of marine water (-3.19°C) is greater than that of broadleaf forest (-2.30°C), and that of inland wetland (-2.17°C) is as significant as that of broadleaf forest. This should be considered in future urban planning.

Second, land coverage explains local temperatures better than does land use. This is because in summer, land coverage has a greater impact on temperature than does artificial heat resulting from land use. This result and the comparison of the temperature-reduction effect of wetland and waterfront and forest areas did not appear in previous studies. This study was able to achieve this result thanks to an integrated model considering a wide range of variables. This suggests that the development of a more specific and comprehensive model is required for the effective management of local temperatures.

Third, natural environmental factors such as altitude and wind speed have a meaningful relation to local temperatures. Considering the fact that Model 6, which included natural environmental elements, had more than 32% more explanatory power than did Model 5, which did not consider these factors, a plan for wind paths using topography and CFD should be employed in order to reduce the heat island effect in micro spaces.

Fourth, factors affecting measurement methods, such as season, weather, and measurement unit for wind speed, should be considered as well. A comparison of the results of the 18 measurement models shows that when conducting research in summer, a sunny day in August is more appropriate and a wind speed of 10 mps serves as a better measuring tool than a wind speed of 1 mps. The fact that the difference in the explanatory power of the worst (Model A-4) and best models (Model B-5) is as great as 54.96 percent should be noted as well.

This study is differentiated in that it verified heat island reduction through an integrated model considering various factors such as natural elements, land use, and land coverage. It is also meaningful in that it laid a foundation for establishing effective urban planning strategies for creating more sustainable neighborhoods.
In further studies, commercial areas should be introduced into the model. Considering the fact that most land use variables and the inland water variable show little relevance to local temperatures, further study to identify the root of this finding should be carried out. In order to devise more specific urban planning guidelines for combating the heat island effect, the floor area ratio, layout and shape, and location of buildings should also be added to the model. In this specified model, analysis of topography and CFD and consideration of wind speed should be included. Further studies should also investigate the impact on local temperature of particular urban characteristics that this study has not addressed.

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