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# Constructing a Green Network to Alleviate the Urban Heat-Island Phenomenon: Focusing on Daegu Metropolitan City in Korea

*Jae-Gyu CHA, Eung-Ho JUNG, Ji-Won RYU, Dae-Wuk KIM*

(Cand. Ph.D. Jae-Gyu Cha, Keimyung University, Department of Environmental Planning, Dalseo-Gu Shindang-Dong 1000, Daegu, top4mir@naver.com;
Prof. Dr.-Ing. Eung-Ho Jung, Keimyung University, Department of Environmental Planning, Dalseo-Gu Shindang-Dong 1000, Daegu, turep21@kmu.ac.kr;
Ph.D. Ji-Won Ryu, Daegu Environmental Technology Development Center, Dalseo-Gu Shindang-Dong 1000, Daegu/South Korea, jiwon97@paran.com;
Dr.-Ing. Dae-Wuk Kim, Keimyung University, Department of Environmental Planning, Dalseo-Gu Shindang-Dong 1000, Daegu, dwkim@kmu.ac.kr)

## 1 INTRODUCTION

Modern cities, like living beings, change and alter their shapes somewhat every day. These changes are different from previous agrarian, with their low populations situated in decentralized areas societies, which adapted themselves to circumstances and made significant changes only over the course of decades. The changes of modern cities eventually cause aggravation to city environments due to pressure from frequent, purposeful, dynamic changes occurring over short times in centralized areas to increase citizens' comfort, productivity and efficiency(Su-bong Kim et al., 2006). Among these environmental problems occurring in cities, urbanization, especially including the change of the surface of the earth and the change of land usage alters various important factors of cities, and it leads to Urban Heat-Island phenomenon. Urban Heat-Island phenomenon, which increases the temperature of the central area of city,and damages citizens' health and the economy has become an important social issue. Compared to the past, industrialization, urbanization, and population increase are progressing in all areas to be more productive and efficient. Also, Urban Heat-Island phenomenon including city environmental problems is more common in more places than before. Recently, to solve environmental problems of cities with large areas, remote sensing and geographic information systems have been widely utilized. For Urban Heat-Island-related research, Kyong-hun Park and Sung-kwan Jung (1999) analysed Urban Heat-Island phenomenon and vegetation index using satellite images for metropolitan greenspace planning. Myung-hee Jo et al. (2001) analyzed urban surface temperature and the earth surface temperature according to spatial distribution characteristics. Young-ah Kwon (2002) researched the effect of urban parks on the temperatures of in and around them using satellite images. Gi-ho Kim (2004) studied green network construction for Urban Heat-Island mitigation based on the Dalseo district in Daegu Metropolitan City using remote sensing. Through the extraction of the surface temperature using remote sensing, distribution of Urban Heat-Islands of a metropolitan city can be quickly analysed, and also Urban Heat-Island mitigation effect can be provided quantitatively by analysing temperature distribution relativity according to components of the earth surface(Gallo et al., 1993).

Urban Heat-Island phenomenon repeats every year in metropolitan cities of Korea. Among cities, Daegu has higher temperatures than other cities in summer, and reached 40.0□ on Aug. 1. 1942, which is the highest temperature since meteorological observation began. When summer temperatures and the tropical night phenomenon are raised as social issues, Daegu is never excluded. Since 1995, Daegu has planted ten million trees to reduce Urban Heat-Island phenomenon, establish itself as an environment-friendly city, and solve social issues like citizens' health and the economy. In 1997, Daegu secured water in the Sincheon River, which passes north and south of city. It is thought that efforts such as city afforestation and hydroponic facility expansion have established the foundation for excluding Daegu as one of hottest cities of Korea in the future.

Therefore, this study aims at alleviating Urban Heat-Island phenomenon by establishing a green network as one of method of city planning based on existing city afforestation and hydroponic facility expansion, and decreasing summer temperatures in the city using temperature decreasing effect (Hyun-chan Sung, 1996) among right functions of biotop scattered in the city. Also it carried out an investigation to identify the current situation of Urban Heat-Islands and various kinds of city characteristics, to analyze the possibility of connection and wind corridor based on the condition of the earth surface, and to propose a green network construction project considering current situation.

## 2 RESEARCH METHOD

### 2.1 Present Condition of Research Target Place

Daegu is located in the southeast inland (east longitude 128° 21′ □ 128° 46′, and the north latitude 35°36′ □ 36°01′) of the Korean Peninsula. Palgong Mountain is located in the northern part of Daegu, Daeduk and Biseul Mountains are in its southern part, and the east and west sides are surrounded by hilly areas. So Daegu is basin-type city. Inside the city, the Sincheon River flows. The Gumho River in the north flows and combines with the Nakdong River and then flows toward the south. Daegu has a total of 884.46㎢ in area and is on average 40.69 m above sea level.

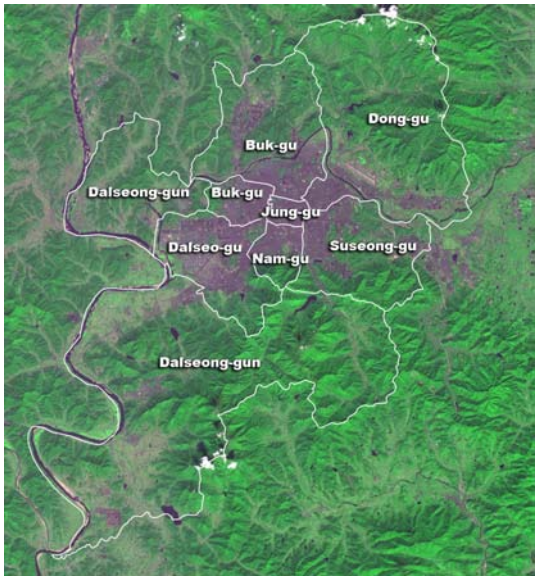


Figure 1. Present condition of Daegu Metropolitan City

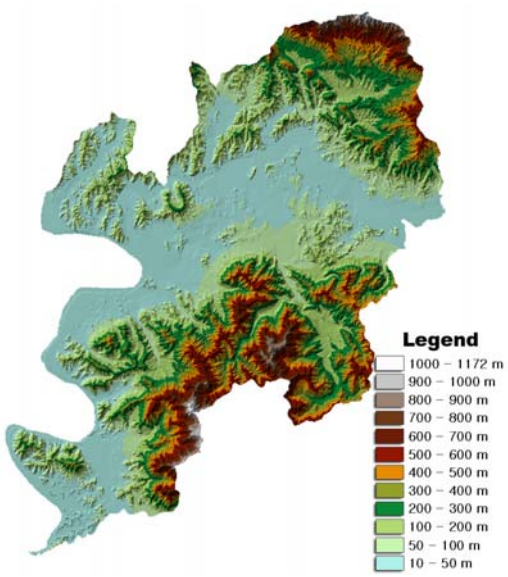


Figure 2. Altitude of Daegu Metropolitan City

### 2.2 Research Method

This study found out the current condition of Urban Heat-Islands to construct a green network in a way to alleviate the Urban Heat-Island phenomenon of the target area. Also, it identified the correlation with land cover, analyzed the connection with a green network, and implemented a wind corridor simulation.

First, the overall Urban Heat-Island phenomenon and wind corridor simulation of Daegu was analyzed, and then a target place where Urban Heat-Island phenomenon could be effectively alleviated through the construction of wind corridor was selected. Second, the Urban Heat-Island phenomenon, and the correlation between Urban Heat-Island phenomenon and land cover were analysed after arranging target places by districts. On the basis of this result, the possibility of a green network connection was also analyzed. Also, a more detailed wind corridor analysis than previous research was implemented. Third, the future construction of a green network and areas needed to secure a wind corridor in the target place were proposed based on the analyzed results.

The analysis of Urban Heat-Island phenomenon of Daegu and its target place was carried out based on Landsat 5 TM satellite images (Path/row:114/35) from Aug. 8th in 2004, and 1/5000 and 1/25000 digital map. The surface temperature of the earth was extracted by PG-STEAMER 3.0, ARC GIS 9.1, and AUTO CAD 2005 programs. In analyzed Urban Heat-Island phenomenon conditions, analyzed temperatures were divided into 5 levels and given weight classifying them into 10 groups. Then, a grid file of 10×10 m. comparable with land cover was produced. A grid file with 10×10 m, which can be compared with the Urban Heat-Island phenomenon condition, was produced through implementing land cover classification using PG-STEAMER 3.0, ARC GIS 9.1, and AUTO CAD 2005 programs, and referring field research, digital map of target places, satellite image data, and a land cover classification map of the Ministry of Environment. To analyze correlation between generated land cover and Urban Heat-Island phenomenon, SPSS 12 program was used and weight according to land cover was verified. Green network connection possibility was analyzed by producing a 1×1㎞ grid according to temperature based on the present condition of target places researched. For identifying cold wind generation and wind corridor (wind flow) of target places,

metropolitan analysis of Daegu Metropolitan City (spatial scale: 20×20 m) and target place analysis (spatial scale: 10×10 m) used land cover distribution and topography data as attribute data. And then the simulation using KLAM_21 developed in the German Meterological Office was carried out.

## 3 METROPOLITAN ANALYSIS AND MAIN TARGET PLACE SELECTION

### 3.1 Analysis of Urban Heat-Island Phenomenon of Daegu Metropolitan City

All objects with more than an absolute temperature 0o K on the earth emit heat energy corresponding to certain temperatures in the shape of electromagnetic waves so that temperature information of the object can be acquired by measuring emitted electromagnetic waves. Temperature extraction using satellite image data is based on thermal infrared from the earth surface so that it can differ from the temperature measured in the certain distance above the earth surface. Therefore, satellite image data is usually used for relative comparison among target areas, and analysis of Urban Heat-Island distribution patterns and characteristics of strength, rather than used for measuring the exact temperature of the earth surface.

In this study, the earth surface temperature was extracted to relatively compare the surface temperatures among target areas, and analyze current conditions of Urban Heat-Island phenomenon using digital number of Band 6 of Landsat 5 TM. Korea Advanced Institute of Science Technology suggested 4 models to extract the earth surface temperature from satellite images. Followings are the equations (Young-Ah Kwon, 2002) :

(i). Two-point linear model

Temperature(˚K) = 203.2 + 0.541176 × TM6

(ii). Linear regression model

Temperature (˚K) = 219.97218 + 0.525959 × TM6

(iii). Quadratic regression model

Temperature (˚K) = 209.830966 + 0.834313 × TM6 - 0.001372 × TM62

(iv). Cubic regression model

Temperature (˚K) = 206.127 + 1.054 × TM6 - 0.003714 × TM62 + 6.60655 × 10-6 × TM63

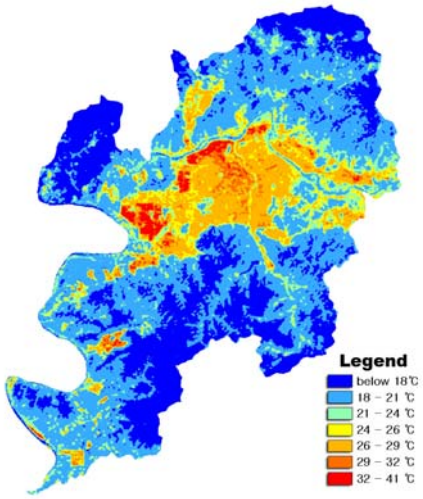


Figure 3. Present condition of Urban Heat-Island Phenomenon

The results of the above four equations present absolute temperature. Therefore, subtract 273.15 from the result to convert absolute temperature into Celsius.

C= K - 273.15

According to existing research on the earth surface temperature, spring and autumn have higher relativity with quadratic regression model among four models done by Landsat 5 TM band 6, summer with linear regression model, and winter with cubic regression model (Myung-hee Jo et al, 2001). To identify Urban Heat-Island phenomenon in summer, therefore, this study used the second equation, linear regression model

and Landsat 5 TM satellite image (Path/row :114/35 2004.8.8) of target areas, and analyzed the Urban Heat-Island phenomenon by utilizing PG-Streamer satellite image analysis program and Arc GIS 9.1.

For satellite image processing before analysis, geometrical compensation was carried out to compensate distorted phenomenon of satellite images based on 1/25000 digital map of starting point. Urban Heat-Island phenomenon of Daegu Metropolitan City was analyzed by compensated image.

As shown in the figure 3, industrial areas in Daegu, 3rd industrial complex of Buk-gu, Seodaegu industrial complex in Seo-gu, and Seongseo industrial complex in Dalseo-gu were analyzed as presenting very high temperature of the earth surface. Jung-gu areas centralized with commercial and business facilities shows a higher temperature than other areas.

Parks or school zones scattered in a mountainous district or central city, and river side such as the southern part of the Gumho River passing from east to west in the outskirts of the city and the Sincheon River flowing central city from south to north showed relatively lower temperatures.

### 3.2 Wind Corridor Analysis of Daegu Metropolitan City

This study was carried out focusing on constructing a green network as one of the methods of alleviating Urban Heat-Island phenomenon. Not only simple connection between green and water space, but also a green network can provide alleviation of Urban Heat-Island phenomenon and the spread of air pollutants as the area of a wind corridor.

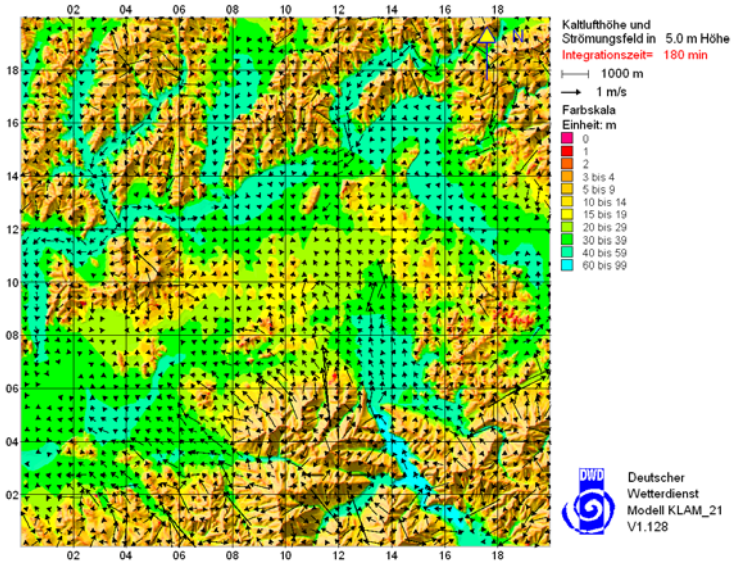


Figure 4. Wind Corridor Simulation of Daegu Metropolitan City ( 3hours passed)

From the judgement that a wind corridor is needed to be considered in planning a green network, the analysis of cold wind generation and a wind corridor considering spatial characteristics of the target area was implemented.

The wind corridor analysis was carried out with KLAM_21 model developed by The German Meterological Office which can operate simulation of cold wind generation and wind flow reflecting topographical chracteristics. Used attribute data was applied by processing land cover data and topographical data of the target place.

The KLAM_21 model has nine land cover classifications, which are high density residential area (1), low density residential area (2), forest (3), urbanization area (4), industrial area (5), park area (6), unpaved land (7), paved land (8), and waters (9). Average building height and density was decided according to designated land cover classification. For topographical data, altitude value of target place produced by processing 1/25000 digital map was used.

As basic setting, grid interval was 20 m. The standard of applying model is 5 m height above the ground in the 1000×1000 grid(20 km×20 km scale) including the central area of Daegu Metropolitan City.

The simulation of this model was implemented from 20:00 to 06:00 the next morning when cold wind is most actively generated.

In the result of the simulation, cold wind generated mostly in a mountainous area appeared to be flowing into the center of city through valley. However, it was identified that cold wind did not get into the center of city continuously. Some areas showed a smooth flow of wind, and especially the areas near river sides or mountainous areas presented distinct trends of smooth flow. As the area of flowing cold wind into the center of the city, Jung-gu and Nam-gu districts covering the Sincheon River and Apsan Mountain showed a high possibility of continuous wind flowing.

### 3.3 Select the Main Target Area


Figure 5. Location of Main Target Area

Urban Heat-Island phenomenon usually occurs in the center of a city. The main target area was selected based on the result of previously done Urban Heat-Island phenomenon and wind corridor analysis. The main target area was Jung-gu (the center of the city) and Nam-gu. Jung-gu is located in the middle of Daegu and was expected to show a very high level of Urban Heat-Island phenomenon, and Nam-gu is located next to Jung-gu and a green network can be constructed connecting the center of the city by linking greens in the outskirt of the city and the river. To improve efficiency of a green network and construct a wind corridor, a rectangular target area was selected measuring 9 km by 7 km which connects a river (Sincheon River) adjacent to the boundary between Jung-gu and Nam-gu into core green areas (Apsan and Duryu Park).

## 4 ANAYSIS AND STUDY OF MAIN TARGET AREA

### 4.1 Analysis of Urban Heat-Island Phenomenon

| | Daegu Weather Station | Nam-gu AWS | Seo-gu AWS |
|---|---|---|---|
| Temp. of the earth surface | 28.4□ | 28.4□ | 33.0□ |
| Measured Temperature | 32.2□ | 32.5□ | 32.7□ |

Table 1. Comparison of the earth surface temperature and measured temperature

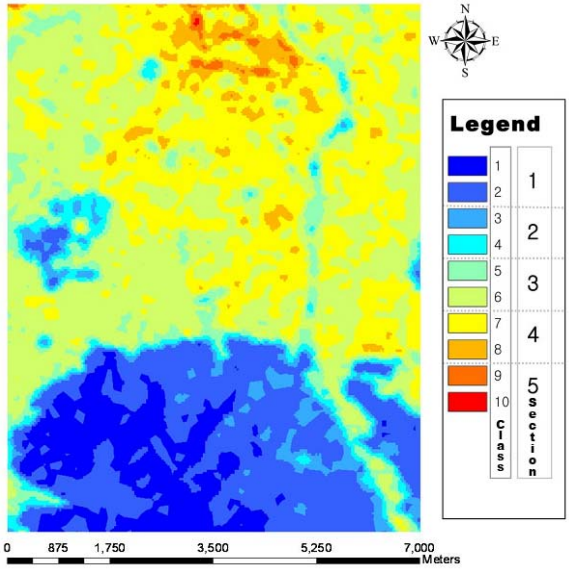


Figure 6. Analysis of Urban Heat-Island Phenomenon (Target Area)

As shown in the table 1, the earth surface temperature extracted from satellite images was compared with actually measured temperature. Seo-gu area showed almost no difference between the two temperatures; however, Nam-gu presented 4 differences. The satellite image has lower temperature than actually measured temperatures. Differing from the satellite image which measures the surface temperature, the actually measured temperature can have other variables according to the surrounding environments such as wind speed, humidity, the state of the earth surface, and artificial heat occurrence. Also, satellite images can have an average difference caused by limited resolution of the image.

In the existing research on Urban Heat-Island phenomenon, there is a study of implemented regression analysis with the actually measured earth surface temperature and satellite images. It calculated the temperature using regression equation with very convincing explanations. However, the target place of this study, Daegu, does not operate Automated Weather Station by Gu-distrcit. Also the main target places are located in Nam-gu areas only so there is not enough data to carry out regression analysis comparing the measured earth surface temperature. Also, it is assumed the temperature does not have much meaning in this study.

As compared with the actually measured temperature, the earth surface temperature from satellite images presented a little difference. However, this study used the earth surface temperature from satellite images to compare relative temperature among areas according to land cover of metropolitan area. Therefore, temperatures extracted from Landsat 5 TM were divided into 5 phases with ultra high, high, medium, low, and ultra low temperature sections. For more detailed analysis, each temperature section was classified into two weights, so 10 classification grid file were produced.

| Temperature Section | Ultra High | | High | | Medium | | Low | | Ultra Low | |
|---|---|---|---|---|---|---|---|---|---|---|
| Phase | 5 | | 4 | | 3 | | 2 | | 1 | |
| Weight | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Table 2. Weight Application on the Earth Surface Temperature

As presented in Figure 5, Jung-gu located in the center of the city shows more high temperature areas than Nam-gu. Neighborhood parks and greens including Dalseong and Duryu park, the Sincheon River area, and the mountainous area including Apsan Park presented relatively low temperatures.

## 4.2 Land Cover Classification

### 4.2.1 Land Cover Classification

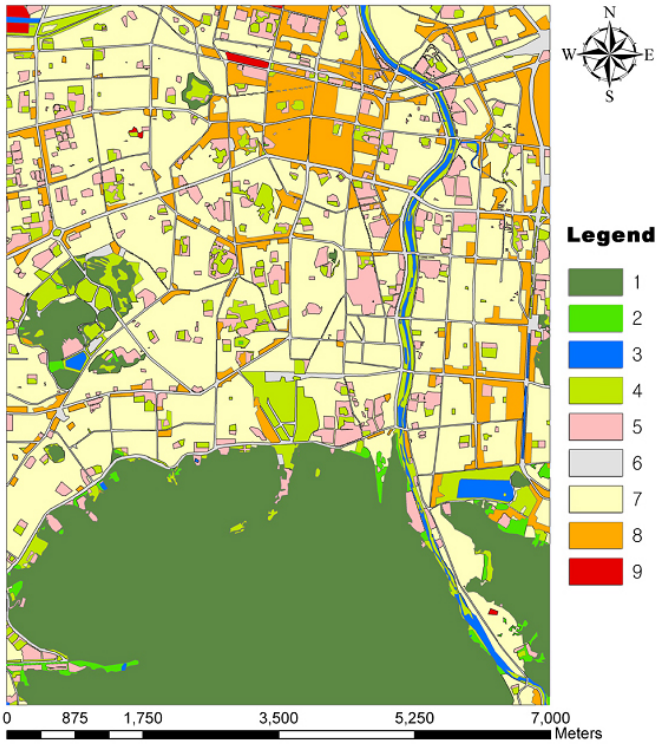


Figure 7. Land Cover Classification of Main Target Areas

To find out the effects of land cover state on Urban Heat-Island phenomenon, this study referred to land cover classification of the Ministry of Environment, and carried out land cover classification considering temperature effects on target areas. Land cover is classified into 9 categories. The standard of classification was the state of land cover and temperature change according to land cover.

Considering the effects on temperature, re-classified items were given weight. The weight becomes low if classified land cover has an important factor decreasing temperature, and the weight becomes high if it has temperature increasing factors.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Mountainous area and city forest | Farming area and grassland | Water area | Leisure complex, Other grassland and Other bare land | Apartment Complex and Public facilities area | Traffic area | Residential area | Commercial area | Industrial area |

Table 3. Weight by Land Cover Classification

### 4.2.2 Correlation Between Land Cover Classification and Temperature

To verify weight of land cover classification set according to the degree of effect on the temperature, correlation with present condition of Urban Heat-Island was analyzed. The land cover map and Urban Heat-Island present condition map have different spatial resolution. To compare them spatially accurately, they were converted into raster file consisting of 630,000 cells to unify spatial resolution of 10×10 m. Correlation analysis was implemented using statistical analysis program, SPSS 12.0.

| | Stat | TEMP | LANDCOVER |
|---|---|---|---|
| TEMP | Pearson Coefficient of Correlation | 1 | .898(**) |
| | Significance Probability (both sides) | | .000 |
| | N | 630000 | 630000 |
| LANDCOVER | Pearson Coefficient of Correlation | .898(**) | 1 |
| | Significance Probability (both sides)) | .000 | |
| | N | 630000 | 630000 |
| ** A coefficient of correlation is significant in 0.01 level (both sides) | | | |

Table 4. Correlation between Land Cover and Temperature

In the results of analyzing correlation of 630,000 cases, a coefficient of correlation was 0.898 in both sides.

This result represented that static correlation of increasing amount of temperature weight as land cover weight increases was shown high.

As the weight increases, therefore, land cover classification having effects on temperature set by this study can be considered as a factor of increasing temperature

### 4.3 Analysis of Connection Possibility of Green Network

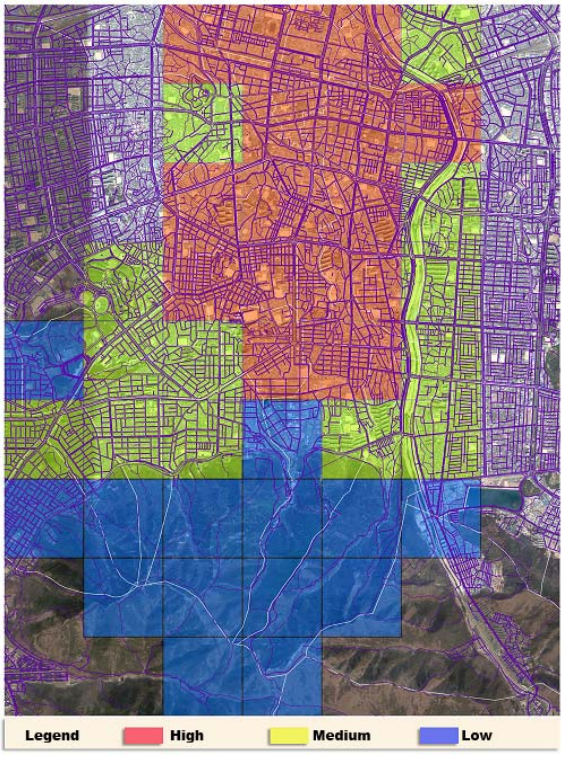


Figure 8. Temperature division of 41 districts

To analyze connection possibility for proposing a green network in the target area, this study planned to carry out possibility analysis by comparing temperatures and considering land cover state based on administrative districts (Dong) of target area of 7×9 km. However, comparative analysis was not able to be carried out due to dimension differences among administrative districts. So 41 grids with 1×1 km size including Jung-gu and Nam-gu area were produced and they were drawn after classifyng into high, medium and low temperature zone.

In the result, Jung-gu area, the center of the city, mostly accounted for high temperature zones. Dalseong Park and the Sincheon River area, even located in the middle of city, and near Apsan Parks of south area showed medium temperature zone. Duryu Park area and Apsan Mountain area represented low temperature zone. This looks like a typical type of Urban Heat-Island phenomenon. Although there are places which have high or low temperatures, places located more closely in the center of the city have higher temperatures on average.

The river (Sincheon) side area, even though located in the middle of city, areas with a certain amount of greens and parks represented relatively low temperatures.

As overall target area was examined, the Apsan area located in the south is a core area of constructing a green network. Due to the Apsan Beltway, there are many places cut. However, it is considered that green network of north and south direction based on the Camp Walker area using roads and river axis, and passageway of central city direction (north), linking spot region can be constructed.

It is also thought that the east and west direction network from Camp Henry (Daebong Park) to Sincheon passing through Duryu Park, Camp Henry and Daemyung 2 Park can be constructed. The east and west direction of Jung-gu connecting Dalseong Park and Jung-gu neighborhood park, and linking with Sincheon can be constructed.

### 4.4 Analysis of the Wind Corridor

A more detailed analysis than overall Daegu Metropolitan City was implemented by setting a basic set value of grid interval as 10 m, writing 700×900 grid which is the same interval as previously analyzed Urban Heat-Island present condition and land cover classification, applying the standard of model to 5 m height above the ground , and implementing simulation from 20:00 to 06:00 the next morning when cold wind is most actively generated. After considering all the results from simulation, the rear part of Camp Walker in Apsan, Songhyun water reservoir area, and the entrance of the GaChang Valley area (Padong) were shown with a very high wind flow. Suseong Bridge in the Sincheon area was shown as the most proper place to introduce winds to the center of the city.

Therefore, increasing the connection on the consideration of the rear part of Camp Walker and the Suseong Bridge area in constructing a green network can help cold wind generated in the Apsan area flow into the center of the city.

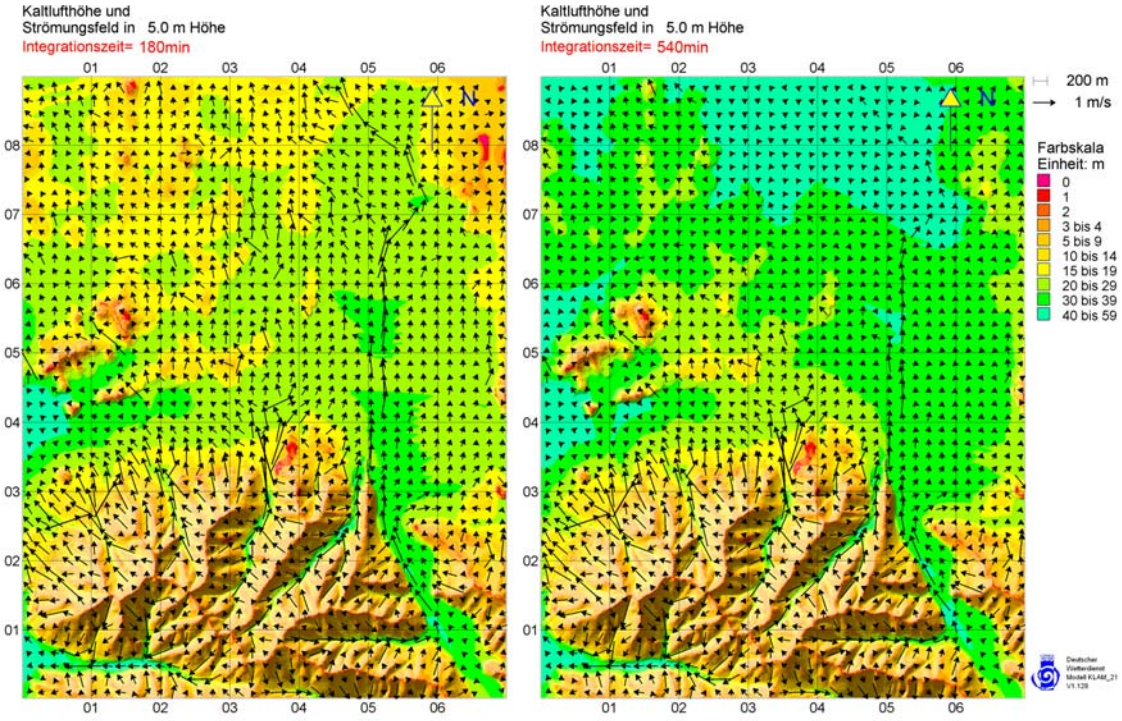


Figure 9. Wind Corridor Simulation of Target Area (3 hours passed, 9 hours passed)

## 5 CONCLUSION AND PROPOSAL

This research aims at improving the urban environment by reducing the temperature of the city through constructing a green network, as one urban planning approach to alleviate Urban Heat-Island phenomenon among city environmental problems. So it proposed a green network construction through the case studies carried out based on the target area showing Urban Heat-Island phenomenon.

Urban Heat-Island phenomenon represented relatively high in the industrial and commercial areas. In the residential area, the conditions differ from highly-populated areas, non-residentail areas of spot area (park), and so on according to neighboring environment (land cover). Places like the 3rd industrial complex of Buk-gu, Seodaegu industrial complex of Seo-gu, Seongseo industrial complex of Dalseo-gu, and Jung-gu area represented relatively high temperatures of the earth surface. Neighborhood parks, school zones, and river sides like the Gumho River passing from the east to the west in the outskirts of the city and the Sincheon River flowing through the central city from south to north showed relatively lower temperatures. In the target areas, Jung-gu has more high-temperature areas than Nam-gu. Neighborhood parks and greens including Dalseong Park and Duryu Park, the Sincheon River area, and mountainous areas including Apsan Park showed relatively very low temperatures.

In the land cover classification, it was classified as 1. Mountainous area and city forest, 2. Farming area and grassland, 3.Water area, 4. Leisure complex 5. Apartment complex and public facilities 6. Traffic area, 7. Residential area, 8. Commercial area and 9. Industrial area. As a result of analyzing correlation of the earth surface temperature, a coefficient of correlation in both sides showed 0.898. Land cover classification affecting the temperature set in this study is an important factor which increases temperature as weight increases.

Green network connection was analyzed based on the Urban Heat-Island phenomenon and land cover classification. Based on the results, a green network of Jung-gu and Nam-gu on the consideration for the green network of the whole city proposal to alleviate Urban Heat-Island are as follows.

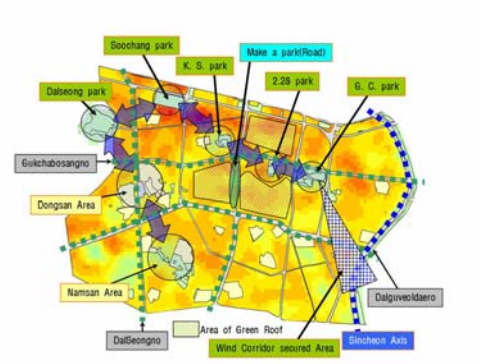


Figure 10. Green Network Concept of Jung-guq

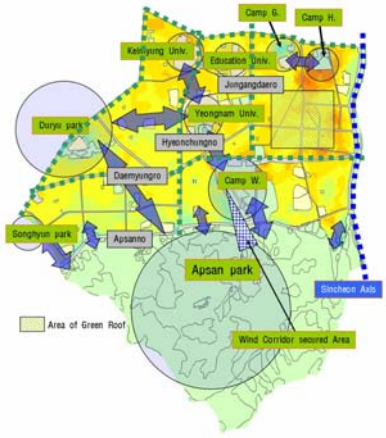


Figure 11. Green Network Concept of Nam-gu

1. In the Jung-gu area, the following is proposed; setting Dalseong Park as a spot and construct a green network by connecting parks neighboring central city and Sincheon River, securing maximum greens and biotop in and around Jung-gu, proposing changing parking lot into water permeable material, establishing wind corridor secured area in the between Dongduk road and Samduk Elementary School to secure wind passage, proposing changing roads in the central city to park, and establishing overall Jung-gu green axis by setting Gukchaebosangno and Dalgubeoldaero as east and west axis, and Dalseongro as north and south axis.

2. In the Nam-gu area, connect Duryu Park and Songhyun Park located near Nam-gu area with Nam-gu, make three US armies and Keimyung University park and connect Daemyung water reservoir, establish the north and south axis using Hyeonchungno, Jungangdaero, and Sincheon riverside, set the east and west axis using Daemyungro, and connect spot area of neighboring area. It is hard for Nam-gu office area to secure spot area so that the introduction of Green-Roof is proposed.

Developed central city showed very insufficient with spot areas. Except parks, schools and neighboring areas represented low temperatures. Therefore, it is needed to utilize school areas and positvely introduce Green-Roof to secure spots insufficient in the city.

This study was significant by examining the Urban Heat-Island phenomenon of target places, identifying the correlation between land cover and Urban Heat-Island present condition, proposing a detailed green network plan, and analyzing cold wind generation and wind corridors.

However, it did not cover the whole Daegu area so that area excluded in this study can have a low connection. Wind corridor analysis did not carry out verification of the whole target area due to lack of weather data. The green network proposed in this study was to alleviate Urban Heat-Island phenomenon so that other functions of a green network such as passageway of organisms can be deteriorated.

In the future, research on overall green network construction is needed to be carried out continuously through time-series Urban Heat-Island phenomenon and wind corridor analysis including Daegu and its neighboring areas.

## 6 APPRECIATION

This research was implemented as a part of establishing web-based wind information systems (R-01-2006-000-10543-0), specialized fundamental research of the Korea Science and Engineering Foundation.

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