IJHSR
ijhighschoolresearch.org
■ RESEARCH ARTICLE

Air Temperature Effects by an Urban Stream, Seongnam

Junghoon (Trent) Kim, Seungho Kang, Jamie Kim

Northfield Mount Hermon (NMH), 1 Lamplighter Way, Mount Hermon, Massachusetts, 01354, USA; jamiekim2005@gmail.com

ABSTRACT: The climate, along with temperatures, is getting hotter globally. To understand the temperature distribution according to the land use types (nearby & covered streams, parks, commercial, residential), Pangyo area (a new city involving the Unjung stream) and Moran area (an old city involving the covered stream) in Seongnam City were chosen for observation. Temperature and humidity were measured on July 17, 24, and 25, 2021. The temperature and humidity of the stream were observed to know the influence of the stream on the reduction of temperature of the surroundings as well. The highest temperature difference between the Pangyo area and around Unjung Stream was 3.5℃, and the highest difference in the Moran area and around the covered stream was 3.2℃. The average temperature difference between the stream area and its surroundings was 3.1℃ in the Pangyo area, which is considered to be the result of the combination of the difference in planning for each phase of the city, including the reflection of green areas, the presence or absence of urban streams, and the density of development. As a result of measuring the Unjung Stream to investigate the temperature reduction effect of urban streams, the point just below the Unjung Stream in the morning was up to 1.9℃ lower than the surrounding area. The influence of the stream on temperature reduction was observed clearly.

KEYWORDS: Climate change; Heat island; Land use; Covered Stream; Unjung Stream; Pangyo; Moran.

■ Introduction

With the increasing impacts of climate change evident in our society, ranging from sea level rise to an overall heating of 1℃, climate change is an imminent problem. Even with a 1.5 ℃ overall global warming, 99% of the Great Barrier coral reef will die, leading to catastrophic disaster in the ocean, which supplies 50% of the oxygen humans breathe in.

These problems of climate change have been getting exacerbated by rapid urbanization. The underlying surface structure in urban areas has been changed dramatically by decreasing vegetation ratio and increasing impervious surface, which results in serious environmental issues, e.g., urban heat island (UHI) problems. Indeed, cities worldwide have been warming up in the summer over the years due to this problem. Seoul and surrounding areas in Korea are also examples of how a city was transformed into an urban heat island. However, in these cities, there are also areas called green areas that produce social, economic, and environmental benefits in highly populated urban areas.

In the city, the urban cover is one of the main factors influencing its temperature. Emmanuel (1997)[1] found that in terms of spatial distribution characteristics, heat island and cold island phenomena may appear together because urban land cover or land use affects the daytime urban temperature when the atmosphere is stable. The regression analysis of the relationship between various land use types and temperature showed that forests and farmland had a cooling effect. In contrast, urban areas composed of asphalt or concrete showed a temperature increase effect of about 2°C, both in the average and minimum temperatures. In a study on the impact of land cover and land use on the difference in daytime temperature, Shudo[2] and Gallo[3] said that the seasonal daily temperature difference was significantly larger depending on the land use condition of the observation point. In addition, Lee[4] analyzed the characteristics and scale of land use change over 20 years in Seoul and the metropolitan area to understand the impact of this change on the local climate.

On the other hand, research has been carried out to determine the air temperature decreasing effects of urban streams.[5] UHI characteristics have been studied during the past several decades. UHI shows the difference between heated urban areas and rural (stream) areas, and it is known that UHI intensity is obvious in nighttime, winter, windless and cloud-free conditions.[8-10] The purpose of this study is to 1) find out the special-temporal distribution characteristics of summer temperature by land use, 2) check the effect and range of urban streams on temperature, and 3) propose basic data accumulation for urban temperature reduction effect.

■ Methods

1. Study Site:

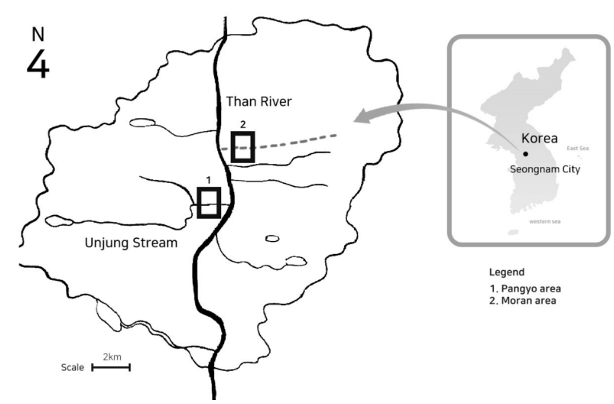


Figure 1: Study area map of Seongnam, Korea. Pangyo and Moran's areas are shown as 1 and 2, respectively.

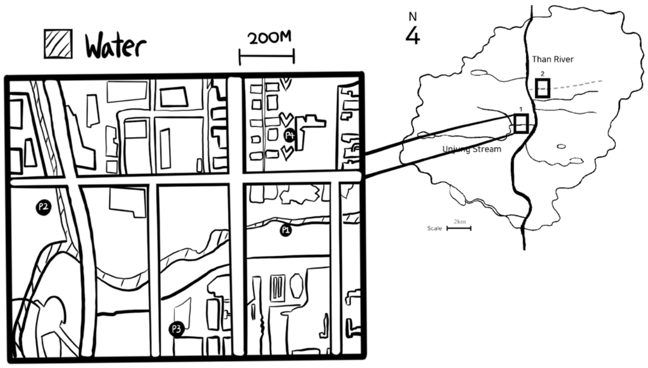


Figure 2: Study Area 1, Pangyo. It was chosen for four land use types. It is characteristic of the Unjung stream across the new city in Pangyo.

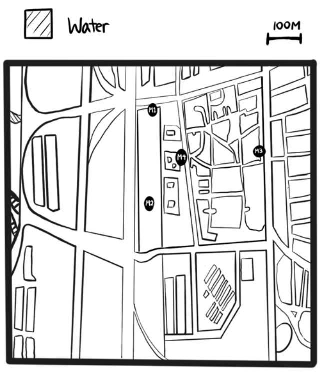


Figure 3: Study Area 2, Moran. It was chosen for four land use types. It is characteristic of a covered stream across the old city of Moran. A covered stream has been used for the road and parking station since the 1990s.

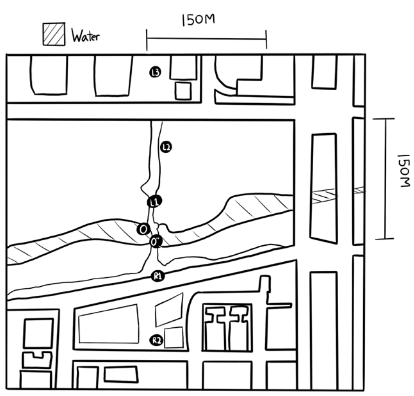


Figure 4: Unjung Stream Cross Section.

The main research areas were selected in the Pangyo area (a new city) through which the Unjung Stream flows located and in the Moran area (an old city center), which consists of a covered stream at Seongnam-si, the metropolitan area of Korea. The Pangyo area is in number 1, and the Moran area is in number 2 in Figure 1. The Unjung stream shown in Figure 1 is 7.98 km and is about 23~140 meters wide, and the slope is 1:500. The stream originates from the Unjung reservoir itself and joins the Than River, which eventually leads to the Han River (Figure 1).

The Pangyo area, including the Unjung stream, adopted a low-density urban development method in the early 2000s. It shows a relatively low area and population density ratio. It is classified into four zones by land use and has nature-friendly infrastructure such as parks and streams (Figure 2). On the other hand, the Dandae stream, which flows through the peony area, is currently covered and used as a road, losing its urban stream function, and it is an area with high population density due to poor development (Figure 3).

In the two regions where the difference in urban planning according to the period of city formation is markedly different, the effect of the presence or absence of a stream in the summer was examined. Four separate sections of each land were chosen for a more accurate demonstration of the temperature and humidity (near & covered stream, park, commercial, and residential).

2. Data Observation

Figure 5: Field Photo by Zones (TOP LEFT) commercial, (TOP RIGHT) park, (BOTTOM LEFT) stream and (BOTTOM RIGHT) residential).

To look at the temperature distribution pattern, we measured temperature and humidity data using Testo 608–H1 temperature-humidity (T-H) sensors at eight observing positions on July 17, 24, and 25, 2021. These eight observing positions are shown in Figures 2 and 3. The basic characteristics of the Pangyo and Moran areas and study zones are summarized in Table 1.

Table 1: Summary of the characteristics of the Pangyo and Moran areas. It is classified into four land use types.

area	Pangyo	Moran
characteristics	good urban planning, low density	poor urban planning, high density
stream types	natural stream (flow water in stream)	covered(artificial) stream-using road
stream zone	P1	M1
Park zone	P2	M2
Commercial zone	P3	M3
Residential zone	P4	M4

* P1 (Unjung stream), M1 (Dandae stream)

DOI: 10.36838/v5i3.9

On the other hand, to see if the stream actually had an impact on decreasing the surrounding temperature, we did another study where we selected points that are 150m left and right of the Unjung stream (0) and the bridge of the stream (total of 5 locations- L3, L2, L1, 0“, R1, R2 in Figure 4 and measured in 30-minute intervals with the sensor mentioned above. We selected these points as these points were effective in showing us the temperature difference between the area near the stream and the points on the bridge, as well as telling us the temperature difference across the river areas.

Results and Discussion

1. Temperature distribution along the different areas in Moran and Pangyo area:

From the data collected on July 17 at Pangyo and July 24 at Moran in the eight zones, we put these data points in Table 2. If we compare the two areas and their average temperatures, we can see that P1 (stream, Pangyo) had a temperature of 33.2 ℃ whereas M1 (covered stream, Moran) had a temperature of 37.7 ℃. P2 (park, Pangyo) had a temperature of 32.8 ℃, whereas M2 (park, Moran) had a temperature of 38.1 ℃. In P3 (commercial district, Pangyo) temperature was 31.2 ℃, and in M3 (commercial district, Moran) was 34.9 ℃. Lastly, in P4 (housing district, Pangyo) temperature was 34.7 ℃, whereas in M4 (housing district, Moran) was 36.9 ℃.

Table 2: Shows temperature data in 8 locations according to daylight times. Temperature measurement is accounted for by land use and city planning.

(unit : ℃)

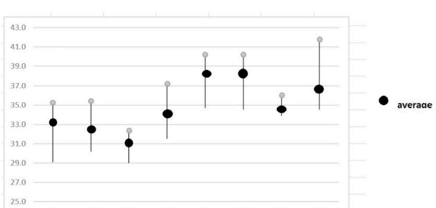
Time (17, July)	P1	P2	P3	P4	Time (24, July)	M1	M2	M3	M4
11:00	29.1	30.2	29.0	31.5	11:00	34.7	34.5	35.7	34.5
11:30	31.9	ND	29.4	34.6	11:30	35.6	36.4	36.0	36.0
12:00	32.5	32.2	30.0	34.6	12:00	36.0	36.2	35.9	35.5
12:30	33.1	ND	30.8	36.0	12:30	36.3	36.9	35.8	35.7
13:00	33.7	33.9	31.2	35.0	13:00	37.7	37.8	35.2	37.3
13:30	33.0	ND	31.2	34.8	13:30	37.4	38.6	34.8	37.1
14:00	33.6	33.2	31.7	35.1	14:00	38.3	38.5	34.8	41.8
14:30	33.9	ND*	32.0	34.6	14:30	39.0	38.7	34.8	38.2
15:00	34.3	35.4	32.4	34.2	15:00	38.5	39.4	34.9	38.1
15:30	34.1	ND	32.3	34.7	15:30	39.0	40.0	35.0	37.9
16:00	32.9	32.7	31.7	33.4	16:00	40.2	40.2	34.7	37.4
16:30	34.5	32.6	31.6	33.8	16:30	40.0	39.6	34.3	36.7
17:00	35.3	33.1	31.8	35.4	17:00	37.8	38.9	34.3	36.7
17:30	33.7	32.7	31.6	35.1	17:30	37.6	38.0	34.1	35.7
18:00	32.5	31.6	31.6	37.2	18:00	36.8	37.3	33.9	35.3
Average	33.2	32.8	31.2	34.7	Average	37.7	38.1	34.9	36.9

*ND : not determined

For the maximum and minimum temperature differences for the measured times, for the stream zone, we had P1 of 6.2 ℃ and M1 of 5.5 ℃. For the park area, we had P2 as 5.2 ℃ and M2 as 5.7 ℃. For the commercial area, we had P3 of 3.4 ℃ and M3 of 2.1 ℃. Lastly, for the residential district, we had P4 of 5.7 ℃ and M4 of 6.3 ℃. The more specific values for the temperature in these different zones are in Figure 6. (Table 3 shows Basic statistical data on the temperature in each of the 8 locations)

Table 3: Basic statistical data of temperature in Pangyo and Moran areas during 17 July (Pangyo) and 24 July (Moran).

	P1	P2	P3	P4		M1	M2	M3	M4
Average	33.2	32.8	31.2	34.7	Average	37.7	38.1	34.9	36.9
Min	29.1	30.2	29.0	31.5	Min	34.7	34.5	33.9	34.5
Max	35.3	35.4	32.4	37.2	Max	40.2	40.2	36.0	41.8
Range	6.2	5.2	3.4	5.7	Range	5.5	5.7	2.1	7.3



In the average temperature for the Pangyo region, the temperature increases in this order: P3 (commercial zone), P2 (park), P1 (near the stream), and P4 (residential zone). The order increases at the highest temperature: P3 (commercial zone, P2 (park), P1 (near the stream), and P4 (residential zone). On the other hand, in terms of average temperature in the Moran area, the order is as follows: M3 (commercial zone), M4 (residential zone), M1 (covered stream), and M2 (park). At the highest temperatures for each region in Moran, the order is as follows: M3 (commercial zone), M1 (covered stream), M2 (park), and M4 (residential zone). From this data, if we don't consider the residential district temperature of 41.8 ℃ at 2 pm, the trend is similar to the average temperature trend. Therefore, additional research is needed to determine if this temperature recording was an error or not.

It is a reversed relationship between the temperature and humidity of the Pangyo area. Looking at the Pangyo area's humidity, we see that the average humidity of the residential zone is 44%. In contrast, the other zones have an average humidity of 52.4 to 52.6% (Table 2). So, we see that the residential zone has a high temperature and low humidity, whereas the other zones show the opposite pattern (Figure 7). Therefore, we say that the amount of water in the zone can play a role in decreasing the temperature, but more research is needed to see the impact of humidity.

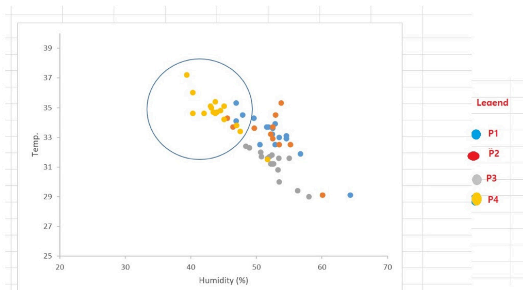


Figure 7: Relation between temperature and humidity in Pangyo 4 area on 17 July 2021.

Summer temperatures in Seoul city are mitigated in the area 100m from the river and 300m from the park[12]. Also, it is detailed in this study that in the regions surrounding Seoul, the areas of the city were 7.3 ℃ higher than those of the surrounding green land areas. Also, according to Kwon and Lee[16], analyzing the temperature distribution by land types, they found that the highest temperature zone was the commercial area, and the lowest temperature occurred in the green open space (park). Commercial zones had a low temperature compared with other zones in the Pangyo and Moran areas. This could be due to two main reasons: 1) the temperature could have been influenced due to air conditioning from surrounding buildings, and 2) it may be due to the impact of the air conditioning coming from the underground railroad system. As these could have impacted the temperature measurement, more research is necessary to determine what caused this temperature drop.

Something surprising is the fact that the highest temperature recorded in the Moran region was in the park. However, as Moran Park has only been around for five years and the trees in that park are so young and only a little leafy, it is hard to say that the park functions like other parks in its impact to decrease temperature. Therefore, we can assume that the land type is in between an entire park and bare land. Also, if we take a look at the density of air conditioning used per human inhabitant, the residential district is something that we should take note of. As the air conditioning mechanism brings the inside heat outside, the temperature-increasing impact that this brings should also be considered. The reason for the little fluctuation of temperature within the residential district shows that humans could cause the main effect on the temperature of a particular zone.

2. Analyzing the impact of the stream on temperature:

Table 4 shows the temperature measurement results around Unjung Stream and surrounding areas in Pangyo. The reference point is the point (0 mark) located just below Unjung Stream. The comparison point is about 5m vertical (0" marked) and 50m left and right.

Table 4: Temperature and humidity in 7 locations of Unjung stream and surroundings. It measured temperature and humidity from sunrise to morning on 17 July 2021.

Time	0		R1		L1		L2	
	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity
6:00	26.3	79.2	27.6	71.1	27	74.9	26.9	74.1
7:00	27.6	72.7	28.5	70.3	28.4	71.6	27.6	73.8
8:00	28.0	76.3	29.1	69.9	29.9	67.4	28.9	70.8
9:00	31.5	66.9	31.3	60.3	32.6	59.4	33.0	58.5
10:00	33.6	55.00	35.3	50.2	35.1	51.6	36.5	47.7
Average	29.4		30.4		30.6		30.6	

Time	0		R2		0"		L3	
	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity
6:30	26.5	79.7	27	75.2	26.7	75.7	27.1	75.1
7:30	27.9	76.7	28.3	70.5	28.7	71.2	27.8	75.2
8:30	30.9	69.3	29.4	68.2	32.5	57.7	28.9	70.3
9:30	31.8	62.7	31.6	58.7	33.5	54.1	31.1	67.8
Average	29.3		29.1	그림 영역	30.4		28.7	

Unit is followning: Temperature is oC, humidity is %.

The reference point of 0 has an average temperature of 29.3°C and shows a distribution between 26.5°C and 31.8°C. The temperature difference is 5.3℃. The 0" point (middle point of the Gaenari Bridge) vertically above 5m has an average temperature of 30.4℃ and a distribution between 26.7℃ and 33.5℃. The temperature difference is 6.8℃. The temperature immediately after sunrise showed a slight difference of 0.2°C, but the difference of 1.7°C was observed when measured at 9:30 a.m. Meanwhile, the temperature between the comparison points (L1, L2, and R3 points) of about 50 m apart from the reference 0 point does not show much difference from the bridge point (0" point) (Table 4). The temperature difference between the point where the water flows in Unjung Stream and the point 5m vertical after sunrise indicates that the spatial range of the water path affecting the actual temperature is limited, and similar temperature distribution between the vertical point and the surrounding point supports this.

The phenomenon that the temperature difference increases as time go by in the morning is an index that measures the urban heat island phenomenon. Urban Heat Island Intensity can explain it. According to a study by Morris and Simmonds[11], the temperature difference between time zones gradually increases during the day. It progressively cools the surface after sunset, resulting in a minimum heat island intensity in the morning and a maximum in the evening.

According to a study by Myung[12], the distance of about 100m from the waterway in Seoul was lower than the city's overall temperature, so it was estimated that about 100m was the effective distance of the temperature drop. However, since this study was also analyzed as a national river on the scale of the Han River, the direct temperature drop effect is judged to be less than 5m on the scale of the local stream on the tributary level. It is necessary to study the relationship between the scale of the stream and temperature in the summer period.

In terms of temperature change characteristics due to streams, the Commercial zone (R2) and Techno business working facilities (L3) show a distribution lower than or similar to the Unjung stream reference point (0) temperature (Figure 8). Although there is a limit to our specific sample time from sunrise to 10 a.m., the temperature reduction effect at R2 was similar to the reference point (0) under the stream's influence. This is estimated to be the effect of direct sunlight blocking it from the winding road and the shade of a building in the morning, and the L3 point is judged to be the street tree effect of an evergreen forest. According to previous studies, the presence or absence of street trees planted in the city center makes it vary up to 10°C.[13]

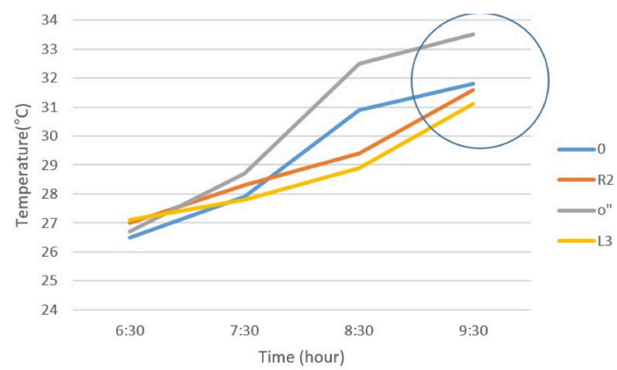


Figure 8: Temperature distribution in 4 points of Unjung stream and surrounding on July 17, 2021. Remarkably, the temperature of L3 and R2 is similar to or lower than that of the stream reference point at 9:30 (0).

Since there are not only rivers but also green areas and other landscape elements in the city, it is difficult to conclude that the result of temperature distribution is due to the temperature drop caused by only waterways. Therefore, further research should be conducted on more points in the future.

3. Implication Urban planning to influence temperature:

On 25 July, eight representative points for each land use in Pangyo and Moran areas were selected to measure the temperature (Table 5). It was also the day when a heat wave above the average temperature of 35°C was recorded. Still, first of all, looking at the temperature difference by area, the average temperature in Pangyo was 36.1°C, while the Moran area was 37.3°C. The Moran area was 1.2°C higher, and the monitoring results conducted by Seongnam-si showed that the old city center (e.g., the Moran area) was higher by about 3°C for each type of land use.

The temperature by land use is 1) Pangyo (36.5°C) vs. Moran (37.6°C) in the stream, and the difference is 0.9°C. 2) Pangyo (35.8°C) vs Moran (37.6°C) in the park, and the total difference is 1.9°C. 3) In commercial facilities, Pangyo (35.8°C) vs. Moran (36.0°C), the difference is 0.2°C. 4) In

DOI: 10.36838/v5i3.9

Table 5: Temperature and humidity in 8 locations in the Pangyo and Moran areas from morning to afternoon on 25 July 2021.

	P1		M1		P2		M2		P3		M3		P4		M4	
Time	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature
0.5	43.6	33.1	44.8	34.1					45.0	32.9	34.5	35.5				
0.5					43.2	35.0	43.6	35.8					42.6	34.9	36.1	37.8
0.5	42.4	35.7	37.8	37.2					43.0	34.6	38.4	36.6				
0.5					43.5	35.6	40.0	36.7					41.2	36.2	39.6	36.7
0.5	41.2	37.7	35.6	38.8					35.8	38.3	41.1	35.6				
0.6					40.1	36.2	36.1	38.4					37.1	37.2	37.3	37.7
0.6	43.3	37.9	35.2	38.3					36.1	37.6	36.3	37.0				
0.6					40.2	36.9	34.1	38.8					37.5	37.3	33.6	38.7
0.6	38.5	37.9	33.6	39.3					38.7	36.3	40.5	35.4				
0.6					39.9	36.2	34.8	38.2					40.1	36.9	36.5	37.0
0.7	38.1	37.7	35.8	39.1					40.1	36.0	40.4	36.5				
0.7					43.3	35.6	38.2	37.5					40.8	36.8	33.6	39.7
0.7	41.0	36.8	38.0	38.1					43.5	35.2	44.0	34.4				
0.7					44.1	35.4	39.9	37.6					43.5	35.7	36.5	37.0
0.8	44.1	35.4	44.1	36.2					43.6	35.1	46.3	34.0				
Average	41.5	36.5	38.1	37.6	42	35.8	38.1	37.6	40.7	35.8	38.2	36.0	40.4	36.4	36.2	37.8

Unit is followning: Temperature is ℃, humidity is %.

Residential zones (apartment houses), the Moran area was high, with Pangyo (36.4˚C) vs. Moran (37.8˚C), and the difference was 1.4˚C. The average temperature in Pangyo area shows stream > residential zones (apartment houses) > parks = commercial facilities, while the average temperature in Moran area is residential zones (apartment houses) > stream = parks > commercial facilities. The retardation in measurement time in 30 minutes should be considered. The key is to compare the temperatures between the two areas, which show differences in representative urban planning sweets.

The Moran and Pangyo areas have a history of urban development in the Korean metropolitan area. The Moran area was created in the process of dispersing the concentration of the population in the metropolitan area during the modernization process. In contrast, the Pangyo area is a thoroughly planned city based on high-tech industries. The former was mainly built in the 1970s and 1980s, while the latter was built in the early and mid-2000s. The decisive variance appears to be the difference between the plans and the use of the stream crossing the city center. While the Moran area has built roads on streams where water flows due to a lack of basic urban infrastructure, the Pangyo area is an area where the importance of streams occupied by urban infrastructure is reflected. In summary, the former is typical of an old city center with a high population density made up of reckless development, while the latter is a symbol of a new city center developed according to a thorough urban plan.[14]

The difference between streams in Pangyo and Moran is noteworthy in the two areas. In fact, M1 is used as a road with the loss of stream function, P1 has a temperature reduction effect, and M1 in the Moran area causes a temperature increase effect. Currently, there is a 0.9˚C difference, and according to previous studies, it is known that the effect of reducing the temperature by a river is much more pronounced at sunset and night.[17] In addition to health aspects and psychological considerations, the effect of reducing the temperature of rivers requires continuous investigation and monitoring of urban infrastructure.

The park shows the largest temperature difference between the two areas, with an average of 1.9˚C. It seems to be the result of the year of the park's establishment, the park's size, the difference in tree species, and the park's location. The Moran area seems to have little role as a park, but the Pangyo area has a park as a green area. In the existing study of Myung[12], it can be seen that the spatial temperature reduction range of green areas is about 300m, which is more effective than rivers. Meanwhile, to reduce heat wave damage in Daegu, the green area ratio in the city center was expanded to reduce the actual summer temperature.[15]

In the case of the Moran area, uncovering the current stream is necessary to alleviate the heat wave, but considerable adjustment of understanding between residents considering the existing road and parking conditions. Therefore, securing various green spaces in a decentralized manner is worth considering as one of the practical alternatives.

Conclusion

Starting with studies that we have referenced; nature had a foreseeable impact on lowering the temperature in a metropolitan city. As we have referenced these papers as well as thought of ways that we could differentiate our research from these other efforts, we sought to conduct our research on the Tan stream area using both temperature and humidity data. To look at how this newly added stream influenced both the temperature and humidity of surrounding areas, we divided the surrounding locations into four sections. We took measurements simultaneously for these 4 study sites on June 14 and June 15, 2021. The results that we got were different from our hypothesis. We initially thought that areas 1 or 2, close to the stream, would have the lowest temperature. However, we found that that wasn't the case, and the lowest temperature recorded was actually in the surrounding commercial area. However, our hypothesis for the region with the highest temperature was correct, as the residential area had the highest temperature. For humidity, as we expected, the lowest humidity occurred near the residential area, and the highest humidity occurred near the stream. From these results, we can conclude that having a stream in a city somewhat decreases the temperatures that the citizens feel, which tells us that we should strive to incorporate more of nature in our future city designs.

To study the temperature distribution across the different types of land use, we measured the 4 study sites in the Pangyo area and Moran area in Seongnam, Korea, on July 17 and 24. To see the impact of temperature control, we studied the Unjung stream. The temperature distribution for the different area types for Pangyo and Moran are as follows. 1) stream zone: P1 (33.2˚C) vs M1 (37.7˚C), park zone: P2 (32.8˚C) vs M2 (38.1˚C), commercial zone: P3 (31.2˚C) vs M3(34.9˚C), residential zone: P4 (34.2˚C) vs M4(36.9˚C). There needs to be more research done to determine why the region with the lowest temperature was the commercial area. The average temperature between the two areas was 3.1℃ lower in the Pangyo area, which is judged to be the result of the combination of the difference in planning for each phase of the city, including the reflection of green zones as the presence or absence of urban streams, and the density of development. To investigate the temperature reduction effect of urban streams, the point just below the Unjung Stream at sunrise was up to 1.9℃ lower than the surrounding area. To construct a city that is prepared for the future, more research is needed to see the seasonal temperature and humidity patterns of areas near the stream from the past to get a more accurate explanation.

References

1. Emmanuel, R., 1997, Summertime Urban Heat Island Mitigation: Propositions based on an Investigation of Intra-Urban Air Temperature Variations, Architectural Science Review, 40(40, 155-164
2. Shudo, H., J. Sugiyama, N. Yokoo, and T. Oka. 1997. "A Study on

Temperature Distribution Influenced by Various Land Uses". Energy and Buildings, 26: 199-205. of Intra-Urban Air Temperature Variations, Architectural Science Review, 40(4), 155-164.
3. Gallo, K. P., D. R. Easterling and T. C. Peterson, 1996, The Influence of Land Use/Land Cover on Climatological Values of the Diurnal Temperature Range, J. Climate, 9, 2941-2944.
4. Lee, H. Y., 1995, The Impact Assessment of Urbanization on the Atmospheric Environment, J. Environment Impact Assessment, 4(3), 73-86.
5. (Woo-Gon Do, Jeong-Gin Cho and Pyung-Jong Yoo, 2010, A study on the air temperature decreasing effects resulting from restoring streams in urban area, The Annual Report of Busan Metropolitan City Institute of Health and Environment 20(1), 168-177 (in Korean)
6. Oke, T. R., 1987, Boundary Layer Climates, 2nd ed., Routledge.
7. Arnfield, J., 2003, Two decades of urban climate research: A Review of turbulence, exchanges of energy and water, and the urban heat island, lnt. Jour. of Climatology, 23, 1-26.
8. Klik, K., and K. Fortuniak, 1999, Temporal and spatial characteristics of the urban heat island of Lodz, Poland. Atmos. Environ., 33. 38 85-3895.
9. Steyn, and I. D. Watson. 1991, Simulation of surface urban heat islands under 'ideal' conditions at night. Part 2: Diagnosis and causation. Bound. -Layer Meteor. 56, 339- 358.
10. Kim, Y-H, J-J Baik, 2002, Maximum Urban Heat Island Intensity in Seoul. Atmos Environ., 41, 651-659.
11. C.J.G. Morris and I. Simmonds, 2010, Associations between varying magnitudes of the urban heat island and the synoptic climatology in Melbourne, Australia, International Journal of Climatology, 20(15), 1931-1954,
12. Myung S-J, 2009, A Study on Strategies to Mitigate Urban Heat Island Effects as Part of Climate Change Adaptation in Urban Areas, Korea Environment Institute, 37p (in Korean)
13. Lee, S-M, O, C-H, Lee, G-O, 2010, Urban Heat Island (UHI) Alleviating Effect of street trees in Seoul, Proceedings of the Korean Institute of Landscape Architecture Conference, Pages.93-96 (In Korean)
14. Seongnam si, 2035 Seongnam City Basic Plan, 2020
15. Kwon, Y-S, 2015, Consideration for an environment-friendly city by reducing the urban heat effect, DAEGU GYEONGBUK DEVELOPMENT INSTITUTE (in Korean)
16. Kwon Y-A and Lee H-Y, 2003, The Characteristics of Air Temperature Distribution by Land-use Type, Environment Effect Assessment, 12 (4), 281-290. (in Korean)
17. Lee G-S, Shin D-H, Kim J-C, Lee S-H, Lee, H-J, Jin W, Zheng H., 2010, Air Temperature Decreasing Effects by Restored Urban Stream, Environment Effect Assessment, 19 (1), 75-81. (in Korean)

Authors

Junghoon Kim is a senior attending Northfield Mount Hermon. He has always been interested in sciences that involve something to do with weather and the environment. Therefore, he is considering going to college and majoring in something related to the environment or weather.

Jamie Minsung Kim is a junior attending Saint Paul Preparatory Seoul. He enjoys learning about science and history.

Seungho Kang is a senior attending Saint John's School Guam. He is interested in hydrology and urban planning.

DOI: 10.36838/v5i3.9