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Research on the Correlation between the Elements of Visual Landscape and the Micro-thermal Environment in Universities and Its Optimal Design—A Case Study of Sichuan Agricultural University

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Abstract. The research on the micro-thermal environment of universities is conducive to improving the environmental quality of the campuses, however, there are few related Microscopic empirical research. The research goal of this paper is to take the Dujiangyan Campus of Sichuan Agricultural University as an example to explore the correlation between campus visual landscape elements and micro-thermal environment, and then propose a landscape optimization approach to improve the thermal environment. By way of a panoramic camera, a temperature measuring instrument, and a thermal imager, the panoramic view, air temperature and the surface temperature of the main landscape of 120 sites on the campus were collected through the system sampling method, elements of visual landscape and their spatial distribution were graded and quantified using artificial intelligence image recognition method and ArcGIS. The air temperature was taken as the dependent variable, and the elements of visual landscape and their surface temperature were taken as the independent variables during the experiment to analyze the coupling relationship between the campus micro-thermal environment and the landscape elements by way of the geo-detector. The results show that the campus landscape consists of five major elements: roads, buildings and structures, vegetation, people and vehicles. The distribution regarding the proportion of the field of view has significant spatial differentiation. Among the five visual landscape components, the artificial environment, such as roads, buildings and structures, has a relatively larger impact on the spatial differentiation of the campus thermal environment compared with other factors; The temperature of people, proportion of vehicles and vegetation surface temperature have less explanatory power for spatial differentiation of campus thermal environment; The proportion of the five types of elements and their surface temperature have no significant correlation with the campus thermal environment.

1. Introduction
Since the reform and opening up, the level of higher education in China has been continuously improved. The number of students enrolled in universities has increased year by year and has shown a rapid growth rate[1], which puts new demands on the environmental quality of college campuses. The outdoor environment of the campus is what people are in direct contact with and an important component of the university environment. So, it should be a comfortable space for communication, sporting, viewing and

other activities, in which people are able to have a good feeling of hot and cold. The outdoor thermal environment on campus has an important impact on the campus microclimate, and it also affects the user's comfort experience.

In order to improve the outdoor thermal environment of colleges and universities, many domestic scholars have carried out related research on the campus thermal environment[2]. As for the campus environment of Tianjin University, Chen Yu systematically studied the effects of environmental design with different greening rates on outdoor thermal environment in summer based on the combination of site environmental parameter measurement and computer numerical simulation. The research drew a conclusion that the summer environment can be effectively improved by increasing the greening rate based on the original environment[3]. The computer numerical simulation method was used by Fu Yuting to analyze the overall thermal environment of the campus, simulate the ventilation and thermal environment comfort of the outdoor-activity sites from the perspective of the design of building groups and single buildings and provide an optimization strategy for the thermal environment comfort of outdoor-activity sites[4]. Li Jie conducted a survey and simulation of the enclosed courtyards of Huaqiao University Xiamen Campus, analyzed the influence of the thermal performance regarding the architectural shadow and the paving materials of the enclosed buildings on the ventilation and thermal environment of the courtyards, and analyzed the improvement measures of the courtyard thermal environment from the perspective of architectural design[5]. For a long time, more attention has been paid to physical environment as to how to create a comfortable indoor microclimate environment, such as creating appropriate temperature and humidity, wind speed, and introducing fresh air, whereas less attention has been paid to thermal comfort in the outdoor environment[6].

At present, the research on thermal comfort of outdoor environment is mainly based on residential areas [7]. There are few quantitative studies on the influence of university campus landscape elements on outdoor thermal environment. Studies on landscape elements and micro-thermal environments from the perspective of human vision, in particular, are fewer. In the traditional design process, designers often rely on traditional concepts and experience to weigh the proportions of each component, without a quantitative indicator used. Therefore, it is of great guiding significance to study the coupling relationship between campus landscape component and micro-thermal environment, and to explore ways to improve the outdoor thermal environment.

2. Research area and data source

2. 1. Overview of the research area
Sichuan Agricultural University Dujiangyan Campus is located in Dujiangyan City, Chengdu, Sichuan Province, China. Dujiangyan City is located on the northwestern edge of the Chengdu Plain. It belongs to the mid-subtropical humid monsoon climate zone of the Sichuan Basin. The architectural climate zone is divided into hot summer and cold winter regions. It features less sunshine and more rainy weather, with large morning and evening temperature difference and great humidity.

2. 2. Data source
The data used in this study were mainly derived from 120 campus streetscapes, 480 thermal images, and air temperatures measured. The data applied were: the proportion of visual landscape component, the surface temperature of the main landscape component, and the air temperature.

2. 2. 1. Extraction of the component of the main campus visual landscape.
In this study, a total of 120 shooting points marked from No. 0 to No. 119 were determined according to the principle of equidistant selection of each road, and a total of 120 campus streetscape images were collected using the panoramic camera Ricoh THETA SC; The training set based on Deeplab and Cityscapes image semantic segmentation recognizes streetscapes semantically and obtains nineteen kinds of visual elements, including road, sidewalk, building, wall, fence, pole, traffic light, traffic sign, vegetation, terrain, sky, person, rider, car, truck, bus, train, motorcycle, and bicycle. According to the nature and proportion of each element, nineteen identified

campus visual landscape elements are classified, of which, roads, buildings and structures, vegetation, people and vehicles are finally determined as the five major visual landscape components.

2. 2. 2. Statistics on the proportion of major visual landscape components on campus. The programming language Python was used to account for the proportion of the five major visual landscape components on campus, namely, roads, buildings and structures, vegetation, people and vehicles and the proportion of the five types of elements on the selected 120 sites was obtained.

2. 2. 3. Temperature extraction of the major visual landscape components on campus. Using a FLIR thermal imaging camera, a total of 480 infrared images of landscape elements at 120 sites were taken. The average temperature was extracted as the temperature of this type of elements at this site by way of the measurement function of FLIR Tools, thus the surface temperatures of various landscape elements could be obtained.

2. 2. 4. Air temperature data acquisition. The air temperature is also the temperature, which is the physical quantity indicating the degree of heat and cold of the air. The meteorological temperature generally refers to the air temperature 1. 5m away from the ground. In this study, the measurement time of air temperature was selected when the spring was sunny and the cloud was low. The specific time was 15: 00-15: 30 on April 4, 2019. Testo810 was selected as the measuring instrument. The research team was divided into ten groups to measure the air temperature of the above-mentioned 120 sites. The measurement conducted in the afternoon with clear spring and few clouds was mainly due to the significant climate change in spring. It is easier to observe and analyze the microclimate change law than other seasons, and the temperature change is more obvious around 15: 00 in the day[8]. When measuring the temperature, the temperature measuring instrument was placed 1. 5 meters above the ground, and as far as possible away from the human body to reduce the error caused by human body heat radiation, breathing, etc. After the instrument value was basically stable, the temperature data was recorded, and the whole measurement process was controlled to be completed within 30 minutes and the air temperature values corresponding to 120 sites was finally obtained. The lowest air temperature measured at 120 sites on the day of the measurement was 22. 3 ° C, the highest value was 31. 9 ° C, and the average air temperature was 26. 1 ° C.

2. 3 Statistics and verification
The detection of the abnormal value of the measured temperature data was conducted by using the drawing function of the StataSE-64 box plot with the result that the air temperature values of site 31 and site 33 were abnormal and the deviation was large. However, after comparing the actual measurement, it is found that points 31 and 33 are located on the road leading to the gymnasium. The road has few vegetation and almost no shelter. The higher temperature value here is in line with the actual situation, thus it will not be removed from the statistics.

3. Research methods
- The artificial intelligence image recognition technology was used to perform semantic recognition and segmentation statistics on streetscapes and to obtain the major visual landscape components.
- ArcGIS was used to quantify the proportion of the major visual landscape components, their surface temperature and spatial distribution.
- Ten independent variables were selected to detect the correlation between the visual landscape components and the micro-thermal environment on campus by using the spatial heterogeneity analysis model of geo-detector.

3. 1. Artificial intelligence image recognition and hierarchical quantization
The development of science and technology has led to the rapid development of artificial intelligence technology whose development has also entered a new level. At present, machine learning is the most important method to realize intelligence. As a sub-field of machine learning research, deep learning has become a hot research direction in recent years, of which, image recognition is the most potential

research direction in many application fields of deep learning [9]. Deep learning is a deep convolutional neural network architecture, which provides a basis for efficient image space feature recognition. Through the relatively small sample image training, the various elements needed for research are extracted, thus the quantitative measurement of multiple human-scale spatial elements in a built environment can be realized[9]. In this study, the Dujiangyan Campus of Sichuan Agricultural University was selected as the research object, and 120 panoramic images were taken along the road. Using Python programming, importing tensorflow and other function libraries, and calling the image recognition deep learning training set deeplabv3_cityscapes_train_2018_02_06 to semantically identify and count the panoramas, and get the proportion of various landscape elements in the panorama. By using GIS software, the proportion data of each site was put on the segmented road for seven-level quantification and visual analysis.

3. 2 Geographical detector
Geo Detector is a geo-probability model developed by Wang Jinfeng's research team based on Excel. It is mainly used to measure the degree of interpretation of spatial heterogeneity of research objects by various impact factors, revealing the influence factors and multi-factor interactions [10]. The main areas of application of geo-detectors include land use[11], regional economy [12], and ecological environment [13]. This study mainly uses factor detection and interactive detection in geo-detectors to comprehensively analyze the relationship between visual landscape components and micro-thermal environment on campus.

3. 2. 1 Factor detection. Factor detection is used to detect the spatial differentiation of the micro-thermal environment on the campus, and to detect the degree of interpretation of the spatial differentiation of the campus micro-thermal environment by a factor, expressed by the q value[14]. If the stratification variable is generated by the independent variable X, the larger the q value is, the stronger the interpretation of X on the spatial differentiation of the micro-thermal environment of the campus ; the weaker the opposite. In extreme cases, the q value is 1, indicating that Factor X completely controls the spatial distribution of the microscopic thermal environment; the q value is 0, indicating that Factor X has no correlation with the microscopic thermal environment.

3. 2. 2 Interactive Detection. The interaction detection is used to determine the relationship between each influence factor on the spatial differentiation of the microthermal environment. It consists of the following expression: if $q(X_a \cap X_b) < \min(q(X_a), q(X_b))$, the factor X_a and X_b is nonlinearly weakened after interaction; if $\min(q(X_a), q(X_b)) < q(X_a \cap X_b) < \max(q(X_a), q(X_b))$, X_a and X_b interact with single-factor non- Linear attenuation; if $q(X_a \cap X_b) = q(X_a) + q(X_b)$, X_a and X_b are independent of each other; if $q(X_a \cap X_b) > q(X_a) + q(X_b)$, the factor X_a and X_b is linearly enhanced after interaction[14].

4. Results and analysis
According to the statistical results of artificial intelligence image recognition streetscape on campus and thermal imaging camera, combined with ArcGIS technology, the proportion and surface temperature of the major visual landscape components of the five types of visual landscapes of Sichuan Agricultural University Dujiangyan Campus was obtained.

4. 1. Analysis of the proportion of major landscape components
According to the analysis of the statistical results of the major landscape components, in terms of proportion, the proportion of people is the smallest, the maximum is less than 2%, the proportion of vehicles is less than 10%, and the roads and vegetation are relatively large; in terms of the extent of change, vegetation (52. 85%)>Buildings and structures (32. 33%)>Roads (25. 64%)>Vehicles (6. 53%)>People (1. 22%). The minimum proportion of roads, buildings and structures, people, vehicles, etc. , and the maximum proportion of vegetation are located in the northwest leisure recreation area （**Table 1.** ）.

(a) Artificial Intelligence image Recognition results   (b) The proportion of roads   (c) The proportion of buildings and structures

(d) The proportion of vegetation   (e) The proportion of people   (f) The proportion of vehicles
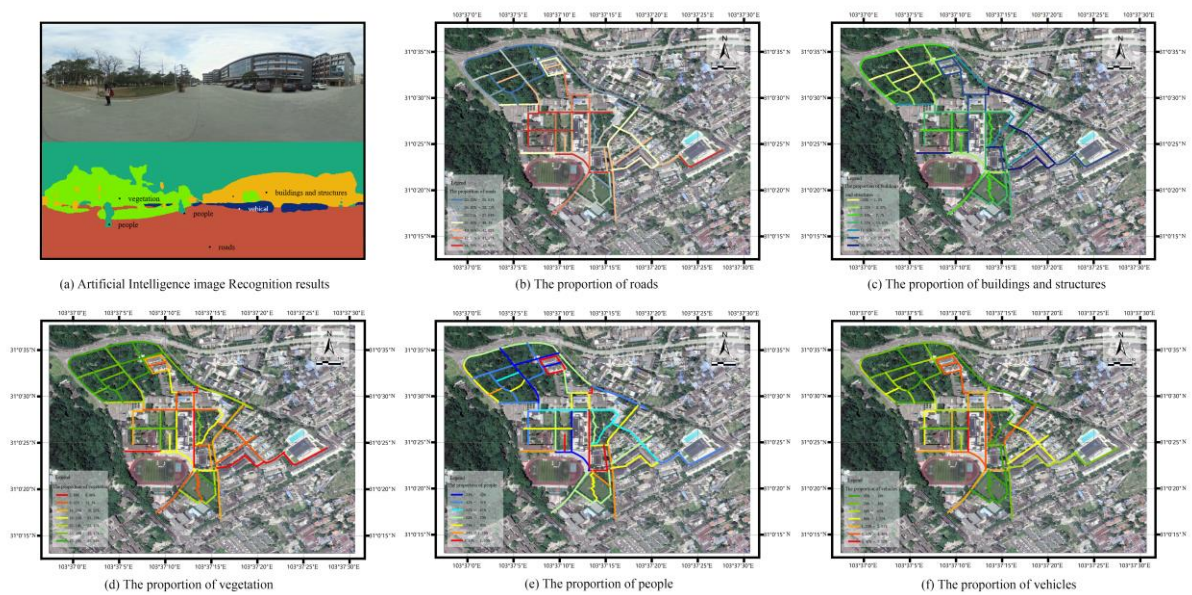
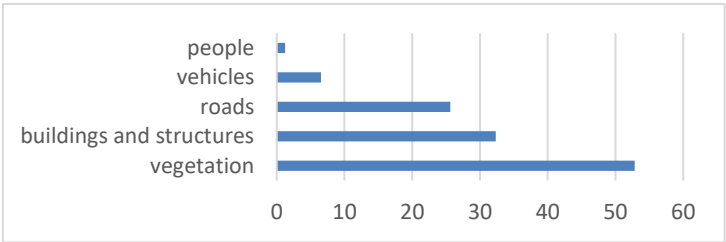Figure 1. The proportion of the major visual landscape components

Figure 2. The proportion of the major visual landscape components' variations

Table 1. Analysis of the Main Visual Landscape Elements

	Roads	Buildings and Structures	Vegetation	People	Vehicles
Proportion Interval Value	20. 24%~45. 88%	0. 02%~32. 35%	2. 48%~55. 33%	0. 31%~1. 53%	0. 5%~7. 03%
Minimum distribution	Northwest leisure recreation area	Northwest leisure recreation area	Southeast living area	Northwest leisure recreation area	Northwest leisure recreation area
Maximum distribution	Southeast living area	Southeast living area	Northwest leisure recreation area	Teaching area∩Living area	Teaching area
Features	Incremented from the periphery to the center	Living area accounts for the largest proportion	leisure recreation area accounts for the largest proportion	Large difference in level	Teaching area accounts for the largest proportion

4. 2. Surface temperature analysis of major landscape components

From the statistical results (**Figure 3.**), it can be seen that the temperature level of vehicles and people is higher, and the maximum surface temperature of other elements is lower than 20 °C; In terms of temperature difference, the surface temperature of the element of the vehicle varies the most, is the largest and the surface temperature of the vegetation changes the least.
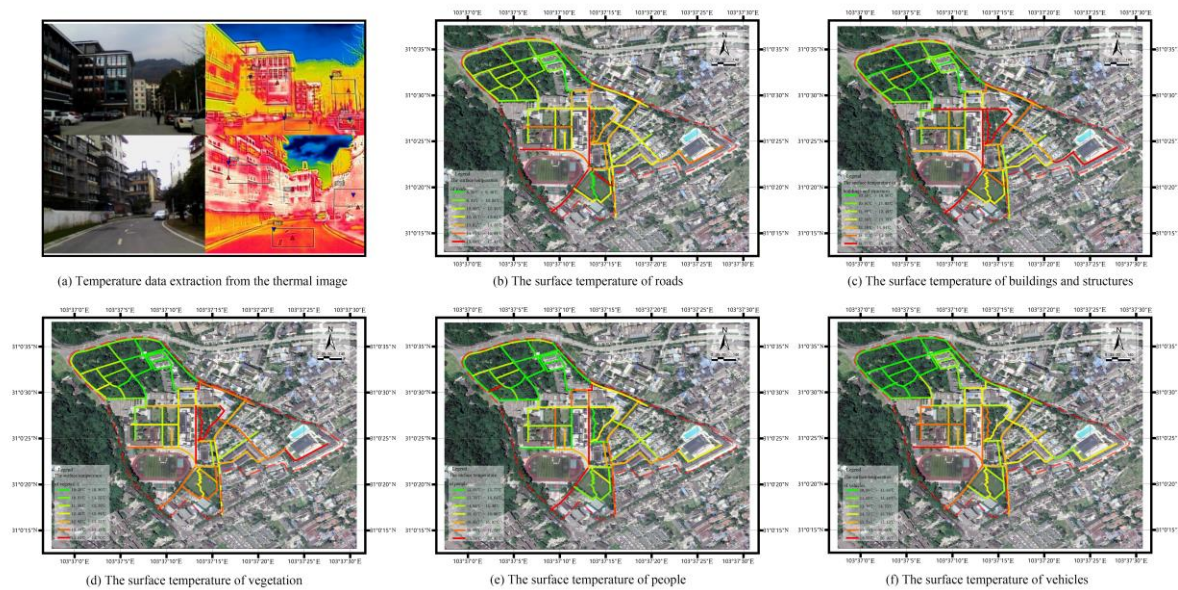
(a) Temperature data extraction from the thermal image   (b) The surface temperature of roads   (c) The surface temperature of buildings and structures

(d) The surface temperature of vegetation   (e) The surface temperature of people   (f) The surface temperature of vehicles

Figure 3. Main visual landscape components surface temperature

Table 2. Analysis of major visual landscape elements in surface temperature

	Roads	Buildings and Structures	Vegetation	People	Vehicles
Temperature range	8. 20℃~17. 44℃	10. 05℃~16. 30℃	10. 30℃~14. 90℃	13. 05℃~20. 95℃	10. 99℃~20. 94℃
Min distribution	Northwest leisure recreation area	Northwest leisure recreation area	Northwest leisure recreation area	Northwest leisure recreation area	Northwest leisure recreation area
Max distribution	Teaching area∩Living area	Southeast living area	Southeast living area	Teaching area∩Living area	Teaching area
Features	The highest in teaching area∩living area	The highest in middle area	The highest in southeast area	Large difference in level	The highest in middle area

4. 3. Quantitative analysis of the influence factors of air temperature changes

4. 3. 1. Differentiation and factor detection. With the help of geo-detection factor detection, the q values of each impact factor were obtained (Table 3), that is, the explanatory power of each factor to the change of air temperature is as follows: X1 road proportion (25. 7421%) = X6 road surface temperature (25. 7421%)> X2 building and structure proportion (9. 1165%) = X7 building and structure surface temperature (9. 1165%)> X3 vegetation proportion (18. 4687%) > X4 proportion of people (16. 8323%)>X10 Vehicle surface temperature (13. 2911%)>X9 people temperature (6. 4513%)>X5 vehicle proportion (5. 3135%)>X8 vegetation surface temperature (4. 0761%). However, from the P value, except for the detection value of the proportion of buildings and structures and the influence of surface temperature on space temperature is 0. 1, which is close to 0. 05, there is no significant correlation between other data.

Table 3. The intensity of each factor (Geographic Detection q Value)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
q	0. 26	0. 09	0. 18	0. 17	0. 057	0. 26	0. 09	0. 04	0. 06	0. 13
p	0. 276	0. 10	0. 58	1. 00	1. 00	0. 27	0. 10	0. 99	1. 00	1. 00

[a] X1 is the proportion of roads; X2 is the proportion of buildings and structures; X3 is the proportion of vegetation; X4 is the proportio n of people; X5 is the proportion of vehicles; X6 is the surface temperature of the road; X7 is the surface temperature of buildings and structures; X8 is the vegetation surface temperature; X9 is the people temperature; X10 is the vehicle surface temperature, the same below.

4. 3. 2. Interaction detection. In the natural environment, the change of air temperature is the result of a combination of factors. In the actual environment, there is no single factor that can affect the temperature change. Through the geographic detector, using 10 impact factors, the two-two interaction detection is carried

out to further identify the interaction between the various impact factors. The role between the impact factors is primarily a nonlinear synergy (Table 4). It can be seen from the interaction results that different influence factors have different explanatory powers for air temperature changes, and the interaction that ranks one and two are65. 4%(proportion of buildings and structures∩proportion of vehicles), (building and structure surface temperature and 64. 0%(proportion of roads and vegetation), (road surface temperature ∩ vegetation surface temperature), which shows that among the visual landscape components that affect air temperature changes, buildings and vehicles have the greatest influence. The interaction between the proportion of buildings and structures and the proportion of people and the proportion of vehicles (the proportion of buildings and structures ∩ the proportion of people> (the proportion of buildings and structures + the proportion of people), (the proportion of buildings and structures ∩the proportion of vehicles) >(the proportion of buildings and structures +the proportion of vehicles). When compared . the interaction between the proportion of buildings and structures as well as the proportion of vehicles is greater than the interaction between the proportion of buildings and structures as well as the proportion of people. The explanatory power of vehicles is less than the proportion of vegetation, indicating that when the buildings are enhanced, the intensity of the vehicle's proportion affecting the temperature change of the air is greater than the proportion of people.

Table 4. Interaction between Air Temperature Change Impact Factors

Factor Interaction (C)	Comparison of Interaction Values (A+B)	Results	Explanation
X1 ∩ X2=0. 571	>0. 349=q(X1= 0. 257)+ q(X2= 0. 091)	C>A+B	Nonlinear enhancement
X2 ∩ X3= 0. 535	>0. 276=q(X2=0. 091)+ q(X3= 0. 185)	C>A+B	Nonlinear enhancement
X3 ∩ X4= 0. 542	>0. 353=q(X3= 0. 185)+ q(X4=0. 1685)	C>A+B	Nonlinear enhancement
X4 ∩ X5= 0. 427	>0. 221=q(X4=0. 1685)+ q(X5=0. 0535)	C>A+B	Nonlinear enhancement

[b] There are too many factor interactions, only some of the interaction results are listed above.

5. Results and Discussion

This study takes the Dujiangyan Campus of Sichuan Agricultural University as an example to explore the correlation between campus visual landscape elements and micro-thermal environment. The results show:

• Roads, buildings and structures, vegetation, people, and vehicles are the five major visual landscape components on campus; In terms of proportion, the proportion of people is the smallest, and the proportion of vegetation is the largest; In terms of the extent of change, vegetation (52. 85%)> buildings and structures (32. 33%)> roads (25. 64%)> vehicles (6. 53%)> people (1. 22%). The result has significant spatial differentiation.

• The temperatures of vehicles and people were relatively high, and the maximum surface temperature of other elements was lower than 20 °C; In terms of the extent of temperature difference, the change of surface temperature of vehicles is the largest, and that of vegetation is the smallest.

• The factor detection results show that the artificial environment, such as roads, buildings and structures, has a relatively larger impact on the spatial differentiation of the campus thermal environment compared with other factors; The temperature of people, proportion of vehicles and vegetation surface temperature have less explanatory power for spatial differentiation of campus thermal environment, but the P value is greater than 0. 05, and the effect of the proportion of landscape on the space temperature is not significant.

• The results of interactive detection show that among the visual landscape components that affect the change of air temperature, the buildings and vehicles have the greatest influence.

Compared with previous studies, this study has carried out microscopic research on campus landscape and thermal environment through panoramic shooting, intelligent semantic analysis, thermal imaging and geographic detectors. On the one hand, the study has analyzed and successfully drawn the conclusion of the spatial distribution characteristics of the proportion of the five major visual landscape components and their surface temperatures which provides a more effective empirical analysis method

for the subsequent micro-landscape and thermal environment research；On the other hand, in the coupling analysis of landscape and thermal environment, the expected effective results were not obtained. The landscape composition with different perspectives has certain influence on the spatial differentiation of campus thermal environment, but there is no significant impact. From the perspective of P value, none of them were less than 0. 05. For one thing, it may be due to insufficient sample size; For another it may be that the proportion of static landscape does not directly affect the ambient temperature; In addition, there are many factors affecting the space temperature, and the problem of missing variables may have a certain impact on statistical analysis. This study will further select a number of university campuses for investigation and geographic exploration analysis in order to draw more scientific conclusions.

Acknowledgments

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