A New Urban Planning Approach for Heat Island Study at the Community Scale

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ABSTRACT

Urban heat island is a necessary issue in urban planning. However, there lacks a good way to study the heat island at the view of planning. This paper tries to combine Remote Sensing technology to establish an urban planning approach, which can study community scale of urban heat island and provide scientific way of heat environment study for urban planners. Tsinghua University is used as a case study to do the analyzing of heat environment using the approach mentioned above. It can be seen various surfaces have different contributions to the heat island in the campus and should be arranged premeditatedly. Therefore, the research of heat island is necessary for urban planning and a good planning project can reduce the heat island.

1. Introduction

Urban planning is one of the main causes of urban heat island generation. Unreasonable planning can result in exacerbation of the urban heat island effect, worsening microclimate environment, and lowering the human settlement level of the community which results in more energy consumptions and pollution. So urban planning should seek an approach to suit local climate and decrease the effect of the heat island.

Remote Sensing, the tool for space study is used in this research and to form an urban planning approach based on the study of urban heat island. Remote sensing can deduce the condition of underlying surface based on different resolutions (Huilan Yang 2006). The satellite images can present the whole condition of an area and record the status of everything's characteristics by digital data, which researchers can deduce urban planning indexes though these data and thus receive scientific decision. The heat island at the community scale is important for the human environment and will be the focus of this research. Therefore, the analysis of heat island at community scale using Remote Sensing technology will be an important way to assist in urban planning and make it more reasonable.

2. Methodology

2.1 Research approach

The approach which is formed to deal with the relationship between heat island and urban planning should break up the limitation of each profession and consider about the heat environment at community scale. The concrete flow can be deduced like following way.

Community condition at medium scale will be analyzed. This step will use medium resolution satellite images to deduce certain indexes of underlying surface, such as surface temperature index and vegetation index, to analyze the medium scale characteristics of community and its heat environment.

Then high resolution satellite images are used to analyze the land utilization of the studied community, underlying surface classification and landform characteristic which will make the research field clearly studied. In this step, planners can analyze the characteristic of planning and its influence on the heat island combined with the analysis result of medium resolution satellite image. Thus the flaws in community planning can be found.

Based on studies above and existing condition of buildings, roads and landscape, final revision plans can be summarized and provide reference for other relative projects.

2.2 Points for attention

This approach is divided into several small parts based on the requirement of heat island research. In the real application, some matters should draw attention. Digital study should be closely related with real design and planning of target community. Therefore, the approach can have applicability for real heat island research.

The research of urban heat island should not be limited to the detection of temperature index and heat field but should include the indexes of vegetation overlay, water surface and styles of buildings in the group. Then the analyses of inside mechanism of heat field can be done. The technology of Remote Sensing needs many environment parameters as interchange parameters and can produce many underlying surface indexes as assistant factors of urban heat island research and planning project.

The static value is the representation of heat environment of one spot and one time only and this value will change continuously. The characteristic and space structure of heat environment basing on the change of time and environment in the city should be the focus in this research.

2.3 Relevant literature

There are many research papers on urban heat islands, but they all have some flaws. Soushi Kato and Yasushi Yamaguchi use ASTER and ETM+ Data to study the urban heat-island effect and separate anthropogenic heat discharge and natural heat radiation from sensible heat flux (Soushi Kato & Yasushi Yamaguchi 2005). But this research focuses on the analysis of medium resolution satellite image and can not study characteristics of underlying surfaces in great detail. Liang Ji et al studied technique of regional wind environment simulation based on GIS (Liang Ji, Hongwei Tan & N. Sakata. 2008). But GIS data cannot be obtained easily. Ben-Dor, E. and Saaron, H. used airborne video thermal radiometry as a tool for monitoring microscale structures of the urban heat island (Ben-Dor, E. & Saaron, H. 1997). But this study is very expensive and cannot spread popularly. Lin Wang et al. studied effective factors on thermal environment in campus by experimental data such as outdoor air temperature, relative humidity and so on (Lin Wang, Yongan Li & Peilei Liu 2008). Their researches need plenty of manual work and are influenced often by subjective decisions.

The above studies have paid their attentions to one point and have limitations at the other points. The approach in the present work establishes a system of urban heat island study involving various scales of Remote Satellite images into research, which can make the planning process more scientific and rational.

3. A case study for this approach

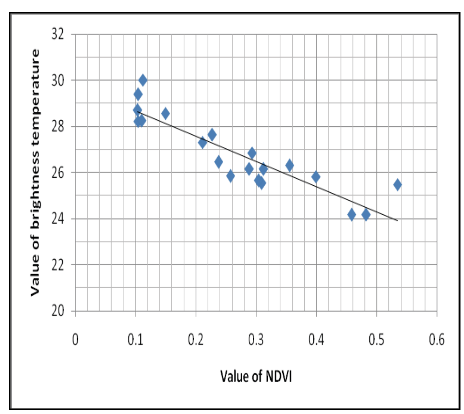
The urban heat island studying approach will be displayed by a case study of a large community zone in Beijing and developed with steps mentioned above. The study will use high resolution satellite image and medium resolution satellite image as the studying resource. The medium resolution image will use ASTER satellite image[1]; it has five thermal infrared bands with resolutions of 90 m. The thermal infrared bands will be used to deduce the brightness temperatures of underlying surfaces. The brightness temperature will reflect the structure of the heat island and can build relationship between the heat island and the underlying surfaces. The high resolution satellite image will use CBERS-02B HR images[3] with spatial resolution of 2.35 m. It can reveal the information of underlying surface and can allow investigation of the study area carefully.

The case study will concentrate on Tsinghua University, which is a university in Beijing, P. R. China. It is a special community, which divides into several parts such as teaching area, dormitory area, greening area and so on. Vegetation underlying surface in the campus is plentiful and concentrated. Building underlying surface lays orderly and water surface is obvious. So this study area has usual underlying surfaces and can reflect the characteristic of urban heat island.

Figure 1. The Image of Brightness Temperature Taken by ASTER Satellite

Figure 2. The Image of NDVI Taken by ASTER Satellite

Figure 3. Scatter Diagram of Brightness Temperature (°C) and NDVI



1 The data of ASTER satellite used in this paper is provided by China Remote Sensing Satellite Ground Station: Http://www.rsgs.ac.cn.

[3] Figures 1, 2 and 3 are deduced from ASTER data

The data of CBERS satellite used in this paper is provided by the China Centre for Resource Satellite Data and Applications (CRESDA): http://www.cresda.com.

The date of the ASTER satellite image is April 22, 2006. From the brightness temperature should be deduced the heat structure of this region. Though it is not the real surface temperature and has deviation made by reflection and refraction of sunlight, it also can represent the heat island phenomena well in the small scale like city or city region, which has approximately same condition of moisture and atmosphere (Yunhao Chen, Jing Li & Xiaobing Li 2004). Figure 1 shows the status of the brightness temperature of Tsinghua University. The structure of heat island is a sequential and illegibility field and has no clear boundary, which can be seen in the Figure 1. So the analysis of temperature field focuses on its distribution of temperature segments. For example, it can be seen that the parts which have high brightness temperature lie at the regions of high density buildings in campus.

Then we should obtain the index of vegetation, which is called NDVI (Figure 2). NDVI represent the condition of vegetation coverage (Xiaoli Bi, Hui Wang & Jianping Ge 2005). Using ASTER satellite as example, the derivation of NDVI uses the second and third bands and the value is the ratio of difference-value and sum of two bands (Peng Qin & Jianfei Chen 2008).

Then, these two values of indexes can be connected together to see the relationship between brightness temperature and greening condition of underlying surface. The ASTER satellite image used is generated at early summer. So it shows that good vegetation can effectively relieve the heat island. In the area at the east part of campus there exist many big buildings and it represents comparatively high temperature. The landscape area, on the contrary, has lower temperature. Following these tendencies, a series of points' values of brightness temperature and NDVI are picked out and form the Scatter Diagram (Figure 3). In this figure, Y axis is the value of the brightness temperature and X axis is the value of NDVI, which can be used to do some studies. It can be seen that these two indexes have an inverse relationship. Then regions of interest can be chosen to see the distribution of some special regions. For example, the places where the values of NDVI exceed zero can be chosen and the result shows that most parts of campus have been classified in this way. This means the campus has very good greening coverage. Most regions have moderate temperature. Then the regions of interest can be changed again to those which have higher NDVI value and lower brightness temperature value. This time, the regions chosen are greatly reduced and include the parts of landscape area and administrative area, which have buildings of low density and many trees. Then the regions of low NDVI and high brightness temperature are chosen. It can be seen that those regions include parts of teaching areas and research institutes which have some high buildings and less trees. Similar studies can be done and finally it can be found that dormitory areas have moderate balance of NDVI and brightness temperature. It is because the dormitory areas have many buildings which are not very high and considerable green areas.

The above research is based on the medium resolution satellite image. But this image has some limitations because it can not explore underlying surface well. High resolution satellite image has no thermal infrared band, but it can clearly analyze the underlying surfaces especially in the small scale of city region and thus it can remedy the shortage of medium resolution satellite image and do deeper research. In our case, three different areas are selected to do the classification of underlying surface and to make the condition of these areas clearly, using high resolution band of CBERS satellite image with resolution is 2.35 m and the date is Dec. 6, 2007. One pixel in the CBERS image represents an area of 2.35 m x 2.35 m at real underlying surface and ground objects can be seen clearly such as buildings, roads and water surfaces. Then, fine classification and following studies can be done by calculating the amount and property of pixels. The dates of ASTER image and CBERS image used in this research are close so the underlying surface has had little change and thus these images can be used together.

The first area selected is the teaching area which is at the east part of campus (Figure 4). The main types of underlying surface of this area are buildings, roads and piazzas, lawns, forests. Their percentages are presented as Table 1. It can be seen that buildings occupy very large percentage and will raise the brightness temperature. Roads and piazzas also have large percentage and do the same function. However, buildings are arranged in orderly ranks along the roads. This benefits the ventilation and can bring the heat out. What's more, vegetated surfaces have sizeable area and can decrease the intensity of heat island. So this area is a high temperature part of the campus but it still remains the appropriate condition.

The second area selected is the administrative area in campus. This area is also made up by buildings and roads, water surfaces, lawn and vegetated surfaces. The area's greening coverage occupies a large percentage and has beautiful landscape (Figure 5). The greening surface here can prevent the radiation of sunlight and absorb much heat. The water surface can also stabilize the temperature. Buildings and roads in the area are few and many of them are sheltered by trees. So the temperature of this area is relative low.

Figure 4. Teaching Area of Tsinghua University

Figure 5. Administrative Area of Tsinghua University

Figure 6. Dormitory Area of Tsinghua University

The third area selected is the dormitory area in campus which has proper proportion between building and plant area (Figure 6). The classifications of underlying surface are including: buildings, roads and vegetated surfaces. Buildings are arranged in rows and the spaces among buildings are enough for ventilation. Vegetated surfaces are in abundance among the buildings and greening condition of adjacent area is good. Most buildings in this area are multilayer buildings and are not very high. All these can benefit a lessened heat island.

Table 1. Percentage of Underlying Surface of Three Areas

Teaching area						
Surfaces	Total area	Building	Road	Piazza	Lawn	Trees
Percentage	100%	35.0%	7.6%	11.6%	3.2%	42.6%
Administrative area						
Surfaces	Total area	Building and road		Water	Vegetated surface	
Percentage	100%	22.0%		8.4%	69.6%	
Dormitory area						
Surfaces	Total area	Building		Road	Vegetated surface	
Percentage	100%	37.8%		32.0%	30.2%	

4. Conclusion

From the studies above, it can be seen that this new research approach can study the heat island well, based on the frame of urban planning. Conclusions can be gotten as follows:

(1) Traditional urban planning can not provide effective measures to detect underlying surface and the structure of heat island. Our approach uses Remote Sensing technologies to do relevant research, which can guide the real planning projects more scientifically.

(2) Heat island of small scale is hard in research because of the requirement of high precision of observing ground objects. Thermal infrared band of a satellite is needed in analyzing the structure of heat island but it has only medium resolution and can not do the fine research. High resolution images can be used to study the concrete underlying surface, which can do the research at micro level and adapt the request of human settlement.

(3) Each types of underlying surface should be kept at a reasonable percentage. Buildings and roads will make heat island more serious but too little building will limit the requirement of human beings. Therefore, measures such as multilayer building, enough space among buildings and planting vegetations as possible may be efficient for decreasing the effect of urban heat island.

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