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LEED Certification and Its Effectiveness on Urban Heat Island Effect

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ABSTRACT: The Leadership in Energy and Environmental Design (LEED) has provided abundant resources and guidelines for a new project to become a sustainable anchor in the neighborhood. Paired with a range of checklist, LEED has strong influence on the standards for a sustainable building, and it also has played an iconic role in energy-efficient architecture. However, it is still unclear as to whether or not an LEED certified building enhances environmental benefits to its surroundings. If an LEED certification promises a baseline for an eco-friendly building, then a group of these structures should ensure significant environmental benefits to the society. This is the main question of this study, and the authors answer this hypothesis by examining the relationship of LEED certificates and their influence on outdoor temperature, especially in terms of urban heat island effect. The goal of this paper is to analyze the influence of the LEED certification on urban temperature as an indicator of sustainable architecture's regional interactions. If an LEED certificate is regarded as a strong contributor to a sustainable built environment, then a group of these certificates should result in greater benefits to society. To this extent, the authors question if there is any possible relationship between a large concentration of LEED certified sites and the temperature of their surroundings. To properly assess the research direction, Global Moran's I analysis, Local Moran's I analysis, and Hot Spot analysis are implemented to find the clustered areas of LEED certified buildings. For examining relationships between clustered area and its temperature, correlation efficients are calculated.

KEYWORDS: Urban Heat Island Effect; LEED; Geographic Information Systems (GIS); Spatial Autocorrelation; Temperature

1. Introduction

1.1 Research Background

Sustainable building performance has become one of critical concerns in recent architecture and urban planning disciplines. Because a building, including its construction and maintenance, intersects with various professional fields, efficient and energy-effective performance largely drives the level of architecture's sustainability. In this extent, the Leadership in Energy and Environmental Design (LEED) has provided abundant resources and guidelines for a new project to become a sustainable anchor in the neighborhood. Paired with a range of checklist, LEED has strong influence on the standards for a sustainable building, and it also has played an iconic role in energy-efficient architecture.

However, it is still unclear as to whether or not an LEED certified building enhances environmental benefits to its surroundings. If an LEED certification promises a baseline for an eco-friendly building, then a group of these structures should ensure significant environmental benefits to the society. This is the main question of this study, and the authors answer this hypothesis by examining the relationship of LEED certificates and their influence on outdoor temperature, especially in terms of urban heat island effect. If LEED truly is an effective system to help with environmental sustainability, then its grouping should illustrate better energy and environmental performance when compared with its counterparts.

1.2 Research Boundary & Methodologies

LEED was announced by the U.S. Green Building Council (USGBC) to certify high-performance buildings and sustainable neighborhoods (USGBC 2009). Since its beginning in 1998, LEED certificate's effectiveness has been studied widely by various scholars.

Of those studies, however, LEED's effectiveness on

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urban scale problems is yet to be determined. For example, urban heat island effect, which is a significantly warmer metropolitan area than its adjacent rural areas due to human activities, is frequently left over research areas when researchers conduct the effectiveness studies on the LEED. The main cause of urban heat island effects is modification of land surfaces. It means building construction and modification business could be one of significant factors affecting the temperature rise inside a city. If this is plausible, then it should be noted that the LEED system may need to provide a remedy to ease the problems in such matters. This is the main quest of this study and the authors try to answer by relating heat temperature of a region with the quantity of LEED certified buildings.

The goal of this paper is to analyze the influence of the LEED certification on urban temperature as an indicator of sustainable architecture's regional interactions. If an LEED certificate is regarded as a strong contributor to a sustainable built environment, then a group of these certificates should result in greater benefits to society. To this extent, the authors question if there is any possible relationship between a large concentration of LEED certified sites and the temperature of their surroundings.

To properly assess the research direction, Global Moran's I analysis, Local Moran's I analysis, and Hot Spot analysis are implemented to find the clustered areas of LEED certified buildings. For examining relationships between clustered area and its temperature, correlation efficients are calculated.

2. LEED Certification Systems

Past studies have articulated LEED certificate's effect on land prices (Miller, Spivey et al. 2008, Eichholtz, Kok et al. 2010, Wiley, Benefield et al. 2010, Fuerst and McAllister 2011) or in terms of cost saving aspects (Kats, Alevantis et al. 2003, Kats 2006, Kats, James et al. 2008). In other words, it has been proven that the LEED certifications provide a certain types of benefits to the owners and users.

There are four levels of LEED certifications based on a 100-point scale with an additional 10-bonus point. The four certificate classifications are "Certified" with 40-49 points, "Silver" with 50-59 points, "Gold" with 60-79 points, and finally "Platinum" with 80+ points (USGBC 2009). This LEED score is also based on several categories: Sustainable Site (26 possible points), Water Efficiency (10 possible points), Energy and Atmosphere (35 possible points), Materials and Resources (14 possible points), Indoor Environmental Quality (15 possible points), Innovation in Design (6 possible points), and Regional Priority (4 possible points) (USGBC 2010). Previous literature about post-occupancy evaluation investigates the total energy use intensity (EUI) measuring the Energy & Atmosphere credit (R. Diamond, M. Opitz et al. 2006, Gifford 2008, Lstiburek 2008, Richter, Goldston et al. 2008, Turner, Frankel et al. 2008, Newsham, Mancini et al. 2009, Scofield 2009).

There are two possible problems with these studies, however. First, although the Energy and Atmosphere credit accounts for 35% of the base points, it is just one agenda among many LEED certifications. Thus, more comprehensive perspectives on building performance, such as Sustainable Site, Water Efficiency, and Indoor Environmental Quality are often left behind. Second, these studies have clarified that the benefits of LEED certification mostly fall to the owners. If energy saving is only one part of the greater environmental benefits, then LEED certification should promote a diverse aspect of sustainability, such as its interactions with the surrounding environment or green structure as a part of sustainable urbanism.

The heat island credits in LEED are categorized into local and regional environmental sectors. The current practices, however, do not distinguish such regional differences and a unified measurement is utilized to determine whether to earn the credits. As mentioned earlier, material property of buildings is correlated with the metrological air temperature thus, influencing the degree of the heat island effect (Heidt and Neef 2008, Santamouris, Synnefa et al. 2011). Therefore, in order to accommodate the different local climates and to provide a more accurate measurement in the LEED's regional credits, geographical weights should be customized depending on regions (Kumar 2002, Cavanaugh 2008). Although LEED addresses building material issues as well as regional issues in the categories such as Sustainable Site, its analysis between the heat island credit and its impact on urban temperature is rather sparse and yet unreliable in many ways.

As previously described, there certainly are certification credits geared toward regional context. If these are truly effective measurements, then the regional credits such as Sustainable Site or Heat Island Effect will provide more solid groundwork for the success in LEED evaluation process.

3. Analysis

3.1 LEED Buildings & Geocoding

To confirm whether the urban temperature changes by LEED buildings, this paper uses Moran's Index (I) and correlation analysis. Moran's I measures the spatial auto-correlation of geographic features based on locations and number of clusters. The result presents whether the pattern of LEED buildings is spatially clustered, dispersed, or random. It is essential to check the pattern of LEED buildings since urban heat island is mainly derived from the aggregation of buildings. Also, correlation analysis is useful to identify the connection between temperature and the level of LEED clusters.

USGBC provides each LEED building's address, certification level, certification date, and rating system. It has 47,946 building information in the U.S. as of January 2014. After data clearing process, 13,273 building data are left. Using Geographic Information Systems (GIS), all the buildings are geocoded to assess the distribution pattern. Doing so provides the number of LEED buildings by each state in the U.S. Figure 1 shows the LEED distribution across the states and most of the certifications concentrate on urban areas. The study boundaries of this study are the State of California, and the main reason for choosing is because it represents the LEED buildings in the Sun Belt States. In other words, its annual temperature shows more consistency compared to other states such as, New York or Illinois.

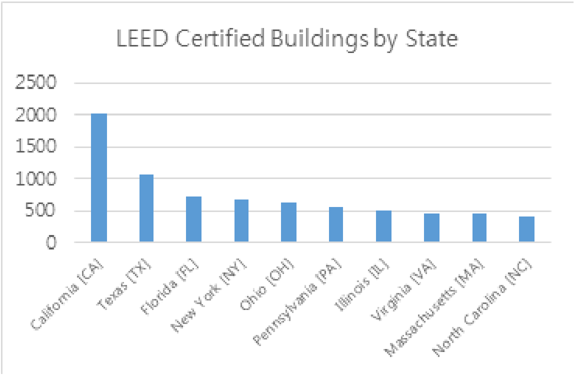

Figure 1 Number of LEED buildings by each state

3.2 Temperature Data

Temperature dataset is another requirement to calculate the correlation coefficient between the level of LEED cluster and its annual temperature. The Daymet data supported by the National Aeronautics and Space Administration (NASA) Earth Science Data and Information System (ESDIS), and the Terrestrial Ecosystem Program provides 1 km by 1 km gridded estimates of daily weather parameters for North America from 1980 to 2012. It offers 7 different types of information: daily minimum and maximum temperature; precipitation occurrence and amount; humidity level; shortwave radiation; snow water equivalent; and day length. In this study, daily maximum, daily maximum temperature on January 1^{st}, April1^{st}, July1^{st}, and October1^{st} in 2012 are used for temperature data point as they represent possible seasonal transitions.

Well known for its natural assets, California has a larger number of distinct climate zones such as, desert, grasslands, mountains, inland, and coaster areas. Accordingly, the mean temperature in the summer season shows higher figure compared to the national average. Table 1 shows the summary of mean temperature for seasonal changes in California. Therefore, if LEED buildings have temperature mitigation effect, especially in the summer, then it is more advantageous in the study area to make greater environmental benefits.

3.3 Spatial Autocorrelation

To assess the relationship between the temperature and LEED certification systems, it is important to figure out how LEED buildings are concentrated. Spatial autocorrelation is a good way to identify whether or not the dataset indicates clustering or dispersions. The authors measure spatial auto-correlation based on locations and attribute values using the

Table 1 Summary of temperature in California

	California			
	Jan 1	Apr 1	Jul 1	Oct 1
Min	-11	-9.5	1.5	-4
Max	30.5	33.5	44.5	44.5
Mean	16.6	15.1	29.2	33.3
Std dev.	5.3	7.5	6.8	5.4

Global Moran's I Summary	
Moran's Index:	0.003465
Expected Index:	-0.000124
Variance:	0.000000
z-score:	12.367954
p-value:	0.000000

Dataset Information	
Input Feature Class:	Census_Tracts_CA_JoinedCSGP
Input Field:	COUNT_
Conceptualization:	INVERSE_DISTANCE
Distance Method:	EUCLIDEAN
Row Standardization:	False
Distance Threshold:	0.747739 Degrees
Weights Matrix File:	None
Selection Set:	False

Figure 2 Moran's I result

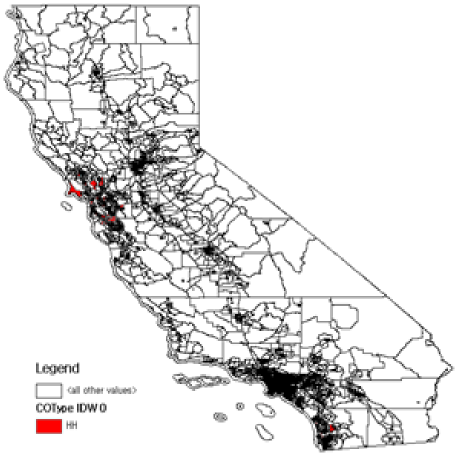

Figure 3 Anselin's local Moran's I result

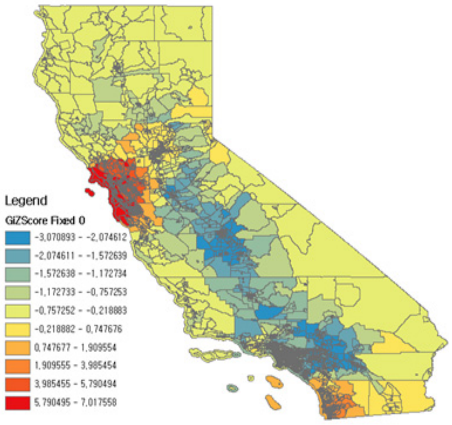

Figure 4 Hot spot analysis result

Global Moran's I statistics. The null hypothesis states that the LEED buildings are randomly distributed.

Spatial autocorrelation is often measured with different indicators. Of those differences, Moran's Index is frequently adopted indicator. Moran's I tests whether LEED buildings are randomly distributed across the states. If we can reject the null hypothesis, which assumes a normal distribution in the data used, with the statistical significance, then we could argue that LEED buildings have tendency to cluster or disperse across the study boundary.

Figure 2 shows the result of Moran's I test with the dataset. As can be seen the p value came out as $p<0.001$, meaning that we can reject the null hypothesis and assume that the data represents clustered or dispersed pattern. Looking at the Moran's I value identifies that the data has clustering pattern as the value is greater than 0.0, which is the standard value for a random distribution.

Another way to measure the distribution pattern is Anselin's Local Moran's Index. Anselin's Index shows where the most clustered or dispersed pattern occurs. It means that Anselin's I is the way to determine the location of distributions. Figure 3 shows the results of California. As can be seen, San Francisco and Los Angeles show the most clustered pattern of LEED certified buildings. This is plausible result as the two cities are the biggest cities in the State of California, meaning that the probability of constructing LEED certified buildings may be the highest. The red areas in the Figure 3 indicates where LEED buildings are also surrounded by LEED buildings, and San Francisco and Los Angeles are the two red areas in California. The political boundary used in the map is census tracts and the red areas' number of census tracts are 8,057.

The last way to identify the location of clustering pattern is the hot spot analysis. The hot spot analysis calculates the Getis-Ord statistic for each feature in a dataset. The resultant Z score tells where features with either high or low values cluster spatially. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well.

The results for the study area show that there are 1,977 statistically significant hot spots (95% confidence level) from 8,057 census tracts in California. Figure 4 shows the results of hot spot analysis and the red-colored areas are the places where most LEED buildings are located and where they are also surrounded by another LEED certified buildings. Simply stating, the red-colored areas are where the most LEED buildings are concentrated.

4. Results

Based on the pattern analysis, the authors have identified that there is a clear clustering in LEED buildings spatial distribution. Then the question becomes if they are also related to outdoor temperature, meaning that the clustering of LEED buildings may or may not affect the heat effect on the locations. To identify this, correlation between Daymat dataset and LEED buildings' distribution are implemented.

Table 2 shows the correlation results. As can be seen, correlations between the numbers of LEED certified buildings and maximum temperature have negative values. Despite the fact that the relationship is not very significant, it still implies an interesting result. The difference between the certification levels does not explicitly show a distinctive result. However, it is still showing that they all relate to the temperature in a negative way. It means the higher the number of LEED buildings in an area, the lower the temperature would drop to a certain degree within the State of California.

Even though the certification levels do not differ to a great degree, clustering density does show a different result. As can be seen in Table 3, both hot spot areas and local Moran's I areas (high clustering areas) imply higher correlation coefficients than the certification level results. High local clustering results, based on Anselin's Moran's I shot negative 0.168 and the hot spots identified by the hot spot analysis show negative 0.392. It may mean that the clustering density of LEED certified buildings may impact the outside temperature with a higher degree.

Table 2 Correlation by certification levels

Certification Levels	No. of LEED Buildings	Correlation Coefficients
Certified/Gold/Silver	2,011	−0.037
Silver/Gold/Platinum	1,675	−0.043
Gold/Platinum	1,128	−0.042
Platinum	357	−0.012

Table 3 Correlation by hot spots

Clusters	Correlation Coefficients
Local Moran's Index	−0.168
Hot Spot Analysis	−0.392

5. Conclusions

With the analysis results shown above, it is hard to affirm that LEED certification levels and the mass effect of LEED buildings do have significant influence on regional climate. The result shows that the relationship of LEED clusters and their effects on regional heat has minimal interactions and thus, we may possibly question the effectiveness of LEED's regional credit process, such as Sustainable Sites or Heat Island Effect credit. However, it still is an meaningful result that the State of California resulted in an interesting output as it showed negative coefficients for the LEED concentration areas, and all the coefficients showed negative correlation with the regional climate.

One thing should be regarded that correlation is one of many ways to diagnose possible relationship and it does not indicate causation. Also, measuring correlation coefficient provides a possible foundation to the research questions, but it does not give an affirmative answer about whether or not the relationship is reliable. In other words, just calculating correlation coefficient does not assure that a group of LEED certificates does not have any influence on the greater environmental benefits, the degree of urban heat in this case, nor does it prove whether the LEED certificates do have positive influences.

Finally, capturing the heat of the first day of four months as a proxy for the annual temperature may have simplified the weather variation and thus, more thorough measurements should be taken into account for the future research works.

Nonetheless, the main point of this paper addresses a meaningful attempt that could imply possible directions for future research. As mentioned earlier, the main purpose of this paper is to address the LEED certificate and credit system's effectiveness in terms of its broader environment. We have enough studies about owner benefits of LEED buildings, such as cost savings and energy savings. But not many have been directed under the domain of benefits to users. In this extent, the authors think the analysis in this study indicates a possible development direction for both USGBC and other proponents of the LEED certification system. If the LEED could become a more interactive measurement with its regional context, which is indeed a required perspective in a broader context of sustainability, it would become a true sustainable building standard as it actively considers architecture a semi-public asset. Also, LEED will become a more comprehensible measurement due to the fact that it enhances the relationship of urban environmental problems with the architectural performance.

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