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Research Paper

How is environmental greenness related to students' academic performance in English and Mathematics?

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ABSTRACT

Background: Previous studies point out a positive association between academic performance and school surrounding greenness, but the population included in these studies only recruited single-grade students.
Objectives: To design a more all-rounded investigation of the association between school surrounding greenness and students' academic performance in general in Massachusetts, USA.
Methods: We included a total of 27,493 3rd–10th grade students from public schools over 9 years (2006–2014) in the study. Academic performance (i.e. English and Mathematics achievement level) were primarily based on Composite Performance Index (CPI) as well as the percentage of students who scored "Proficient and Higher" (AP%) in the examination. Normalized Difference Vegetation Index (NDVI) and green land use area (within 250–2000 m circular buffer) were used to server the index of school surrounding greenness). We applied generalized linear mixed models (GLMMs) to investigate the relationship between surrounding greenness and academic performance with adjustment on socio-economic and demographic factors.
Results: We found a significant positive association ($p < 0.05$) between school surrounding greenness and academic performance based on AP% or CPI, after adjusting for the potential confounders. Higher exposure to green land use area was also significantly associated with increased academic performance. Using different buffer levels did not dramatically change the major findings. The positive relationship between school surrounding greenness and academic performance was consistent across different sub-populations.
Conclusions: A higher surrounding greenness contributes a better academic performance in students of all grades. This finding could serve as a reference for designing green landscape especially near school areas.

1. Introduction

Scientific research had demonstrated the positive relation between vegetation and environmental quality. For instance, urban green space can improve the air quality by removing the pollutants from the air (Yang, Yu, & Gong, 2008). Greenness can also lower urban air temperature, which helps to minimize the heat island effect in urban area and improve the level of comfort in urban environment (Santamouris, 2014). Plantation reduces soil erosion by holding soil in place so as to decrease risk of landslide in steep slope (Stokes, Atger, Bengough, Fourcaud, & Sidle, 2009). Green land use area such as forest, park, grassland, shrubs land, and gardens, are valuable places for recreational use, which provide habitat for wildlife, mitigate emission of greenhouse gases and so on.

Exposure to green environment has been reported to benefit human health both physically and mentally by promoting physical activity, decreasing stress, reducing air and noise pollution, and heat exposure (James, Banay, Hart, & Laden, 2015; Stigsdotter et al., 2010; van den Berg et al., 2015; Speak, Rothwell, Lindley, & Smith., 2012). Surrounding greenness and proximity to green space has strong association with the improvement of health for human beings (Dadvand et al., 2016). Studies have also shown that green spaces are especially

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important for children's development and well-being (Chawla, Keena, Pevec, & Stanley, 2014). The presence of green space plays an important role in reducing stress and restoring mental fatigue of children from their school pressure (Akpinar 2016; Corraliza, Collado, & Bethelmy, 2012), enhancing concentration and attentiveness (Kuo & Faber Taylor, 2004), bettering cognitive development (Dadvand et al., 2015), increasing students' self-discipline level (Faber Taylor, Kuo, & Sullivan, 2002) and classroom engagement (Kuo, Browning, & Penner, 2018). These functions are indicated to enable students to effectively absorb academic content and increase their ability to have better academic performance (Duckworth & Seligman, 2006; Li & Sullivan, 2016). With limited access to green environment in urban areas, children in particular, are more vulnerable to health and behavioral problems (Veitch et al., 2011; Wolch, Byrne, & Newell, 2014) which may hinder their ability in concentrating and completing tasks, hence affecting their academic performance (Bratman, Daily, Levy, & Gross, 2015).

Recently, growing evidence to uncover the relationship between students' performance results and surrounding greenness. Previous studies have focused on the relationship between green space and academic benefit of specific group of students. According to Wu et al. (2014) and Hodson and Sander (2017), there is positive significant association between surrounding greenness and academic performance among 3rd grade students in Massachusetts, and reading performance of 3rd grade students in Minneapolis-St Paul, Minnesota respectively. Matsuoka (2010) pointed out that larger amount of vegetation in school campuses is related to the higher academic performance for grade 9 students in Michigan. Kweon, Ellis, Lee, and Jacobs (2017) separated landscape into serval types by using GIS technologies and aerial photos, and found that trees were positively related with student examination result. However, negative association between adjacent green space and student examination results were also found in Chicago (Browning, Kuo, Sachdeva, Lee, & Westphal, 2018). Yet, no research has examined the effect of overall surrounding greenness on the academic performance of students throughout all school grades.

In this study, we investigated the relationship on environmental greenness (i.e. Normalized Difference Vegetation Index (NDVI) and green land use) and the English and Mathematics academic performance for students from all school grades, including students from elementary school, middle school and high school. So as to check whether the importance of green space on academic benefit of students do the same effect across all grades.

2. Materials and methods

2.1. Study area

The selected study area was the state of Massachusetts in United States. We obtained the data of the location of schools (2006–2014) from Massachusetts Geographic Information System (MassGIS) which provided by the Massachusetts Office of Information Technology. This point datalayer indicates the locations of all pre-kindergarten to high school attended by students in Massachusetts, based on the Massachusetts Department of Elementary and Secondary Education. Fig. 1 showed the distribution of public schools and population density in Massachusetts.

2.2. Greenness measurement

Two quantitative metrics were used to assess the surrounding greenness in Massachusetts, including NDVI and green land use area. Circular buffers of 250-meter, 500-meter, 1000-meter, and 2000-meter were drawn around each school to estimate the greenness exposure of students at school and their neighborhood (Wu et al., 2014). Information of NDVI was collected from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). NDVI data were generated every 16 days at 250-m spatial resolutions, providing temporal and spatial comparisons of canopy of vegetation greenness, representing the overall information of greenness, including characteristics like: leaf area, chlorophyll, and canopy structure (Gascon et al., 2016). MODIS NDVI Version 6 was applied in this study, which allows a higher temporal resolution, since in the 16-day period, two 8-day composite reflectance granules (MxD09A1) were used to generate a 16-day composite from (Didan, 2015). NDVI in March (the month when most MCAS tests were held) and October from 2006 to 2014 were taken for comparison of greenness in spring and fall of the school year. Fig. 2 shows the NDVI distribution in March in Massachusetts.

Data of green land use area were obtained from the land use and open space datalayer in MassGIS. This statewide digital datalayer of land use in Massachusetts is based on the 0.5 m resolution digital ortho imagery captured in April 2005 (MassGIS, 2009). Only the land areas of forest (> 50% coniferous or deciduous tree canopy cover), brushland/successional (> 25% shrub or immature trees cover), or parks were included in this study as these areas are opened to the public and can be accessed by the students. Fig. 3 shows the distribution of green land use of Massachusetts.

2.3. Academic performance

Record of students' academic performance (2006–2014) were obtained from the Massachusetts Comprehensive Assessment System (MCAS). MCAS is a statewide standard-based assessment program developed by the Massachusetts Department of Education in 1993. All students enrolled in 3th to 10th grade in Massachusetts who were public funded have participated in the MCAS tests. Since no student individual detail was collected, all of the data were expressed based on the school unit. Achievement level on "English Language Arts" (ELA) and "Mathematics" (MTH) of students were measured by Composite Performance Index (CPI) – a measure of the extent to which students are progressing toward proficiency – and the percentage of students who scored "Proficient and Higher" (AP%) in the tests (Brennan, Kim, Wenz-Gross, & Siperstein, 2001).

This study analyzed the academic results based on AP% and CPI of students from 3th, 4th, 5th, 6th, 7th, 8th, and 10th grade from 2006 to 2014, including student from elementary school, middle school, and high school. The original data which obtained from MCAS were n = 43,001 in total. However, not every school has complete data in their enrollment details (e.g. socio-demographic information). Any missing information might lead to bias in the final result of the analysis, uncompleted informative data were excluded. So, in this study, only 27,493 data were used for the analysis. In yearly average, we had 659, 619, 598, 353, 286, 284, and 255 schools, for 3rd grade, 4th, 5th grade, 6th grade, 7th grade, 8th grade, and 10th grade, respectively. The academic results of grade 10 were reported based on students' best performance on any test taken in grade 9 or grade 10; only students continuously enrolled in the state, district, or school from fall of grade 9 through spring of grade 10 were included in state, district, or school results, which leaded to the lack of academic results in grade 9. Since greenness of the students' living environment was also considered, only test results from public schools were included in the analysis. As public school students were required to attend schools that were in close proximity to their homes, their living environment would fall under the buffer area of the schools.

Socio-demographic factors were used for adjustments in the final analysis on difference between academic performances (Capraro, Capraro, & Wiggins, 2000). Statistical data from 2006 to 2014 were obtained from the Elementary/Secondary Information System (ElSi) provided by the National Center for Education Statistics. The information included statistics on sex (Pomerantz, Altermatt, & Saxon, 2002), race and ethnicity (Glick & Hohmann-Marriott, 2007), student-teacher ratio (Finn, Gerber, & Boyd-Zaharias, 2005), the percentage of students with limited English proficiency (Martirosyan, Hwang, &