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Assessing the relationship between greenspace and academic achievement in urban New Zealand primary schools

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Abstract: Greenspace can have a significant positive effect on improved concentration duration, behaviour in the classroom, and educational and social development for school-aged children. This paper uses Geographical Information Systems to explore academic achievement and greenspace in New Zealand. Using multivariate linear regression, the association between greenspace exposure and the percentage of children achieving above academic attainment expectations was examined, controlling for gender, ethnicity, and socioeconomic status. Socioeconomic status was the most significant predictor of academic achievement. Weak associations between greenspace, academic achievement, gender, and ethnicity were observed. Unexpectedly, academic achievement negatively correlated with greenspace.

Key words: academic achievement, children, gender, GIS, greenspace, socioeconomic status.

Introduction

The potential mechanisms for how greenspaces can positively contribute to health and education outcomes in urban spaces have been explored in multiple disciplines, such as environmental psychology (Taylor *et al.* 2002; Moore 2003), horticultural sciences (McFarland *et al.* 2010), education (Blair 2009), and health geography (Richardson *et al.* 2010, 2013; Nutsford 2014). This paper contributes to this work by examining whether exposure to greenspace influences academic achievement in New Zealand. While the literature on the potential effect of greenspace exposure on education outcomes is largely small scale and qualitative, this paper takes a broader, socio-spatial ecological approach on a national scale in an attempt to quantify previously identified impacts of greenspace exposure on academic achievement. Such work is important as a better understanding of how academic achievement is affected by environmental factors may help to improve learning outcomes. This is particularly relevant given that in recent years, opportunities for spontaneous and regular contact with the natural world have decreased significantly for many children (White 2004).

Three dominant and interrelated themes exist in the literature relating to greenspace and academic achievement: the influence of exposure to greenspaces on childhood

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development, how greenspace exposure can positively affect the ability to concentrate, and how access to greenspace contributes to better physical health outcomes. First, in the case of developmental processes, the natural world offers numerous opportunities for children to develop the ability to label, classify and 'know' the world around them. These faculties are central to the first stage of a child's cognitive development, and greenspaces are known to promote not only intellectual but emotional development as well (Kellert 2005). Spencer and Blades (2006) note that a number of studies support the hypothesis that greenspaces support the healthy emotional development of a child as natural environments promote positive emotional states. Emotions, as Iozzi (1989) states, can be considered the building blocks for the motivation to acquire knowledge. As children learn through play, Bell and Dyment (2006) argue that green school grounds strengthen opportunities for cognitive development as greenspaces promote more cohesive play and social interactions compared to spaces where nature access is limited or absent. More recently, Dadvand *et al.* (2015) observed a positive correlation between greenspace and enhanced working memory and a reduction in inattentiveness. Limited access to natural environments can negatively impact childhood development, and can have serious physical and psychological health ramifications (Strife & Downey 2011).

Second, greenspace exposure has also been shown to improve the ability to concentrate and the duration of how long children can concentrate. The results of a Swedish study comparing daycare centres with low versus high greenspace exposure demonstrated that children in settings with more outdoor greenspace had better motor skills and attentional abilities (Wells 2000). Taylor and Kuo (2009, 2011) and Taylor *et al.* (2001, 2002) revealed that the ability to concentrate was significantly improved by greenspace exposure, particularly for children with attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD). Similar trends were found in non-disabled children by Schutte *et al.* (2015), where attention tasks and spatial working memory were better in children who went on a nature walk compared to those who went on an urban walk. Similarly, a US study of high school environments found that better concentration scores were found in students attending high schools that have 'mostly natural' views compared to those attending high schools with 'mostly built' views (Matsuoka 2010). The ability to concentrate is important as it directly relates to the development of impulse control and the ability to delay gratification, faculties that enhance positive decision making throughout life (Taylor *et al.* 2002). Previous research has indicated that concentration skills and the associated ability to delay gratification is a significant predictor of academic achievement (Mischel *et al.* 1988; Matsuoka 2010).

Third, the literature relating to the importance of greenspace exposure in relation to physical health outcomes is inconclusive, although Ward *et al.* (2016) note that research has generally shown that time spent in greenspaces positively correlates with children's physical activity. Macintyre *et al.* (2008) concluded that the inequitable distribution of greenspace in Scotland, which favoured areas of low social deprivation, may account for low physical activity rates in deprived areas. Ross (2000), however, found that household income was a better predictor of physical activity rates than the amount of neighbourhood greenspace exposure. In the New Zealand context, Richardson *et al.* (2010) found no evidence that greenspace access influenced health outcomes in relation to cardiovascular disease (CVD), while a positive correlation between greenspace and physical activity was found by Richardson *et al.* (2013). Ward *et al.* (2016) examined cognitive development, emotional well-being, ability to appraise risk, and sensation-seeking tendencies in relation to greenspace and how much moderate-to-vigorous physical activity (MVPA) participants engaged in. Within the cohort of 118 participants aged 11–14 years, a positive correlation was found between greenspace exposure and MVPA. Greenspace exposure was also positively correlated with greater emotional well-being (Ward *et al.* 2016).

While research into how environmental factors can impact childhood development and academic achievement has offered valuable insights, when examining the potential role greenspace may have, few studies have controlled for ethnicity or socioeconomic status (SES). SES is an important factor to consider when researching academic achievement as 50 years of research has shown that children from low SES families tend to have significantly lower education outcomes relative to their middle and high SES peers (Ball 2000). In the international context, the difference in New Zealand between students of average SES and students from a more advantaged socioeconomic background (those in the top seventh) is among the highest in the 66 OECDs and participating countries involved in the 2009 Programme for International Student Assessment (PISA) project (OECD 2010). According to the OECD (2010) report, mean scores placed New Zealand students at the seventh best in terms of academic proficiency, but showed New Zealand as having the highest inequality in educational attainment relative to the PISA index of economic, social, and cultural status.

Strife and Downey's (2011) review paper offers an excellent perspective regarding the inequalities that exist in relation to greenspace access in the US context. Further research in the US suggests that poorer communities and ethnic minorities have less exposure to natural spaces (Gobster 2002; Dai 2011). Wu *et al.* (2014) identified a positive correlation between greenspace and academic achievement when controlling for SES. Given the important role that the natural world plays in childhood development, understanding and addressing the pernicious effects of unequal access is important to ensure that children from low SES backgrounds can have opportunities to use greenspaces. This, combined with the fact that children from all social classes have less and less access to greenspaces (White 2004), means that analysis is timely.

Thus, the primary focus of this research is to examine whether the presence and quantity of greenspace within school grounds, and in the local area where many of the school students live, influences academic achievement. Due to the effect that SES has on academic achievement, we also examine whether greenspace accessibility and academic achievement varies across SES strata. Gender and ethnicity trends are also explored.

Data and methods

To assess the relationship between greenspace and academic achievement, five datasets were acquired: school locations, school zone boundaries, school academic achievement data, greenspace coverage, and school parcel boundaries. To compensate for the fact that the home location of students was unknown, a number of spatial and demographic limitations were chosen in order to provide a proxy for greenspace exposure.

In the absence of the student home location, school enrolment zones[1] were used as a proxy to link a given school's students to the potential for greenspace exposure in the vicinity of the school. This approach was deemed appropriate as approximately 80%[2] of students attending the schools in this study live in-zone. School zones vary significantly as schools are able to determine their own boundaries, subject to approval by the Ministry of Education (MoE). Although primarily used to manage the potential for overcrowding, the odds of a school having a zone increase as SES increases. For instance, for the schools in this study, the odds of the highest SES schools having a zone are twice that of the lowest SES schools ($P < .001$).[3] The administrative status of the school also influences zone size. Zones for integrated schools (partially state-funded, often with 'special character', e.g. Christian schools) are, on average, between 10.47 and 13.95 times larger than fully state-funded (referred to in New Zealand as non-integrated) schools. Furthermore, integrated and private school attendance tends to reflect the social character of the school rather than being biased towards geographic proximity. Similarly, the zones of rural schools are, on average, six times larger than those in urban areas. Non-integrated secondary school zones are, on average, 5.42 times larger than non-integrated primary schools. As such, the degree of certainty relating to the amount of greenspace (particularly publicly accessible greenspace) within the vicinity of where children live is far lower for schools that are not fully state-funded or that are rural. For this reason, non-integrated urban Kura Kaupapa Māori (Māori language full immersion ($n = 20$)), bilingual (Māori-medium immersion ($n = 1$)) and designated character schools (n = 1) were also excluded from analyses. No Kura Kaupapa Māori schools have zones, and the bilingual and designated character schools that did have a zone were excluded previously as they were rural.

School location data obtained from the MoE schools directory were geocoded in ArcGIS. Analysis was limited to urban, non-integrated primary schools (n = 1,587) and students up to school year 6.[4] This, in part, was due to the more limited greenspace access urban dwellers have relative to their rural counterparts. Furthermore, the focus was on accessible greenspace, such as parks and playgrounds. Schools in rural areas tended to be surrounded by greenspace that was privately owned, such as farms and small lifestyle blocks. This did not preclude analyses incorporating privately owned greenspace as the effects of proximity to privately owned greenspace such as farms, particularly for peri-urban dwellers, is worthy of inclusion as the presence of farmland in urban spaces arguably has a greater impact than for rural dwellers. Mismatched or incorrectly located addresses (n = 23) were manually edited.

The urban/rural classifications within the schools directory, and those employed by Richardson *et al.* (2010), are based on those defined by Statistics New Zealand (StatsNZ) for the New Zealand Census. The criteria used by StatsNZ to determine urban and rural classifications often result in areas adjacent to urban centres being designated as urban when they are primarily of a rural character. The New Zealand Postcode Network File (PNF)[5] contains urban and rural attribute data and provides a better approximation of urban areas compared to the StatsNZ data. For this reason, the PNF was used to perform a spatial join on the schools data. Postal area classes of rural (RD) and non-rural were assigned to the school point data. Using aerial imagery, each primary school was then checked to ensure it was correctly classified. Through this process, 74 non-rural delivery schools were re-classified as rural, and three RD schools were reclassified as urban. In total, 838 schools covering 230,929 students met the criteria for this research. As not all 838 schools have a zone, an average zone area was calculated (22.13 km^2), and this figure was used as a basis for assigning a Euclidean buffer (radius = 2,653 m) around each school location. Euclidean distance was chosen over network distance as although children are most likely to travel to school via transport networks, their view of greenspace is not bound to the route that they travel along.

The greenspace dataset used in the analyses was based on the GIS layer produced by Richardson *et al.* (2010). Three nationwide datasets – the Land Cover Database (LCDB2), Land Information New Zealand's (LINZ) 2004 Core Records System and the Department of Conversation (DoC) 2003 Boundaries dataset – contributed to the greenspace layer. The layer was updated for this study using the most recent Land Cover Database (LCDB3.3). A number of school parcels were missing greenspace extents, so the greenspace within each school boundary was manually digitised. The percentage of public and private greenspace within the school parcel boundaries and zone buffers was then calculated for each school.

The most recent (2012) National Standards data were obtained from the MoE and appended to the school greenspace data. The National Standards data contain four categories for academic achievement: achieving well below the standard, achieving below the standard, achieving at the standard, and achieving above the standard. Students are assigned a grade for mathematics, reading, and writing. Data were supplied fully redacted and were broken down by gender, ethnicity, and SES. SES data are based on the decile ranking of each school (1 = most deprived, 10 = least deprived), calculated based on neighbourhood census variables relative to where students live (MoE 2016b). For ethnicity, only counts for Māori and Pasifika students were available. The percentage of students achieving at each standard was calculated for each school, and data were analysed in R software using multivariate linear regression.

Results

Analysis using the percentage of all students achieving above the national standard as the dependent variable showed a weak,

Table 1 Students achieving above national standard and greenspace exposure.

Above national standard	Greenspace type	Estimate	95%	*P*-value
Mathematics	School ground	−0.145	(−0.20 to 0.09)	<0.001
	Public in-zone	0.021	(−0.06 to 0.11)	0.627
	Total in-zone	−0.075	(−0.1 to 0.05)	<0.001
Reading	School ground	−0.145	(−0.22 to 0.07)	<0.001
	Public in-zone	−0.078	(−0.2 to 0.04)	0.202
	Total in-zone	−0.046	(−0.09 to 0.01)	0.022
Writing	School ground	−0.077	(−0.13 to 0.03)	0.004
	Public in-zone	−0.019	(−0.11 to 0.07)	0.668
	Total in-zone	−0.036	(−0.06 to 0.01)	0.015

statistically significant negative association across all three measures of mathematics, reading, and writing when controlling for school ground and total in-zone greenspace (Table 1). The only result showing a positive association was percentage of students achieving above the national standard in mathematics in relation to total in-zone greenspace, but as for reading and writing, the association was weak and not statistically significant.

When examining the relationship between most deprived and greenspace, a weak, negative correlation is evident for school ground greenspace and total in-zone greenspace. Unlike overseas studies (Gobster 2002; Comber *et al.* 2008; Dai 2011), as SES increases in New Zealand, greenspace decreases. Schools in areas of high SES have lower school ground greenspace and less access to total in-zone greenspace relative to low SES schools. For every unit increase in school decile score (1 = most deprived/low SES, 10 = least deprived/high SES), a 0.87 unit decrease in school ground greenspace and 0.79 unit decrease in total in-zone greenspace was predicted. Public in-zone greenspace also decreased as deprivation decreased (0.1 unit decrease for every unit increase in decile score), but this was not significant.

Decile score was modelled against academic achievement above the national standard, and for mathematics, reading, and writing, a moderate and significant positive correlation was observed (Table 2). The strongest association was observed for mathematics ($r^2 = 0.315$), followed by reading ($r^2 = 0.282$) and writing ($r^2 = 0.135$). Compared to the most deprived schools (decile 1), with the exception of decile 2, higher SES was positively correlated with higher percentages of students achieving above the national standard. Relative to the lowest SES schools, decile 10 schools are predicted to have 17.90% more students achieving above the national standard for mathematics, 24.15% more for reading, and 11.40% more for writing. The inclusion of greenspace saw a minimal decrease in percentage, explained by the negative correlation between greenspace and higher SES.

Modelling the relationship between gender and greenspace exposure relative to academic achievement predicted statistically significant correlations for all combinations apart from decile 1 schools (Table 3). For mathematics (female = 113,231 and male = 119,808), males performed better than females in every SES category, and the gap between females and males increased as SES increased. Females performed better in reading (female = 112,961 and male = 119,392) across all deciles relative to males, and this difference was relatively constant across all deciles. Mirroring observations for mathematics, females performed better than males in writing (female = 113,129 and male = 119,692), and the difference between females and males increased as SES increased.

Results by ethnicity were limited to Māori and Pasifika, as National Standards data supplied by the MoE for only record counts for these two ethnic groups. Unlike observations made for all students, no linear or significant relationship was found for SES and Pasifika students achieving above standard in mathematics, reading, or writing (Table 4). For Māori, a significant positive correlation was observed for mathematics, reading, and

Table 2 Percentage achieved above the national standard and decile (SES).

Decile	Mathematics			Reading			Writing		
	Estimate	95%	*P*-value	Estimate	95%	*P*-value	Estimate	95%	*P*-value
1	1.00			1.00			1.00		
2	2.39	(0.10–4.68)	0.041	7.01	(3.76–10.26)	<0.001	1.98	(−0.60 to 4.56)	0.133
3	5.00	(2.63–7.38)	<0.001	8.53	(5.16–11.89)	<0.001	4.75	(2.08–7.43)	0.001
4	5.86	(3.33–8.39)	<0.001	12.76	(9.17–16.35)	<0.001	4.49	(1.64–7.34)	0.002
5	7.74	(5.08–10.4)	<0.001	12.72	(8.94–16.50)	<0.001	6.48	(3.48–9.48)	<0.001
6	7.80	(5.20–10.39)	<0.001	15.88	(12.2–19.57)	<0.001	6.60	(3.67–9.52)	<0.001
7	9.85	(7.18–12.53)	<0.001	17.92	(14.12–21.72)	<0.001	7.93	(4.91–10.95)	<0.001
8	11.37	(8.76–13.98)	<0.001	16.84	(13.13–20.54)	<0.001	8.26	(5.32–11.21)	<0.001
9	14.52	(11.97–17.07)	<0.001	21.30	(17.68–24.92)	<0.001	10.78	(7.90–13.65)	<0.001
10	17.90	(15.66–20.15)	<0.001	24.15	(20.96–27.34)	<0.001	11.40	(8.86–13.93)	<0.001

Reference category: Decile 1 (most deprived/lowest SES).

writing, but this was only consistent for all three at deciles 7–10.

When controlling for the percentage of each priority ethnicity at schools, a marked increase in the percentage of Pasifika students achieving above the national standard was observed; however, this association was not significant for the most part (Table 5). The most significant positive correlation between decile and percentage of Pasifika students at schools was observed for reading, with the exception of deciles 3, 7 and 8. Conversely, as the percentage of Māori students at schools increased, the percentage of Māori achieving above the national standard for mathematics and reading decreased. This association was most significant for mathematics, with only deciles 9 and 10 being significant for reading. A small increase in Māori achieving above national standard for writing relative to the percentage of Māori at schools was observed, but this was only significant for deciles 3, and 7–10.

Discussion

While a statistically significant correlation was found between greenspace and academic achievement, this negative association was weak, with 4% or less of the variability explained by the model. The negative association between greenspace and academic achievement found in this study, however, is indicative of how access differs between countries relative to SES. Greenspace access relative to SES in New Zealand differs from overseas studies (Gobster 2002; Comber *et al.* 2008; Dai 2011), as low SES areas tend to have better access to greenspace. This may be a result of lower population density coupled with land values resulting in greater greenspace access, particularly in lower SES areas. Such findings suggest that researching the impact of greenspaces is spatially and socially specific, and a myriad of other influences may offer stronger associations.

Although only a weak effect was observed between greenspace and academic achievement, interesting associations were observed when examining SES and gender. Of the factors controlled for in this study, SES somewhat predictably had the most significant

Table 3 Difference between females and males achieving above national standard by decile and greenspace.

Greenspace type	Decile	Mathematics			Reading			Writing		
		Estimate	95%	*P*-value	Estimate	95%	*P*-value	Estimate	95%	*P*-value
Total in-zone, public in-zone and school ground[†]	1	0.70	(−1.69 to 3.09)	0.565	−7.13	(−10.31 to −3.94)	<0.001	−6.25	(−8.58 to 3.90)	<0.001
	2	2.90	(0.86–4.95)	0.006	−7.17	(−10.48 to 3.85)	<0.001	−6.37	(−8.80 to 3.93)	<0.001
	3	2.70	(0.22–5.18)	0.033	−7.94	(−11.70 to 4.18)	<0.001	−9.38	(−12.49 to 6.27)	<0.001
	4	3.33	(0.66–6.00)	0.015	−9.54	(−13.09 to 5.98)	<0.001	−8.36	(−11.42 to 5.30)	<0.001
	5	4.33	(1.67–6.99)	0.002	−8.16	(−11.89 to 4.44)	<0.001	−9.76	(−12.59 to 6.92)	<0.001
	6	6.59	(3.74–9.43)	<0.001	−7.74	(−12.52 to 2.96)	0.002	−8.58	(−13.25 to 3.91)	<0.001
	7	6.36	(3.40–9.33)	<0.001	−7.99	(−12.37 to 3.60)	<0.001	−11.15	(−14.38 to 7.91)	<0.001
	8	6.16	(3.15–9.16)	<0.001	−8.15	(−12.44 to 3.86)	<0.001	−10.22	(−14.05 to 6.39)	<0.001
	9	8.04	(5.18–10.90)	<0.001	−7.17	(−11.39 to 2.94)	0.001	−9.66	(−13.06 to 6.27)	<0.001
	10	8.60	(5.47–11.72)	<0.001	−8.16	(−11.84 to 4.49)	<0.001	−12.01	(−15.03 to 9.00)	<0.001

Reference category: Females.
[†] Estimates and CIs for all three greenspace types were identical at five decimal places.

association with a school's 'above the national standard' achievement rates. The percentage of students achieving above the national standard at low SES schools was consistently lower relative to middle and high SES schools. While this trend has been reported elsewhere (Horwood & Fergusson 1998; Biddulph *et al.* 2003), these studies did not compare gender differences within each SES category. Gibb *et al.* (2008) did not find a significant interaction between gender and SES, although the measure used relied solely on parental occupation. To the authors' knowledge, these findings have not been reported elsewhere, and we argue that further research exploring the statistically significant observed gendered differences found in this study is of merit. This is particularly true for mathematics, where the gap between male and female students increased with SES, and showed the most pronounced differences relative to both reading and writing.

Again, while greenspace showed no discernible effect on academic achievement relative to ethnicity, patterns of academic achievement for Māori generally mirrored those for total students, where SES was the most significant predictor of attainment. Interestingly, compared to individual count data, fewer Māori were predicted to attain above the national standard for reading and mathematics when controlling for SES and the percentage of Māori at the schools in this study. For writing, a slight increase in Māori achieving above the national standard was predicted when controlling for SES and the percentage of Māori at school. The increase of Pasifika students at school showed an increase in the number of Pasifika students achieving above the national standard when controlling for SES, but this was only linear for reading, and very few results were statistically significant for mathematics, reading and writing. As far as the authors are aware, no research has looked into this at an ecological scale. While school neighbourhood SES was the only spatial aspect of these results, it is included here to highlight a pattern worthy of further investigation.

Determining areas that are urban or rural in New Zealand can be problematic. Rural delivery parcels based on the New Zealand Post PNF were used in this study, but this proved

Table 4 Priority ethnicities achieving above national standard by decile.

		Mathematics			Reading			Writing		
	Decile	Estimate	95%	*P*-value	Estimate	95%	*P*-value	Estimate	95%	*P*-value
Pasifika above standard	1	1.00			1.00			1.00		
	2	2.75	(−0.71 to 6.21)	0.12	**6.81**	**(1.49–12.13)**	**0.012**	1.68	(−1.78 to 5.15)	0.341
	3	−0.25	(−3.90 to 3.40)	0.892	2.85	(−2.89 to 8.58)	0.33	1.95	(−1.77 to 5.68)	0.304
	4	−0.72	(−4.54 to 3.10)	0.712	4.52	(−1.33 to 10.38)	0.13	−0.15	(−4.01 to 3.70)	0.939
	5	0.24	(−3.91 to 4.40)	0.908	2.57	(−3.87 to 9.00)	0.433	1.77	(−2.45 to 6.00)	0.41
	6	0.30	(−3.80 to 4.40)	0.886	4.24	(−2.15 to 10.63)	0.193	0.45	(−3.69 to 4.59)	0.829
	7	2.89	(−1.41 to 7.20)	0.188	6.46	(−0.16 to 13.09)	0.056	**4.38**	**(0.00–8.77)**	**0.05**
	8	−0.16	(−4.46 to 4.15)	0.943	−0.51	(−7.08 to 6.07)	0.88	−2.56	(−6.91 to 1.80)	0.249
	9	3.72	(−0.32 to 7.77)	0.071	**10.91**	**(4.71–17.10)**	**0.001**	2.90	(−1.19 to 6.99)	0.164
	10	3.29	(−0.29 to 6.86)	0.072	**5.88**	**(0.41–11.35)**	**0.035**	2.00	(−1.61 to 5.61)	0.277
Māori above standard	1	1.00			1.00			1.00		
	2	1.84	(−0.96 to 4.64)	0.197	**4.64**	**(0.59–8.70)**	**0.025**	1.31	(−1.59 to 4.22)	0.376
	3	**3.38**	**(0.48–6.28)**	**0.022**	3.69	(−0.49 to 7.88)	0.084	3.41	(0.42–6.40)	0.026
	4	**3.84**	**(0.77–6.92)**	**0.014**	**6.44**	**(1.98–10.90)**	**0.005**	2.41	(−0.78 to 5.60)	0.138
	5	**4.85**	**(1.65–8.05)**	**0.003**	4.00	(−0.64 to 8.65)	0.091	**3.51**	**(0.19–6.83)**	**0.038**
	6	3.07	(−0.05 to 6.20)	0.054	**7.39**	**(2.85–11.93)**	**0.001**	2.75	(−0.49 to 5.99)	0.096
	7	**5.37**	**(2.13–8.60)**	**0.001**	**9.87**	**(5.20–14.54)**	**<0.001**	**4.79**	**(1.44–8.14)**	**0.005**
	8	**6.23**	**(3.09–9.37)**	**<0.001**	**7.85**	**(3.30–12.41)**	**0.001**	**4.89**	**(1.62–8.16)**	**0.003**
	9	**9.72**	**(6.63–12.81)**	**<0.001**	**12.47**	**(7.99–16.96)**	**<0.001**	**7.03**	**(3.83–10.24)**	**<0.001**
	10	**12.57**	**(9.80–15.34)**	**<0.001**	**14.14**	**(10.14–18.14)**	**<0.001**	**7.46**	**(4.59–10.33)**	**<0.001**

Reference category: decile 1 (most deprived). Bold denotes significance at $P < 0.05$.

Table 5 Priority ethnicities achieving above national standard by decile and percentage school population.

	Decile	Mathematics Estimate	Mathematics 95%	Mathematics P-value	Reading Estimate	Reading 95%	Reading P-value	Writing Estimate	Writing 95%	Writing P-value
Pasifika above standard	1	1.00			1.00			1.00		
by % Pasifika students	2	**4.33**	**(0.77–7.89)**	**0.017**	**9.35**	**(3.88–14.82)**	**0.001**	2.93	(−0.67 to 6.52)	0.11
	3	1.67	(−2.13 to 5.47)	0.388	5.80	(−0.13 to 11.73)	0.055	3.34	(−0.53 to 7.22)	0.091
	4	1.78	(−2.29 to 5.85)	0.391	**8.56**	**(2.31–14.81)**	**0.007**	1.72	(−2.40 to 5.85)	0.413
	5	3.32	(−1.19 to 7.83)	0.149	**7.50**	**(0.52–14.48)**	**0.035**	4.08	(−0.52 to 8.69)	0.082
	6	3.27	(−1.16 to 7.71)	0.148	**9.00**	**(2.10–15.90)**	**0.011**	2.69	(−1.81 to 7.19)	0.241
	7	**5.95**	**(1.30–10.60)**	**0.012**	**11.38**	**(4.23–18.53)**	**0.002**	**6.69**	**(1.94–11.44)**	**0.006**
	8	3.01	(−1.66 to 7.69)	0.206	4.55	(−2.58 to 11.69)	0.211	−0.19	(−4.93 to 4.55)	0.938
	9	**6.99**	**(2.53–11.46)**	**0.002**	**16.15**	**(9.31–22.99)**	**<0.001**	**5.35**	**(0.83–9.88)**	**0.021**
	10	**6.68**	**(2.59–10.76)**	**0.001**	**11.34**	**(5.07–17.60)**	**<0.001**	**4.55**	**(0.41–8.69)**	**0.031**
Māori above standard	1	1.00			1.00			1.00		
by % Māori students	2	1.59	(−1.25 to 4.43)	0.273	3.94	(−0.18 to 8.07)	0.061	1.37	(−1.60 to 4.33)	0.366
	3	**2.90**	**(−0.15** to **5.95)**	**0.063**	2.40	(−2.03 to 6.82)	0.288	**3.51**	**(0.33–6.69)**	**0.031**
	4	3.22	(−0.10 to 6.54)	0.058	4.77	(−0.07 to 9.60)	0.053	2.54	(−0.94 to 6.01)	0.152
	5	**4.09**	**(0.55–7.63)**	**0.023**	1.99	(−3.16 to 7.15)	0.447	3.66	(−0.04 to 7.37)	0.053
	6	2.21	(−1.37 to 5.78)	0.226	5.09	(−0.12 to 10.30)	0.055	2.93	(−0.82 to 6.68)	0.126
	7	**4.40**	**(0.64–8.16)**	**0.022**	**7.32**	**(1.85–12.78)**	**0.009**	**4.98**	**(1.04–8.93)**	**0.013**
	8	**5.24**	**(1.53–8.96)**	**0.006**	5.24	(−0.16 to 10.65)	0.057	**5.09**	**(1.18–9.00)**	**0.011**
	9	**8.64**	**(4.87–12.41)**	**<0.001**	**9.62**	**(4.12–15.11)**	**0.001**	**7.25**	**(3.29–11.21)**	**<0.001**
	10	**11.41**	**(7.80–15.02)**	**<0.001**	**11.08**	**(5.82–16.34)**	**<0.001**	**7.69**	**(3.89–11.50)**	**<0.001**

Reference category: decile 1 (most deprived). Bold denotes significance at $P < 0.05$.

time consuming due to the number of schools that needed to be checked manually. A better proxy could potentially be derived from LINZ 'Residential Areas' topographic data,[6] which indicate the extent of built-up areas. The authors suggest that a combination of the topographic data, overlaid with population data from the New Zealand Census (population density and population count), could serve as a better approximation for urban versus rural. Zhao and Exeter's (2016) work on developing administrative geography boundaries, which includes urban/rural distinctions, could also offer potential improvements to the selection of schools.

We were not able to control for the quality or desirability of the greenspaces in this study, which may impact the effect a given greenspace has on those accessing it. Unlike Wu *et al.* (2014) and Dadvand *et al.* (2015), we were able to control for whether greenspace was publicly accessible. Controlling for publicly accessible greenspace did not predict a significant result. As this study was conducted from an ecological perspective, the actual exposures for each student were unknown. Further analysis would benefit from more detailed information relating to the amenity values of the greenspaces. In addition, viewshed analysis from the school sites may also help to provide a better proxy for exposure, with the assumption that it is the visibility of greenspace that has a greater degree of influence.

Endnotes

1 School zones are common in New Zealand and are designed to manage enrolments at schools and encourage and guarantee children a place at their local school. For more information, see MoE (2016a).

2 Figure provided via personal correspondence with the MoE Information Officer and is an indication based on the data at hand.

3 The politics informing this trend are beyond the scope of this paper and will be explored in future.

4 Some primary schools in this study had data for year 7 (n = 286) and year 8 (n = 275).

5 The New Zealand PNF is a proprietary dataset maintained by New Zealand Post. Urban postal delivery areas (n = 369) are assigned a four-digit code. Rural delivery areas (n = 711) are assigned a four-digit code and an additional 'RD' code.

6 LINZ topographic data are derived from satellite images and provide a better level of spatial detail than the PNF or StatNZ datasets.

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