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Mitigating Environmental Sustainability Challenges and Enhancing Health in Urban Communities: The Multi-functionality of Green Infrastructure

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ABSTRACT

Green Infrastructure (GI) facilities have capacity to enhance health and mitigate Environmental Sustainability Challenges (ESC). However, the extent of the mitigation and health benefits is unclear in developing countries. This study examined the impact of GI on ESC and Perceived Health (PH) of urban residents in Lagos Metropolis, Nigeria. Multi-stage sampling technique was used to select 1858 residents of Lagos Metropolis who completed semi-structured questionnaires. Descriptive statistics and chi-square test were used to explore data distributions and assess association of the availability of GI with resident's PH and ESC. Odds ratio with 95% confidence interval (OR;95%CI) were estimated for good health and ESC mitigation. Participants were mostly men (58.9%) and younger than 50 years old (86.3%). Good health (20.5%) and high mitigation of ESC (collection and disposal of waste-52.7% and official development assistance-63.9%) were reported where GI is mostly available. Participants were more likely to report good health (OR:1.40; 95%CI:1.02-1.92) and high mitigation of ESC [water quality (OR:1.42; 95%CI:1.12-1.81) passenger transport mode (OR:1.41; 95%CI:1.06-1.89)] where GI are mostly available. Availability of Green infrastructure is supporting health and mitigating environmental sustainability challenges in the study area. Green infrastructure should be provided in urban areas where environmental sustainability is under threat.

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1. Introduction

Urban sprawl, rapid depletion of forest areas and urban degradation among others has constituted daunting challenges to the environment in recent time. In addition, other more wide-spread land-uses, such as agriculture and industrial activities, have split up valuable landscapes, intensified the use of more energy, fertilizer and water (Jongman, 2003; Gutman, 2007).

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This uncurbed urbanisation and shift from forest systems to mechanized and grey infrastructure laden environment has resulted in the reduction of species' richness and weakened the capacity of ecosystems for natural food production, rejuvenation of human health, maintenance of aquatic and terrestrial resources, regulate micro-climate and air quality in the built environment (Tzoulas *et al.,* 2007; Ward Thompson, 2011). To ameliorate some of these negative consequences of urbanization, strategies of green infrastructure was proposed as solution to tackle environmental sustainability and human well-being especially in rapidly developing urban centres (Pakzada & Osmonda, 2016).

Green infrastructure (GI) is a network of multi-functional green space facilities that can increase connectivity between existing natural areas, encourage ecological coherence while improving the quality of life and well-being. Various research efforts in the built environment are currently geared towards improving ecosystem services through the development of GI (Wolch, Byrne & Newell, 2014; Maes *et al.,* 2015), mostly as a strategy to cope with divers' environmental sustainability challenges. However, in spite of the numerous benefits of the green infrastructure, rapid population growth and changes in land uses have put these facilities under pressure. This poses questions regarding the quantity and types of GI within a neighbourhood/community which are required to mitigate environmental sustainability challenges and enhance human health (Maes *et al.,* 2015; Ward Thompson *et al.,* 2016).

Specifically, empirical evidences show that activities or living around green spaces promotes physical health, psychological well-being, and the general public health of users (Takano, Nakamura, Watanabe, 2002; Wolch *et al.,* 2014; Maes *et al.,* 2015). Exposure to street trees, vegetation, green parks, gardens and other green spaces in urban areas has been connected with multiple health benefits, including reduced mortality, morbidity, mental fatigue, stress, and being more physically active (Takano *et al.,* 2002; de Vries *et al.,* 2003; Maas *et al.,* 2009). Other environment-related benefits range from carbon sequestration, improved air and water quality, control of air pollution to urban heat island effect (Gómez-Mu˜noza, Porta-Gándarab & Fernándezc, 2010).

In addition, studies from Australia (Humpel *et al.,* 2004; Sugiyama, Leslie, Giles-Corti & Owen, 2008) have identified that the quality of parks and landscapes in people's neighbourhood may contribute to more active lifestyles. Similar studies in Netherlands demonstrated the benefits of green spaces near homes and their impact on stress and other patterns of morbidity associated with accessing distance green spaces (Maas, Verheij, Spreeuwenberg & Groenewegen, 2008; Maes *et al.,* 2015). Apart from that, in a recent study among poor black and minority ethnic (BME) communities in the UK, result suggested that health and recreation policy in the UK needs to create more opportunities and green facilities closer to BME communities in order to address the health inequalities experienced by these groups (Roe, Aspinall, & Ward Thompson, 2016; Ward Thompson *et al.,* 2016). Also, availability of green spaces has been reported to enhance factors such as community cohesion and revitalization, improved housing conditions, neighbourhood pedestrian corridors, job availability, and more active youths in productive ventures (Jennings, Baptiste, Jelks & Skeete, 2017).

In general, green infrastructure has the capacity to enhance health and mitigate environmental sustainability challenges (Pakzada & Osmonda, 2016; Jennings *et al.,* 2017), but the aspect or dimension of the challenges, the extent of the mitigation and the effect that these will have on the health of urban residents in developing nations like Nigeria is unclear. The present study therefore, examined the mitigating effects of GI on selected environmental sustainability issues as well as the extent to which availability of GI can enhance self-reported (perceived) health of urban residents in Lagos Nigeria.

2. Methods

2.1. Participants and procedure

A total of 1858 residents of Lagos state, Nigeria participated in this study. Participants were household heads or adult representative who can and were willing to provide the needed information. The sampling frame consisted of the 16 Local Government Areas (LGAs) in Lagos Metropolis. Selected LGAs were sub-divided into participants' neighbourhood defined by Enumeration areas (EAs). In each EA, households were systematically sampled from the list of numbered houses (households) until the required sample size allocated to the EA was reached. Consenting participants (household heads) were given the study questionnaire to complete in English language. Ethical approval (with number MOE/OES/7250/52) for this study was obtained from the Lagos State Ministry of Environment Ethical Review Committee.

2.2. Measures

Demographic information

The study used a semi-structured questionnaire to collect data on participant's demography. Some of the information in the socio-demographic section of the questionnaire included gender, age, family size, marital status, household size, ethic group, religion, occupation and rank in occupation/income level.

Availability of green infrastructure

Preliminarily, participants were asked to specify if green infrastructure is available in their neighbourhood, the approximate distance of the GI facilities from their location, the type of GI facilities available in their neighbourhood, reasons for visiting GI sites and other related questions. To measure the availability of GI in the neighbourhood; the literature was used to ascertain GI types (Takano *et al.,* 2002; Wolch *et al.,* 2014) while the authors verified and documented all available GI types in the study area. The available GI in the study areas were grouped into four namely: Green spaces GI, Tree features GI, Water features GI and other spaces green infrastructure *(consisting of green infrastructure facilities that cannot be categorised into any of the first three groups)*. Respondents were required to identify from the list of GIs in each group, all GI facilities present in their neighbourhood.

2.2.3. Health Benefits of Green Infrastructure (HBGI).

The Health Benefits of Green Infrastructure (HBGI) was measured with the 12-item General Health Questionnaire (GHQ) developed by Goldberg. This (GHQ) instrument is a measure of current mental health of participants. The GHQ has been previously used and validated in different nations, settings and cultures with very reliable results (Goldberg, 1992). Originally, the questionnaire was developed as a 60-item instrument but shortened versions of the questionnaire were later developed in response to some criticisms of the instrument. Such versions include GHQ-30, the GHQ-28, the GHQ-20, and the GHQ-12. The scale assessed recent experiences of respondents on a particular symptom or behaviour. Each item is rated on a 4-point scale *(1=less than usual, 2=no more than usual, 3=rather more than usual and 4=much more than usual)* (Golderberg et al., 1998). Examples of items include "been able to enjoy your normal day to day activities", "been able to concentrate on what you're doing" etc (Supplementary Table S1). In the present study, HBGI of the participants was measured in relation to whether or not they visit green infrastructure sites over the past 4 weeks. This selected duration (one-month) was considered sufficient to assess the health impacts of GI on users based on recommendations of the British Heart Foundation National Centre (Milton, Bull & Bauman, 2011). The 12-item GHQ has been used to assess health benefits in some settings with reasonable coefficient of reliability. In particular, Montazeri et al. (2003) reported an alpha coefficient of 0.87 for the GHQ scale in a study conducted in Iran, to assess the reliability and validity of the 12-item instrument.

2.2.4. Environmental Sustainability Challenges

Five facets measuring general environmental sustainability challenges were extracted from 27 facets of sustainability in a Report of the Joint UNECE/OECD/Eurostat working group on statistics for sustainable development. (UNECE/OECD/Eurostat, 2008). The five facets were selected (for their relevance to the issues of environmental sustainability in the study setting) for the present study: Air Pollution (APL), Collection and Disposal of Waste (CDW), Water Quality (WQT), Passenger Transport Mode (PTM) and Official Development Assistance (ODA). Literature informed indicators or items relevant to the selected facets were used to measure sustainability challenges related to the facet (SCI, 2012; Müller et al., 2009; Bonaiuto et al., 2003). Participants were required to show their agreement or disagreement to the 21 indicators (arranged within 5 facets) on a 7-point scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*. Examples of indicators include "residents' health in this neighbourhood is threatened by air pollution" and "residents have access to clean drinkable water in this neighbourhood" (Supplementary Table S2).

2.3. Data Management and Statistical Analysis Techniques

Initially, frequency tables and cross tabulations were used to explore the distribution of the data and to enhance data cleaning/editing. Total raw score was calculated for each group of the GI type [i.e Total Green spaces GI (TGRS), Total Tree Features GI (TTRF), Total Water Features GI (TWTF) and Total Other Spaces GI (TOTH)] as the sum of GI facilities available in the area as indicated by the respondent. A GI availability index was created using the total raw score as a percentage of the total GI facilities listed in the group. An overall GI index was created for each respondent as a total of the group specific indices. The four groups of GI availability indices (TGRS, TTRF, TWTF, TOTH), were categorized into 3 using the mean (M) and the standard deviation (SD) as follows: *poorly available* (if score < M+SD), *moderately available* (if M-SD ≤ score ≤ M+SD), and *mostly available* (if score > M+SD). Similarly, the total score for the Health Benefits of GI (HBGI) was categorized into 3 using the mean (M) and the standard deviation (SD) as follows: *poor health* (if score < M+SD), *fair health* (if M-SD ≤ score ≤ M+SD), and *good health* (if score > M+SD). Each facet of the Environmental Sustainability Challenges were also categorized into 3 using the mean (M) and the standard deviation (SD) as follows: *low mitigation* (if score < M+SD), *moderately mitigation* (if M-SD ≤ score ≤ M+SD, and *high mitigation* if ≥ M+SD (Issa & Bayeiwu, 2006; Akpa & Bamgboye, 2015).

The Chi-square test was used to assess whether level of mitigation of the environmental sustainability challenges and good health benefit were associated with availability of GI facilities in the study area. The categories of the HBGI and each facet of the Environmental sustainability challenges were further dichotomized by combining the two upper categories so as to form only two outcomes. Binary logistic regression analysis (Adjusted and unadjusted analyses) was performed to estimate the odds ratio (OR) and their respective 95% Confidence Intervals (CI) for factors associated with HBGI and each facet of environmental sustainability challenges. Covariates were included in the logistic regression depending on whether or not, there significant in the bivariate (Chi-sqaures) test. All analysis were performed using IBM SPSS statistics version 20 with significance level set at 5%.

3. RESULTS

3.1. Participants' Demography and Social Factors

More than half (58.9%) of the participants are men while 41.1% of them are women. Participants are mostly younger than 50 years (86.3%) and approximately 57% of them are married. Although most of them had completed tertiary education (59.9%), 12% of them did not complete secondary education. About 43% of the participants were self-employed, 28.2% were employees of public/private organizations while 11.9% of them are unemployed (Table 1).

Table 1: Socio-demographics Characteristics of Respondents (N=1858)

Variables		Frequency	Percentage (%)
Sex			
	Male	1095	58.9
	Female	763	41.1
	Total	1858	
Current Age			
	<30	699	37.6
	30-49	905	48.7
	>=50	222	11.9
	Not Reported	32	1.7
	Total	1858	
Marital Status			
	Never Married	711	38.3
	Married	1049	56.5
	Formerly Married	85	4.6
	Not Reported	13	0.7
	Total	1858	
Household Size			
	<=4	1063	57.2
	>4	786	42.3
	Not Reported	9	0.5
	Total	1858	
Ethnic Group			
	Yoruba	1298	69.9
	Others	559	30.1
	Not Reported	1	0.1
	Total	1858	
Highest Educational Qualification			
	Less than Secondary Education	223	12.0
	Secondary Education	516	27.8
	Tertiary Non Degree Education	604	32.5
	Tertiary Degree/Postgraduate Education	510	27.4
	Not Reported	5	0.3
	Total	1858	
Occupation			
	Unemployed	221	11.9
	Self Employed	797	42.9
	Private/Public Employees	524	28.2
	Students & Others	316	17.0
	Total	1858	
Rank in Occupation/Income Level			
	Junior Staff	478	25.7
	Senior Staff	275	14.8
	Management Staff/Business Owners	597	32.1
	Not Reported	508	27.3
	Total	1858	

3.2. Factors associated with participants' perceived Health Benefits of Green Infrastructure

The proportion (20.5%) of participants reporting perceived good health was significantly higher among those reporting that GI (overall) is mostly available in their neighbourhood. Also, the proportion of younger participants, aged <50 years (85.1%) reporting perceived good health was significantly higher compared to participants aged > 50 years (14.8%). Participants who have completed tertiary education (58.8%) reported perceived good health than those who did not have more than secondary school education (41.1%). Poor health was mostly reported among participants who were not yet married (23.6%) (Table 2).

Table 2: Factors associated with perceived Health Benefits of Green Infrastructure

		% with poor health	% with fair health	% with good health	P
Green Space GI					0.04
	Poorly Available	33(17.0)	119(61.3)	42(21.6)	
	Moderately Available	206(22.7)	559(61.5)	144(15.8)	
	Mostly Available	136(19.3)	421(59.9)	146(20.8)	
Tree Feature GI					0.59
	Poorly Available	120(20.3)	369(62.4)	102(30.7)	
	Mostly Available	255(21.0)	730(60.1)	230(69.3)	
Water Feature GI					0.48
	Moderately Available	220(19.7)	691(61.8)	208(81.6)	
	Mostly Available	57(22.9)	145(58.2)	47(18.4)	
Other Spaces					0.22
	Moderately Available	204(21.6)	580(61.4)	160(48.2)	
	Mostly Available	171(19.8)	519(60.2)	172(51.8)	
Overall GI index					0.03
	Poorly Available	72(25.5)	174(61.7)	36(12.8)	
	Moderately Available	131(20.1)	403(61.9)	117(18.0)	
	Mostly Available	172(19.7)	522(59.8)	179(20.5)	
Participants' Demography					
Sex					0.29
	Male	221(20.3)	679(62.4)	189(56.4)	
	Female	168(22.1)	447(58.7)	146(43.6)	
Current Age					0.01
	<30	173(24.9)	405(58.3)	117(35.3)	
	30-49	164(18.2)	572(63.5)	165(49.8)	
	>=50	45(20.3)	128(57.7)	49(14.8)	
Marital Status					0.009
	Never Married	166(23.6)	410(58.3)	127(38.4)	
	Married	194(18.5)	666(63.5)	189(57.1)	
	Formerly Married	27(31.8)	43(50.6)	15(4.5)	
Household Size					0.34
	<=4	233(22.0)	644(60.8)	182(54.5)	
	>4	156(19.9)	475(60.7)	152(45.5)	
Ethnic Group					0.98
	Yoruba	270(20.9)	787(61.0)	234(69.9)	
	Others	119(21.3)	338(60.6)	101(30.1)	
Highest Educational Qualification					0.04
	Less than Secondary	41(18.5)	128(57.7)	53(15.9)	
	Secondary	97(18.9)	332(64.7)	84(25.2)	
	Tertiary Non Degree	138(22.9)	348(57.7)	117(35.1)	
	Tertiary Degree/Postgrad	112(22.1)	316(62.3)	79(23.7)	
Occupation					0.17
	Unemployed	59(26.8)	119(54.1)	42(12.5)	
	Self Employed	149(18.7)	506(63.6)	140(41.8)	
	Private/Public Employees	113(21.6)	318(60.7)	93(27.8)	
	Students & Others	68(21.9)	183(58.8)	60(17.9)	
Rank in Occupation					0.32
	Junior Staff	92(19.3)	296(62.1)	89(38.0)	
	Senior Staff	56(20.4)	180(65.5)	39(16.7)	
	Management Staff	135(22.7)	355(59.6)	106(45.3)	

Note: *percentages were calculated based on the row total of the the 3 categories of each facet of the Environmental Sustainability challenges*
GI-*Green Infrastructure*

The results of the logistic regression analyses are presented as adjusted and unadjusted odd ratios (OR and aOR) with their respective 95% confidence intervals (CI) in Table 3. The odds of reporting good health was higher for participants in areas where GI (overall) are mostly available (OR: 1.40; 95%CI: 1.02-1.92). Similarly, the odds of reporting good health was higher among participants that are aged 30-49 years (OR: 1.49; 95%CI: 1.17-1.90) compared to participants that are less than 30 years of age. Being formerly married (OR: 0.47; 95%CI: 0.28-0.81) and aged 30-49 years (OR: 1.39; 95%CI: 1.06-1.61) are independently associated with perceived health benefits of GI (Table 3).

Table 3: Association of Green Infrastructure with Perceived Health benefit of GI

Factors		Odds of Good Health (95% CI)	Adjusted Odds of Good Health (95% CI)
Green Space GI			
	Poorly Available	-	-
	Moderately Available	0.70(0.47-1.05)	0.64(0.42-0.99)
	Mostly Available	0.86(0.56-1.30)	0.72(0.46-1.13)
Overall GI Index			
	Poorly Available		
	Moderately Available	1.36(0.98-1.89)	1.39(0.98-1.96)
	Mostly Available	1.40(1.02-1.92)	1.37(0.95-1.97)
Current Age			
	<30	-	
	30-49	1.49(1.17-1.90)	1.39(1.06-1.61)
	>=50	1.30(0.90-1.89)	1.24(0.83-1.85)
Highest Educational Qualification			
	Less than Secondary	-	
	Secondary	0.97(0.65-1.46)	0.85(0.55-1.32)
	Tertiary Non Degree	0.76(0.52-1.13)	0.67(0.44-1.02)
	Tertiary Degree/Postgrad.	0.80(0.54-1.19)	0.67(0.44-1.03)
Marital Status			
	Never Married	-	-
	Married	1.36(1.08-1.72)	1.19(0.91-1.55)
	Formerly Married	0.66(0.41-1.08)	0.47(0.28-0.81)

3.3. Adjusted Effects of Green Infrastructure on Environmental Sustainability Challenges and Participant's Health

Proportion reporting high mitigation of CDW (52.7%) and ODA (63.9) challenges were significantly higher in areas were GI (overall) are mostly available. High mitigation was equally reported for WQT (48.0%) and ODA (65.0%) challenges where tree features and green spaces GI were respectively mostly available in the study area (Table 4).

Table 4: Association between Availability of GI and Environmental Sustainability challenges

	Air Pollution		Collection and Disposal of waste		Water Quality		Passenger Transport Mode		Official Development Assistance	
Green Infrastructure	**% reporting High mitigation**	***P***	**% reporting High mitigation**	***P***	**% reporting High mitigation**	***P***	**% reporting High mitigation**	***P***	**% reporting High mitigation**	***P***
Green Space GI		0.16		0.52		0.80		0.71		0.03
Poorly Available	97(50.0)		102(52.6)		91(46.9)		111(57.2)		114(58.8)	
Moderately Available	474(52.1)		470(51.6.2)		437(48.0)		524(57.8)		520(57.4)	
Mostly Available	327(46.2)		384(54.2)		340(48.0)		387(55.0)		457(65.0)	
Tree Feature GI		0.89		0.25		0.007		0.78		0.76
Poorly Available	288(48.7)		327(55.3)		281(47.5)		333(56.6)		360(61.2)	
Mostly Available	610(50.0)		629(51.5)		587(48.1)		689(56.7)		731(60.2)	
Water Feature GI		0.33		0.33		0.38		0.99		0.49
Moderately Available	565(50.4)		583(52.0)		556(49.6)		647(58.1)		688(60.0)	
Mostly Available	119(48.0)		139(56.0)		112(45.2)		144(58.1)		159(64.1)	
Other Spaces		0.77		0.82		0.21		0.05		0.30
Moderately Available	473(49.9)		505(53.3)		468(49.4)		532(56.4)		563(59.7)	
Mostly Available	425(49.2)		451(52.2)		400(46.3)		490(57.0)		528(61.4)	
Overall GI Index										
Poorly Available	158(55.8)	<0.001	130(45.9)	0.02	142(50.2)	0.45	172(61.2)	0.23	161(57.3)	0.02
Moderately Available	323(49.5)		364(55.8)		312(47.9)		365(56.2)		372(57.3)	
Mostly Available	417(47.5)		462(52.7)		414(47.2)		485(55.6)		558(63.9)	

Note: *percentages were calculated based on the row total of the 3 categories of each facet of the Environmental Sustainability Challenges*
GI- *Green Infrastructure*

The results of the logistic regression further show that the odds of reporting high mitigation of water quality challenges was higher in areas where tree feature GI are mostly available (OR: 1.42; 95%CI: 1.12-1.81) than where they are poorly available. Similarly, the odds of reporting high mitigation of challenges relating to passenger transport mode (transportation systems in the cities) was higher in neighbourhoods where other spaces GI are mostly available (OR: 1.41; 95%CI: 1.06-1.89) than where they are moderately available (Table 5).

Table 5: Association of Green Infrastructure with Mitigation of Environmental Sustainability Challenge

	Odds of APL (95% CI)	Odds of CDW (95% CI)	Odds of WQT (95% CI)	Odds of PTM (95% CI)	Odds of ODA (95% CI)
Green Space GI					
Poorly Available					-
Moderately Available					0.92(0.58-1.45)
Mostly Available					0.96(0.59-1.55)
Tree Feature GI					
Poorly Available			-		
Mostly Available			1.42(1.12-1.81)		
Other Spaces					
Moderately Available				-	
Mostly Available				1.41(1.06-1.89)	
Overall GI					
Poorly Available	-	-			-
Moderately Available	0.44(0.29 -0.68)	1.08(0.75-1.54)			1.34(0.91-1.99)
Mostly Available	0.63(0.41- 0.97)	1.29(0.91-1.82)			1.42(0.94-2.16)

GI-*Green Infrastructure,* ***APL-****Air Pollution,* ***CDW-*** *Collection and Disposal of waste,* ***WQT-****Water Quality,* ***PTM-*** *Passenger Transport Mode,* ***ODA-****Official Development Assistance*

4. Discussions

In this study, we report comparative results for the mitigating effects of GI on selected environmental sustainability variables. We as well measured the extent of self-reported improvement on health of urban residents in Lagos Metropolis, in relation to the availability and access to green infrastructure. This study was premised on the literature (Takano et al., 2002; Tzoulas *et al.,* 2007; Pakzada & Osmonda, 2016; Ward Thompson *et al.,* 2016; Jennings *et al.,* 2017) addressing links between access to GI facilities and health, particularly levels of reported good health in areas with green spaces and poor health induced by environmental sustainability challenges in urban centres. We explored potential mitigating effects of GI on selected environmental sustainability issues as well as the extent to which availability of GI can enhance self-reported (perceived) health of urban residents in Lagos Nigeria.

First, we attempted to discover the socio-demographical factors associated with perceived health benefits of GI facilities so as to isolate the independent capacity of GI to impact health in the study area. A number of socio-demographic characteristics of the study participants were found to impact perceived health. For instance, health benefit of GI was reported mostly among younger participants and individuals who have completed tertiary education. In particular, more of participants aged 30-49 years reported health benefit of GI than any other age group. Actually, the links between socio-economic and demographic status and health are well ascertained (e.g. Dunn & Hayes, 2000; Ross, 2000; Tzoulas *et al.,* 2007). The 30-39 years age group consists of energetic and productive individuals compared to ages below or above the range. Consequently, participants within this age group have higher opportunity and possibly better emotional and social orientations to enjoy access to green infrastructure facilities in their neighbourhood compared to other individuals (Conedera, 2015). When controlled for age, sex, marital and socio-economic status, among older adults, past studies have provided evidence of a positive association between self-reported health (including longevity) and green space (de Vries *et al.,* 2003; Takano *et al., 2002*).

Although we also observed that married participants and those who were formerly married reported health benefit of GI than those who had never being married, we are unable to provide any immediate explanation for this. However, this result seems to suggest that people are more likely to benefit from their recreation/outdoor activities and access to GI facilities when they engage in such activities with other people than doing so alone. This finding is not alien to the literature as previous studies have reported evidences of the positive effect gained by nearby green spaces since this provides a place of contact between people and nature, increases the potential of meeting neighbours, and enables social well-being and social cohesion (Kuo, Bacaicoa & Sullivan 1998; Wolch *et al.,* 2014).

Furthermore, we found that availability of street trees, green garden and parks, private garden or allotment, fountain, streams and other GI facilities even when available moderately, have provided improved health to residents in the study area. The link between green spaces and health has been demonstrated in a number of studies. For instance, Payne et al. (1998) found that park users reported better general perceived health, higher levels of activity and improved ability to relax than non-users. Also, it has been shown in previous studies that those who visit green spaces at least once a month in winter reported significantly better health than those who refused to visit green spaces (Ward Thompson *et al.,* 2016). In fact, research has also been focussed on the effect of nearby trees and grass visible from apartment buildings on residents' effectiveness in facing major life problems including intra-family aggression by enhancing mental health (Kuo & Sullivan, 2001; Tzoulas et al., 2007). However, it must be acknowledged that, even though these and other related studies were controlled for possible confounders, it is impossible to completely exclude the possibility of confounding factors; especially in relation to lifestyle that may inform health in neighbourhoods/communities near parks.

The impact of green infrastructure on environmental sustainability in the present setting is unclear. Participants in the present study reported high mitigation of environmental sustainability challenges (including collection and disposal of waste, poor water quality, passenger transport mode and official development assistance) in neighbourhoods where green infrastructure are moderately or mostly available. Previous studies in this area/direction confirmed that green infrastructure helps to maintain a healthy urban environment by using trees and other vegetations to screen and providing clean air, improving the urban climate and preserving the delicate balance of nature (Tzoulas *et al.,* 2007; Nowak, Crane & Stevens, 2006). It is therefore not surprising to found in the present study, that participants from areas where tree feature GI are mostly available where 42% more likely to report high mitigation of water quality challenges than where they are poorly available. There are many evidences in the literature supporting our findings. Tavakol-Davani et al. (2015) reported that GI facilities can reduce the amount of storm water entering urban drainage systems and thus improve water quality at urban centres. Many other studies have also evaluated the roles of various types of GI on storm water management, carbon sinks and emission controls (Liu, Chen & Peng, 2014; Liu *et al.*, 2015). The roots of some trees have also been reported to serve as filters for underground water and thus improving the quality of drinking water. (Dong, Guo & Zeng, 2017). Also, participants from areas where other spaces GI (such as non green open spaces, non green Parks, school yards etc) are mostly available were 41% more likely to report high mitigation of challenges relating to passenger transport mode (transportation systems in the cities) than where they are moderately available. Similarly, recent studies have advocated for more street trees to create tree corridors where pedestrian can treck or cycle to various destination in the city (Singh, 2016; Thaiutsa *et al.*, 2008). This measure has been suggested as a mitigation strategy against environmental challenges related to passenger transport mode or the transportation systems within the cities. The approach is seen as a sustainable transport mode that can eventually encourage sustainability in the cities.

5. Strengths and limitations

The present study is a strong and comprehensive contribution to literature on the impact of GI availability on health and environmental sustainability challenges from this study setting. The epidemiological nature of the study provides a great opportunity for targeted policy and intervention strategies. The major limitation of this study may be the self-administered nature of the questionnaires which might have introduced some biases. Also, the GHQ-12 version of the General Health Questionnaire adopted for this study may equally provide a limitation to the robustness of our findings as we considered no criteria in our selection of the GHQ-12 among several other versions (GHQ-60, GHQ-30, GHQ-28, GHQ-20) of the scale. There were no local studies with which to immediately compare our findings, this may confer some contextual limitations on the conclusion of the present study.

6. Conclusion

Green infrastructure plays an integral role in supporting health in the urban communities studied, through the provision of environmental, social and economic benefits. There are also evidences that green infrastructure mitigates environmental sustainability challenges in the urban communities studied. In particular, green infrastructure improves the liveability of the built environment through maintenance of ecosystems, storm water reduction, improved air, water and habitat quality and enhances landscape connectivity for urban flora and fauna.

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Conflict of Interest

The authors have no conflict of interest to report for this research.

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Supplementary Tables

Table S1: Health Benefits of Green Infrastructure

Item	Less than usual (%)	No more than usual (%)	Rather more than usual (%)	Much more than usual (%)
Been able to concentrate on what you're doing?	238(12.9)	339(18.3)	671(36.3)	602(32.5)
Lost much sleep over worry?	922(49.8)	480(25.9)	306(16.5)	142(7.6)
Felt that you are playing a useful part in things?	160(8.6)	354(19.1)	791(42.8)	545(29.5)
Felt capable of making decisions about things?	141(7.6)	273(14.8)	779(42.1)	655(35.5)
Felt constantly under strain?	791(42.8)	545(29.5)	327(17.7)	187(10.1)
Felt you couldn't overcome your difficulties?	717(38.8)	581(31.4)	310(16.8)	242(13.1)
Been able to enjoy your normal day to day activities?	214(11.6)	256(13.8)	821(44.4)	559(30.1)
Been able to face up to your problems?	188(10.2)	305(16.5)	764(41.3)	593(32.0)
Been feeling unhappy or depressed?	770(41.6)	598(32.3)	292(15.8)	190(10.3)
Been losing confidence in yourself?	790(42.7)	669(36.2)	229(12.4)	162(8.7)
Been thinking of yourself as a worthless person?	788(42.6)	624(33.7)	285(15.4)	153(8.3)
Been feeling reasonably happy, all things considered?	160(8.6)	242(13.1)	736(39.8)	713(38.4)

Table S2: General Environmental Sustainability

STATEMENT	Strongly disagree (%)	Disagree (%)	Undecided (%)	Agree (%)	Strongly agree (%)
Air pollution (APL)					
Residents' health is threatened by air pollution in this neighbourhood	417(22.5)	581(31.3)	314(16.9)	319(17.2)	223(12.0)
The air in this neighbourhood is clean i.e free from automobiles, industry or farming pesticides and chemicals pollution.	570(30.7)	377(20.3)	381(20.5)	396(21.3)	130(7.0)
The heavy traffic in this neighbourhood is very annoying	292(15.7)	733(39.5)	360(19.4)	288(15.5)	182(9.8)
Air pollution caused by cars is very heavy in this neighbourhood	333(18.0)	739(39.8)	336(18.1)	269(14.5)	178(9.6)
Air pollution caused by industry is very noticeable in this neighbourhood	191(10.3)	557(30.1)	430(23.2)	401(21.7)	271(14.6)
Air pollution caused by pesticides and chemicals used in farming is very noticeable in this neighbourhood	123(6.6)	285(15.4)	476(25.6)	494(26.6)	478(25.8)
Collection and disposal of waste (CDW)					
Residents in this neighbourhood avoid dirtying the environment	159(8.6)	289(15.6)	265(14.3)	773(41.6)	370(19.9)
In this neighbourhood, residents find personal solution to their waste management	136(7.3)	226(12.2)	326(17.6)	824(44.4)	344(18.5)
We have proper provision for waste disposal and management in this neighbourhood	125(6.7)	217(11.7)	287(15.5)	848(45.7)	379(20.4)
Residents make good use of the neighbourhood waste collection effort effectively	138(7.4)	205(11.0)	289(15.6)	834(44.9)	390(21.0)
Water quality (WQT)					
Residents have access to clean drinkable water in this neighbourhood	136(7.3)	245(13.2)	411(22.1)	638(34.4)	426(23.0)
Available water in this neighbourhood is not clean enough for drinking	137(7.4)	327(17.6)	618(33.3)	404(21.8)	370(19.9)

Many residents have to make personal bore holes to get clean drinkable water in this neighbourhood	350(18.9)	648(34.9)	422(22.7)	261(14.1)	175(9.4)
The underground water in this neighbourhood is contaminated	151(8.1)	264(14.2)	649(35.0)	368(19.8)	424(22.8)
Passenger transport mode (PTM)					
The quality of public transportation is poor in this neighbourhood	162(8.8)	285(15.4)	289(15.7)	526(28.5)	584(31.6)
In this neighbourhood, there are specific and adequate provisions for cycling routes.	663(35.9)	539(29.2)	341(18.5)	221(12.0)	82(4.4)
There are enough tree corridors under which people can treck on sunny days	706(38.2)	469(25.4)	352(19.1)	223(12.1)	96(5.2)
If you like cycling, this neighbourhood is not suitable	720(39.0)	693(37.5)	217(11.8)	128(6.9)	88(4.8)
Many residents in this neighbourhood support the use of public transport (such as public bus) instead of constantly driving their private cars	92(5.0)	124(6.7)	259(14.0)	689(37.3)	682(36.9)
Official development assistance (Government support) (ODA)					
Government support for green infrastructure facilities is noticeable in this neighbourhood	464(25.1)	611(33.1)	472(25.6)	200(10.8)	99(5.4)
The Local Government in this area should strive to increase greenery in all neighbourhoods	41(2.2)	115(6.2)	223(12.1)	898(48.6)	569(30.8)
Government to ensure sustainability as the future of all environmental projects	38(2.1)	81(4.4)	162(8.8)	806(43.7)	759(41.1)
Government should regularly orient citizens about benefits of green infrastructure	42(2.3)	57(3.1)	133(7.2)	703(38.1)	911(49.3)

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