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LETTER

‘At-risk’ places: inequities in the distribution of environmental stressors and prescription rates of mental health medications in Glasgow, Scotland

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Abstract

Using geospatial analytical methods, this study examines the association between one aspect of the built environment, namely, the concentration of vacant and derelict land (VDL), and the prevalence of mental health disorders (using the proxy variable of mental health medication prescription rates) in Glasgow, Scotland. This study builds on our previous research, which demonstrated the spatial correspondence between the locations of VDL in Glasgow and several physical health outcomes. Numerous studies of other locales have found similar correspondence between different elements of the built environment and various health outcomes. This is the first study of its kind to look at the spatial concentration of vacant and derelict land in relation to mental health, socio-economic indicators, environmental justice, and health inequities. The findings of this study demonstrate an inequity with respect to the distribution of vacant and derelict land, as confirmed by Pearson correlations between VDL density and deprivation ($r = .521, p < .001$). This suggests that many deprived communities are disproportionately burdened with environmental impacts and psychosocial stressors associated with this land use. Regression analyses show a significant positive association between the proportion of the population who were prescribed medication for anxiety, depression, or psychosis and the density of vacant and derelict land while adjusting for socio-demographic characteristics. This indicates that areas with higher VDL densities tend to exhibit higher rates of mental health issues. Based on these findings, strategies for constructive re-use of VDL are proposed.

Background

‘Characteristics of places may be as important as the characteristics of people for an understanding of particular patterns of health’, (Phillimore, 1993:176).

The built environment and mental health

This study examines the potential association between one aspect of the built environment, namely, the concentration of vacant and derelict land (VDL), and the prevalence of mental health disorders (using the

proxy variable of mental health drug prescription rates), in Glasgow, Scotland. Previously, Maantay (2013) constructed an index called PARDLI (Priority Areas for Re-use of Derelict Land Index). This previous research had demonstrated the spatial correspondence between the locations of VDL in Glasgow and several health outcomes (i.e., Male Life Expectancy, Respiratory Hospitalizations, Cancer Hospitalizations, and Low Birth Weight Infants); likewise, numerous studies of other locales have found similar correspondence between different aspects of the built environment and health outcomes (see review article

on this topic by Brender *et al* 2011). While there have been previous studies of the relationship between the built environment and mental health outcomes, the research reported in this paper makes a significant and unique contribution by spatially analyzing the specific correspondence between VDL (as one aspect of the built environment), and mental health medication prescription rates.

The built environment has strong direct and indirect impacts on health (Jackson 2003, Deary 2004), and the link between environmental stressors and physical and mental health has been well established (Diez-Roux 2001, Downey and Van Willigan 2005, Galea *et al* 2005, Guite *et al* 2006, Maantay 2007, Croucher *et al* 2007, Mair *et al* 2008, Ellaway *et al* 2009, Sarker *et al* 2013). Additionally, there are environmental justice implications regarding the relationship between the built environment and health: 'Because exposure to poor environmental conditions is not randomly distributed and tends to concentrate among the poor and ethnic minorities, we also need to focus more attention on the health implications of multiple environmental risk exposure', (Evans 2003:536).

The overall health of Glaswegians, in general, is worse than that of the populations of Scotland (MacIntyre 2007) and the United Kingdom (UK) as a whole by almost every measure (Shaw *et al* 2008). Population health in Glasgow is also demonstrably worse than other similar formerly-industrialized cities in the developed world (Gray 2008). Male Life Expectancy in Glasgow is lower than in Scotland and the rest of the UK, overall mortality rates are much higher, and health is not improving as quickly (Hanlon *et al* 2005, Mitchell *et al* 2005, Taulbut *et al* 2009, Walsh *et al* 2010). Scotland as a whole suffers from inequities in health, based on degree of deprivation, as compared to other parts of the UK and Europe (MacIntyre 2007), but even within Scotland, Glasgow stands out as having worse health overall and sharper inequities.

Over the years, there has been considerable debate in the public health and epidemiological communities over which factors account for more of the health outcome burden: individual ('compositional') factors, or community, place-based ('contextual') ones (Gatrell and Elliott 2009). The majority of research on mental health has focused on individual and family determinants of mental well-being. Only relatively recently have researchers started to investigate the impacts of area-level determinants on mental health outcomes (O'Campo *et al* 2009). In general, it is now widely recognized that 'health outcomes cannot be simply reduced to individual characteristics', (Jones and Duncan 1995:38), and although one can not discount the effects of individual-level characteristics—such as age, gender, smoking and eating behavior, exercise, income, social class, and so forth—the contextual factors seem to have higher-level effects. Moreover, when considering mental health in particular, chronic stressors, such as neighborhood disorder, appear to have a

markedly greater influence. According to Avison and Turner, 'chronic strains have a greater long-term impact on psychological well-being than do life events', (1988:262), and Mair *et al* conclude that 'Measures of the built environment appeared to be more consistently associated with depression than socio-economic deprivation, residential stability, or race', (2008:952). This lends credence to the concept that 'place' matters as much, if not more, than individual characteristics and behavior in the prevalence of mental disorders.

There is a significant body of evidence showing that physical disorder and psycho-social and environmental stressors in the neighborhood are associated with various mental health issues, especially depression, anxiety, and substance abuse. Even as far back as 1939, a study done in Chicago found that rates of schizophrenia and substance abuse were highest among those living in disordered neighborhoods (Faris and Dunham 1939).

This appears to be the case throughout much of the world, according to the results of studies conducted on the relationship between various aspects of the built environment and mental health amongst populations in Santiago, Chile (Araya *et al* 2007); King County, Washington state, US (Berke *et al* 2007); Perth, Australia (Francis *et al* 2012); New York City, US (Galea *et al* 2005); Greenwich, England (Guite *et al* 2006); Glasgow, Scotland (McKenzie *et al* 2013); Miami, Florida, US (Miles *et al* 2012); Jamaica, West Indies (Mullings *et al* 2013); Toronto, Canada (O'Campo *et al* 2009); Nakuru, Kenya (Ochodo *et al* 2014); Maastricht, Netherlands (Putrik *et al* 2015); Caerphilly, Wales (Sarker *et al* 2013); Chicago, Illinois, US (Silver *et al* 2002); and Pittsburgh, Pennsylvania, US (Teixiera and Wallace 2013). The neighborhood variables examined in each of these studies differ, and include density of dwelling units, quality of building materials, walkability, presence of street lights, evidence of petty crime (incivilities such as graffiti, litter, vandalism), proximity to railway or road traffic noise, access to green space, and neighborhood levels of deprivation and other socio-demographic indicators.

A number of the studies mentioned above focused on depression as the mental health outcome associated with the built environment variable. Depression is the third leading cause of the Global Burden of Disease (GBD) worldwide, and the leading cause of disease burden in both middle and higher income countries (World Health Organization, 2004, Miles *et al* 2012), and thus represents an extremely costly health issue, a tremendous loss of productivity, and a wasteful tragedy, on both the societal and the individual levels. Glasgow's population has a rate of mental disorders which is double that of the rest of Scotland (Landy *et al* 2010:14, Shipton and Whyte 2011). Even within the city of Glasgow, there is a wide variation in mental health medication prescription rates. Do the at-risk places in Glasgow share any neighborhood

characteristics, such as a concentration of vacant and derelict land?

In a review of 45 different cross-sectional and longitudinal research studies investigating the relationship between neighborhood characteristics and mental health outcomes, Mair *et al* conclude that ‘features of neighbourhoods such as lack of resources, disorder, violence, inadequate housing, and lack of green spaces may function as stressors’, (2008:940). Thirty-seven of the 45 studies that were examined ‘found support for an association between neighbourhood characteristics and depression or depressive symptoms after controlling for a variety of individual-level characteristics, usually a combination of race/ethnicity, age, gender, marital status, education and income’, (Mair *et al* 2008:951).

The studies cited in the Mair *et al* review article that looked at the association between the built environment (specifically, the interior and external built environment, the quality of housing areas, the walking environment, and a negative neighborhood environment, identified by factors such as violence, abandoned buildings, and homeless people on the streets) and depressive symptoms found an association with depressive symptoms (Weich *et al* 2002, Galea *et al* 2005, Berke *et al* 2007).

In a nationwide (US) study of the mental health impacts of living near noxious facilities, Downey and Van Willigan (2005) found that there is a high psychological cost borne by those living near land uses that are perceived to be noxious. They argue that although residential proximity to such noxious land uses might be physiologically and psychologically detrimental because of exposure to environmental pollutants, the more serious psychological harm is due to the noxious land uses being seen as a sign of neighborhood disorder and the stigma attached to living in such a place, which is inherently stressful.

Demonstrating the relationship between the built environment and mental health in a spatial context will allow us to establish some means of identifying the most critical areas and populations, and focus planning attention and resources there. Good environments promote good health and permit coping mechanisms to offset daily pressures and stress. ‘The potential for built environments to promote health outcomes is linked to their effectiveness in facilitating stress coping and restoration. Good designs of the built environment can reduce anxiety, lower blood pressure, and reduce pain. Psychologically unsupportive surroundings are linked to negative effects such as higher occurrence of delirium, depression, and greater need for pain medication’, (Ochodo *et al* 2014:908).

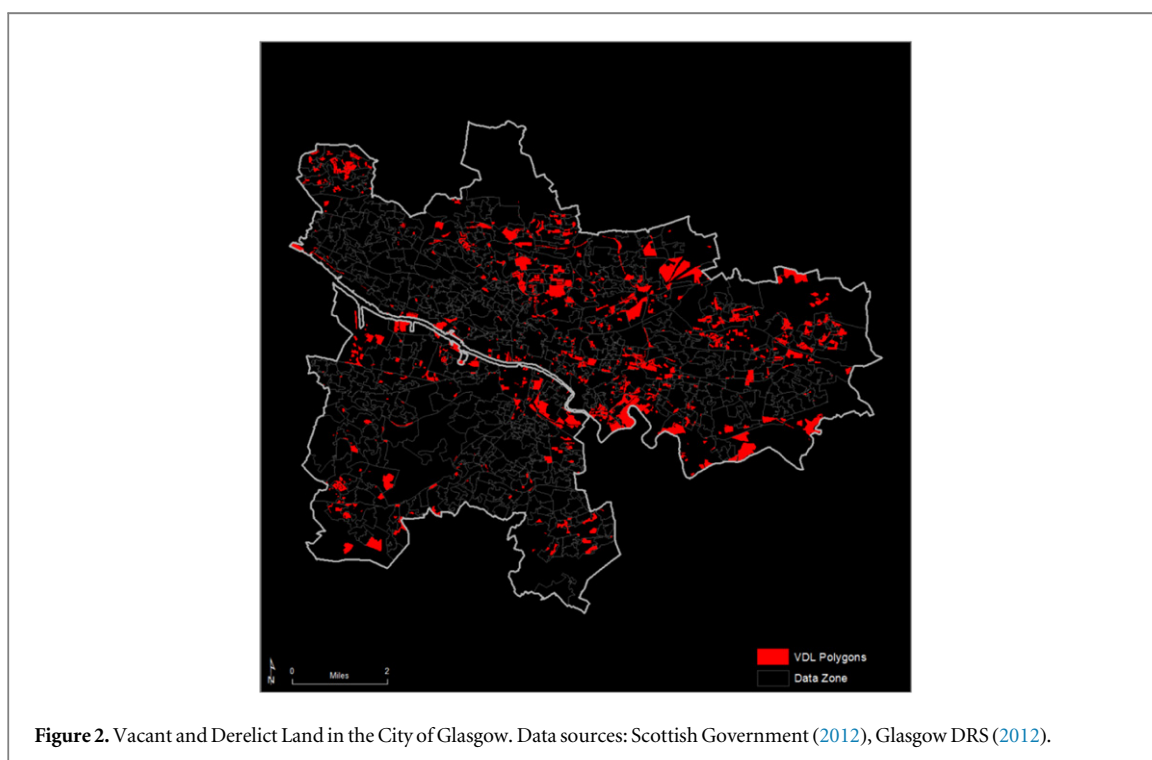
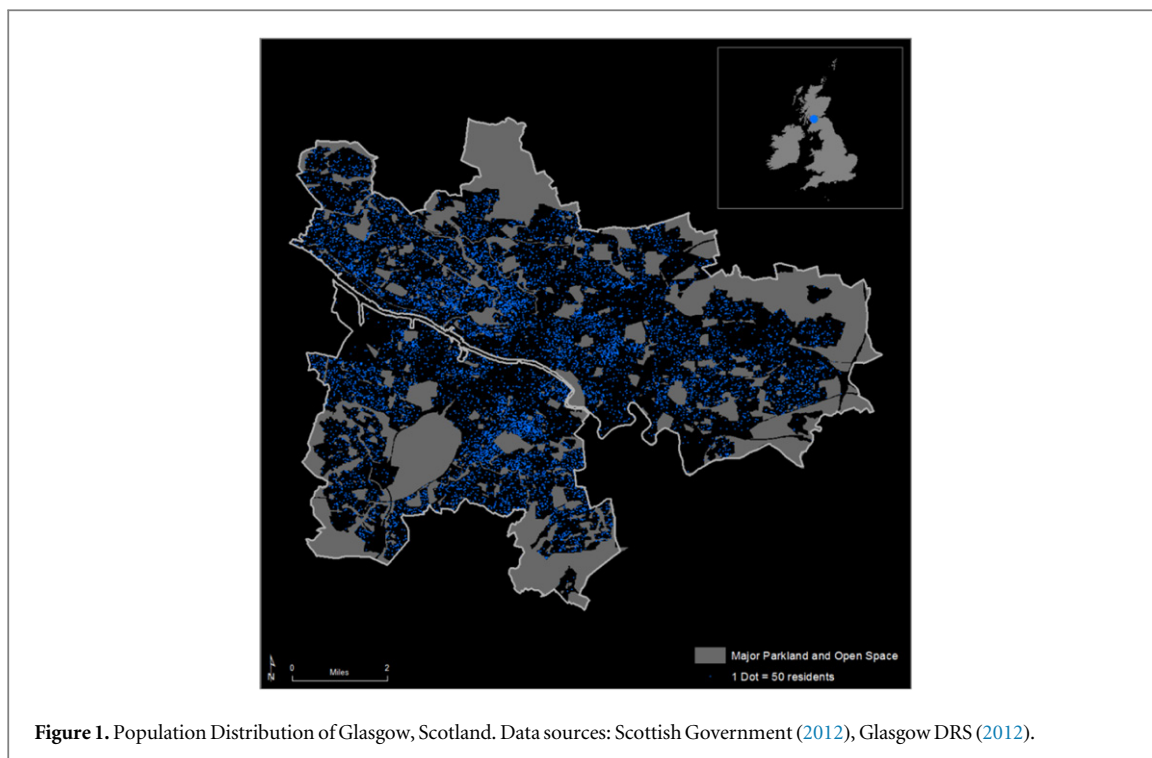
The Glasgow-based research presented in this paper—looking at VDL and mental health prescription drug rates—will advance this body of knowledge by looking specifically at the potential association of VDL with mental health outcomes, using geospatial analytical methods to estimate the effect of

neighborhoods considered to be ‘blighted’. This will also give us the opportunity to deconstruct the previously-developed index (Priority Areas for Re-use of Derelict Land Index, or PARDLI) for prioritizing areas having concentrations of vacant and derelict land in Glasgow neighborhoods (discussed further below, and in Maantay 2013), to see the association amongst some of its components, and to propose ways of developing strategies for constructive change. This is the first study of its kind to look at the spatial concentration of vacant and derelict land in relation to mental health, socio-economic indicators, and health inequities.

Glasgow landscape

Glasgow is situated along the River Clyde in the West Central Lowlands of Scotland, and it is Scotland’s most populous and densely-settled city, with about 600 000 people within 68 square miles. (See figure 1). From the 18th century until about 50 years ago, Glasgow was one of the main industrial cities in the United Kingdom, with textile production, ship building, steel making, dye works, and the manufacture of many other commodities used throughout the world. Most Glaswegians of working age were employed in these various industries, but now, in Glasgow’s more recent post-industrial incarnation, unemployment is very high. Although the economic outlook of the city has been steadily improving in the past decade, aspects of the city’s landscape still exhibit the residual effects of the economic decline, most notably the extent of vacant and derelict land interspersed throughout many neighborhoods, and even dominating certain parts of the city, particularly in the less affluent sections. Glasgow has more VDL, in both absolute amounts and as a percentage of its total land, than any other municipality in Scotland (Scottish Government 2012). Overall, about 4% of Glasgow’s land is vacant or derelict (figure 2).

Much of this VDL is formerly industrial land (nearly 50 percent, by some estimations—see table 1), and since industry in Glasgow was predominantly of the ‘dirty’ variety, which produced considerable contamination, these lands are potentially hazardous, even many years later. In some cases, formerly industrial land was converted to housing during the inter-war and post-WWII periods. Some of this housing has since been demolished and the land again lies fallow, joining the list of the VDL on the Scottish Government’s survey of vacant and derelict land. Therefore, regardless of the fact that housing was the most recent use of some of this land, the land still may have a high potential for containing toxic substances as an artifact, left over from its industrial days. Now in the soil, the contaminants can become airborne, and enter the human body by breathing, or through direct ingestion or dermal contact (Greenberg *et al* 1998). This is particularly likely in the case of children and youth who may use the VDL as informal playgrounds and for sports.



The visual quality of the VDL varies: from lots overgrown with weeds, to lots filled with illegal dumping, to just empty, featureless space. Some of the VDL has dis-used structures still present. Thus, the seriousness of the blight of the VDL upon each neighborhood is not consistent. Many of the larger parcels of VDL do tend to lend an air of disturbing abandonment to the surrounding communities, with the concomitant emotional and perceptual impacts, and also the possible threat of criminal activities taking place therein.

The presence of vacant land in a community also signals to the residents and visitors alike that this is a disreputable and deteriorating neighborhood. It may be seen as a place that the outside world has forgotten and doesn't care about. There may be social stigma attached to living near VDL or in a neighborhood with high concentrations of VDL (Litt and Burke 2002, Litt *et al* 2002, Garvin *et al* 2012, Bambra *et al* 2014). This may also be accompanied by direct economic impacts and financial strains, feelings of lack of control over

Table 1. Characteristics of vacant and derelict land in Glasgow, Scotland. Data source: Scottish Government (2012).

Category	Number of Sites (count)	Area (hectares)	Number of Sites (%)	Area (%)
Residential	264	247.6	28.5	19.0
Unknown	174	166.1	18.8	12.7
Other ^a	100	153.4	10.8	11.8
Manufacturing	71	152.9	7.7	11.7
Agricultural	19	126.5	2.0	9.7
Education	91	124.7	9.8	9.6
Transport	69	109.7	7.4	8.4
Recreation & Leisure	35	81.0	3.8	6.2
General Industry (excl. manufacturing)	57	74.4	6.1	5.7
Community & Health	47	67.0	5.1	5.1
TOTALS	927	1303.2	100	100

^a Other category includes: mineral activity, storage (gas, oil, other), passive open space, wholesale distribution, retailing, utility services, forestry/woodland, offices, business class, and other.

their surroundings and lives, and fears about crime and safety (Lorenc *et al* 2012). Perceptions of one's neighborhood being considered as a dumping ground, or one filled with desolate and dangerous places, promotes a wide-spread sense of defeat and despair in the community.

Previous research (Maantay 2013) on the possible correlation and spatial correspondence between VDL and adverse health outcomes in Glasgow resulted in the creation of the PARDLI index, which was intended to measure conditions in each data zone (an area containing on average about 750 people, and thus roughly equivalent to a US census block group) within the city, and rank the areas in terms of need, vulnerability, and exposure. This was assessed by determining which neighborhoods had data zones with a combination of: (1) the highest exposure to VDL (as estimated by a threshold distance of 100 meters from a VDL parcel); (2) the highest levels of socio-economic deprivation (as measured by the Scottish Index of Multiple Deprivation—SIMD); and (3) the highest rates of adverse health outcomes (using Male Life Expectancy, rates of Low Birth Weight Infants, and rates of Respiratory and Cancer Hospitalizations as health indicators). The purpose of the PARDLI is to inform policy- and decision-makers in an objective and rational manner which areas of the city would be well-served by focusing planning attention and resources on them. The PARDLI scores combine three aspects of vulnerability: overall high deprivation (social vulnerability/need), adverse health conditions (health vulnerability/need), and proximity to an environmental burden/stressor (exposure to VDL).

Some urban planning theories and practices tacitly approve of considering highly vulnerable and needy neighborhoods to be, in effect, 'sacrifice zones'—places that are already ruined and unlikely to be revitalized. These sacrifice zones or throw-away communities are seen as being the appropriate places in which to pile on any other necessary noxious land uses, since they are viewed as being beyond redemption in any event (Lerner 2010). In this way of thinking, the assumption is

that any available resources should instead be pumped into neighborhoods more likely to be improvable and salvageable, rather than throwing good money after bad. Contrary to this viewpoint, the PARDLI scores set out to help determine which neighborhoods are most vulnerable and in need, and to target investment to them, rather than considering these areas to be sacrifice zones.

Methods and results

Overview of methods

An ecological approach was employed in order to examine the environmental justice implications of vacant and derelict land (VDL) and deprivation, as well as to test the association between VDL and mental health (MH) in the City of Glasgow, Scotland (figure 3). Presence of potential environmental injustice was determined by a bivariate analysis of VDL and the SIMD; whereas the relationship between VDL and MH was illustrated using regression models: a global ordinary least squares (OLS), spatial autoregressive (SAR), as well as a local geographically weighted regression (GWR). GWR, parameterized identically to the global models, was used to identify case study areas which could benefit from a deeper qualitative assessment. GWR was used not just as an exploratory tool, but to point out local weaknesses in our OLS model and to try to better understand the relationships amongst the variables.

Spatial data preparation, harmonization, and analytical methods—such as Geographically Weighted Regression and Kernel Density Estimation (KDE)—were done within ArcGIS 10 (ESRI, Redlands, CA). The SAR model was run in GeoDa (GeoDa Center for Geospatial Analysis and Computation, v.1.6). Non-spatial analyses were accomplished using SPSS (IBM), and include multiple ordinary least squares regression and descriptive statistics. Additionally, a qualitative analysis was conducted on two pilot areas to assist in explaining the regression results.

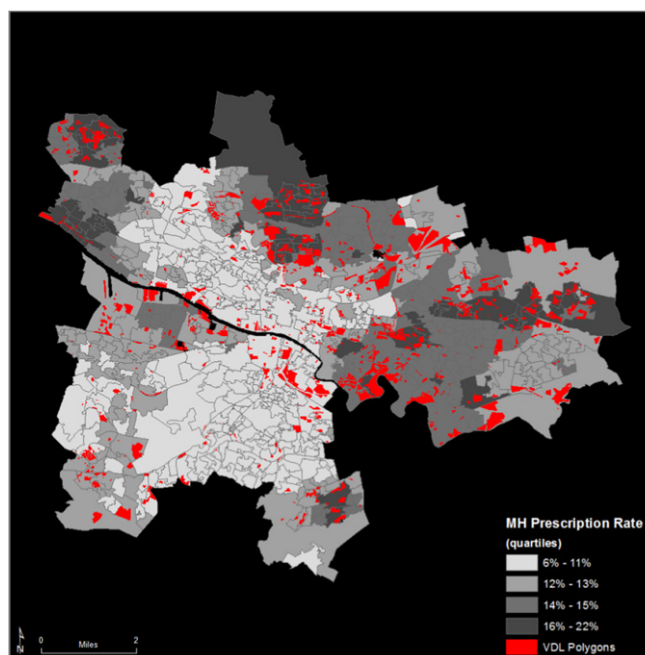


Figure 3. Mental health drug prescription rates by DZ and VDL polygons. Data sources: Scotland Census; Scottish Government (2012), Glasgow DRS (2012).

The City of Glasgow is the geographic extent of the study, and all the variables used in the analyses (socio-demographic, health, and VDL) cover only this extent. The geographic unit used for statistical analysis was the data zone (DZ), a small-area geography used by the Scottish Government to disseminate statistics. There are 694 DZs in the City of Glasgow; 690 DZs were used in these analyses, whilst 4 were omitted due to low population numbers. A DZ contains between 500 and 1000 residents and attempts to maintain somewhat homogeneous social characteristics (Scottish Government 2015). These units are similar to, but contain slightly less population than Census Block Groups in the United States, which generally represent between 600 and 3000 residents (US Census 2015).

Data

The data selected for use in this study were motivated by the previously discussed PARDLI research (Maantay 2013). The current work described in this paper further elucidates the sometimes complex associations among these variables. The VDL attribute data, from the Scottish Government's inventory (2012), contain information regarding when the land initially became vacant or derelict, as well as other characteristics such as previous land use (table 1). Spatial VDL data were acquired from the Glasgow City Council's Development and Regeneration Services (DRS) and are geographically represented as polygons ($n = 927$).

According to the Scottish Vacant and Derelict Land Survey (2012), derelict land is defined as 'land which has been so damaged by development that it is incapable of development for beneficial use without

rehabilitation. Land also qualifies as derelict if it has an un-remedied previous use which could constrain future development. Vacant land is land which is unused for the purposes for which it is held and is viewed as an appropriate site for development. This land must either have had prior development on it or preparatory work has taken place in anticipation of future development....Urban sites must be at least 0.1 hectares in size to be included [in the survey]', (Scottish Government 2012:6).

In the present study, VDL was examined based on the length of time the land was classified as vacant or derelict. This information was binned into various 'time slices' (pre-1981, 1981–1985, 1986–1990, 1991–1995, 1996–2000, 2001–2005, and 2006–2010) (figure 4). The earlier the year, the longer the amount of time which the land was classified as vacant or derelict. The VDL was explored as individual time periods as well as cumulatively (e.g., pre-1981, pre-1986, etc). However, in the statistical models, only the most inclusive data were used (VDL density up to and including 2010) due to stronger relationships with the outcome variables of interest. It should be noted that only land classified as VDL as of 2011 (when the inventory was conducted) are included in this data, and as such, any VDLs which were re-developed previous to this date were not included in the Scottish Government inventory and therefore are not represented in this analysis.

The VDL polygons were converted into points by overlaying a fishnet grid with 10 meter spacing over the entire study area. The points that intersected VDL were given the attributes of the specific property lot

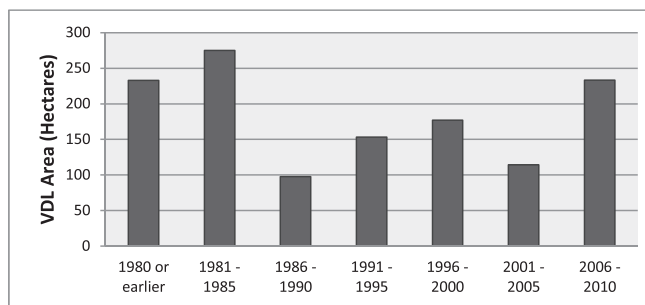


Figure 4. VDL area in hectares per time period. Data shown is not cumulative, and represents VDLs as of 2011 that were initially classified during each time period. Data source: Scottish Government (2012).

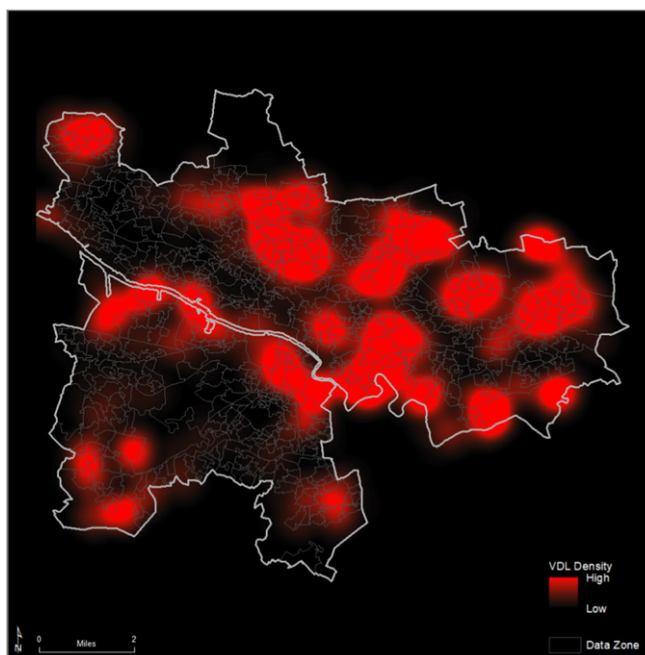


Figure 5. VDL density surface using KDE. Data sources: Scotland Census; Scottish Government (2012), Glasgow DRS (2012).

($n = 130, 115$). Point data was then converted to a continuous statistical surface by using kernel density estimation (KDE) using a search radius of 1 km (figure 5). This surface represents the density of VDL and serves as a proxy for exposure, as per the method detailed in Maroko *et al* (2009).

The KDE surface data were then aggregated to the Glasgow DZs using zonal statistics for analysis ($n = 694$). The result is a dataset which contains all the population-based data (described in table 2) as well as the mean VDL density per DZ, enabling statistical examinations of the associations between VDL exposure (as quantified by VDL density), socio-demographic indicators, and mental health in Glasgow.

Our measure for mental health status was the proportion of the population per data zone which was prescribed medication for anxiety, depression, or psychosis (2010). Although this is not a direct measurement of mental health status, it is believed to be a reliable proxy (McKenzie *et al* 2013), particularly given

the ostensible universal access to health care in Scotland. It should be noted that these data, presented as simple proportions, have somewhat limited precision (two decimal places) and as such may conceal some variation between DZs.

A number of socio-economic and demographic variables from the Scottish Government were explored for inclusion in the model to examine the relationship between VDL and mental health prescription rates. However, to reduce co-linearity, only those listed in table 2 data sources were used in the final models (e.g., measures of income were too strongly associated with the educational attainment variable to be reliable). The condition index for that model was 8.988, suggesting that co-linearity is unlikely to be an issue.

The National Origin variable is included in the model to adjust for possible influences such as cultural differences in the utilization of health care (Bansal *et al* 2014), as well as the ‘healthy immigrant effect’

Table 2. Data descriptions and sources.

Dataset	Date of data	Description	Source
Vacant and Derelict Land (VDL)	Pre-1986 to 2010	Polygons representing vacant and derelict land in Glasgow up to 2010, as of 2011.	Glasgow City Council's Development and Regeneration Services (DRS) 2012
Ordnance Survey Maps	1955, 1965, 1975, 1985, and 2010	Georeferenced Ordnance Survey maps	UK Ordnance Survey, 1955–2010
Glasgow Data Zones	2011	Polygons representing data zones in Glasgow ($n = 694$)	Scottish Neighbourhood Statistics 2011 (http://www.sns.gov.uk/)
SIMD	2012	The Scottish Index of Multiple Deprivation is built from multiple domains (income, employment, health, education, housing, access, and crime) where each DZ is scored (continuous) and ranked (ordinal).	Scotland Census, SIMD 2012 (http://www.gov.scot/Topics/Statistics/SIMD)
Mental Health (MH) Prescription Rate	2010	Proportion of the population per DZ who were prescribed medication for anxiety, depression, or psychosis.	Scotland Census, SIMD 2012 Health Domain (http://www.gov.scot/Topics/Statistics/SIMD)
Geographic Accessibility	2012	Financial cost, time, and inconvenience of having to travel to access basic services (such as medical offices, post office, shopping centers, schools, gas stations), compiled in a metric based on indicators including population-weighted average time taken to reach key services by driving and public transport.	Scotland Census, SIMD 2012 Access Domain (http://www.gov.scot/Topics/Statistics/SIMD)
National Origin	2011	Based on the 'country of birth' data, representing the percentage of population within each DZ which is not born in the UK.	Scotland Census, Table KS204SC (http://www.scotlandscensus.gov.uk/ods-web/data-warehouse.html)
Percent of adults without qualifications	2011	Percent of the population above 16 without 'qualification' (i.e. low educational attainment, similar but not exactly equivalent to 'no high school diploma' in the US)	Scotland Census, Table QS501SC (http://www.scotlandscensus.gov.uk/ods-web/data-warehouse.html)

(Alden and Schneeberg 2014), which are further described in the results discussion below table 5.

Our Environmental Justice analysis used the Scottish Index of Multiple Deprivation (SIMD) as a measure of environmental injustice because it incorporates variables from multiple domains including income, housing, health, geographic access to critical services, employment, educational attainment, and crime. We considered overall deprivation as the salient measure of environmental justice in this study, rather than the race/ethnicity variables typically used in US environmental justice research. Due to the relatively small proportion of the population in Scotland belonging to an ethnic or racial minority, this variable may not adequately or completely capture potential environmental justice outcomes, and race and ethnicity may be less indicative of evidence of inequity or injustice than the more inclusive variable of multiple deprivation that was used.

Statistical analyses and results

Prior to examining the association between vacant and derelict land and mental health, it is important to confirm the potential environmental justice issue that more deprived populations have greater exposure to higher densities of VDL. As can be seen in figure 6, there is a strong spatial correspondence between the

areas with high SIMD (high deprivation) and the locations of VDL.

This was statistically verified by running a simple Pearson Correlation between VDL density and the Scottish Index of Multiple Deprivation score by DZ ($n = 690$; 4 DZs were omitted due to very low populations; $r = .521$, $p < .001$). This positive association suggests that areas with elevated deprivation scores tend to also have higher exposures to vacant and derelict land, confirming the presence of an environmental justice issue in terms of potential environmental stressors.

The relationship between the density of VDL and the proportion of the population per DZ who were prescribed medication for anxiety, depression, or psychosis was explored using three models: an ordinary least squares regression (OLS), a spatial autoregressive (SAR) model (spatial lag model), and a geographically weighted regression (GWR). All models were parameterized the same way, with the mental health (MH) prescription rate as the dependent variable and (1) VDL density; (2) percent of adults without qualifications; (3) geographic access to basic services; and (4) percent non-UK born as the independent variables (table 4).

The results suggest a good performing model ($R_a^2 = .573$) with normally distributed residuals based on a graphical analysis. However, there was spatial

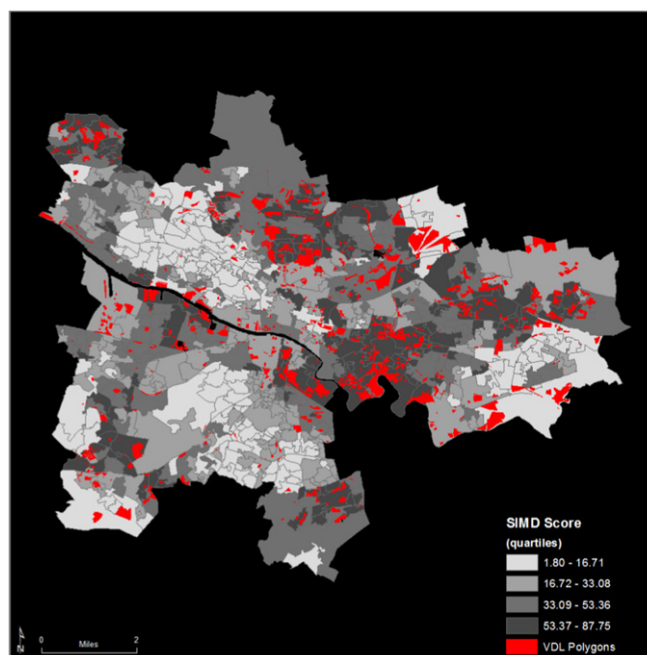


Figure 6. Scottish Index of Multiple Deprivation (SIMD) score by DZ, and VDL polygons. Higher SIMD scores, shown in darker shades of grey on the map, indicate higher levels of deprivation. Data sources: Scotland Census; Scottish Government (2012), Glasgow DRS (2012).

Table 3. Descriptive statistics for bivariate and regression model variables, based on Glasgow data zones ($n = 690$; 4 DZs were omitted from the analysis due to low population numbers).

Variable	n	Minimum	Maximum	Mean	Std. Dev.
VDL Density	690	.09	3670.73	614.40	590.84
SIMD Score	690	1.80	87.75	35.96	22.07
MH Prescription Rates (proportion)	690	.06	.22	.12	.03
Geographic Accessibility Score	690	.07	43.74	9.84	8.48
National Origin (% non-UK)	690	.48	58.82	11.58	9.72
Percent of adults without qualifications	690	2.40	64.38	33.88	15.02

Table 4. Ordinary least squares regression results (dependent variable = mental health prescription drug rate for anxiety, depression, or psychosis). $R_a^2 = .573$, AIC = -3679 . Condition index is 8.988, suggesting that co-linearity is unlikely to be an issue.

Independent Variables	Standardized Coefficients	t	Sig.
VDL Density	0.171	6.076	0.000
Percent without Qualifications	0.534	17.387	0.000
Geographic Access Score	0.058	2.265	0.024
Percent non-UK country of birth	-0.244	-8.468	0.000

dependence in the model which violates the OLS assumptions, based on the Likelihood Ratio Test of Spatial Dependence. These were then accounted for by using a spatial autoregressive model, specifically a spatial lag model utilizing Queen contiguity. The spatial lag model was chosen based on the Robust LM lag statistic. The results of this SAR model, although similar to the results of the OLS, exhibited somewhat attenuated associations compared to the OLS, but overall the SAR model performed better, as evidenced by the lower Akaike Information Criterion (-4504 for the SAR, versus an AIC of -3679 for the OLS) (table 5).

Based on the SAR model, the strongest predictor of MH prescription rates was the lagged version of the dependent variable which is created to control for spatially autocorrelated residuals. VDL exposure and the percentage of adults without qualifications had significant positive associations with the MH prescription rate ($p < .05$, and $p < .001$, respectively), suggesting that DZs with high exposure to VDL and higher proportions of residents with low educational attainment tend to have higher rates of MH prescriptions. The scores for geographic access to basic services were positively associated with prescription rates in the OLS model ($p < .05$), however, in the SAR it was

Table 5. Spatial autoregressive model (lag model) ML estimation results (dependent variable = mental health prescription drug rate for anxiety, depression, or psychosis). Pseudo- $R^2 = 0.89$, AIC = -4504 . Lagged MH Prescription Rate refers to the spatially lagged version of the dependent variable created based on queen contiguity.

Variable	Coefficient	Std.Error	z-value	Probability
VDL Density	1.40×10^{-6}	6.0×10^{-7}	2.25	0.025
Geographic Access Score	-6.49×10^{-5}	3.98×10^{-5}	-1.63	0.103
Percent without Qualifications	2.64×10^{-4}	3.06×10^{-5}	8.65	0.000
Percent non-UK country of birth	-1.63×10^{-4}	3.89×10^{-5}	-4.17	0.000
Lagged MH Prescription Rate	0.831	0.0186	44.59	0.000

not found to be significant. The percent non-UK variable was negatively associated with the prescription rate ($p < .001$) suggesting a protective effect. This protective effect related to DZs with higher proportions of immigrant groups may be a function of a number of phenomena, including the way certain populations may under-utilize mental health resources (Bansal *et al* 2014), as well as the ‘healthy immigrant effect’.

The ‘healthy immigrant’ theory maintains that immigrants may suffer from certain adverse health outcomes less frequently than native-born residents, and in general, perceive themselves to be in good health (Alden and Schneeborg 2014). This may be partially attributable to healthier diets, more physical activity, lower body mass index, and less exposure to cigarette smoke. First generation immigrant status may be protective even after about two decades (Corlin *et al* 2014).

In a study by Chen *et al* (2010) other possible reasons for this apparent protective effect are presented. For example, recent Chinese immigrants in Canada diagnosed with severe and persistent mental illness used fewer mental health services than subjects from the comparison group comprised of non-immigrants. This lower usage may be due to language barriers, lower perceived or actual access to mental health services, or differences in cultural norms regarding mental health issues. Additionally, even though immigrant adolescents are at equal or greater risk of developing internalizing problems as their non-immigrant peers, immigrant adolescents were less likely to seek mental health services, perhaps due to lower levels of emotional problem identification amongst the immigrant sample (Verhulp *et al* 2013). Other research found lower usage of health services, in general, by immigrant groups, due to their stated lack of knowledge about the available services and the health care process (Galanis *et al* 2013).

A geographically weighted regression, specified the same way as the global models, was then performed on the data to explore potential spatial non-stationarity in the associations, using ArcGIS10. This local approach allows the relationships (e.g., the variable coefficients) to vary over space by essentially performing one local regression for each DZ in Glasgow, and as such can aid in identifying areas which behave in unexpected ways.

Locally varying relationships may be a function of various phenomena including possible model misspecification, sampling variation, or simply a relationship that intrinsically varies over space (Fotheringham *et al* 2002, Maroko *et al* 2011). In the case of this study, GWR was used in an exploratory way to examine the spatial variation of the relationships and subsequently generate hypotheses as to the cause of the spatial heterogeneity.

An adaptive kernel was used, employing 65 ‘neighbors’ per local regression as determined by minimizing the AICc, which helps to quantify model performance. The model diagnostics (AIC = -4357 , pseudo- $R_a^2 = .0.89$) suggest a good performing model. By examining the mapped parameter coefficient values we can explore where the model behaved ‘as expected’ (e.g., positive association between VDL density and MH prescription rate, while adjusting for the other socioeconomic indicators) and where it behaved counter-intuitively (e.g., weak or negative association between VDL density and MH prescription rate) as well as where the local R^2 was high versus where it was low (i.e., where the model explained more or less of the variance). The spatial pattern of the model strength and VDL coefficients are complex and can be seen in the maps below [figures 7 and 8].

The GWR model did outperform the OLS based on the AIC, however it did not perform as well as the SAR in this study. Even so, it can be useful to examine the GWR outputs in order to identify areas which may be worth a deeper qualitative analysis. The strongest predictor of MH prescription rates was the lagged version of the dependent variable which is created in the SAR to control for spatially autocorrelated residuals. The percent without educational qualifications was the strongest predictor of MH rates of the socio-demographic variables.

Qualitative assessment

The salient geographic features are often assumed to be similar in studies analyzing equity in access. One of the points of the qualitative assessment is to make clear that the characteristics of the features are likely to have an impact on the health effects, and those qualitative characteristics aren’t often considered in these types of studies.

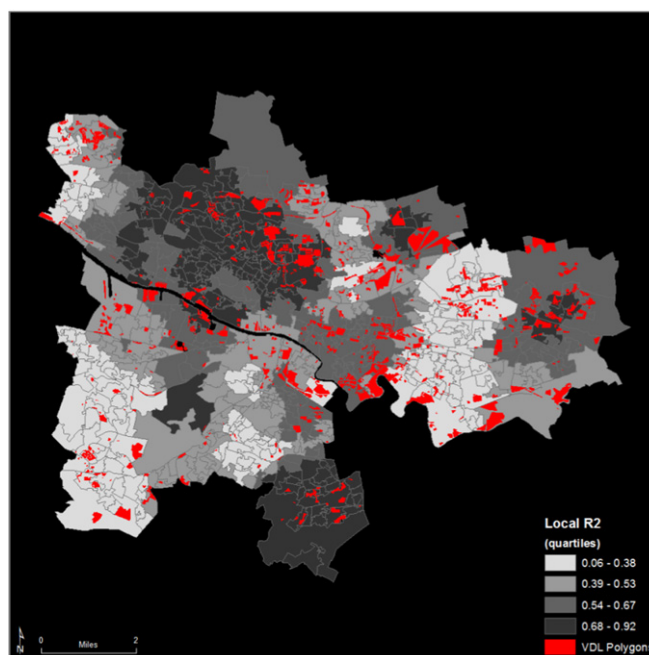


Figure 7. Local R^2 from the GWR model. Lighter shaded DZs suggest a weaker local model where the MH prescription rates are not as closely associated with the explanatory variables. Data sources: Scotland Census, SIMD 'Health Domain 2010' (2012), Scottish Government (2012); Glasgow DRS (2012).

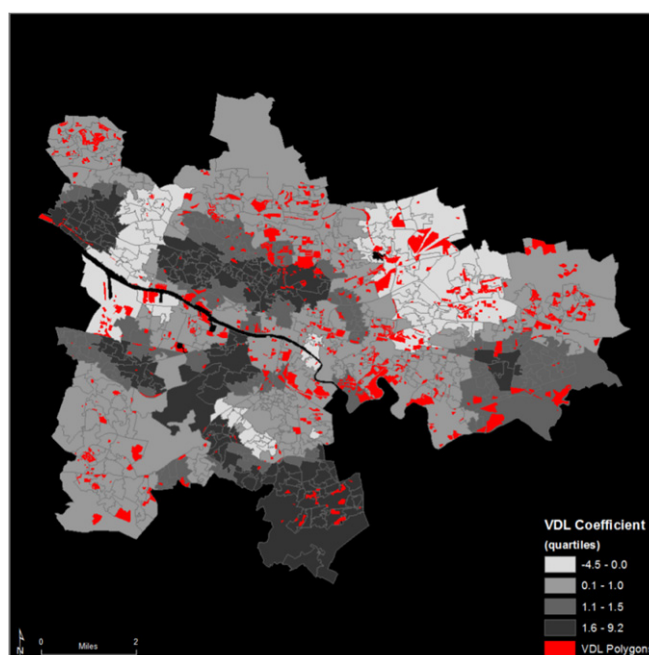
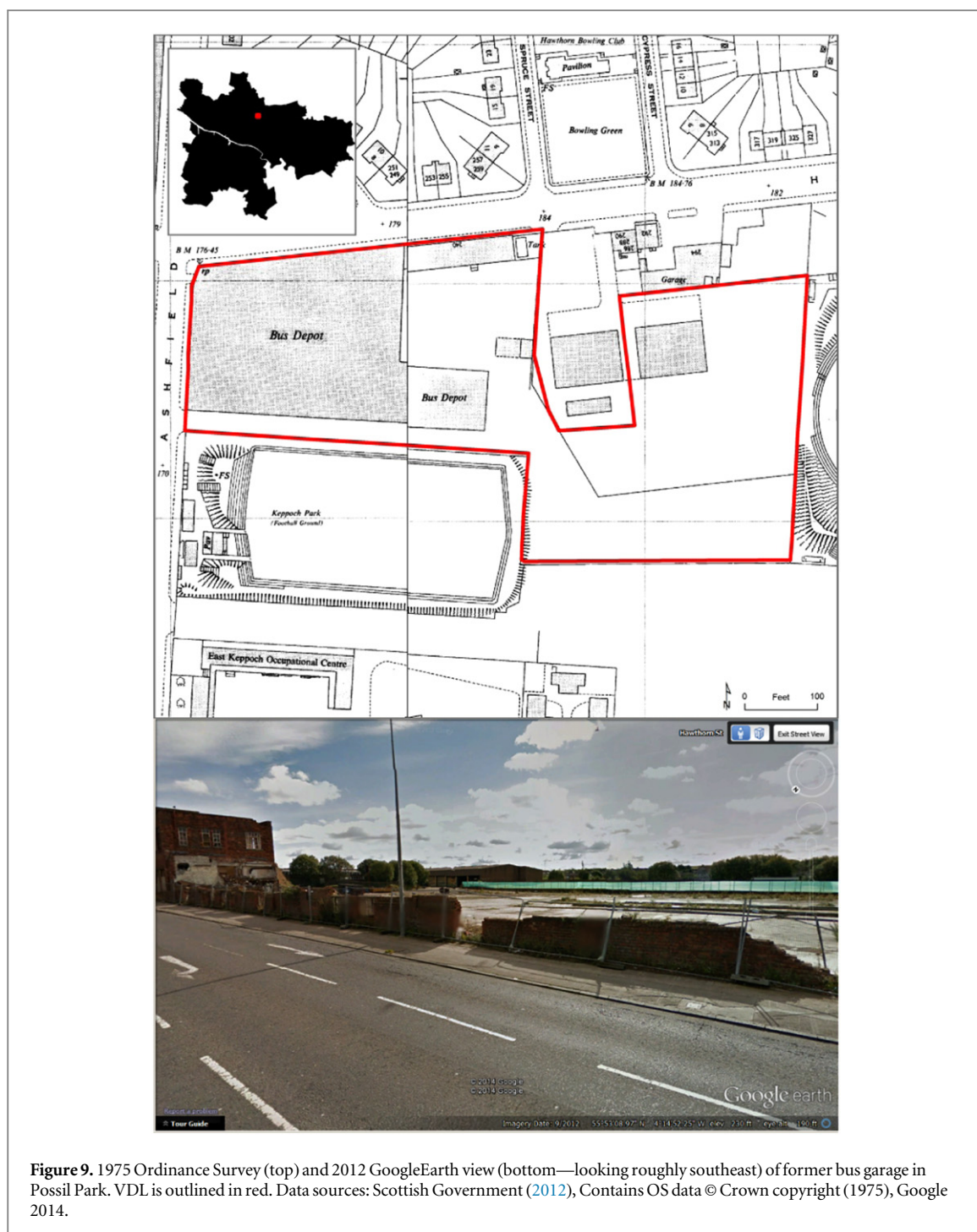


Figure 8. VDL Coefficient from the GWR model (converted by a factor for readability). Darker shades represent DZs with larger coefficients, indicating larger influence of VDL on MH prescription rates. Data sources: Scotland Census, SIMD 'Health Domain 2010' (2012), Scottish Government (2012); Glasgow DRS (2012).

It should be noted that the statistical analyses did not take into account characteristics of the VDL other than area (converted to density), and it seems clear that not all VDL would have the same potentially deleterious effect on nearby populations. For instance, vacant land which is currently used as an informal dumpsite may act as a more potent psycho-social

stressor than one which is more pleasant-looking or benign.

In order to explore how VDL characteristics might impact MH prescription rates, a more qualitative assessment was conducted on two pilot areas, which were selected to be illustrative of many of the VDL environments. Two sites were identified and selected



from relatively high-VDL density areas, but ones which behaved differently from one another in the GWR model: one where VDL is a relatively strong predictor of mental health versus one where it is weaker. These sites were then examined in more detail, using a combination of data sources, including historical ordinance survey maps and GoogleEarth's Street View.

Pilot Site 1 consists of land that was formerly used as a bus garage in Possil Park (an identified PARDLI area), which became derelict between 2001 and 2004 (figure 9). It is within a DZ that shows GWR characteristics of a relatively strong local R^2 (.64) and positive VDL coefficient. This suggests an area where there is

the 'expected' positive association between VDL density and higher rates of MH prescriptions.

Pilot Site 2, near Drumchapel South (another PARDLI area), was used for oil storage, and became derelict between 1996 and 2000 (figure 10). However, in contrast to Pilot Site 1, this area has a more modest local R^2 (.37) and smaller magnitude VDL coefficient, suggesting a weaker relationship between VDL and MH prescription rates.

Although it is possible that both the former oil storage and the former bus depot sites may pose direct threats to health due to the potential presence of toxic materials, it is also possible that the psycho-social



stressors associated with these sites may vary in a way unrelated to previous use or level of toxicity. This effect may play an important role in the influence of VDL on mental health, as suggested by the difference in GWR output as well as differences in visual impact between the two sites, with the former oil storage appearing more bucolic and less daunting than the former bus depot.

By combining quantitative and qualitative approaches in this manner, additional insights can be obtained, enabling the generation of new hypotheses, which would be enhanced by a comprehensive qualitative study.

Discussion and conclusions

The findings of this study demonstrate an environmental health inequity with respect to the distribution of vacant and derelict land in Glasgow, Scotland. Bivariate correlation revealed that populations in higher deprivation areas are typically exposed to higher densities of VDL. This suggests that many deprived communities are disproportionately burdened with the environmental impacts and psychosocial stressors associated with this land use.

Additionally, regression analyses showed the association between VDL density and elevated rates of

prescriptions for depression, anxiety, and psychosis, while adjusting for other socio-demographic factors. Therefore, VDL has implications for mental health in these communities. Spatial variation in the relationship between VDL and MH prescription rates was revealed by the GWR. This spatial non-stationarity may be explained by specific characteristics of the VDL, such as de facto use and visual impact, which can be further investigated by additional qualitative analyses.

There may be inequities, not only in the exposure to VDL and the concomitant health burdens, but also, as previous literature shows (i.e., O'Neill *et al* 2003), inequities in the susceptibility to the impacts of environmental burdens, with the more vulnerable populations, in terms of socio-economic deprivation and poor health, being more susceptible to the impacts of exposure than more affluent and healthier populations, given equal exposures to the hazard.

The relationship between the density of VDL and the rate of mental health prescriptions is not necessarily a causal one, but the strong association between the two points to a good opportunity to transform neighborhoods' VDL from a potential environmental stressor to a positive environmental benefit for the proximate populations.

In order for solutions for the re-use of vacant and derelict land to be effective and accepted by the affected populations, community residents and others must recognize and identify specific health concerns and likely health impacts potentially associated with the VDL, and, importantly, ought to be involved in developing the solutions (Garvin *et al* 2012). Urban planning and budgetary decisions by government and their private development partners should be driven by these health and safety concerns of the community, and not be based solely upon the attraction of profit-seeking investments to decaying neighborhoods.

Many times community improvements in vacant and derelict land have the unfortunate side-effects of raising property values, thus creating interest amongst property developers, and stimulating the gentrification process and the consequent displacement of the original residents, which are undesirable outcomes and counter-productive to the goal of improving life for the community residents (Maantay 2013). A recent school of thought on this matter has posited that it might be in the best interests of the community to make use of VDL as informal greenpaces that would still benefit the current community but not necessarily attract gentrification. In this way, the VDL stays provisional and transitional, retaining some of its marginal qualities and not appearing totally 'domesticated', whilst still being at least partially under the control of the neighborhood residents. Curran and Hamilton (2012) and Wolch *et al* (2014) present this strategy as 'just green enough' interventions.

Whether considered for informal or more 'managed' initiatives, vacant land should be seen as an

opportunity for transforming neighborhoods and contributing to social capacity building, community development, empowerment, and engagement. VDL can be appropriated for a number of urban ecological infrastructure uses, such as food production, absorbing air and water pollution, carbon sequestration, temperature regulation, urban heat island effect mitigation, and providing habitat for biodiversity, as well as cultural ecosystems services, including providing active and passive recreational and mental health rejuvenation spaces, hastening disease/health recovery, and aiding in crime reduction (Kremer *et al* 2013, McPhearson *et al* 2013).

Community-led neighborhood stabilization and revitalization can be encouraged by public policy. There can be modest economic incentives for re-use of vacant lots by the community, or by not-for-profit development organizations. The city can turn over publicly-owned VDL to a community group for use, either on a temporary or permanent basis, as passive open space, community garden, playground, or center for the elderly or children, depending upon the need and the site constraints. The relationship between VDL and inequitable health outcomes presents an opportunity for communities, urban planners, and governmental authorities to improve a neighborhood's physical condition, which in turn will reduce the negative effects of stressors, thereby increasing resilience amongst the population, making them less vulnerable and more likely to stay healthier, both mentally and physically.

This is the first study of its kind to look at the spatial concentration of vacant and derelict land in relation to mental health, socio-economic indicators, and health inequities. As this study has found, the spatial distribution of vacant and derelict land creates a disparate pattern of blight and poor health, which disproportionately affects communities having higher deprivation levels amongst their populations. Without innovative and corrective policy initiatives and mitigation efforts, with the goal of fostering community involvement, at-risk places and their populations are likely to continue to bear unequal burdens.

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