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Research Note: Urban street tree density and antidepressant prescription rates; a cross-sectional study in London, UK

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Abstract

Growing evidence suggests an association between access to urban greenspace and mental health and wellbeing. Street trees may be an important facet of everyday exposure to nature in urban environments, but there is little evidence regarding their role in influencing population mental health. In this brief report, we raise the issue of street trees in the nature-health nexus, and use pre-existing data to examine the association between the density of street trees in London boroughs and rates of antidepressant prescribing. After adjustment for potential confounders, including unmeasured area-effects using Bayesian mixed effects models, we find a small inverse association, with a decrease of 1.18 prescriptions per thousand population per unit increase in trees per km of street (95% credible interval 0.00, 2.45). Further research is needed to confirm this and to investigate mechanisms, but this study indicates that street trees may be a positive urban asset for mental health.

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1. Introduction

Growing urbanisation appears to be a threat to mental health and well-being (Peen, Schoevers, Beekman, & Dekker, 2010). Modern lives are often busier and more hectic (Kegan, 1995) than the more traditional rural lifestyles which humans have experienced for much of their recent history, and to which they are thus best psychologically adapted. (Wilson, 1984). Consequently, the demands of urban living may be greater than some people's abilities to cope which can result in feelings of stress, perhaps not unlike behaviors shown by many species when removed from their natural habitat (Broom, 1993). Importantly, chronic stress is associated with a range of mental and physical illnesses, including psychiatric disorders such as unipolar depression (Kessler, 1997), which may help explain why rates of depression are often higher in highly urbanised areas (Maas et al., 2009); (Peen et al., 2010).

There is also evidence that exposure to the kinds of natural environments and elements to which we may be more accustomed can help reduce feelings of stress (Ulrich et al., 1991). In turn this may help to explain why indices of poor mental health and symptoms of depression tend to be lower in urban areas with more natural elements such as parks and gardens (Astell-Burt, Mitchell, & Hartig, 2014); (White, Alcock, Wheeler, & Depledge, 2013b). That is, people who live in urban areas who have better access (physically or visually) to elements of nature such as parks may be coping better with the day-to-day demands of urban living because of the physiological and psychological "restoration" these natural environmental elements promote (Ulrich, 1986).

To date, however, much of this literature has relied on self-reported psychological states, with the various limitations entailed, and correlated this with the *amount* of natural elements near individual's homes using land cover data such as the amount of local space taken up by parks and gardens. Far less work has used objective indices of psychiatric disorders, such as anti-depressant prescription rates, or examined the impact of specific elements of nature, such as street trees (de Vries, van Dillen, Groenewegen, & Spreeuwenberg, 2013). Such an examination is important both theoretically and practically. In terms of theory, a park may promote stress reduction, and thus help prevent depression in the long-term, through various mechanisms including encouraging physical activity or socialisation (Hartig, Mitchell, de Vries, & Frumkin, 2014). Street trees, by contrast, are more likely to aid stress reduction via a visual amenity pathway, although they may also provide an urban cooling effect and reduce some types of pollution (Hartig et al., 2014).

Some studies have measured the associations between urban nature and mental health; individuals score worse on the General Health Questionnaire when living in less green urban areas in England (Astell-Burt et al., 2014; White, Alcock, Wheeler, & Depledge, 2013a), and higher rates of depression and anxiety disorder have been found in less green areas of the Netherlands (Maas et al., 2009). Depression is a common form of mental illness, with a prevalence in Britain of around 11%, similar to elsewhere in Europe (Martin-Merino, Ruigomez, Johansson, Wallander, & Garcia-Rodriguez, 2010). The epidemiology of depression is complex, but its impact on society in terms of both economic costs and social burden is great (Pincus & Pettit, 2001). A recent meta-analysis of studies from developed countries concluded that urban living is associated with an increased risk of developing psychiatric disorders, including depression, compared with residing in a rural area (Peen et al., 2010). It has been reported that walking in a nature reserve is restorative to markers of positive affect, and decreases levels of anger, when compared with the same activity in urban areas (Hartig, Evans, Jamner, Davis, & Gärling, 2003), and taking exercise in green spaces has been shown to be associated with bigger improvements in psychological factors such as self-esteem, than the same activity in urban spaces (Pretty, Peacock, Sellens, & Griffin, 2005).

Street trees are a widespread, common form of urban nature, found in cities and towns even in the absence of nearby parks and other green spaces. The aim of the current study was to examine these issues in London, which benefits from comprehensive street tree audits and highly detailed prescription data, using spatial and Bayesian analyses. Our basic hypothesis was that areas with more trees are those with lower levels of depression as indicated by anti-depressant prescription rates, after controlling for appropriate confounders.

2. Methods

London, United Kingdom (UK), is a large conurbation with just over 8 million inhabitants (Office for National Statistics, 2010). The city is divided administratively into 33 boroughs, with mean population around 250,000 and mean area of approximately 50km^2. Primary health care is provided largely through National Health Service (NHS) general practitioners (GPs), at the time of data collection working within local Primary Care Trusts (PCTs). PCT and borough boundaries are mostly co-terminous.

This is an ecological study using several openly accessible data sources from the city.

2.1 Prescribing data

The quantity of antidepressant prescriptions in financial years 2009-2010 in the PCTs serving each London borough, was obtained from the publicly available repository at data.london.gov.uk (Greater London Authority, 2011). Antidepressant drugs are defined here as pharmaceutical agents included in the British National Formulary (BNF) Chapter 4, Section 4.03, (Joint Formulary Committee, 2011). In the UK, all citizens who consult their

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physician are registered with the NHS as standard, and are entitled to receive health provision. The proportion of UK citizens opting to use private health care instead is approximately 11-12% (Klein, 2005), and antidepressant drugs are only legally available in the UK with a prescription (Wheeler, Gunnell, Metcalfe, Stephens, & Martin, 2008). Populations of each London borough for the year 2009 were obtained from the Greater London Authority (GLA), (Office for National Statistics, 2010), allowing calculation of borough rates of antidepressant prescriptions per 1000 population.

2.2 Street tree data

Data concerning the quantity of street trees in each London borough were obtained from the same source (Greater London Authority, 2011). These figures are required for the borough to claim a per-tree maintenance allowance from central government. All street trees are counted together, whether they are deciduous or evergreen. The data concern only street trees, as opposed to those in non-residential/non-commercial areas such as parks. Figures may omit a few recently planted trees, but are thought to be complete with regard to mature trees (London Assembly Environment Committee, 2011). The routinely collected data did not provide information on the number or length of streets in each borough. Consequently we calculated this information from street data from the Ordnance Survey (April 2010), using ArcGIS 9.3, giving a density of trees per linear kilometer of street. Streets are treated equally, regardless of traffic lanes or private residences, as even those without housing may form important thoroughfares.

2.3 Analysis

Linear regression models were used to explore the association between borough street tree density and antidepressant prescribing rates, adjusting for potential confounders. Confounders considered included: Socio-economic status (SES) using mean scores from the

Government's 2010 Index of Multiple Deprivation (McLennan et al., 2011), percentage of residents claiming job seekers' allowance (JSA), prevalence of smoking (HM Government, 2013), and borough mean age. The number of GP consortia in each borough was used as a proxy for service accessibility.

The boroughs of City and Hackney are served by the same PCT, as are Sutton and Merton. In these cases data were combined as sum totals or population-weighted means as appropriate.

Owing to concern regarding unknown/unmeasured confounders at borough level, Bayesian mixed effects models were employed. This predicts effect size with associated credible intervals, after adjustment for measured confounders and an additional parameter representing unknown and random area-level influences. In the Bayesian framework, parameters are treated as random variables whose "prior" distribution expresses our uncertainty about their value before any data are observed. Prior distributions (priors) are combined with the observed data through Bayes' theorem to produce the posterior distributions for each parameter (posteriors). The posteriors express the uncertainty about model parameters after data are observed and all statistical inference is based solely on the posteriors. Markov chain Monte Carlo (MCMC) is a numerical technique which produces samples of values that eventually converge (after a certain "burn- in" number) to samples of values from the posterior (distribution) of each parameter.

The borough-level random effects also pool information across space, hence boroughs with little information borrow strength from other boroughs. Geographical and statistical analyses were performed in R, WinBUGS (Speigelhalter, Thomas, Best, & Gilks, 1996) and ArcGIS.

3. **Results**

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In 2011, the street tree density per km of street in the 31 boroughs/PCTs ranged from 15.7/km to 81.7/km, with mean (SD) of 40.2 (14.0) trees/km. Antidepressant prescribing rate varied from 357.9 to 577.8 prescriptions per 1000 population. No data were available for one borough. The scatter plot (Figure 1) shows rates of prescriptions for antidepressants plotted against street tree density.

Areas with higher rates of antidepressant prescription rates had lower densities of street trees (r=-0.368, p=0.045) and higher prevalences of smoking (r=0.374, p=0.042, Table 1). Correlations between the outcome variable and other confounders can also be found in Table 1.

[Insert table 1 here]

Simple regression analysis indicated that a greater tree density (i.e. one tree per km of street) was associated with 1.38 fewer prescriptions for antidepressants (95% CI 0.03 to 2.72) per 1000 population. Parameter estimates and 95% credible intervals from the mixed effects model are shown in Figure 2. Results suggest borough smoking prevalence and mean age are associated with higher antidepressant prescribing. Accounting for measured and unmeasured confounders, a greater density of street trees was still associated with slightly fewer prescriptions of anti-depressant medication (-1.18 prescriptions per thousand per tree/km, 95% credible interval -2.45, 0.00). This finding should be interpreted along with the random borough effect estimates (Figure 3). This shows the variation in data captured by random effects, and identifies boroughs with positive/negative effect on prescription rate given all other confounders, i.e. the estimated unobserved borough effect. Even though many point estimates for the random effects are close to zero, some boroughs indicate a noticeable effect other than that explained by the predictors.

4. Discussion

4.1 Key Findings

Our analysis indicates that boroughs of London with a higher density of street trees tend to have lower antidepressant prescription rates. This effect remains after controlling for potential confounders and allowing for the influence of unmeasured area effects. These findings complement previous research suggesting the benefits of street greenery for mental health (van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012).

Although we cannot say how this relationship is mediated, the opportunity presented by nature for improved psychological restoration has been cited before as a benefit of urban greenery, contributing to lower reported levels of stress and depression (Astell-Burt et al., 2014; Ulrich et al., 1991). A number of other possibilities exist, concerning the ways in which street trees may contribute to a positive living environment, such as more pleasant views from home (Velarde, Fry, & Tveit, 2007), a more agreeable or active daily commute (Nielsen & Hansen, 2007), better perceived opportunities to undertake physical activity (Pretty et al., 2005), and the provision of an environment which supports stronger neighborhood social ties (Kuo, Sullivan, Coley, & Brunson, 1998). It could also be linked to the findings of a recent review, showing that narrower roads or trees close to roadways appear to be linked to slower or safer driving (Ewing & Dumbaugh, 2009). Whilst not focused on street trees, evidence on streetscape greenery and health suggests that stress reduction and social cohesion may be the most important mediators (de Vries et al., 2013). These suggestions are also consistent with previous research indicating reduced levels of stress and anxiety with increased greenspace (de Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Velarde et al., 2007; White et al., 2013a).

4.2 Strengths and limitations

Antidepressant prescription data used here provide a relatively complete picture of antidepressant provision in London, since antidepressant drugs are only available on prescription and the vast majority of patients receive care through the NHS. However, individuals with depression may a) not consult health services or b) be offered/prefer other treatments (e.g. cognitive behavioral therapy), or may not take their medication (due to side effects or other reasons), thus antidepressant prescription rates are an imperfect proxy for the prevalence of depression. In addition to this, different prescriptions may entitle the patient to different types or quantities of drugs. Nonetheless, as each prescription represents a single incident of one person requiring treatment, we considered them a reasonable proxy indicator of the relative prevalence of depression locally.

This is a study of association; we do not ascribe causation to the results observed, and the ecological fallacy (whereby aggregate associations may not accurately reflect individual level associations) may be at play. We have controlled for a number of potential confounders, but with relatively few data points and aggregated data, residual confounding is possible. However, the mixed effects modeling approach allows us to control for the potential influence of unmeasured confounders on the relationship at borough level.

The data are of coarse geographical resolution, and there will be within-borough heterogeneity of exposures and outcomes. For example, although we control for SES in our analyses, an area such as a London borough will contain considerable internal variability in SES. It is possible that more affluent (and healthier) populations are attracted to live in areas with more street trees (Hitchmough & Bonugli, 1997; Landry & Chakraborty, 2009). Although the NHS data used here comprise around 89% coverage of the UK population (Klein, 2005), it is also possible that private prescribing, which is omitted from these data, is higher in areas of higher SES. However, although there may be considerable prevalence of depression among lower SES groups in Britain, even with universal health care, higher SES

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individuals may be *more* likely to be prescribed treatment for depression (Kivimaki et al., 2007), so any confounding by SES may be small, or may even obfuscate a greater benefit from urban nature.

Finally, street tree density could be acting as a proxy for related, unmeasured area-level factors influencing population mental health, such as population density; boroughs with more street trees may also invest more in neighborhood quality measures (e.g. vandalism reduction, traffic calming).

5. Conclusions

Street trees may have a role to play in supporting neighbourhood mental health. Street trees are on the urban policy agenda: the UK government's 'Big Tree Plant' plans to plant one million trees in cities, towns and neighbourhoods during 2010-2015 (DEFRA, 2013), and Million Trees New York City plans to plant 220,000 street trees as part of the "plaNYC programme" (New York City, 2014). This study provides evidence to support such projects' aims of stress reduction and improving mental health of urban populations.

Future Research

Finer spatial scale street tree data, individual-level outcome data and more frequent prescribing data could allow more detailed investigation of the association between tree density and mental health. For example, the direction of effect could be established and causal mechanisms explored using other study designs. Additional factors may modify the associations of interest, for example, seasonal variations may exist, as reported by Hartig et al in the dispensation of one group of antidepressants when related to mean daily temperatures in vacation seasons (Hartig, Catalano, & Ong, 2007). Another potential effect modifier is

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gender. Our data, which are aggregated for all people over a single year, cannot examine interactions with gender or season. These would be important issues to explore in future work, using more amenable data. Such future research could inform ongoing planting programmes or the preservation of street trees in urban areas.

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Figures

Figure 1: Scatter plot of street tree density and rate of antidepressant prescriptions.

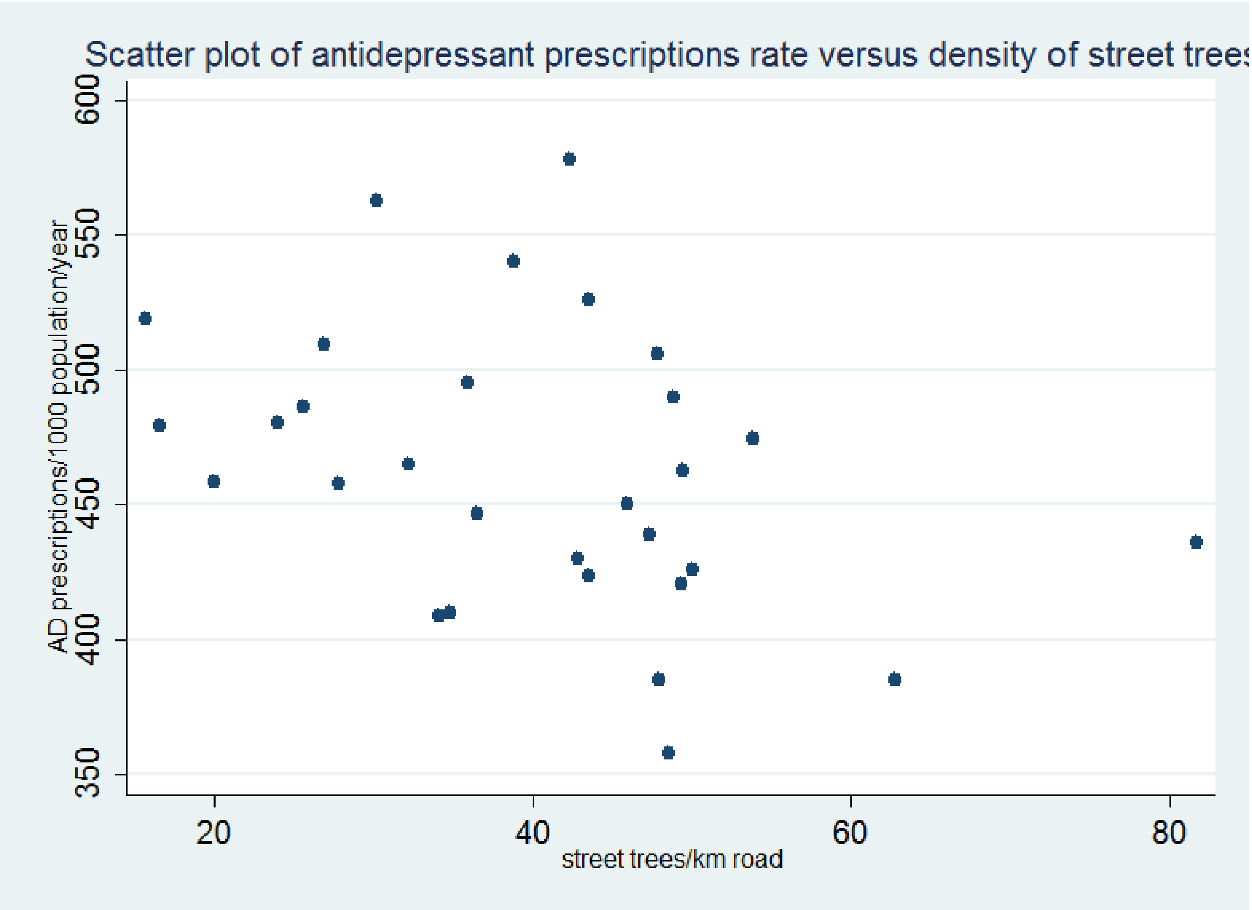

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Figure 2: Parameter estimates and 95% credible intervals from the mixed effects model.

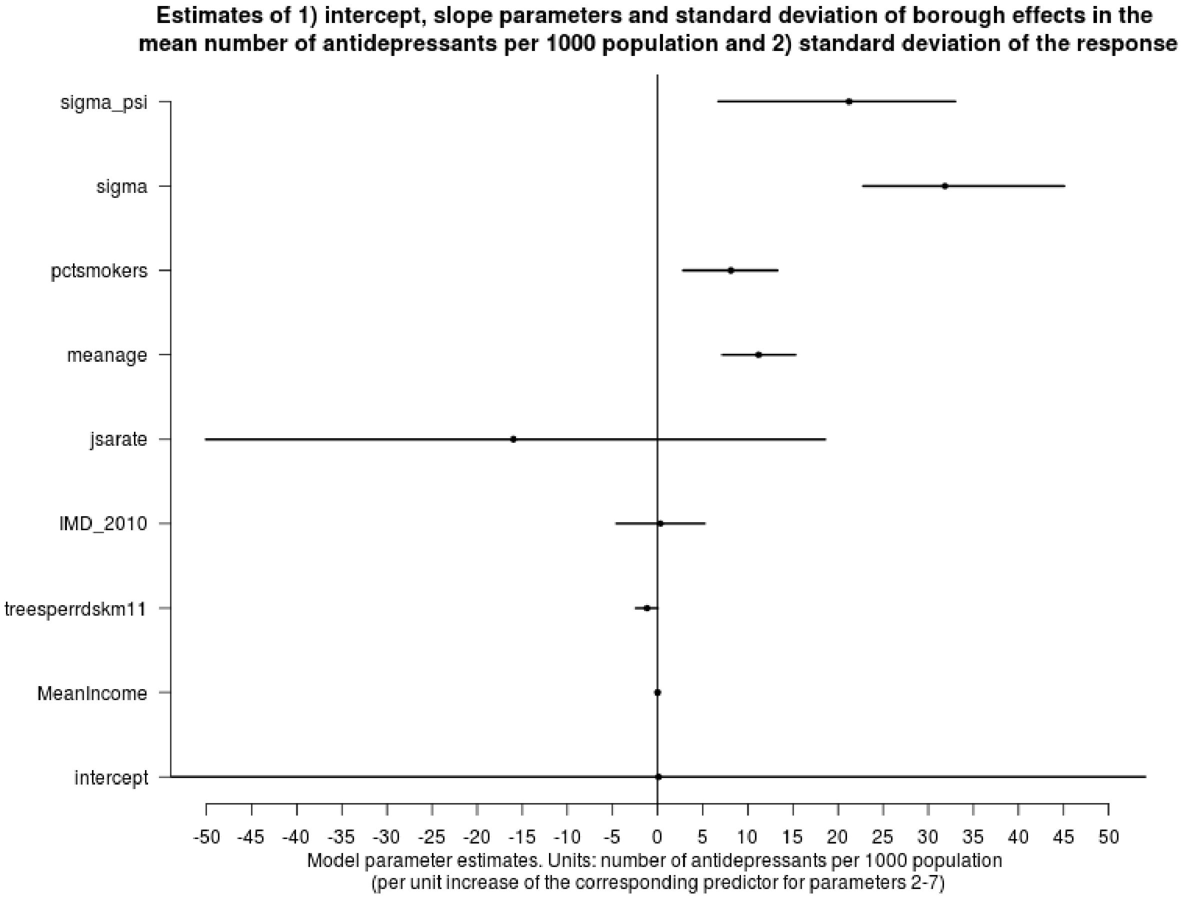

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Figure 3: Random borough effect estimates from the mixed effects model.

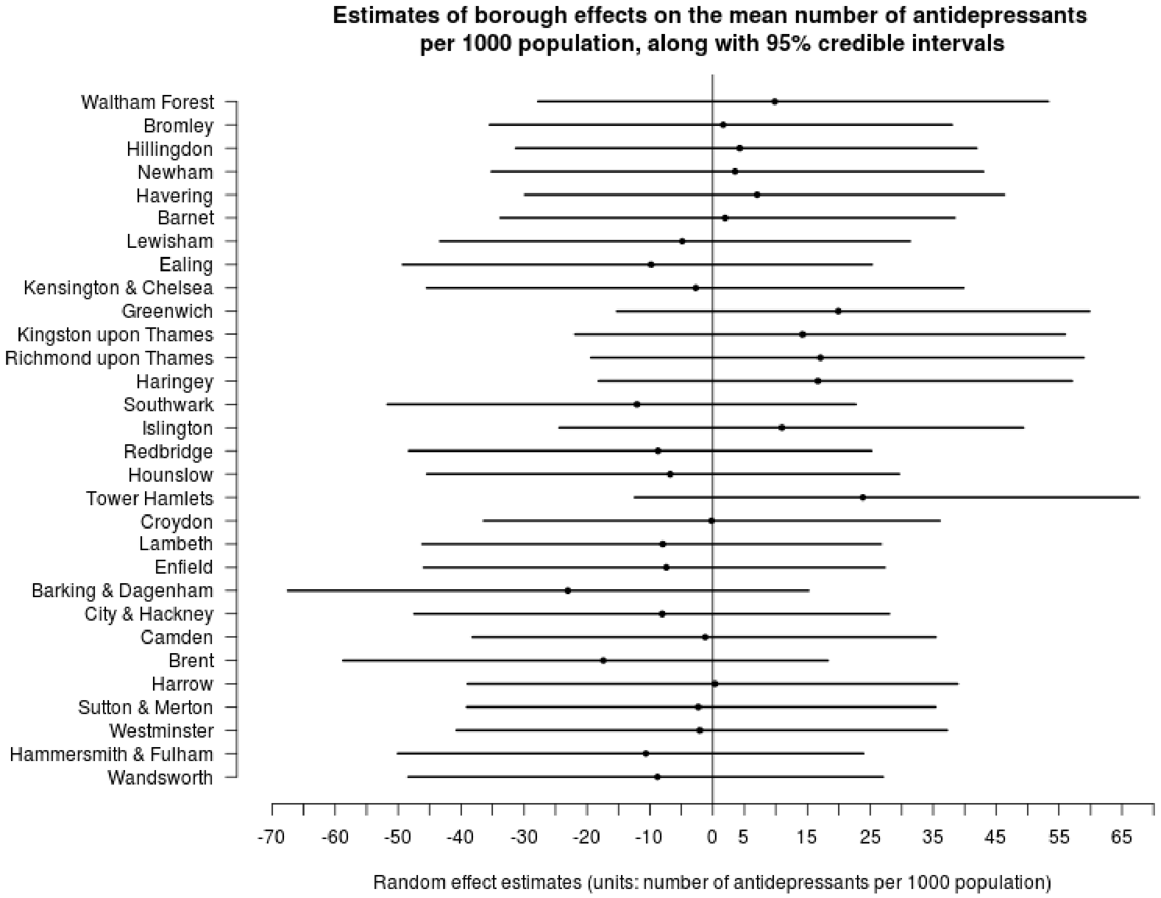

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Table 1: Correlations between street tree linear density/km and other measured confounders

	Street trees/km	Mean income	IMD score (deprivation)	Claiming job seekers' allowance	Mean age	Percentage smokers	Number of prescribers
Street trees/km	1	-0.190	-0.137	-0.087	0.197	-0.353	0.175
Mean income		1	-0.160	-0.418	0.158	-0.231	-0.131
IMD score (deprivation)			1	0.917	-0.799	0.573	0.012
Claiming job seekers' allowance				1	-0.711	0.591	0.08
Mean age					1	-0.417	0.02
Percentage smokers						1	-0.21
Number of prescribers							1