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The natural environment and social cohesion: Tree planting is associated with increased voter turnout in Portland, Oregon

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ABSTRACT

Research suggests that social cohesion partially mediates the health benefits of being exposed to the natural environment. However, past studies have relied on self-reported measures of social cohesion that have well-documented limitations. Therefore, we evaluate the impact of tree planting on social cohesion using voter-turnout data as an objective metric of social cohesion. Our study area is the 141 Census tracts in Multnomah County, Oregon that fall within (>50% area) the City of Portland. We used biennial primary and general-election turnout data from 2002 to 2020, and tree-planting data from the Portland based non-profit Friends of Trees. We estimated mixed models of voter turnout including tract-level random effects and controlling for socioeconomic status. Voter turnout and tree planting may be codetermined, so lagged tree-planting variables were used in all regression models. We found that each tree planted 10–11 years before an election was associated with a 0.020% (95% CI: 0.013–0.027) increase in general election turnout and a 0.016% (95% CI: 0.0089–0.023) increase in primary turnout. As the length of the planting lag decreased, the association between tree planting and voter turnout, in both primary and general elections, declined in significance and magnitude. Our results add to the body of evidence suggesting that social cohesion partially mediates the health benefits of exposure to the natural environment.

Introduction

A rapidly expanding body of literature has linked exposure to the natural environment to a wide range of positive health outcome (Twohig-Bennett and Jones, 2018). This protective effect is likely mediated by a range of mechanisms including improved air quality (Nowak et al., 2006), increased physical activity (de Vries et al., 2013), enhanced immune function (Donovan et al., 2018), stress reduction (Li and Sullivan, 2016), and improved social cohesion (Hartig et al., 2014) (social cohesion refers to feelings of connectedness, solidarity, and sense of community among social groups). There are differing amounts of scientific evidence supporting a role for each of these mechanisms in linking exposure to nature and improved health. In particular, only a handful of studies have shown that exposure to the natural environment is associated with improved social cohesion (de Vries et al., 2013; Dzhambov et al., 2018; Liu et al., 2020, 2019; Orban et al., 2017; van den Berg et al., 2019), and these studies are cross-sectional (as opposed to longitudinal) and rely on self-reported data on social cohesion, and both cross-sectional study designs and self-reported data have well-reported shortcomings (Elgar et al., 2005; Schneeweiss et al., 2009). Therefore, to address the limitations of the extant literature, we longitudinally examine the impact of tree planting on social cohesion in Portland, Oregon, using voter turnout as an objective measure of social cohesion. We chose to use voter turnout as a metric of social cohesion because it is objective (not self-reported), and multiple studies have shown that social cohesion and voter turnout are positively correlated (Langenkamp, 2021; Mattila et al., 2013; Reilly, 2017). Formally, we test the hypothesis that increased tree planting, at the Census tract level, is associated with increased voter turnout. Evaluating this hypothesis is important both because improved social cohesion is an important societal goal, and because social cohesion may partially mediate the relationship between exposure to the natural environment and improved public-health outcomes.

Literature review

Multiple studies have examined how social cohesion mediates the relationship between greenness, and health. De Vries et al. (2013)

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studied the association between three self-reported measures of health (general health, number of acute health issues, and mental health) and greenness in 80 neighborhoods of four Dutch cities. They found that exposure to greenness was associated with improvement in all three health outcomes and that this protective effect was partially mediated by increased social cohesion. Using the same health metrics as De Vries et al., Maas et al. (2009) studied the association between greenness and self-reported health in a sample of 10,089 Dutch children and adults. They found that greenness within 1 km of a participant's residential address was associated with improvements in all three health metrics, and that social cohesion (measured as loneliness and lack of social support) partly mediated this association. Sugiyama et al. (2008) examined the relationship between perceptions of neighborhood greenness and self-reported mental and physical health in 32 neighborhoods in Adelaide, Australia. The authors found that social cohesion was associated with improvements in mental, but not physical, health. In a cohort of 4480 German adults, Orban et al. (2017) quantified the relationship between greenness within 100 m of residential address and self-reported overall health. They found that greenness was associated with higher overall-health scores, higher neighborhood social capital, and greater neighborhood satisfaction. Van den Berg et al. (2019) focused on the association between time spent visiting greenspace and self-reported mental health in 124 neighborhoods of four European cities. They found a modest association that was partly mediated by physical activity, social cohesion, and loneliness. Using data from the US nurses study (a large cohort study of US nurses), James et al. (2016) showed that residential greenness was associated with lower rates of mortality from all causes, and this protective effect was partly mediated by social cohesion. Dzhambov et al. (2018) examined the relationship between residential greenness, and distance to the nearest greenspace, and mental health in a sample of 399 Bulgarian students. The authors did not find a direct association between either green metric and mental health, but using mediation analysis, they found that physical activity and social cohesion were associated with improved mental health. Using data from the 2016 China labor-force dynamics study (20,533 participants from 394 neighborhoods), Liu et al. (2019) showed that residents of greener neighborhoods had lower rates of depression. This protective effect was completely mediated by physical activity, stress, and social cohesion. Liu et al. (2020) examined the relationship between greenness and self-reported mental health in 23 neighborhoods in Guangzhou, China. They decomposed social cohesion into three dimensions: neighborhood attachment, neighborly interaction, and community participation, finding that greenness (measured using street-view images) was associated with improved mental health. In addition, greenness was associated with two dimensions of social cohesion (neighborhood attachment and community participation), and these two dimensions partially mediated the protective effect of greenness.

In summary, multiple studies have shown that cohesion mediates the association between greenness and a range of health outcomes. However, the majority of these studies are cross-sectional (all observations are at a single point in time), so the observed associations may be subject to residual confounding (Schneeweiss et al., 2009). This may be a particular concern in green-health studies, where exposure metrics are correlated with other drivers of health outcomes (Schneeweiss et al., 2009). In addition, the use of self-reported measures of social cohesion may be problematic, if measures of greenness are also self-reported. This is because some common factor (optimism, for example) may lead healthy people to rate both social cohesion and greenness positively resulting in a bias towards a positive association. Therefore, there is an opportunity to advance our understanding by longitudinally studying the relationship between exposure to the natural environment and social cohesion using an objective, not self-reported, metric of social cohesion.

We chose to use voter turnout as a metric of social cohesion, because it is an objective measure, and multiple studies have shown that social cohesion and voter turnout are positively associated. For example, using data from the US module of the 1992 cross national election study, Reilly (2017) found that more socially isolated people vote less. Mattila et al. (2013) used data from five rounds of the European social survey to study the relationship between self-reported health, social cohesion, and voter turnout. The authors found that better health was associated with a higher likelihood of voting, and the relationship was partially mediated by social cohesion. Botterman et al. (2011) examined the determinants of social cohesion in Belgium. Although the authors note that no single metric can fully describe social cohesion, they do conclude that "willingness to go out and vote can be interpreted as a summary measure for civic and political engagement". More recently, Langenkamp (2021) examined the relationship between loneliness and voter turnout in separate Dutch and German cohorts. In both cases, loneliness was associated with lower voter turnout, and the relationship was partly mediated by a reduced sense of civic duty. Kawachi and Kennedy (1997) examined the relationship between income inequality, social cohesion, and health. They note that, in the US, there is a strong correlation between social cohesion, civic trust, and voter turnout.

The rest of the paper is structured as follows: Methods (Data and study area; Voter turnout data; Tree-planting and tree-cover data; Demographic covariates; Statistical analysis), Results, and Discussion.

Methods

Data and study area

Our study area is part of Multnomah County, Oregon (Fig. 1) in the United States. Specifically, observational units are the 141 Census tracts in Multnomah County that fall (>50% area) within the City of Portland. We chose tracts as our observational unit, as many of the covariates used in our analysis were observed at the tract level. In the 2010 Census, the population of these tracts was 582,468. We chose Multnomah County as our study area because it is the most populous county in Oregon and we restricted the analysis to the portion of the county that fell in Portland, as some data (tree-planting data and tree-canopy cover, for example) were only available for Portland. The time frame for the analysis is biennial primary and general elections from 2002 to 2020.

Voter turnout data

Since the passage of Oregon Ballot Measure 60 in 1998, which was implemented as an amendment to Statute ORS 254.465 (State of Oregon, 2019), mail-in voting has been the only form of voting in Oregon, although turnout data are still reported by geographically-defined electoral precincts. Because most covariates that we used in our regression models were reported at the Census-tract level, we converted precinct-level turnout data to Census-tract level data. The basis for these precinct-tract conversions was the proportion of a tract's area that was made up of different precincts. For example, If 60% of a tract was composed of precinct A (turnout 70%) and the remaining 40% was composed of precinct B (turnout 50%), then the turnout for that tract would be $(0.6 \times 70)+(0.4 \times 50)=62\%$. Multnomah County precinct boundaries changed in 2001, 2005, 2008, 2009, 2012, 2014, and 2016. For each of these years, we created crosswalks with 2010 Census tract boundaries and used these crosswalks to convert the geographic reporting unit of turnout data from precincts to Census tracts.

Tree-planting and tree-cover data

We used tree-planting data from Friends of Trees, which is a Portland based non-profit. Between 1990 and 2019, they planted 57,985 trees in private yards and parking strips (the grass strip between the road and the sidewalk) in Portland. Although individuals and other organizations planted trees in Portland, Friends of Trees is the dominant tree-planting organization in the city. It organizes neighborhood tree plantings as well as operating tree-planting contracts for the City of Portland. Since 1990, they have planted trees in 136 of the 141 tracts in our sample. To make

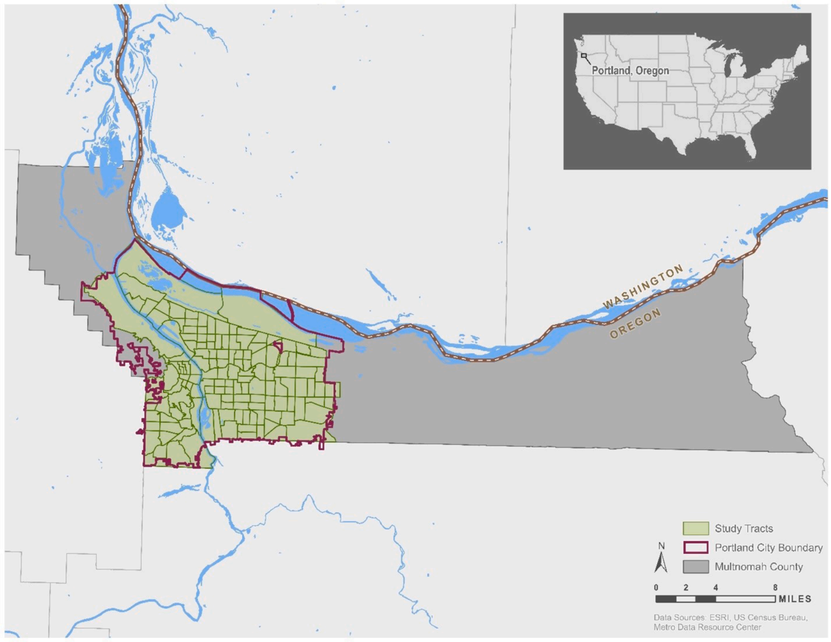

Fig. 1. Study area consists of the 141 2010 Multnomah County Census tracts that fall (>50% area) within the City of Portland.

sure that the number of trees planted was not merely a proxy for existing tree cover, we calculated existing tract-level tree-canopy cover using 1m-resolution classified aerial imagery from the US EPA's EnviroAtlas (2012)(Environmental Protection Agency, 2012). These data were only available for 2012, so, unlike our tree-planting variables, our variable for existing tree cover was time invariant. The correlation coefficient between existing tree cover and number of trees planted was −0.16, so the number of trees planted is uncorrelated with existing tree cover. To further control for a tract's existing natural amenities, we calculated the proportion of each tract that was covered by parks (City of Portland, 2021).

Tree planting may increase social cohesion, but residents of tracts with greater social cohesion may also be more likely to plant trees. Therefore, any regression model of social cohesion and tree planting could suffer from endogeneity. To avoid this issue, we created a series of lagged variables denoting the number of trees planted in two-year bands (we used two-year bands, because election data are biennial). The shortest lag was the number of trees planted 2–3 years before an election, and the lags lengthened up to a maximum lag length of 10–11 years. For example, if 10 trees were planted in a Census tract in 2010, and 15 trees in 2011, then the 2–3 year lag variable in 2013 for that tract would take on a value of 25. The use of lags achieved three things. First, if voter turnout in the current time period is regressed against tree planting in previous years, then endogeneity is no longer an issue, as the number of trees planted is pre-determined. Second, estimating a series of regression models with progressively longer lags allow us to examine the effect of older, larger trees on social cohesion (*a priori* we would not expect trees that had just been planted to have the same effect on social cohesion as mature trees, because research has shown that small trees are less appealing than large ones (Barron et al., 2021)). Third, our use of lags allowed us to make full use of 30 years of tree-planting data despite having access to only 20 years of voter-turnout data.

Demographic covariates

Past research has found an association between voter turnout and a wide range of demographic factors including race (Fraga, 2016), income (Avery, 2015), education (Burden, 2009), housing tenure (André et al., 2017), and age (Bhatti et al., 2012). Therefore, we calculated a range of demographic variables using 2010 Census data (Manson et al., 2020). We used 2010 data, because 2010 is approximately in the middle of the 2002–2020 study period.

Statistical analysis

Our data are structured as panel data: voter turnout is observed repeatedly at the Census-tract level. *A priori*, we would not expect instances of voter turnout within the same tract to be independent. Therefore, to account for this intra-tract dependence, we estimated a mixed model with a random effect at the tract level. Non-stationarity is another statistical issue that can occur with panel data: means, variances, and covariances change over time. To address this issue, we included an indicator variable for year in all regression models. We chose to represent time categorically to avoid an assumption of a linear independent relationship between voter turnout and time. In addition, a categorical year variable can accommodate the well-documented pattern of higher voter turnout in presidential-election years (Caporale and Poitras, 2014).

Voter turnout within a tract may also exhibit temporal trends. Therefore, we included a within-tract autoregressive residual structure. Finally, voter turnout and tree planting may be codetermined. Therefore, we regressed voter turnout on tree planting in early years. The shortest lag we used was 2–3 years and the longest was 10–11 years. We did not include longer tree-planting lags, as this would have reduced the number of years of election data in the sample.

We used a backwards stepwise model-selection process. Variables were dropped using progressively smaller p-value thresholds (final threshold: $p < 0.05$). With groups of similar variables—those describing education, for example—we included the variable with the lowest p-value when individually regressed against voter turnout. Statistically insignificant covariates can still be confounders (Rothman et al., 2008), so we systematically reintroduced insignificant variables and retained them if coefficients of interest changed by more than 10%. To check for multicollinearity (high intercorrelations between two or more independent variables), we estimated simple linear versions of each model (no tract-level random effects or temporal autocorrelation in the error term), which allowed us to calculate variance-inflation factors for all independent variables. We dropped any variable from our models, if it had a variance-inflation factor greater than five.

Results

Table 1 shows descriptive statistics for the analytic sample. Study data, and the code used to estimate models, are available online (Donovan et al., 2021).

When we included a within-tract autoregressive residual structure in our regression models, we found that the autoregressive parameter, rho, was always insignificant, which suggests that model errors were temporally independent. This lack of autoregressivity is perhaps not surprising, given the two-year interval between elections. Therefore, we did not include a within-tract autoregressive residual structure in our final regression models.

Table 2 shows the results from the general election model using the longest (10–11 years) lag on tree planting. Results show that turnout was higher in tracts with a higher proportion of white residents and in tracts with a higher median age. Conversely, turnout was lower in tracts with lower high-school graduation rates. These results are consistent with previous studies (Bhatti et al., 2012; Burden, 2009; Fraga, 2016). The year indicator variable shows a clear pattern of higher turnout during presidential-election years.

Existing tree cover was significantly associated with higher voter turnout, although the magnitude of the association was modest. For example, a 1-SD (12.6 percentage points) increase in tree cover was associated with a 0.93-percentage point increase in voter turnout. Tree planting was also significantly associated with higher voter turnout. A 1-SD increase in tree planting (24.2 trees) was associated with a 0.48-percentage point increase in voter turnout.

The results for the primary model were consistent with the general-election model (Table 3). The year indicator variable did not show the same presidential-election year pattern as the general election. The pattern difference is likely because Oregon's presidential primary is late in the national election cycle, so the presidential nominee has often been effectively decided before Oregon residents vote. Primary turnout patterns are more likely to be affected by down-ballot races. For example, the magnitude of the year indicator variables was greatest in 2006 and 2008. In 2006 there was a competitive Democratic primary for a U.S. House seat, and in 2008 there was a competitive Democratic primary for a U.S. Senate.

Table 1
Descriptive statistic for the analytical sample, which is composed of the 141 Census tracts in Multnomah County, Oregon, which are within (>50% area) the City of Portland.

Variable	Data source	Mean	SD	Min	Max
White (%)	US Census	77.4	11.2	46.8	92.6
Black (%)	US Census	6.31	6.48	0.375	27.9
Hispanic (%)	US Census	7.76	5.34	0	29.1
Median household income	US Census	$56,711	$22,493	$13,699	$141,776
Didn't graduate high school (%)	US Census	6.39	5.09	0	21.5
Media age (years)	US Census	36.6	4.60	22.9	46.9
Own home (%)	US Census	55.8	19.2	9.25	91.3
General election turnout (%)	Multnomah County Elections	76.9	10.0	46.0	94.1
Primary election turnout (%)	Multnomah County Elections	48.1	13.4	17.6	78.6
Tree cover ($)	US EPA EnviroAtlas	25.7	12.6	5.93	73.0
# trees planted	Friends of Trees	18.0	24.2	0	187

Table 2
Association between Census-tract level voter turnout at general elections and tree planting in Portland, Oregon, 2002–2020.

Variable	Coefficient	p-value	95% LCL	95% UCL
# trees planted 10–11 year lag	0.0199	<0.001	0.0133	0.0265
Existing tree cover (%)	0.0741	0.002	0.0266	0.122
White (%)	0.214	<0.001	0.145	0.283
Median age (years)	0.135	0.038	0.00770	0.262
Didn't graduate high school (%)	−0.543	<0.001	−0.688	0.399
YEAR (2002 Excluded)				
2004	17.3	<0.001	16.6	18.0
2006	1.52	<0.001	0.840	2.20
2008	18.8	<0.001	18.1	19.5
2010	1.91	<0.001	1.22	2.61
2012	15.0	<0.001	14.3	15.7
2014	1.51	<0.001	0.820	2.20
2016	13.3	<0.001	12.7	14.0
2018	6.75	<0.001	6.06	7.43
2020	15.1	<0.001	14.4	15.9
Tract-level random effect	8.78		6.78	11.4

Table 3
Association between Census-tract level voter turnout at primary elections and tree planting in Portland, Oregon, 2002–2020.

Variable	Coefficient	p-value	95% LCL	95% UCL
# trees planted 10–11 year lag	0.0156	<0.001	0.00859	0.0227
Existing tree cover (%)	0.0859	0.004	0.0273	0.145
White (%)	0.232	<0.001	0.146	0.317
Median age (years)	0.212	0.008	0.0549	0.369
Didn't graduate high school (%)	−0.518	<0.001	−0.696	−0.339
YEAR (2002 Excluded)				
2004	−6.48	<0.001	−7.20	−5.77
2006	8.82	<0.001	8.10	9.54
2008	8.74	<0.001	8.02	9.46
2010	−18.0	<0.001	−18.7	−17.3
2012	−11.4	<0.001	−12.1	−10.6
2014	−19.9	<0.001	−20.7	−19.2
2016	4.80	<0.001	4.07	5.52
2018	−20.5	<0.001	−21.3	−19.8
2020	1.12	0.004	0.361	1.88
Tract-level random effect	13.7		10.6	17.6

The magnitude of the coefficient on tree planting was modestly lower in the primary model. Specifically, a 1-SD increase in tree planting was associated with a 0.38-percentage point increase in turnout.

Table 4 shows how the coefficient on tree planting changes as the tree-planting lag shortens. In the general-election models, the magnitude of the coefficient on tree planting systematically declined as the lag length shortened from 10 to 11 years to 2–3 years. There was a similar pattern in the primary-election models, with the exception of the 4–5 year lag.

Table 4
Association between primary and general election turnout and different lagged tree-planting variables of different lengths.

Variable	Coefficient	p-value	95% LCL	95% UCL
	GENERAL ELECTIONS			
10–11 year lag	0.0199	<0.001	0.0133	0.0265
8–9 year lag	0.0155	<0.001	0.00987	0.0211
6–7 year lag	0.0125	<0.001	0.0072	0.0179
4–5 year lag	0.0101	<0.001	0.00463	0.0155
2–3 year lag	0.00924	0.001	0.00362	0.0149
	PRIMARY ELECTIONS			
10–11 year lag	0.0156	<0.001	0.00859	0.0227
8–9 year lag	0.0146	<0.001	0.00866	0.0206
6–7 year lag	0.0135	<0.001	0.00775	0.0192
4–5 year lag	0.0191	<0.001	0.0133	0.0248
2–3 year lag	0.00830	0.007	0.00229	0.0143

Discussion

We found that tree planting in Portland, Oregon was associated with increased voter turnout in primary and general elections. These results suggest that tree planting may increase social cohesion.

The magnitude of the association between tree planting and voter turnout was modest. For example, a 1-SD increase in tree planting was associated with a 0.48-percentage point increase in general-election turnout. However, the magnitude of the association is not the primary focus of this study, as we used voter turnout as a proxy for social cohesion. In this context, what is more relevant is that the relationship between turnout and tree planting is highly significant, and the magnitude and significance of this relationship increased as the planted trees aged and grew. The increased magnitude of the association between trees and voter turnout as trees age is consistent with *a priori* expectations: we would expect larger trees to have a bigger impact on social cohesion than smaller ones.

Our finding that tree planting is associated with increased social cohesion (as measured by voter turnout) is consistent with previous cross-sectional studies showing that the natural environment may improve social cohesion (de Vries et al., 2013; Dzhambov et al., 2018; Liu et al., 2020, 2019; Orban et al., 2017; van den Berg et al., 2019). However, our results also strengthen the evidence linking the natural environment to improved social cohesion, because we used voter turnout as an objective measure of social cohesion rather than relying on self-reported community-connectivity metrics. In addition, our longitudinal study design reduced the possibility that the observed association between tree planting and voter turnout was confounded by omitted variables. Our longitudinal study design also revealed that the magnitude of the association between tree planting and voter turnout increased as trees aged and grew. This result is consistent with *a priori* expectations and further strengthens the evidence linking the natural environment and social cohesion.

Our results also suggest that voter turnout may be an objective, inexpensive, and readily-available metric of social cohesion. This contrasts with self-reported measures of social cohesion that require primary data collection. The use of voter turnout would allow future studies of social cohesion as a mediator between the natural environment and health outcomes to use larger datasets. Furthermore, increasing social cohesion is a broad public-health goal, so examining changing voter-turnout patterns may be a quick way of identifying neighborhoods with declining social cohesion. Similarly, voter turnout could be one of several metrics used to evaluate the effectiveness of programs designed to improve social cohesion

This study has several limitations. This is an observational study, so we were unable to show that tree planting causally influences voter turnout or social cohesion. In addition, the validity of our results depends on voter turnout being a valid proxy for social cohesion. With the exception of tree planting, our independent variables were time invariant. However, the processes they described almost certainly did change over the 18-year study period. Representing time-varying processes with time-invariant variables can result in inefficient and attenuated coefficient estimates. In addition, we used tree planting-data from a single source (the non-profit group Friend of Trees). Friends of Trees was the dominant tree-planting organization during the study period. However, results could be biased, if tree planting by other organizations and individuals is correlated with planting by Friends of Trees. Finally, our conversion of turnout data from the precinct level to the Census-tract level may have reduced the efficiency of coefficient estimates.

Our study does, however, have several strengths. In contrast to past cross-sectional studies, our longitudinal study design reduces the chance of residual confounding. In addition, we used an objective measure of social cohesion rather than relying on self-reported data.

In conclusion, our results add to the body of evidence suggesting that community greening is associated with increased levels of social cohesion. This association is of particular interest given that both greenness and social cohesion are associated with improved public-health outcomes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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