Street Tree Ecosystem Services and Health Impacts across Demographics

Authors: Matthew Krempely

Abstract

Ecosystem services are a large array of amenities associated with trees in the environment. However, it is well understood that trees are not equitably distributed, and that multiple disparities exist across economic and racial groups within the US. Many studies show that tree canopy is positively associated with income, and thus those with less income experience fewer benefits associated with tree canopy. However, few studies exist which examine the covariations of ecosystem services provided by trees across various demographics. This study accomplishes four things. First, the study establishes a methodological framework for examining geographic variations in ecosystem services provided across demographic distributions. Second, this study tests how closely variations in tree ecosystem services are linked to variations in public health outcomes. Third, the study establishes covariations of ecosystem services and demographics. Fourth and finally, the study investigates the covariations of ecosystem services and demographics on public health outcomes.

Introduction

Trees are an integral part of the environment and have significant implications for the health and wellbeing of their human cohabitants. They provide numerous benefits, both immediately apparent and inconspicuous, to the environment and people around them. Increased tree canopy significantly reduces urban heat, which subsequently reduces heat-related health hazards such as hyperthermia, respiratory difficulties, heat exhaustion and heat stroke (Elmes et al., 2017; Kolosna & Spurlock, 2019). They improve air quality by absorbing pollutants, including fine particulate matter smaller than 10 microns (PM10) and PM2.5, nitrogen dioxide (NO_2), ozone (O_3), and sulfur dioxide (SO_2), which have serious implications for cardiovascular and neurological health (Nowak et al., 2014).

According to 2022 Wisconsin Department of Health Services statistics, the top five causes of death in Wisconsin are heart disease, cancer, unintentional injuries, COVID-19, and stroke (WDHS, 2024). The World Health Organization names air pollution as the second highest risk factor for non-communicable diseases (WHO, 2022). Air pollution is associated with increases in multiple types of cancers as well as strokes (Chen et al., 2022; Cheng et al., 2022; Lee et al., 2018; Parent et al., 2013; So et al., 2021; Verhoeven et al., 2021). In particular, including fine particulate matter (PM) smaller than 2.5 microns (PM2.5) has been implicated as a significant environmental factor in multiple cardiovascular diseases (Al-Kindi et al., 2020).

The impacts of trees are not limited to mental and physical health; trees provide multiple ecosystem services which also place them into the realm of green infrastructure. Tree canopy intercepts rainwater, which reduces stormwater runoff and erosion, while tree root systems facilitate water infiltration into the soil. Furthermore, evapotranspiration from trees and plants plays an important role in the urban hydrologic cycle (Berland et al., 2017; Dowtin et al., 2023). Trees provide habitat for birds and pollinators, and these contributions continue in the urban environment, making urban trees a critical part of the urban ecosystem (Larson et al., 2022). Furthermore, green spaces have multiple direct health impacts including lowering depression, anxiety, and stress, promoting physical activity, and improving community cohesion (Beyer et al., 2014; Ulmer et al., 2016; Wang & Tassinary, 2024).

While the importance of trees and the ecosystem services they provide are significant, their distributions throughout urban environments are often unequal. Multiple studies have shown that distributions of urban tree canopy vary with income, race, education levels, and other demographic categories. A national study found formerly redlined areas continue to have lower tree canopy coverage, more impervious surface area, and lower ecosystem service levels (Nowak et al., 2022). A study of heat risk-related land cover (HRRLC) found that Black, Asian, and Hispanic people were more likely to experience HRRLC than non-Hispanic White people, implicating trees and the services they provide in the persistent effects of segregation (Jesdale et al., 2013). Another multi-city study found that high income neighborhoods are more likely to experience higher levels of tree canopy, highlighting the financial dimension of these disparities (Schwarz et al., 2015).

The existence of such disparities in urban tree canopy implies the existence of disparities in the ecosystem services provided by the urban forest. While governments may be limited in their capacity to address many of these disparities directly, street trees are one avenue within the direct control of city street and forestry departments. Increasing urban tree canopy via street and park trees, therefore, may be seen as an environmental justice initiative to promote public health. However, while street trees have the potential to alleviate these disparities, they also have the potential to exacerbate them if street tree canopy is not equitably distributed or maintained.

This study will investigate the distribution of street tree ecosystem services in 13 municipalities in the Madison, Wisconsin metropolitan area to address three key questions. First, how do concentrations of street tree ecosystem services affect public health outcomes? Second, do demographic disparities exist in the distribution of street tree ecosystem services? Third, how do demographics and ecosystem services covary with public health outcomes?

To address these questions, I use bivariate and multivariate ordinary least squares (OLS) regression analysis to study the relationships between rates of heart disease, hypertension, cancer, and stroke; street tree carbon sequestration, runoff diversion, pollution removal, and oxygen production; and demographic variables of race, income, education, and age.

Materials & Methods

I obtained public tree inventory data from the "Wisconsin Community Tree Map," a collection of organizational and municipal tree inventories maintained by the Wisconsin DNR (Wisconsin Department of Natural Resources, n.d.). I also obtained supplementary inventory data from the City of Fitchburg (City of Fitchburg, 2024). I used demographic data from the 2021 American Community Survey 5-Year Estimates obtained in a TIGER/Line geodatabase (US Census Bureau, 2021) and public health data from the 2022 CDC PLACES dataset (Centers for Disease Control and Prevention, 2023), with census tracts as the unit of analysis. I used ArcGIS Pro to prepare the data for analysis, i-Tree to model ecosystem services (i-Tree, 2024)[1], and STATA statistical analysis software to conduct multivariate

Municipalities with fewer than 1000 trees, or without necessary information (i.e., diameter at breast height), were removed from the study for being unreliable or incomplete. Street tree delineation within the dataset was inconsistent; to rectify this, I used a 60-foot buffer of road centerlines to designate street trees. As the dataset consists primarily of park and street trees, as well as school districts and municipal properties, errors from incorporating private trees were not a concern.

After spatially preparing the dataset, I exported the data for each municipality into the i-Tree Eco ecosystem services modelling tool. The tool projects the annual benefits of trees based on the Urban Forestry Effects Model (Nowak & Crane, 2000). I imported the results into STATA statistical modelling software and calculated the summed total ecosystem service estimates for each census tract. I then joined the ecosystem services tables with the 2021 ACS and 2022 PLACES data. I transformed ecosystem service estimates into per capita measures by dividing the summed census tract totals by ACS 2021 total population estimates; I similarly derived percentages for race and education variables[2]. Public health variables are in percentages of positive responses among all valid responses.

The analysis is divided into three sections. I first ran a series of bivariate OLS regressions to test the relationship of ecosystem services on public health outcomes. I ran a second set of bivariate regressions to test the relationship of demographics to ecosystem services. I then ran a set of multivariate OLS regressions to test the relationship between combinations of demographics and ecosystem services on public health outcomes. I used robust standard errors in all calculations to correct for heteroskedasticity.

For the multivariate OLS regression independent variables, I used separate models for each ecosystem service to avoid collinearity. I added the percentage of the population with a bachelor's degree, median age, and median income, as well as an interaction effect that allows median income and median age to vary separately.

Results

Tables of results are available in Appendix 1.

[1] The tool used tree species, diameter at breast heigh (DBH), survey date, and geographic coordinates to calculate ecosystem service estimates. I used survey dates where possible; if only survey year was provided, I entered the date as first of June in that year.

[2] Education variables are limited to a sub-population aged 25 or greater.

Ecosystem Services and Health Outcomes

The explanatory power of ecosystem services on public health outcomes was strongest in the cancer regression models. All ecosystem services produced statistically significant results. Gross carbon sequestration per capita had the greatest explanatory power on the cancer rate ($\hat{\beta} = 0.256; R^2 = 0.28$), but pollution absorbed per-capita had the greatest effect ($\hat{\beta} = 0.506; R^2 = 0.25$). A one ounce per-capita reduction in pollution leads to a statistically significant 0.506 percentage point increase in cancer rate, on average. A one pound per-capita increase in oxygen production is associated with a statistically significant, 0.111 percentage point increase in the cancer rate, on average. A one gallon per-capita increase in runoff averted leads to a statistically significant 0.002 percentage point increase in the cancer rate, on average. A one pound per-capita increase in gross carbon sequestration leads to a statistically significant 0.255 percentage point increase in the cancer rate, on average.

Ecosystem services had the next greatest explanatory power on hypertension. Gross carbon sequestration per capita had the greatest explanatory power on the hypertension rate ($\hat{\beta} = 0.520; R^2 = 0.19$), but pollution absorbed per-capita had the greatest effect ($\hat{\beta} = 1.023; R^2 = 0.16$). Each per-capita ounce of pollution removed leads to a statistically significant 1.023 percentage point increase in the hypertension rate, on average. Each one pound per-capita increase in oxygen produced leads to a statistically significant 0.248 percentage point increase in the hypertension rate, on average. A one gallon per-capita increase in runoff averted leads to a statistically significant 0.004 percentage point increase in the hypertension rate, on average. A one pound per-capita increase in gross carbon sequestration leads to a statistically significant 0.520 percentage point increase in the hypertension rate, on average.

The explanatory power of ecosystem services was weaker on chronic heart disease and stroke. While all services had statistically significant effects on the rate of CHD, the largest R^2 value was from gross carbon sequestration per capita ($\hat{\beta} = 0.121; R^2 = 0.15$). Pollution absorbed per-capita once again had the greatest effect ($\hat{\beta} = 0.234; R^2 = 0.12$). Each per-capita ounce of pollution removed leads to a statistically significant 0.234 percentage point increase in the CHD rate, on average. Each one pound per-capita increase in oxygen produced leads to a statistically significant 0.062 percentage point increase in the CHD rate, on average. A one gallon per-capita increase in runoff averted leads to a statistically significant 0.001 percentage point increase in the CHD rate, on average. A one pound per-capita increase in gross carbon sequestration leads to a statistically significant 0.121 percentage point increase in the CHD rate, on average.

Per capita pounds of oxygen produced, and gross carbon sequestered were the only two services to have statistically significant effects on the rate of stroke. The largest R^2 value was from oxygen produced per capita ($\hat{\beta} = 0.023; R^2 = 0.09$), while gross carbon sequestered per-capita had the greatest effect ($\hat{\beta} = 0.038; R^2 = 0.07$). A one-pound per capita increase in gross carbon sequestered leads to an average 0.038 percentage point increase in the rate of stroke. A one-pound per capita increase in oxygen produced leads to an average 0.023 percentage point increase in the rate of stroke.

Demographics and Ecosystem Services

Among racial demographics, the correlative effects were relatively limited on ecosystem services. The proportion of the population that is White is positively associated with pollution reduction, avoided runoff, and gross carbon sequestration. Each one percentage point increase in the White population is associated with a 0.036-ounce, 6.45-gallon, and 0.086-pound increase in per capita pollution reduction, avoided runoff, and carbon sequestered, respectively, on average. Each one percentage point increase in the Asian population is associated with a 0.076-ounce, 0.496-pound 13.812-gallon, and 0.187-pound decrease in per capita pollution reduction, oxygen production, avoided runoff, and carbon sequestered, respectively, on average. Each one percentage point increase in the Native Hawaiian and Other Pacific Islander population is associated with an average 14.663-pound and 4.596-pound decrease in per capita oxygen production and carbon sequestered, respectively; however, only 16 census tracts had non-zero population estimates for this group, and these results should be treated with some skepticism. Each one percentage point increase in the Hispanic population is associated with an average 12-gallon decrease in per capita runoff averted.

The percentage point of high school graduates had a statistically significant positive correlation with the per capita gallons of runoff averted and carbon sequestered; each one percentage point increase in the percentage point of the population with a high school diploma leads to a 31.044-gallon and 0.255-pound per capita increase in runoff averted and carbon sequestered, on average.

The median age had statistically significant effects on all ecosystem services. Each one-year increase in the median age leads to an average 0.09-ounce, 0.422-pound, 19-gallon, and 0.213-pound increase in per capita pollution removed, oxygen produced, runoff averted, and gross carbon sequestered, respectively.

Median household income had statistically significant effects on pollution removed and gross carbon sequestered. Each $1,000 increase in median household income leads to an average 0.037-ounce and 0.078-pound increase in per capita pollution removed and gross carbon sequestered, respectively.

Ecosystem Service and Demographic Effects on Public Health Outcomes

The multivariate regression models were able to explain large proportions of the variance in the dependent variables, able to account for between 70%-88% of the variation in the dependent variables. The R^2 values were greatest in the regressions of the cancer rate on the independent variables. Holding the proportion of the population with a bachelor's degree or higher, the median age, and median income constant, a one-ounce increase in the per-capita pollution removed leads to an increase of 0.220 percentage point in the cancer rate, on average. Similarly, a one-pound per capita increase in oxygen produced leads to an average 0.016 percentage point increase in the cancer rate, all else constant; however, this effect is not statistically significant. A one-gallon per capita increase in averted runoff leads to a 0.001 percentage point increase in the cancer rate, all else constant. A one-pound per capita increase in sequestered carbon leads to a 0.106 percentage point increase in the cancer rate, all else constant. The proportion of the population with a bachelor's degree or higher did not have statistically significant effects on the cancer rate when holding ecosystem services, age, and income constant. However, the median age and median income consistently produced significant results. A one-year increase in the median age leads to an average

0.285-0.3 percentage point increase in the cancer rate, while a $1,000 increase in the median household income leads to a 0.058-0.068 percentage point increase in the cancer rate, all else constant.

Multivariate results were similarly effective at explaining the variation in CHD and hypertension. All else constant. A one-ounce increase in the per-capita pollution removed leads to an increase of 0.788 percentage point in the hypertension rate and 0.176 in the CHD rate, on average. Similarly, a one-pound per capita increase in oxygen produced leads to an average 0.060 percentage point increase in the hypertension rate and a 0.011 percentage point increase in the CHD rate, all else constant; however, these effects are not statistically significant. A one-gallon per capita increase in averted runoff leads to an average 0.002 percentage point increase in hypertension and a 0.0004 percentage point increase in the CHD rate, all else constant. A one-pound per capita increase in sequestered carbon leads to an average 0.368 percentage point increase in hypertension and a 0.082 percentage point increase in the CHD rate, all else constant. The proportion of the population with a bachelor's degree or higher, the median age, and median income consistently produced significant results. A one percentage point increase in the bachelor's degree rate leads to a 0.120-0.141 percentage point increase in hypertension and a 0.02-0.025 percentage point increase in CHD, all else constant. A one-year increase in the median age leads to a 0.56-0.602 percentage point increase in the hypertension rate and a 0.185-0.194 percentage point increase in the CHD rate, while a $1,000 increase in the median household income leads to a 0.123-0.155 percentage point increase in the hypertension rate and a 0.03-0.036 percentage point increase in the CHD rate, all else constant.

The rate of stroke was the least capably explained by multivariate models, with R^2 of 0.7-0.74. Only per-capita pollution absorbed, and per capita carbon sequestered had significant results from ecosystem services. While bachelor's degrees, median age, and median income had mixed results. A one-ounce increase in the per-capita pollution removed leads to an average increase of 0.079 percentage points in stroke, all else constant. A one-pound per capita increase in sequestered carbon leads to an average 0.036 percentage point increase in stroke, all else constant.

Discussion

This study establishes correlations between income, age, and education on key ecosystem services provided by street trees. While these demographics have established correlations with tree canopy and with public health outcomes, the results here show that ecosystem services beyond canopy, provided by municipal governments via public street trees, are not consistently distributed throughout the community, and show disparities along these lines, as well. The relationships of demographics and ecosystem services on public health show not only that ecosystem services have significant relationships with health outcomes, but also that these correlations are a factor made manifest by variations in socioeconomic factors.

Additionally, this study examines the relationship between street trees and public health outcomes. Interestingly, ecosystem services had positive effects on disease rates. This counterintuitive result necessitates further research to identify mediating and suppressing variables which can account for this discrepancy. As street trees are located along streets, greater levels of ecosystem services from such trees would imply more streets in each census tract. Thus, controlling for lane-miles per census tract and average annual daily traffic may be necessary to produce results better aligned to public health research.

While further refinements to this research are necessary, this study provides a methodological framework to generate datasets for studying ecosystem service relationships across geographic areas. These datasets may help municipal governments and regional planning commissions perform detailed research to identify disparities in their jurisdictions and prioritize areas for investment in street and public tree infrastructure. Ideally, this study will facilitate planning practitioners and others to better understand their communities.

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Appendix 1: Tables

Table 1: Bivariate regression results of ecosystem services on public health outcomes. Bolded coefficients indicate statistical significance at 95% confidence.

Hypertension Rate	$\hat{\beta}$	**std. err.**	**t**	**p**	**n**	R^2
Pollution Removed (oz. p.c.)	**1.0228**	0.3745	2.7300	0.0080	68	0.1620
Constant	23.0042	1.2200	18.8600	0.0000		
Oxygen Produced (lbs. p.c.)	**0.2476**	0.0683	3.6200	0.0010	68	0.1553
Constant	22.2965	1.3264	16.8100	0.0000		
Avoided Runoff (gal p.c.)	**0.0040**	0.0017	2.3600	0.0210	68	0.1298
Constant	22.9507	1.3543	16.9500	0.0000		
Carbon Sequestered (lbs. p.c.)	**0.5197**	0.1635	3.1800	0.0020	68	0.1897
Constant	22.4925	1.2570	17.8900	0.0000		

Chronic Heart Disease	$\hat{\beta}$	**std. err.**	**t**	**p**	**n**	R^2
Pollution Removed (oz. p.c.)	**0.2336**	0.0913	2.5600	0.0130	68	0.1203
Constant	3.5603	0.2989	11.9100	0.0000		
Oxygen Produced (lbs. p.c.)	**0.0623**	0.0175	3.5600	0.0010	68	0.1398
Constant	3.3233	0.3031	10.9700	0.0000		
Avoided Runoff (gal p.c.)	**0.0009**	0.0004	2.1400	0.0360	68	0.1036
Constant	3.5262	0.3251	10.8500	0.0000		
Carbon Sequestered (lbs. p.c.)	**0.1209**	0.0410	2.9500	0.0040	68	0.1462
Constant	3.4304	0.3046	11.2600	0.0000		

Cancer	$\hat{\beta}$	**std. err.**	**t**	**p**	**n**	R^2
Pollution Removed (oz. p.c.)	**0.5061**	0.1647	3.0700	0.0030	68	0.2450
Constant	4.2514	0.4800	8.8600	0.0000		
Oxygen Produced (lbs. p.c.)	**0.1112**	0.0280	3.9600	0.0000	68	0.1934
Constant	4.0505	0.5211	7.7700	0.0000		
Avoided Runoff (gal p.c.)	**0.0020**	0.0008	2.6200	0.0110	68	0.2063
Constant	4.1925	0.5529	7.5800	0.0000		
Carbon Sequestered (lbs. p.c.)	**0.2559**	0.0700	3.6600	0.0010	68	0.2843
Constant	4.0053	0.4803	8.3400	0.0000		

Stroke	$\hat{\beta}$	**std. err.**	**t**	**p**	**n**	R^2
Pollution Removed (oz. p.c.)	0.0712	0.0371	1.9200	0.0590	68	0.0518
Constant	1.8854	0.1362	13.8400	0.0000		
Oxygen Produced (lbs. p.c.)	**0.0234**	0.0080	2.9300	0.0050	68	0.0916
Constant	1.7548	0.1387	12.6600	0.0000		
Avoided Runoff (gal p.c.)	0.0003	0.0002	1.6100	0.1110	68	0.0460
Constant	1.8721	0.1438	13.0100	0.0000		
Carbon Sequestered (lbs. p.c.)	**0.0378**	0.0174	2.1800	0.0330	68	0.0665
Constant	1.8399	0.1415	13.0000	0.0000		

Table 2: Multivariate OLS regression results of hypertension on ecosystem services & demographics. Statistically significant coefficients are in bold font.

Hypertension																
	Model 1				**Model 2**				**Model 3**				**Model 4**			
n	67				67				67				67			
R^2	0.815				0.7499				0.7684				0.8126			
	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t
Pollution Removed (oz. p.c.)	**0.7881**	0.1164	6.7700	0.0000												
Oxygen Produced (lbs. p.c.)					0.0601	0.0418	1.4400	0.1550								
Avoided Runoff (gal p.c.)									**0.0020**	0.0006	3.4800	0.0010				
Carbon Sequestered (lbs. p.c.)													**0.3677**	0.0442	8.3200	0.0000
Bachelor's degree (%)	**-0.1405**	0.0238	-5.9100	0.0000	**-0.1204**	0.0279	-4.3100	0.0000	**-0.1302**	0.0258	-5.0600	0.0000	**-0.1398**	0.0240	-5.8200	0.0000
Median Age	**0.5974**	0.0544	10.9800	0.0000	**0.6018**	0.0714	8.4300	0.0000	**0.5599**	0.0687	8.1500	0.0000	**0.5843**	0.0537	10.8800	0.0000
MHI ($1k)	**0.1510**	0.0445	3.3900	0.0010	**0.1549**	0.0571	2.7100	0.0090	**0.1225**	0.0562	2.1800	0.0330	**0.1500**	0.0441	3.4000	0.0010
Median Age x MHI	-0.0035	0.0010	-3.6700	0.0010	-0.0032	0.0013	-2.4700	0.0160	-0.0025	0.0013	-1.9200	0.0600	-0.0034	0.0009	-3.6900	0.0000
Constant	8.0952	2.5490	3.1800	0.0020	6.7904	3.2851	2.0700	0.0430	8.7994	3.0102	2.9200	0.0050	8.2458	2.5347	3.2500	0.0020

Table 3: Multivariate OLS regression results of chronic heart disease (CHD) on ecosystem services & demographics. Statistically significant coefficients are in bold font.

Chronic Heart Disease																
	Model 1				**Model 2**				**Model 3**				**Model 4**			
n	67				67				67				67			
R^2	0.8073				0.7599				0.7711				0.8049			
	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t
Pollution Removed (oz. p.c.)	**0.1761**	0.0299	5.8900	0.0000												
Oxygen Produced (lbs. p.c.)					0.0106	0.0109	0.9700	0.3380								
Avoided Runoff (gal p.c.)									**0.0004**	0.0002	2.2100	0.0310				
Carbon Sequestered (lbs. p.c.)													**0.0816**	0.0131	6.2300	0.0000
Bachelor's degree (%)	**-0.0245**	0.0072	-3.3900	0.0010	**-0.0198**	0.0080	-2.4800	0.0160	**-0.0219**	0.0077	-2.8500	0.0060	**-0.0243**	0.0073	-3.3500	0.0010
Median Age	**0.1913**	0.0236	8.0900	0.0000	**0.1941**	0.0262	7.4100	0.0000	**0.1848**	0.0257	7.2000	0.0000	**0.1885**	0.0238	7.9300	0.0000
MHI ($1k)	**0.0350**	0.0114	3.0700	0.0030	**0.0364**	0.0145	2.5100	0.0150	**0.0297**	0.0142	2.0900	0.0410	**0.0348**	0.0114	3.0500	0.0030
Median Age x MHI	-0.0011	0.0003	-3.6100	0.0010	-0.0010	0.0004	-2.7600	0.0080	-0.0009	0.0004	-2.3300	0.0230	-0.0011	0.0003	-3.6000	0.0010
Constant	-1.5425	0.8477	-1.8200	0.0740	-1.8739	0.9706	-1.9300	0.0580	-1.4533	0.9175	-1.5800	0.1180	-1.5125	0.8514	-1.7800	0.0810

Table 4: Multivariate OLS regression results of cancer on ecosystem services & demographics. Statistically significant coefficients are in bold font.

Cancer																
	Model 1				**Model 2**				**Model 3**				**Model 4**			
n	67				67				67				67			
R^2	0.8822				0.8507				0.8622				0.8829			
	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t
Pollution Removed (oz. p.c.)	**0.2204**	0.0391	5.6400	0.0000												
Oxygen Produced (lbs. p.c.)					0.0158	0.0140	1.1300	0.2630								
Avoided Runoff (gal p.c.)									**0.0006**	0.0002	3.4800	0.0010				
Carbon Sequestered (lbs. p.c.)													**0.1055**	0.0172	6.1200	0.0000
Bachelor's degree (%)	-0.0055	0.0084	-0.6600	0.5140	0.0002	0.0094	0.0200	0.9850	-0.0029	0.0088	-0.3300	0.7440	-0.0055	0.0083	-0.6600	0.5140
Median Age	**0.2971**	0.0214	13.8900	0.0000	**0.2990**	0.0271	11.0500	0.0000	**0.2848**	0.0249	11.4400	0.0000	**0.2931**	0.0214	13.6600	0.0000
MHI ($1k)	**0.0669**	0.0126	5.3200	0.0000	**0.0682**	0.0166	4.1000	0.0000	**0.0579**	0.0163	3.5600	0.0010	**0.0665**	0.0126	5.2800	0.0000
Median Age x MHI	-0.0016	0.0003	-5.0200	0.0000	-0.0015	0.0004	-3.5200	0.0010	-0.0013	0.0004	-2.9800	0.0040	-0.0016	0.0003	-5.0500	0.0000
Constant	-6.1529	0.8223	-7.4800	0.0000	-6.5317	1.0279	-6.3500	0.0000	-5.8898	0.9201	-6.4000	0.0000	-6.0941	0.8271	-7.3700	0.0000

Table 5: Multivariate OLS regression results of stroke on ecosystem services & demographics. Statistically significant coefficients are in bold font.

Stroke																
	Model 1				**Model 2**				**Model 3**				**Model 4**			
n	67				67				67				67			
R^2	0.7436				0.6987				0.7061				0.7397			
	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t	$\hat{\beta}$	std. err.	t	P>t
Pollution Removed (oz. p.c.)	**0.0795**	0.0156	5.1000	0.0000												
Oxygen Produced (lbs. p.c.)					0.0043	0.0053	0.8100	0.4210								
Avoided Runoff (gal p.c.)									0.0002	0.0001	1.6200	0.1100				
Carbon Sequestered (lbs. p.c.)													**0.0361**	0.0068	5.2900	0.0000
Bachelor's Degree (%)	**-0.0171**	0.0036	-4.7400	0.0000	**-0.0150**	0.0039	-3.8400	0.0000	**-0.0157**	0.0038	-4.1400	0.0000	**-0.0170**	0.0036	-4.6600	0.0000
Median Age	**0.0796**	0.0129	6.1700	0.0000	**0.0811**	0.0138	5.9000	0.0000	**0.0777**	0.0136	5.7200	0.0000	**0.0784**	0.0129	6.0600	0.0000
MHI ($1k)	**0.0151**	0.0063	2.4200	0.0190	**0.0159**	0.0075	2.1200	0.0380	0.0133	0.0073	1.8200	0.0740	**0.0151**	0.0062	2.4200	0.0190
Median Age x MHI	-0.0005	0.0002	-3.0700	0.0030	-0.0005	0.0002	-2.5200	0.0140	-0.0004	0.0002	-2.2200	0.0300	-0.0005	0.0002	-3.0600	0.0030
Constant	0.1771	0.4739	0.3700	0.7100	0.0213	0.5145	0.0400	0.9670	0.1804	0.4999	0.3600	0.7190	0.1862	0.4749	0.3900	0.6960

Table 6: Bivariate OLS regression results of per-capita pollution removed on demographics. Statistically significant coefficients are in bold font.

Pollution Removed (oz. p.c.)	$\hat{\beta}$	std. err.	t	p	n	R^2
White Population (%)	**0.0365**	0.0140	2.6100	0.0110	68	0.0445
Constant	-0.3804	0.9972	-0.3800	0.7040		
Black Population (%)	-0.0541	0.0345	-1.5700	0.1210	68	0.0254
Constant	2.8630	0.4664	6.1400	0.0000		
AI/AN Population (%)	-0.2050	0.3144	-0.6500	0.5170	68	0.0020
Constant	2.5576	0.3126	8.1800	0.0000		
Asian Population (%)	**-0.0757**	0.0279	-2.7200	0.0080	68	0.0412
Constant	2.9869	0.2873	10.4000	0.0000		
NH/PI Population (%)	-1.7251	1.0229	-1.6900	0.0960	68	0.0103
Constant	2.5868	0.2728	9.4800	0.0000		
"Other Race" Population (%)	0.0128	0.0887	0.1400	0.8860	68	0.0002
Constant	2.4796	0.3506	7.0700	0.0000		
Multi-racial Population (%)	-0.0552	0.0389	-1.4200	0.1600	68	0.0112
Constant	2.8331	0.4426	6.4000	0.0000		
Hispanic Population (%)	-0.0365	0.0240	-1.5200	0.1330	68	0.0130
Constant	2.7743	0.4417	6.2800	0.0000		
High School Graduate (%)	0.1145	0.0590	1.9400	0.0570	67	0.0451
Constant	-8.3770	5.4099	-1.5500	0.1260		
Bachelor's Degree + (%)	0.0448	0.0237	1.8900	0.0630	67	0.1251
Constant	0.0732	1.1232	0.0700	0.9480		
Median Age	**0.0887**	0.0260	3.4100	0.0010	68	0.1137
Constant	-0.7656	0.8745	-0.8800	0.3840		
MHI ($1k)	**0.0367**	0.0118	3.1200	0.0030	67	0.2323
Constant	-0.2444	0.7104	-0.3400	0.7320		

Table 7: Bivariate OLS regression results of per-capita oxygen produced on demographics. Statistically significant coefficients are in bold font.

Oxygen Produced (lbs. p.c.)	$\hat{\beta}$	std. err.	t	p	n	R^2
White Population (%)	**0.0365**	0.0140	2.6100	0.0110	68	0.0445
Constant	-0.3804	0.9972	-0.3800	0.7040		
Black Population (%)	-0.0541	0.0345	-1.5700	0.1210	68	0.0254
Constant	2.8630	0.4664	6.1400	0.0000		
AI/AN Population (%)	-0.2050	0.3144	-0.6500	0.5170	68	0.0020
Constant	2.5576	0.3126	8.1800	0.0000		
Asian Population (%)	**-0.0757**	0.0279	-2.7200	0.0080	68	0.0412
Constant	2.9869	0.2873	10.4000	0.0000		
NH/PI Population (%)	-1.7251	1.0229	-1.6900	0.0960	68	0.0103
Constant	2.5868	0.2728	9.4800	0.0000		
"Other Race" Population (%)	0.0128	0.0887	0.1400	0.8860	68	0.0002
Constant	2.4796	0.3506	7.0700	0.0000		
Multi-racial Population (%)	-0.0552	0.0389	-1.4200	0.1600	68	0.0112
Constant	2.8331	0.4426	6.4000	0.0000		
Hispanic Population (%)	-0.0365	0.0240	-1.5200	0.1330	68	0.0130
Constant	2.7743	0.4417	6.2800	0.0000		
High School Graduate (%)	0.2567	0.2161	1.1900	0.2390	67	0.0140
Constant	-11.1045	20.2069	-0.5500	0.5850		
Bachelor's Degree + (%)	0.0341	0.0661	0.5200	0.6070	67	0.0045
Constant	11.4950	3.5789	3.2100	0.0020		
Median Age	**0.4222**	0.1044	4.0500	0.0000	68	0.1575
Constant	-2.3580	3.5246	-0.6700	0.5060		
MHI ($1k)	0.0663	0.0451	1.4700	0.1460	67	0.0469
Constant	8.3444	3.1883	2.6200	0.0110		

Table 8: Bivariate OLS regression results of per-capita water runoff avoided on demographics. Statistically significant coefficients are in bold font.

Avoided Runoff (gal p.c.)		$\hat{\beta}$	std. err.	t	p	n	R^2
White Population (%)		**0.0365**	0.0140	2.6100	0.0110	68	0.0445
	Constant	-0.3804	0.9972	-0.3800	0.7040		
Black Population (%)		-0.0541	0.0345	-1.5700	0.1210	68	0.0254
	Constant	2.8630	0.4664	6.1400	0.0000		
AI/AN Population (%)		-0.2050	0.3144	-0.6500	0.5170	68	0.0020
	Constant	2.5576	0.3126	8.1800	0.0000		
Asian Population (%)		**-0.0757**	0.0279	-2.7200	0.0080	68	0.0412
	Constant	2.9869	0.2873	10.4000	0.0000		
NH/PI Population (%)		-1.7251	1.0229	-1.6900	0.0960	68	0.0103
	Constant	2.5868	0.2728	9.4800	0.0000		
"Other Race" Population (%)		0.0128	0.0887	0.1400	0.8860	68	0.0002
	Constant	2.4796	0.3506	7.0700	0.0000		
Multi-racial Population (%)		-0.0552	0.0389	-1.4200	0.1600	68	0.0112
	Constant	2.8331	0.4426	6.4000	0.0000		
Hispanic Population (%)		-0.0365	0.0240	-1.5200	0.1330	68	0.0130
	Constant	2.7743	0.4417	6.2800	0.0000		
High School Graduate (%)		**31.0436**	13.3679	2.3200	0.0230	67	0.0635
	Constant	-2298.5210	1224.2420	-1.8800	0.0650		
Bachelor's Degree + (%)		7.3882	5.8807	1.2600	0.2130	67	0.0650
	Constant	255.5317	278.8737	0.9200	0.3630		
Median Age		**18.9969**	4.4151	4.3000	0.0000	68	0.0995
	Constant	-46.8933	147.2020	-0.3200	0.7510		
MHI ($1k)		6.1457	3.4628	1.7700	0.0810	67	0.1248
	Constant	195.4203	218.2594	0.9000	0.3740		

Table 9: Bivariate OLS regression results of per-capita carbon sequestered on demographics. Statistically significant coefficients are in bold font.

Carbon Sequestered (lbs. p.c.)	$\widehat{\beta}$	std. err.	t	p	n	R^2
White Population (%)	**0.0365**	0.0140	2.6100	0.0110	68	0.0445
Constant	-0.3804	0.9972	-0.3800	0.7040		
Black Population (%)	-0.0541	0.0345	-1.5700	0.1210	68	0.0254
Constant	2.8630	0.4664	6.1400	0.0000		
AI/AN Population (%)	-0.2050	0.3144	-0.6500	0.5170	68	0.0020
Constant	2.5576	0.3126	8.1800	0.0000		
Asian Population (%)	**-0.0757**	0.0279	-2.7200	0.0080	68	0.0412
Constant	2.9869	0.2873	10.4000	0.0000		
NH/PI Population (%)	-1.7251	1.0229	-1.6900	0.0960	68	0.0103
Constant	2.5868	0.2728	9.4800	0.0000		
"Other Race" Population (%)	0.0128	0.0887	0.1400	0.8860	68	0.0002
Constant	2.4796	0.3506	7.0700	0.0000		
Multi-racial Population (%)	-0.0552	0.0389	-1.4200	0.1600	68	0.0112
Constant	2.8331	0.4426	6.4000	0.0000		
Hispanic Population (%)	-0.0365	0.0240	-1.5200	0.1330	68	0.0130
Constant	2.7743	0.4417	6.2800	0.0000		
High School Graduate (%)	**0.2551**	0.1204	2.1200	0.0380	67	0.0496
Constant	-18.3350	11.0646	-1.6600	0.1020		
Bachelor's Degree + (%)	0.0906	0.0474	1.9100	0.0600	67	0.1130
Constant	1.0130	2.2818	0.4400	0.6590		
Median Age	**0.2131**	0.0560	3.8100	0.0000	68	0.1447
Constant	-1.9424	1.8728	-1.0400	0.3030		
MHI ($1k)	**0.0779**	0.0241	3.2400	0.0020	67	0.2316
Constant	0.0879	1.4860	0.0600	0.9530		