Driving Emissions

The Relationship between Household Income and On-Road Emissions in Massachusetts

Introduction

The combustion of fossil fuels from transportation sector has been the largest source of carbon dioxide (CO2) emissions in the US for the past decade. In Massachusetts, during 2016, the transportation sector was responsible for 43% of GHG emissions from which 61% of CO2 emissions came from cars, trucks and buses that used petroleum. While overall levels of CO2 have been decreasing, the on-road emissions continue to rise with increasing population and more vehicles entering the market. This contributes to air pollution which has significant impacts on human health and the environment especially in densely populated urban areas. In fact, there is a large variation of on-road CO2 exposure across different locations and types of communities in Massachusetts

Previously it has been shown that communities of color and low income live near major highways and thus are affected more by on-road emissions. Similarly, it has been agreed that higher income is associated with higher rates of fuel consumption and thus higher level of emissions. This analysis tries to verify both of the relationship between income and CO2 or equivalent emissions from roads.

Methodology

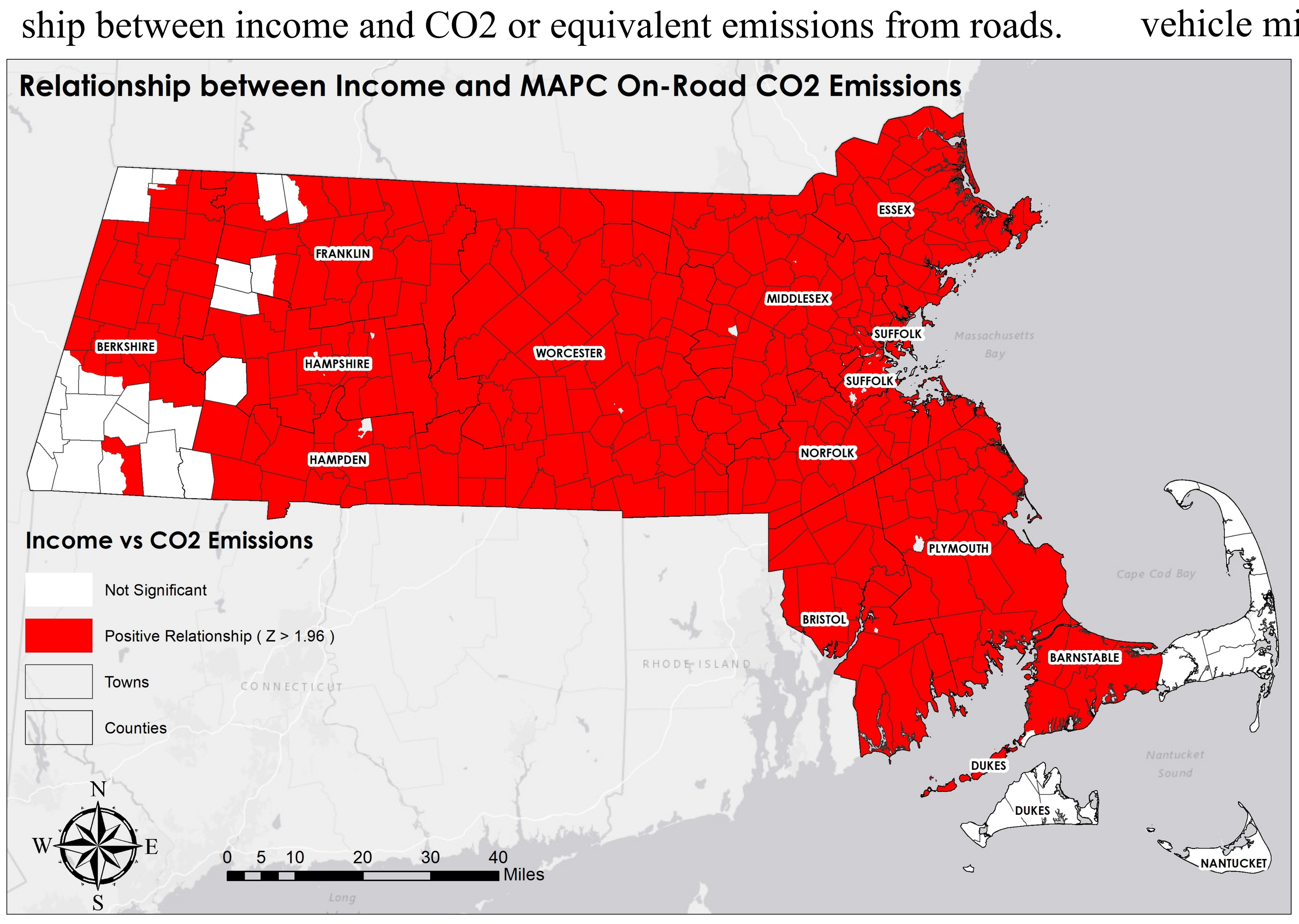
To understand the relationship between income and vehicle emissions, I used two different sources of emission estimates. The first is collected from the MAPC Vehicle Census database which is an estimation of CO2 emissions per passenger per day for each quarter of the year. The amounts are extracted based on the first and last odometer readings of every vehicle in each block group so ultimately, they represent the fuel consumption by the residents in each block group regardless of their driving routes. To find the yearly emissions for 2014, I use a SQL query where I first multiply the tons of CO2 per day per household by 91.25 for each quarter and sum them for all quarters by block group.

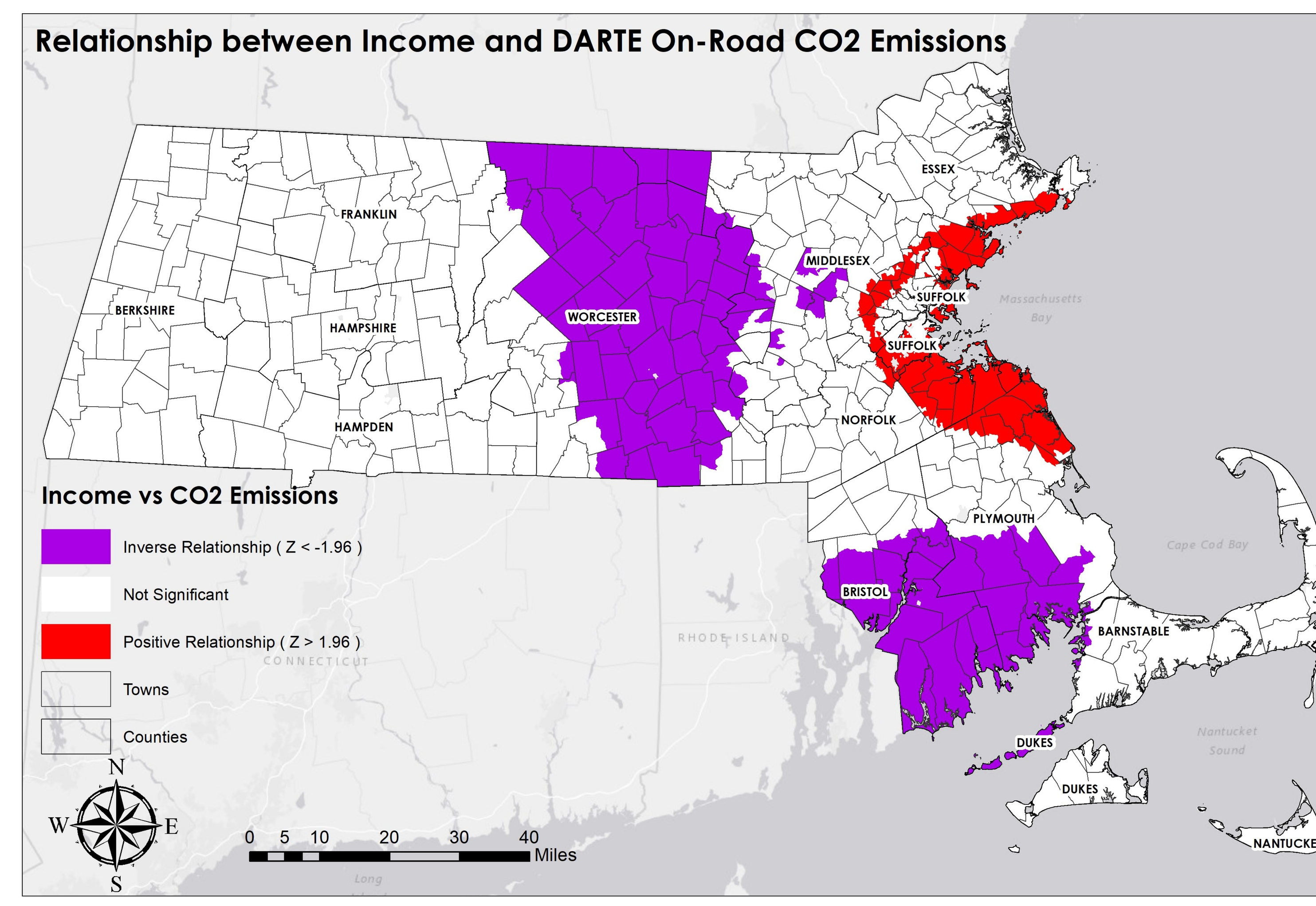
The second source of emission estimates comes from the Database of Road Transportation Emissions (DARTE) prepared by the Oak Ridge National Laboratory. This database uses roadway-level vehicle miles traveled records from Highway Performance Monitoring Systems and state-specific emission factors to estimate emissions. I calculate the emission densities to account for differences in sizes of block groups.

The relationship between income and fuel consumption-based emissions is expected to be positive, meanwhile the same relationship based on emissions within geographical limits is expected to be negative arguing that lower income communities are exposed and affected more from vehicle emissions. To test these assumption, statistically significant hot and cold spots are identified first, using the Local Moran's I statistic for median household income, MAPC and DARTE annual on-road emissions.

Then Geographically Weighted Regressions (GWR) are performed to understand spatially varying relationships between income and the emission estimates. For the MAPC dataset, annual per household emissions are regressed on median household income. For the second GWR, additional attributes are joined to the emissions for each block group. Euclidean distance from major highways, number of jobs within 45-minutes drive as a proxy for urban form and the median household income are the regressors of the per acre emission densities.

Finally, ordinary least square regression is performed to find the relationship between the explanatory variables and on-road emissions. The results are expected to show inverse relationship between income and emissions from motor vehicles.


Relationship between Income and MAPC On-Road CO2 Emissions


Relationship between Income and DARTE On-Road CO2 Emissions

Results

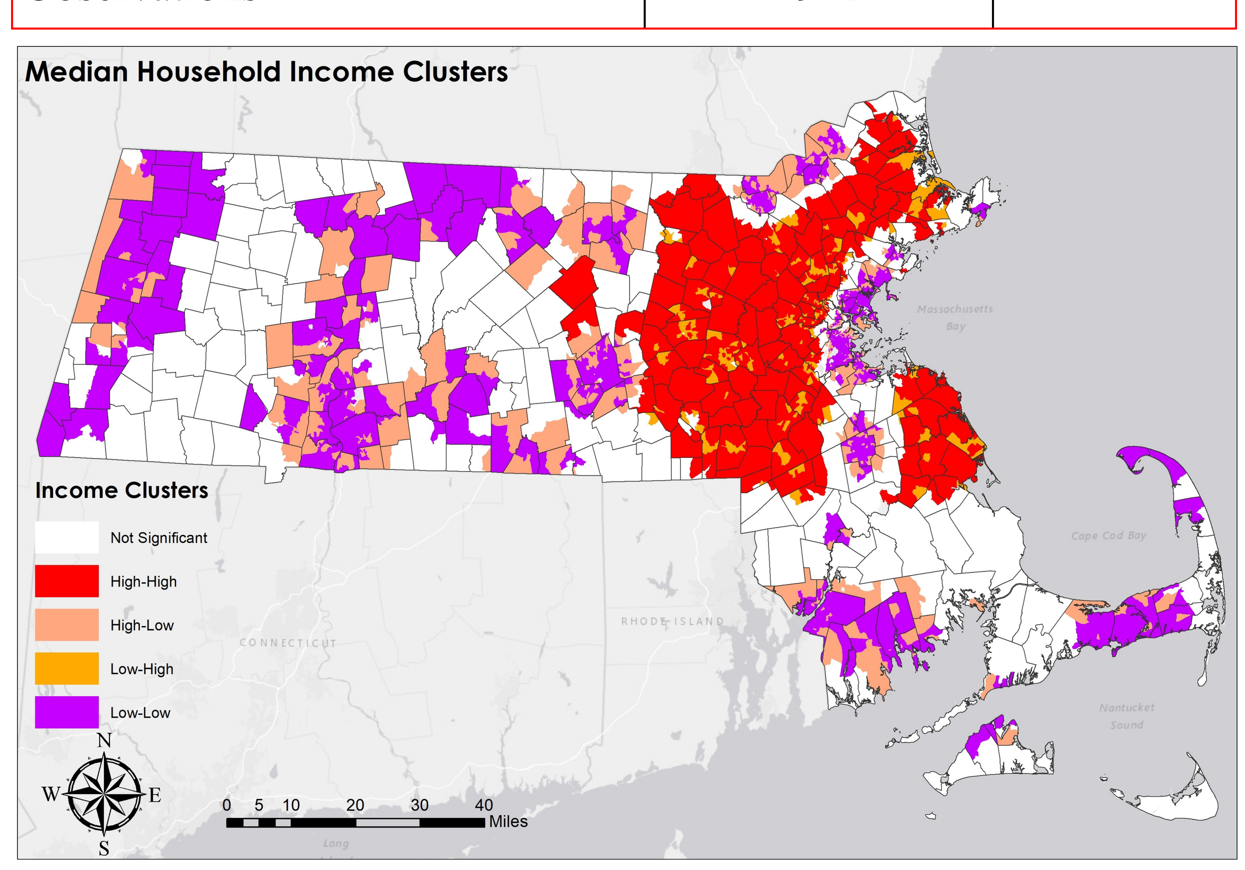
The results from GWR are two-fold. When considering the consumption-based emissions from MAPC, a positive relationship between income and CO2 emissions is found. These results seem to be consistent for the majority of the Commonwealth except for some towns located in the east of Barnstable, Dukes and Nantucket counties as well as in south Berkshire. This relationship seems intuitive as income drives higher fuel consumption and thus emissions.

On the other hand, the relationship between income and emissions is both inverse and positive when considering the geographically bounded DARTE emissions from DARTE. On-road emissions are positively correlated with income in coastal towns surrounding the Massachusetts Bay and the ones along the I-95 ring, while the relationship is negative for most block groups in Worchester, south Bristol and Plymouth counties This means that there is an evidence of low income population and higher levels of vehicle emissions. These findings

Finally, the results from the OLS regression show statistically significant inverse relationship between income and CO2 emissions from driving. Specifically, for every additional $1000 in median household income, on-road emissions decrease by 44kg/acre. Increasing the mean distance to majors roads by 1km decreases emissions by 968kg/acre, while for every additional 1000 jobs within 45-min drive emission density will go up by 106kg/acre. These results are intuitive and consistent with previous literature.

OLS Regression Results (DARTE Emission Density)

Variable	Coefficient	P-value
Median Household Income	-0.044	0.0038
Distance to roads	-0.968	0.0000
Jobs within 45-min drive	0.106	0.0000
Constant	9627.256	0.0000
R-Squared	0.093	
Observations	4941	

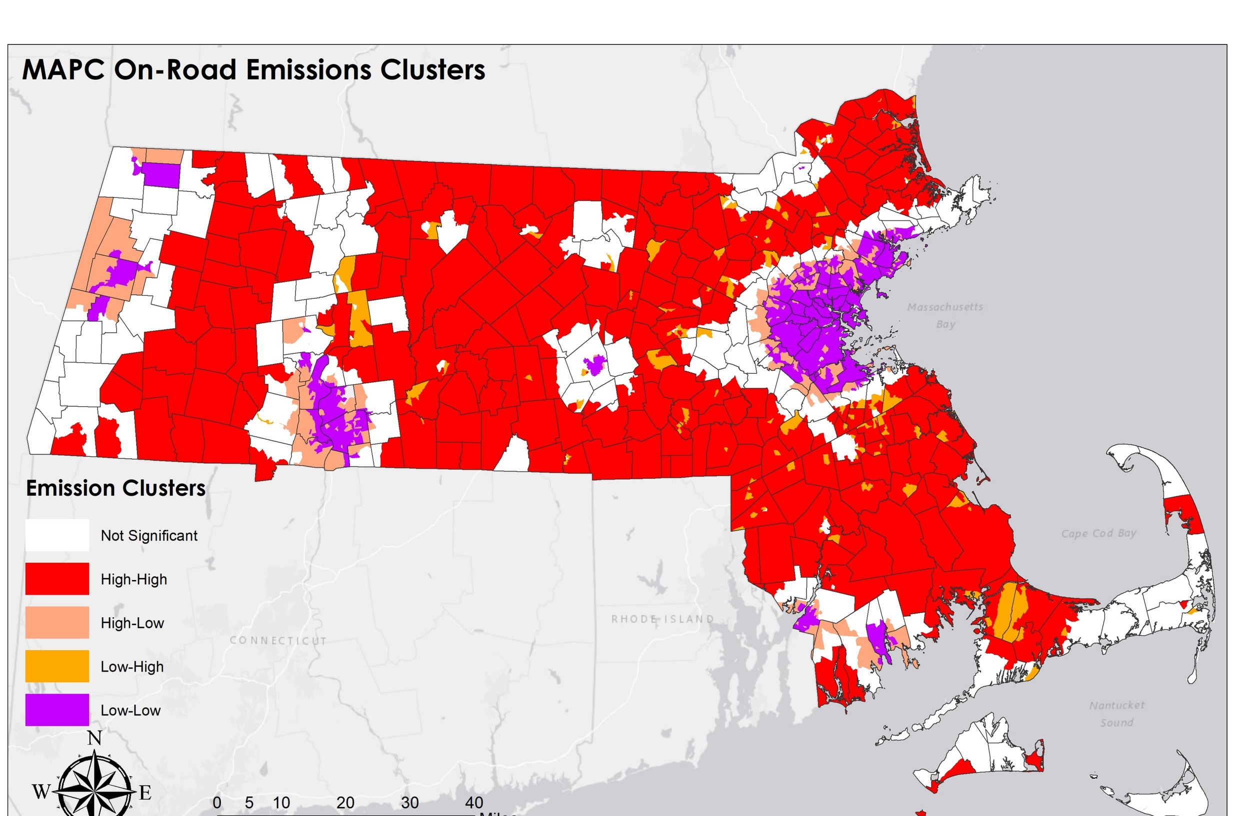

Median Household Income Clusters

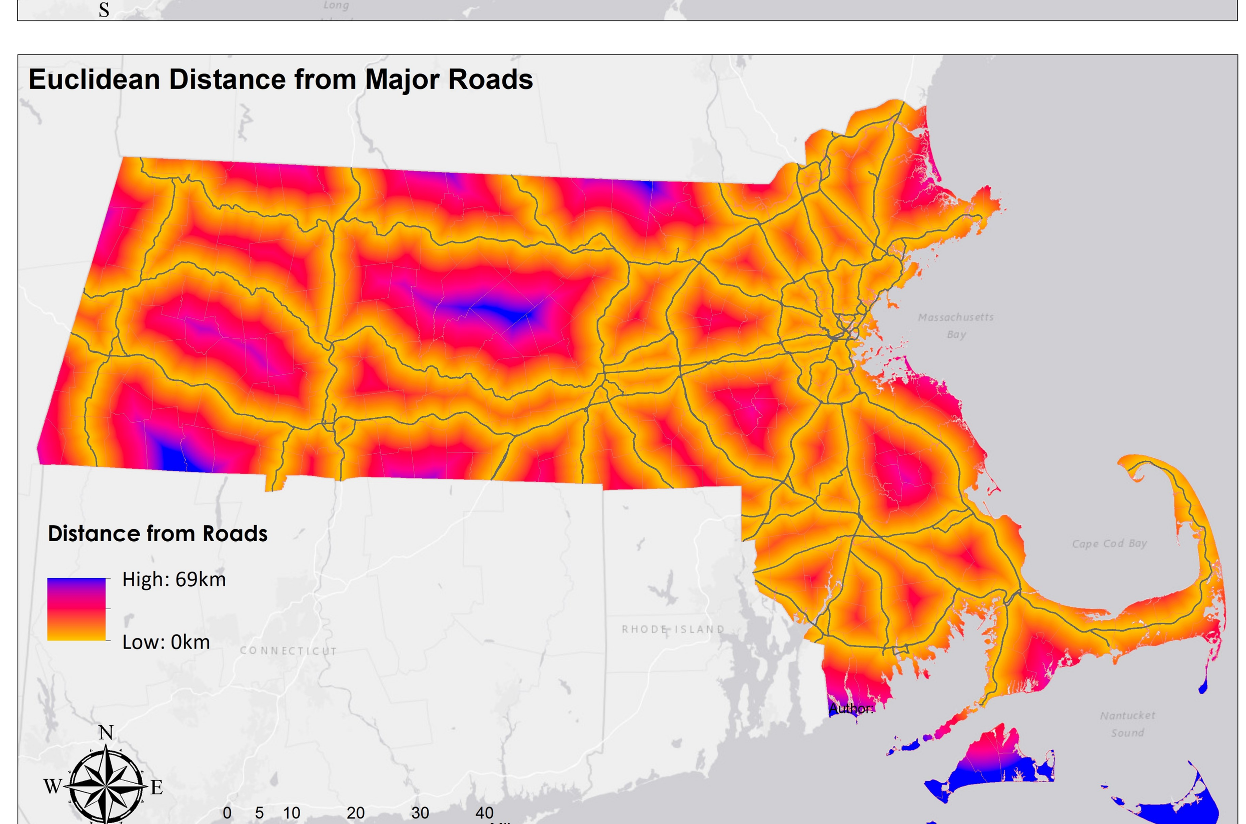
Conclusion

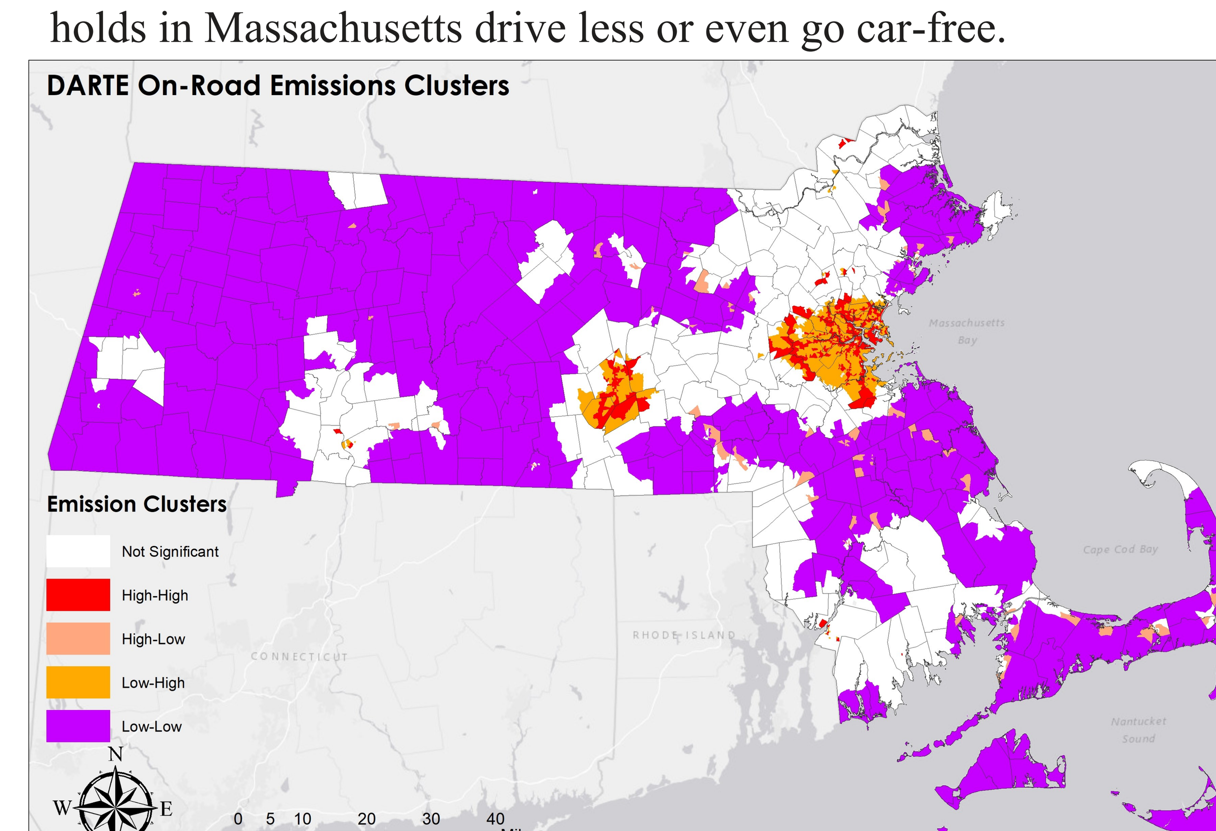
In this analysis, there were two findings. It was identified that higher income drives the emissions associated with vehicle fuel consumption while the ones affected by higher rates of emissions are the lower income communities in Massachusetts. The findings are supporting the notion

One of the limitations was the very low value for the R-square of the OLS indicating that only around 10% of the variance for the dependent variable was explained by the independent variables. This could imply an omitted variable bias and more regressors that explain emissions should be considered. As well, the effects of income on emissions are not reflected immediately, therefore a distributed lag model could be used to improve the findings.

This analysis is an addition to the existing literature to serve as a tool for targeting the state's policies for congestion taxes, vehicle electrification, improving public transportation services and the infrastructure for walking and biking, and increasing the supply of affordable housing in communities close to transit can help households in Massachusetts drive less or even go car-free.


MAPC On-Road Emissions Clusters


Euclidean Distance from Major Roads


DARTE On-Road Emissions Clusters

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Projection: Lambert Conformal Conic
Coordinate System: NAD 1983 StatePlane Massachusetts Mainland FIPS 2001
Data Sources: ORNL—DARTE, Social Explorer—ACS, MAPC Vehicle Census, EPA—Smart Location, MassGIS
Basemap: ESRI, Garman, HERE, OpenStreetMap

References

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