Charging the Future:

Optimal Locations for Electric Vehicle (EV) Charging Stations in the MAPC Region

INTRODUCTION

Fossil fuel-powered private vehicles have made the transportation sector the leading and most rapidly growing contributor to greenhouse gas (GHG) emissions in America. Since the use of private vehicles remains important in the country, different states - including Massachusetts - have described promoting the use of electric vehicles (EVs) as an important policy option for reducing GHG emissions from private vehicles. However, in addition to factors such as high upfront cost of EVs, limited driving range and a lack of EV charging stations have significantly limited EV adoption in different U.S. states. Hence, identifying locations where EV charging stations can better serve current and potential EV owners is critical for promoting the use of EVs. This project aims to identify optimal locations within the Metropolitan Area Planning Council (MAPC) region for deploying EV charging stations using two different multi-criteria suitability analysis methods that consider some key variables associated with EV ownership and EV charging infrastructure.

RESEARCH QUESTION

Where are suitable locations for deploying EV charging stations in the MAPC region considering EV ownership, commute distances, access to EV charging stations, and socioeconomic factors?

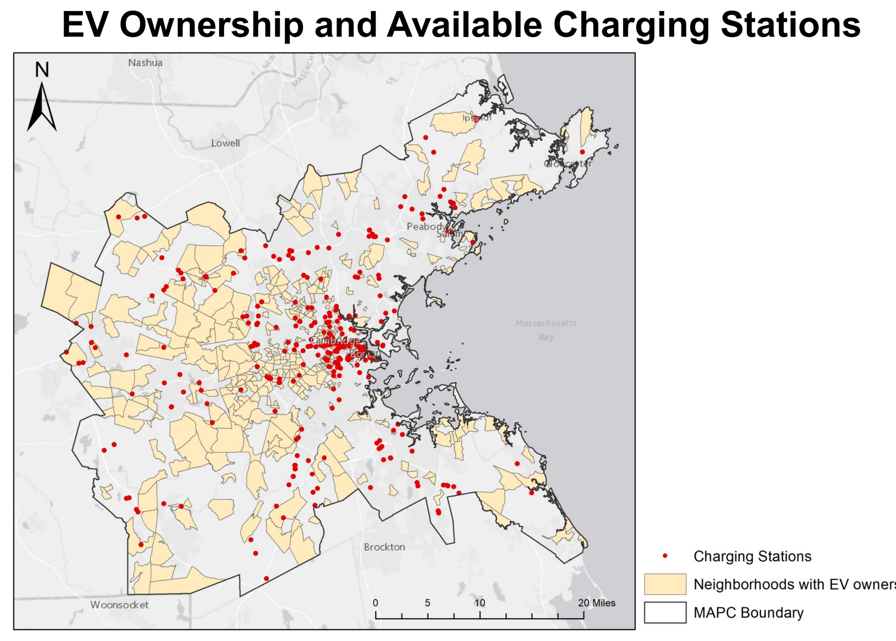
DATA

Census block groups within the MAPC region were defined as neighborhoods for this study. The presence of EV owners in a neighborhood, proximity to already available charging stations, population density, land use classification, commute distances, and income were the main factors used to assess if a location can be suitable for EV charging stations. 2009 to 2014 data from MAPC's Massachusetts Vehicle Summary Statistics were used to identify block groups with at least one EV owner while data for population density, income, and commute distances were obtained from the American Community Survey. Data for such input factors were joined to the Massachusetts census block group layer in a file geodatabase. Additionally, the locations of currently available EV charging stations were retrieved from the Alternative Fuels Data Center and were geocoded; this layer along with layers for land use codes and elevation were also imported into the file geodatabase.

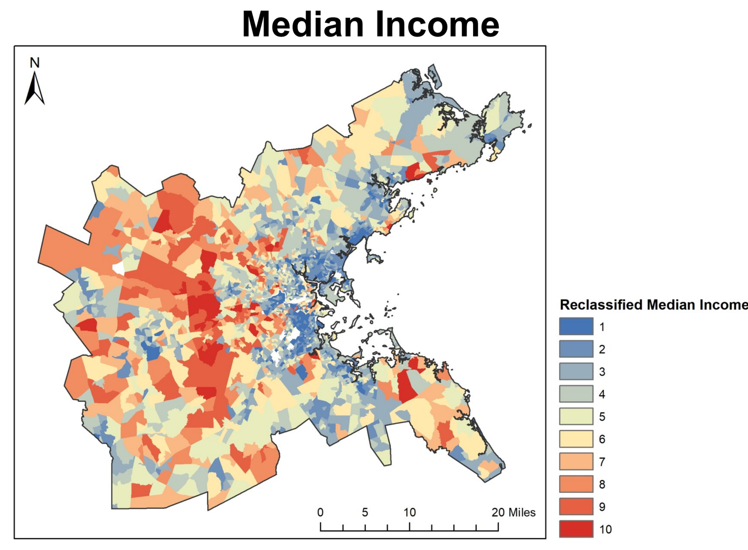
Data Description

Data layer:	Variables of Interest:	Format:
Massachusetts Vehicle Summary Statistics	-Block groups with/ without EV owners	-Polygon feature class
American Community Survey	-Median income -Population density -Median commute distance	-Polygon feature class
Alternative Fuels Data Center	-Locations of EV charging stations	-Point feature class
MassGIS Data: Digital Elevation Model	-Surface elevation	-Raster dataset
MassGIS Data: Land Use	-Land use code	-Polygon feature class

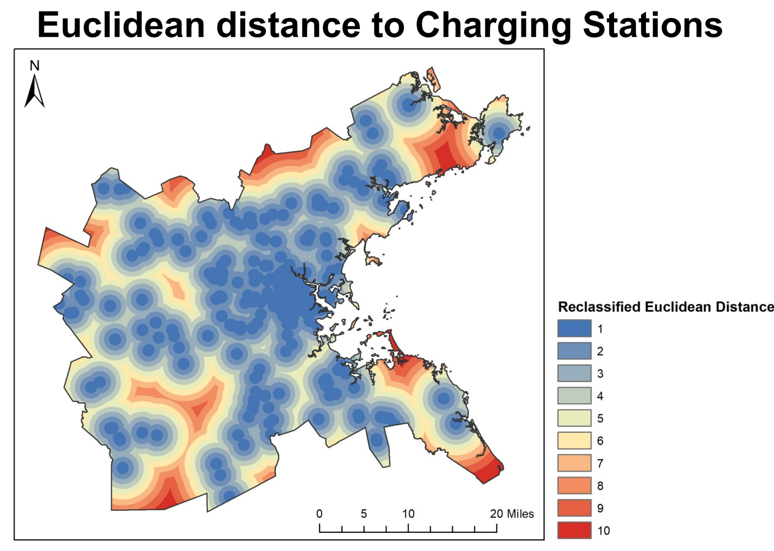
EV Ownership and Available Charging Stations



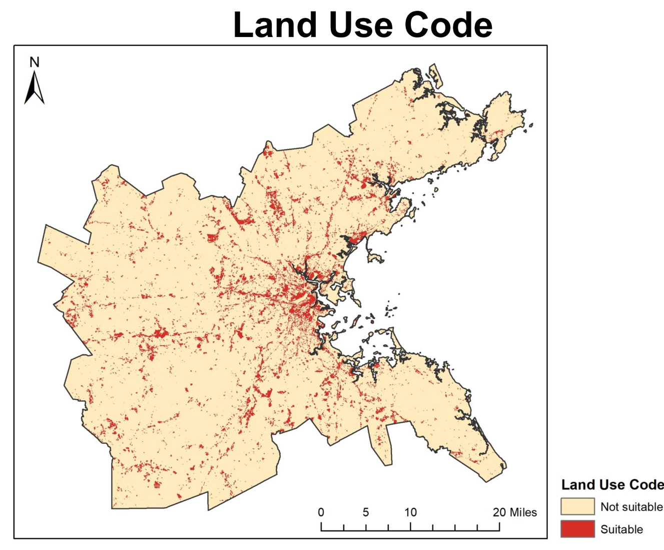
Median Income



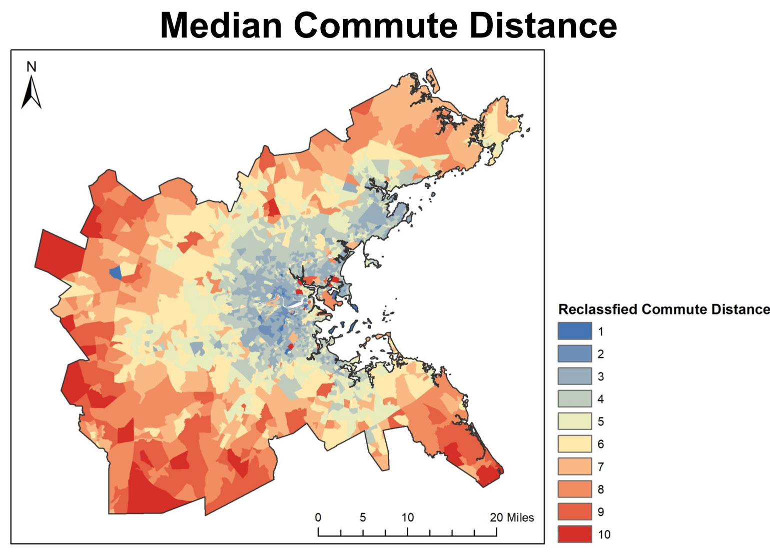
Euclidean distance to Charging Stations



Land Use Code



Median Commute Distance



METHODS

All polygon feature classes were converted to raster datasets using the feature to raster tool. Proximity to currently available charging stations was obtained using the Euclidean distance tool and the slope tool was used to convert the elevation raster into a slope raster. All these input layers were then clipped according to the MAPC region boundary and used to create two final suitability maps using the fuzzy overlay and weighted overlay tools.

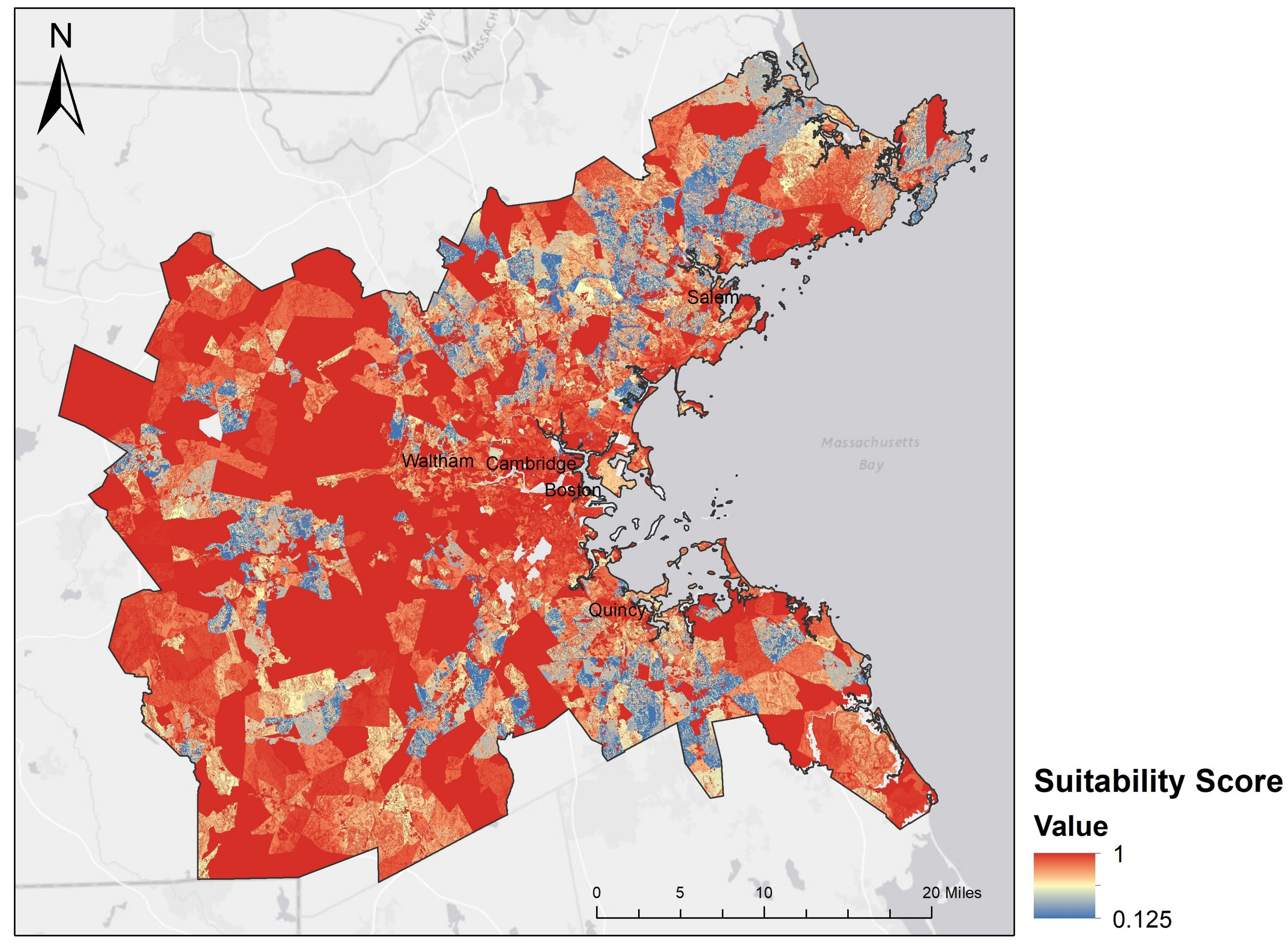
For the fuzzy overlay suitability map, the fuzzy membership tool was used to convert all input layers into values ranging from 0 to 1, with suitable values receiving a score on the higher end of the scale.

For the weighted overlay suitability map, the reclassify tool was used to reclassify all quantifiable layers into a 1-10 scale, with suitable values receiving higher scores. For categorical layers like land use codes, appropriate land use codes were assigned a score of 10 while inappropriate land use codes were assigned a score of 0. Likewise, raster cells within a block group which had at least one EV owner, received a score of 10 while raster cells in block groups without any EV owners received 0. The weighted overlay allowed each input factor to be weighted according to their importance for determining an area's suitability for an EV charging station. The weighting scheme for the final weighted overlay map is shown below.

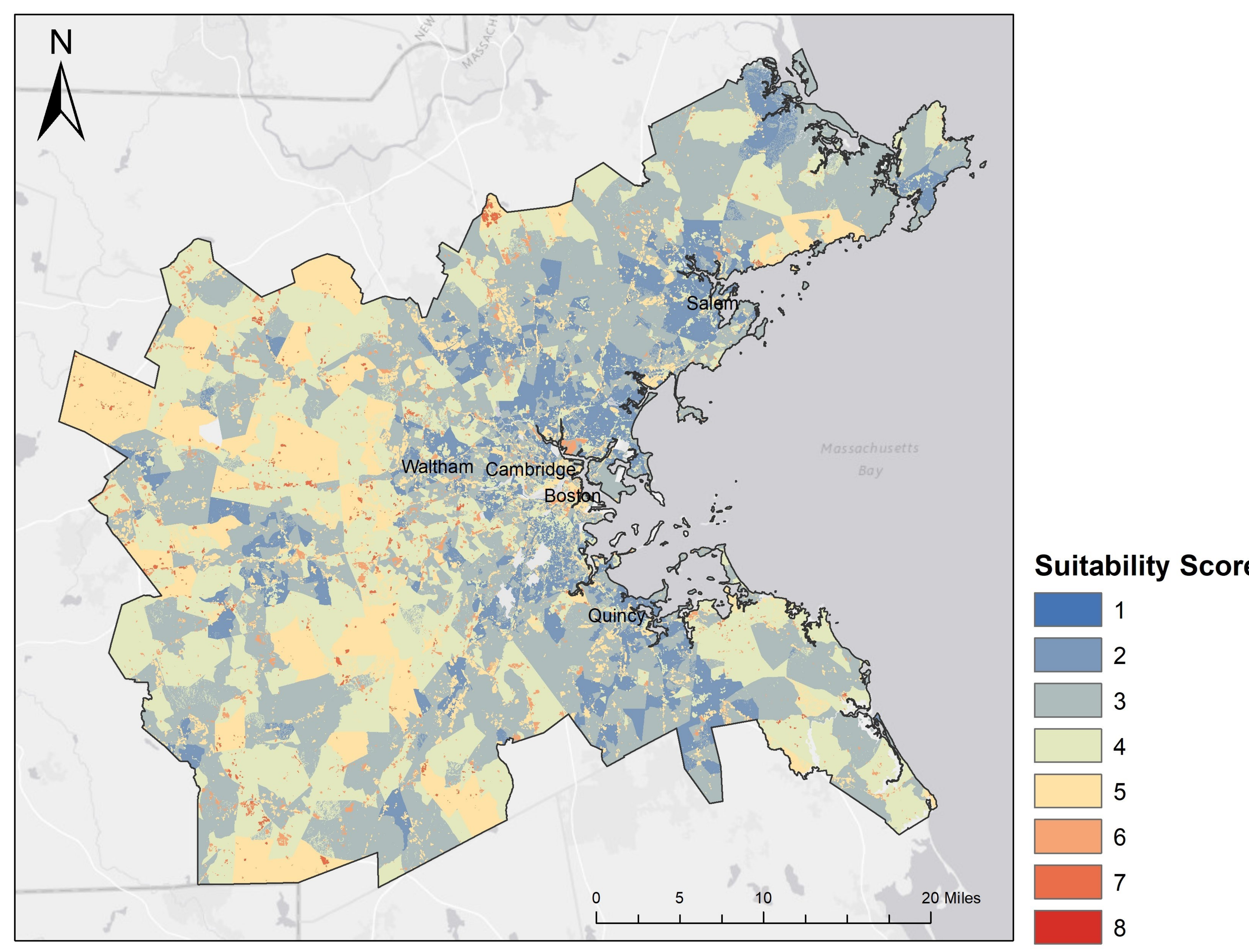
Weighting Scheme Description

Input factor:	Weight
Presence of EV owners	10%
Proximity to available charging stations	15%
Population density	10%
Median income	20%
Median commute distance	15%
Land use code	25%
Slope	5%
Total	100%

FUZZY OVERLAY FOR SUITABLE LOCATIONS



WEIGHTED OVERLAY FOR SUITABLE LOCATIONS



RESULTS

The final two maps show areas that can be potentially suitable for deploying EV charging stations in the future considering the input factors used in the study. According to the fuzzy overlay results, neighborhoods lying east of Waltham and Newton received suitability scores ranging from 0.8 to 1. Additionally, neighborhoods around Franklin and Foxborough towards the southeast of the MAPC region also received suitability scores ranging from 0.7 to 1. Likewise, neighborhoods like Manchester and areas east of Quincy also received high suitability scores. Since the weighted overlay allowed different input factors to be prioritized according to their potential impacts on the suitability for EV charging station locations, the weighted overlay map narrows down on specific areas within suitable neighborhoods identified by the fuzzy overlay map. Different parts of neighborhoods lying east of Waltham and Newton received a weighted suitability score ranging from 4 to 7 and a similar trend is evident for neighborhoods around Franklin, Foxborough, Manchester, and Quincy. The weighted overlay map also classified suitable areas into scores ranging from 5 to 7 in neighborhoods close to Boston such as Roxbury, Somerville, and Chelsea.

CONCLUSIONS

Overall, the final maps identify areas with EV owners, appropriate land use codes, low proximity to already available charging stations, higher population density, higher incomes, population with greater commute distances, and appropriate slopes as suitable areas for EV charging stations. However, this analysis only accounts for a subset of factors that determine the suitability of EV charging station locations. Accounting for other important factors like commute directions, proximity to major roads and other amenities, and development costs can improve suitability results. Additionally, comparing the results of different weighting, fuzzifying, and reclassifying schemes considering vehicle use patterns and local socioeconomic and spatial factors will be important for narrowing down streets or addresses where deploying EV charging stations can be beneficial.

Course Code: Fa19-UEP-0235-01-Advanced GIS
Data Sources: Metropolitan Area Planning Council (MAPC), Alternative Fuels Data Center (AFDC), American Community Survey, MassGIS
Basemap Layer Credit: Esri, HERE, Garmin, (c) Openstreetmap contributors, and the GIS user community
Projected Coordinate System: NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001
Geographer/ Date: Rajat Shrestha/ 12/18/2019

References:
-Zhang, Yongqin, and Kory Iman. 2018. "A Multi-Factor GIS Method to Identify Optimal Geographic Locations for Electric Vehicle (EV) Charging Stations." *Proceedings of the ICA* 1 (May): 1–6. https://doi.org/10.5194/ica-proc-1-127-2018.
Erbaş, Mehmet, Mehmet Kabak, Eren Özceylan, and Cihan Çetinkaya. 2018. "Optimal Siting of Electric Vehicle Charging Stations: A GIS-Based Fuzzy Multi-Criteria Decision Analysis." Energy 163 (November): 1017–31. https://doi.org/10.1016/j.energy.2018.08.140.