# Spatial Distribution of Massachusetts Cities and their Proximity to Natural Hazards

Matthew Ramos

## Introduction

Currently, the locality of many American cities is primarily a function of history, and Massachusetts, especially, is an example of history-based infrastructure, where cities continue to grow in locations that were settled hundreds of years ago, with little regard to natural hazard. Although our predecessors suffered through many extreme natural events in Massachusetts, cities and towns were not relocated, they instead adapted to natural patterns. With global temperatures increasing, one can expect the frequency and severity of extreme natural events to follow suit. This will change the natural patterns that we have adapted to and brings forth the need to reevaluate the risk of natural hazard across the state.

Massachusetts' infrastructure varies spatially in terms of cities and towns, with over 6.5 million people residing within the state. Although the location of many current communities is a product of history, it is important that we identify which existing areas are at risk to possible infrastructure damage and also understand the potential risk of an area long before it is developed. Similar to the methods described by Mende and Astorga in their paper, "Incorporating geology and geomorphology in land management decisions in developing countries: A case study in Southern Costa Rica" in 2007, this study uses ArcGIS to combine various natural hazards (landslides, earthquakes, flood) in Massachusetts with information regarding the geographic location of cities to not only understand the present risk of infrastructure to natural hazards but also to be used during the decision-making process of locating sites for future development. Mende and Astorga used these concepts in Costa Rica to improve on the lack of information and understanding of the natural hazards and land development practices in the country. Although Massachusetts is very different geographically, there is an abundance of information regarding natural hazards, and infrastructure placement, allowing us to determine which areas in Massachusetts are most at risk during a natural event, and whether it is smart to build on these sites.

## Methodology

In evaluating the hazard associated with earthquakes in Massachusetts, I located and geo-referenced a USGS earthquake map into ArcGIS showing earthquake hazard for the New England area. In order to remove excess data from this layer, I clipped the map using a layer of Massachusetts as a spatial reference. Next, I created my own features using the polygon tool, outlining each zone of earthquake hazard on the map. Landslide hazard data for the United States was obtained from ArcGIS Online. Similar to earthquakes, I clipped this layer with the same counties reference and created polygons for each landslide prone area. Using 100-year flood data from FEMA, the hazard associated with flood inundation was evaluated across the state. First the data was filtered to include only sites that would be inundated during a 100-year flood (the Franklin County data is missing). Since the original layer contained dozens of sub-categories, I standardized the hazard and only represented areas that are expected to be fully inundated during a 100-year flood. The spatial distribution of Massachusetts cities was investigated using the cities layer within the USA data the course folder for CEE187. This provided me with every city in the United States, which I then selected by attribute for cities in Massachusetts, and from which I created a layer.

In each layer, I created a "Hazard" field and ranked the various polygons according to the relative values of hazard associated with their location. Additionally, as layers were added, I combined the values of each layer, which allowed me to take into consideration all hazards at the same location, i.e. if a high landslide hazard existed in an area with low earthquake hazard, both will weigh into the overall hazard of the location, rather than their hazards being evaluated separately.

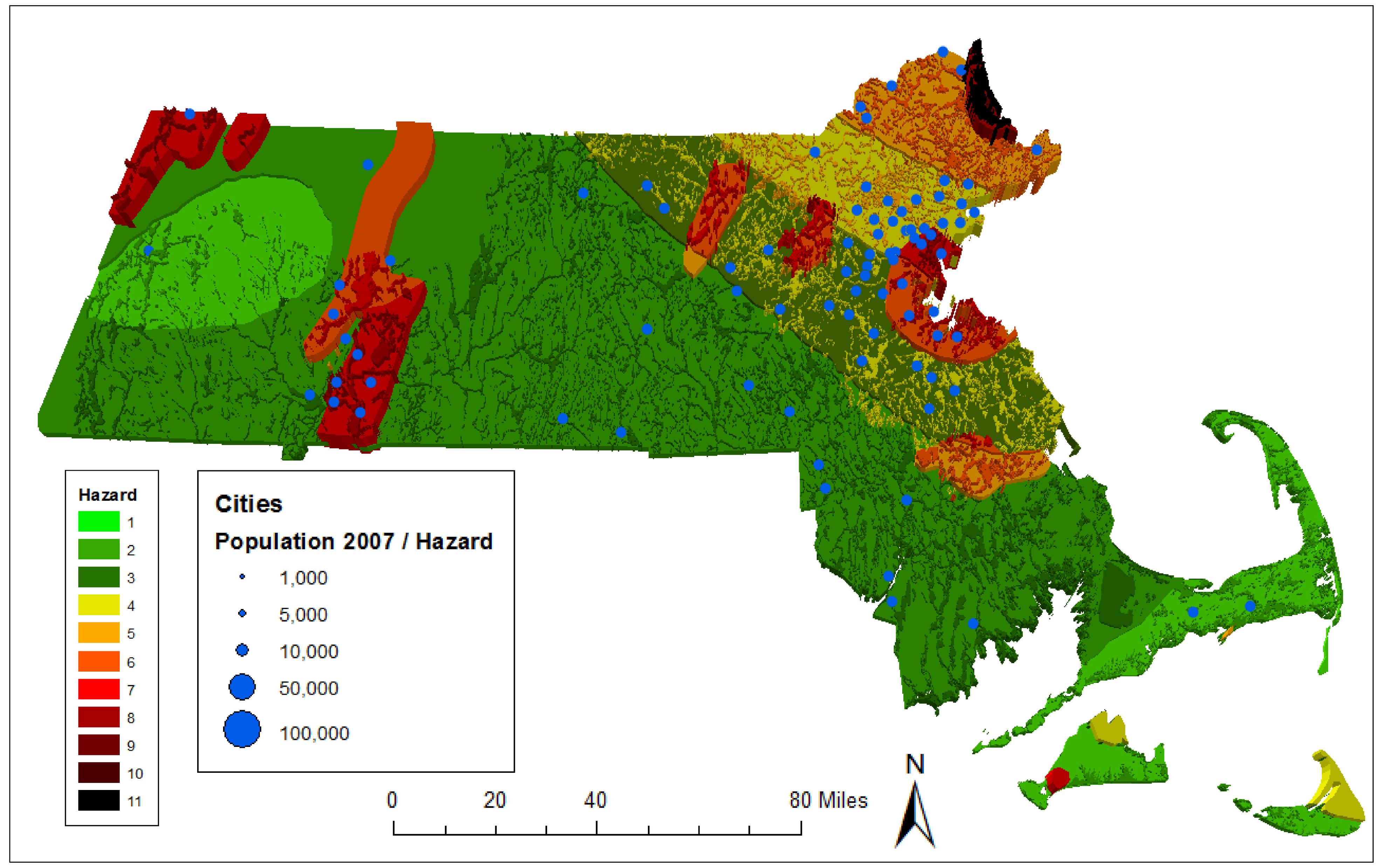


**Figure 1. ArcScene 3D model of Massachusetts Cities and overall hazard across the state**

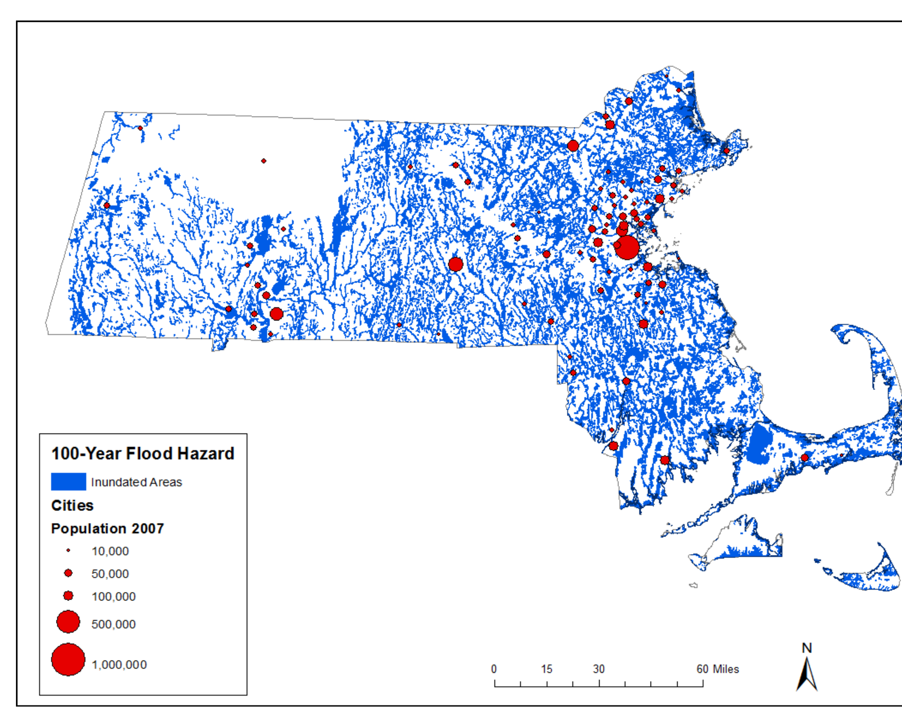


**Figure 2. Distribution of 100-year flood inundation**

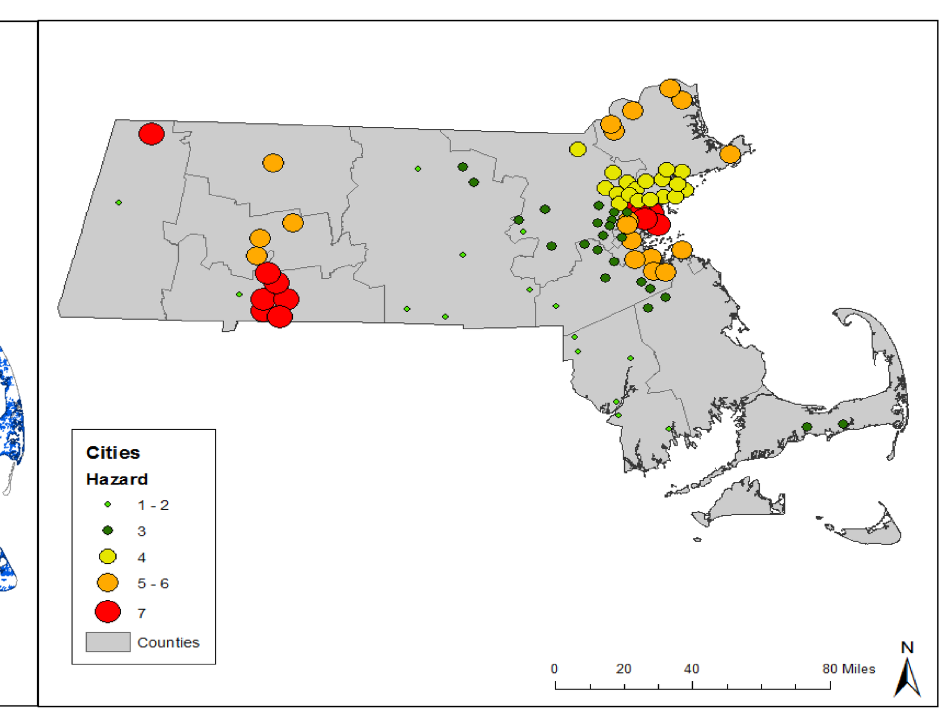


**Figure 3. Distribution of Massachusetts cities and the hazard associated with their location**

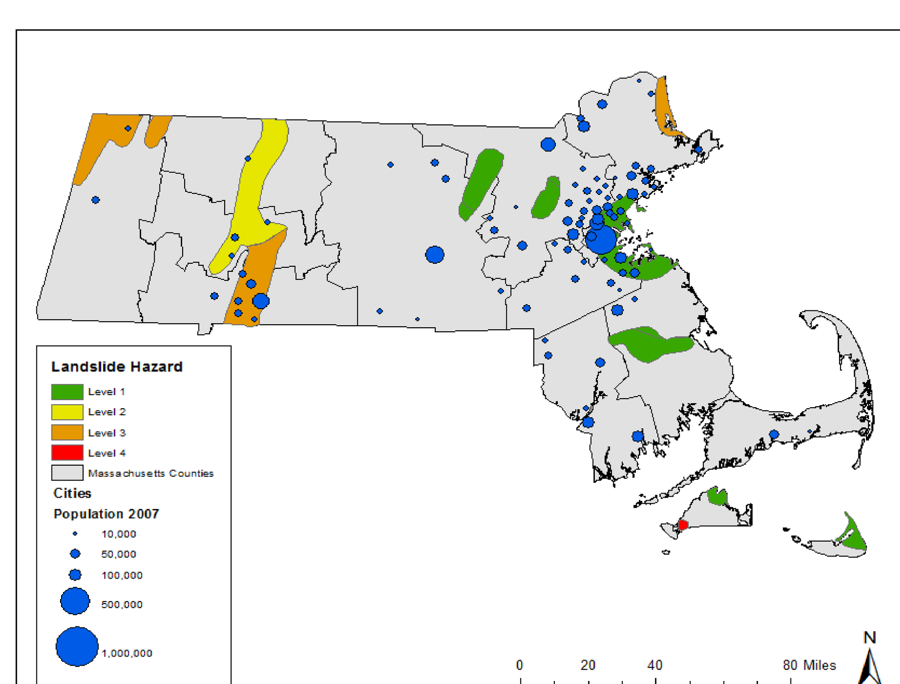


**Figure 4. Distribution of Landslide hazard**

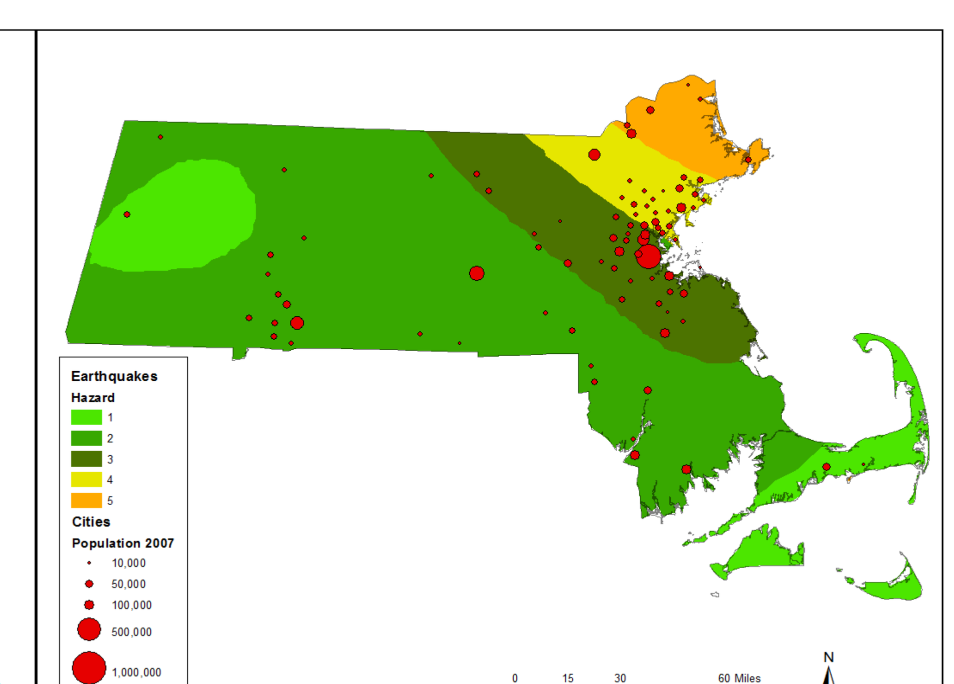


**Figure 5. Distribution of earthquake hazard**

## Results

Many Massachusetts cities are located in areas that show high hazard, including multiple highly populated cities such as Boston and its surrounding cities. The map also shows more cities located toward the coast in the north eastern portion of the state. An interesting feature on the map is the location of cities in Central Massachusetts. The strip of higher hazard represents landslide hazard that cross-cuts the state, however it seems as if cities are located primarily within this area.

Although one of the hazards alone may not have a high hazard associated with it, when these various hazards are combined, they results are quite visible. Areas with an associated landslide hazard tend to be the most hazardous areas in the state, and when they are located in an area with high earthquake hazard, the effect is more pronounced. The flooding areas are much smaller in spatial extent, but are very widespread throughout the state and affect almost every area. Overall, the earthquake hazard seems to dominate the distribution of hazard across the state which increases toward the northeast corner of the state. The landslide areas are not as widespread, and thus have less of an effect on the overall distribution of hazard across the state. Since I standardized the flood layer, one cannot see how varying floods will affect the overall hazard, just which areas are at risk during the 100-year flood, and how the distribution of flooding compounds with these earthquakes and landslides.

## Conclusion

In conclusion, Massachusetts natural hazards vary across the state, and one can easily see how taking multiple hazards into consideration can be more effective in understanding the overall hazard of an area. Although Massachusetts' cities are primarily located in areas of higher hazard, one can draw many assumptions and conclusions as to the historic reasoning behind these locations, but more importantly understand the present hazard that faces each city and use this information to guide future developers. Performing this type of analysis can save vast amounts of money and many lives by preparing cities for these natural events, and building new communities in less hazardous areas. As the patterns of extreme natural events change, hazard analyses will become increasingly necessary for communities to understand how they may be impacted. Fortunately, the US has abundant sources of information regarding natural hazards, and can easily implement these techniques, however, not every country possesses such valuable information. Many developing nations currently face more extreme hazards than the US due to geography and lack the infrastructure and money to prepare for, and rebuild after an event. As global temperatures fluctuate, extreme natural events will not only increase for Massachusetts, but for the entire planet as well. A major effort should be taken to investigate the natural hazards facing all US cities and also that developed countries share their technology and information with developing nations now, as they develop, in an effort to prevent the placement of communities in high hazard zones, similar to Boston and Springfield and minimize the possibility for future disaster.

## References

**Ranking the Risks from Multiple Hazards in a Small Community.** Hua Li, George E. Apostolakis, Joseph Gifun, William VanSchalkwyk, Susan Leite, and David Barber., Risk Analysis Vol. 29, 2009 p438-456

**Incorporating geology and geomorphology in land management decisions in developing countries:** A case study in Southern Costa Rica, Mende Andreas, Astorga Allan Geomorphology 87 (2007) 68–89