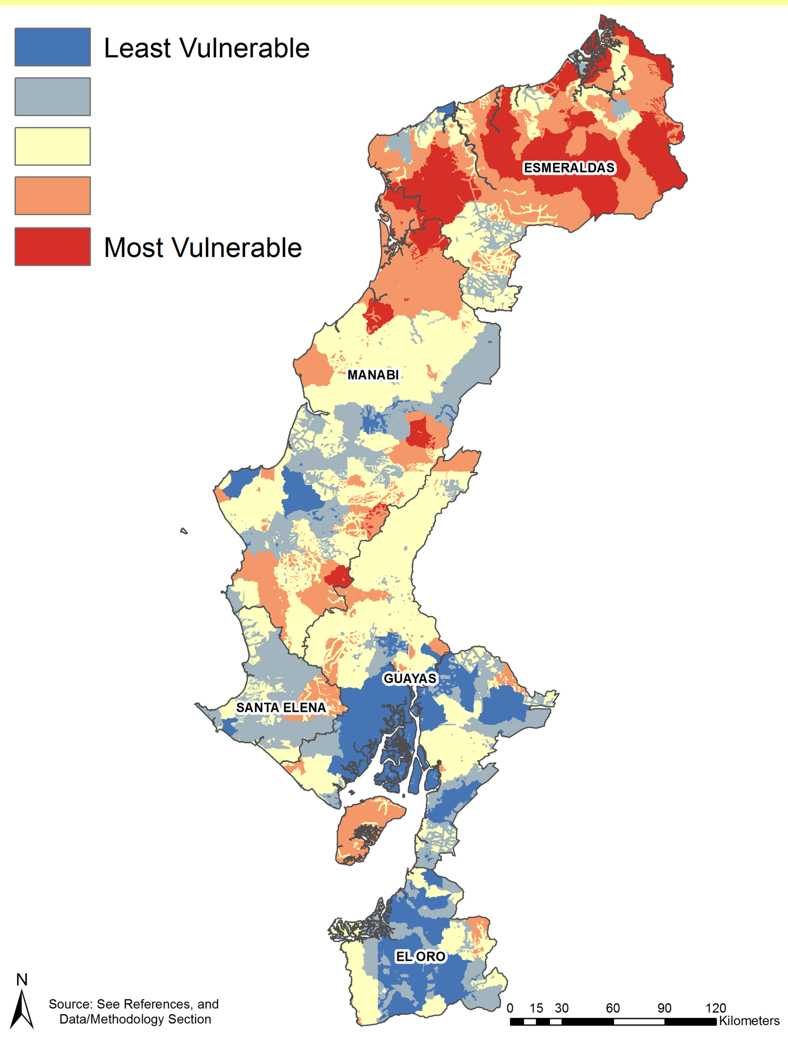
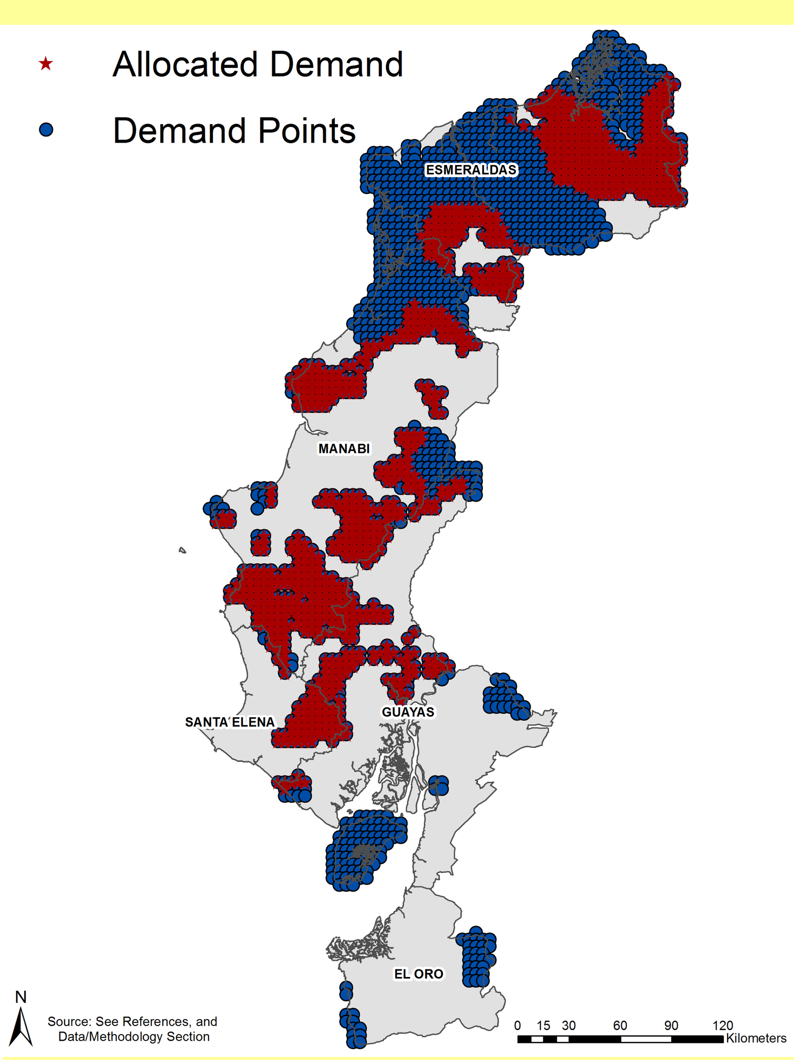
Allocating Health Centers in a Resource-Constrained Setting in Ecuador

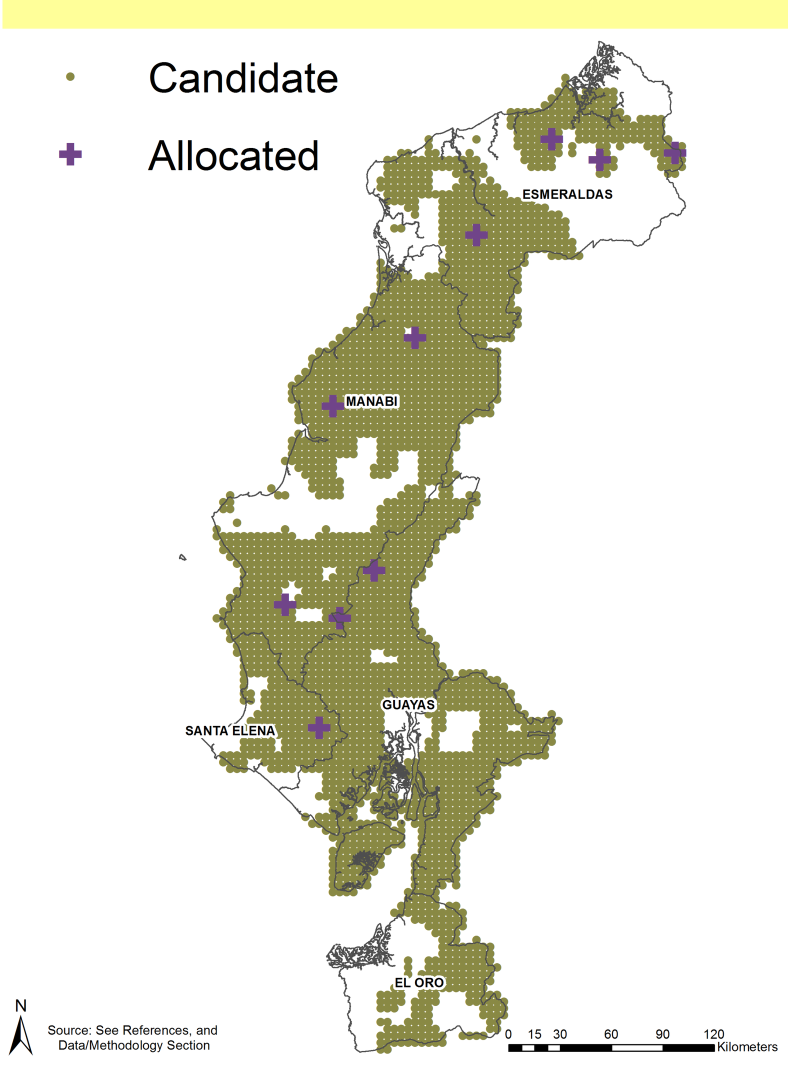
Vulnerability Analysis for Demand Points



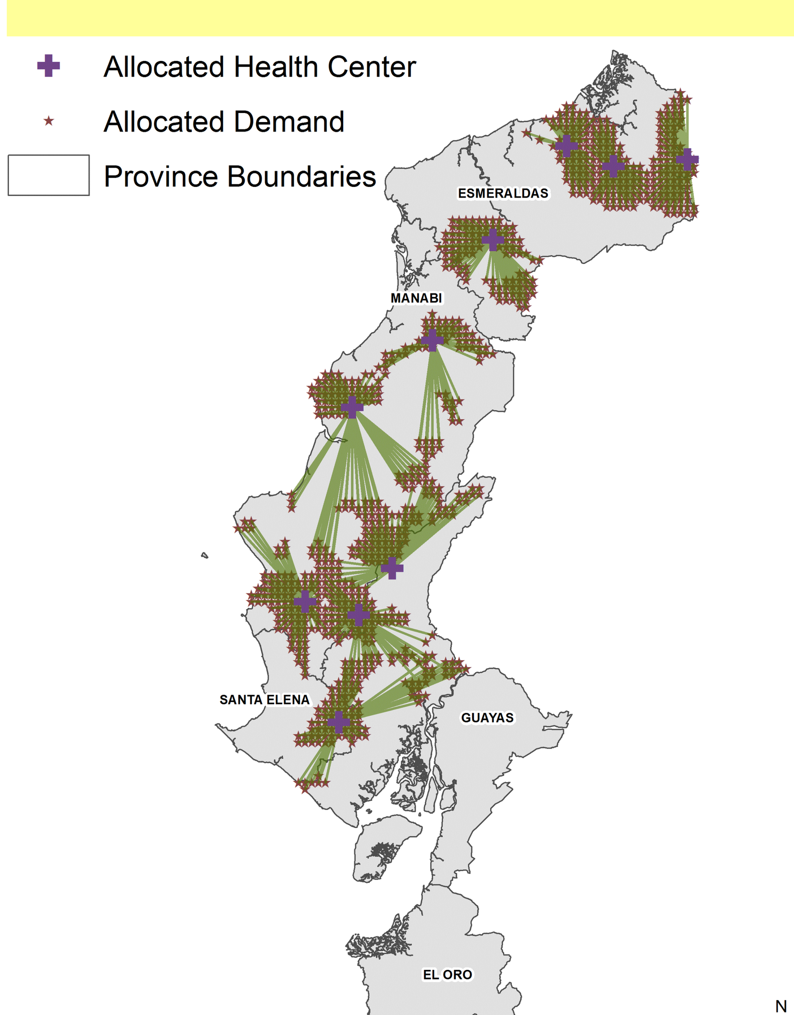
Potential Demand Points and Allocation



Candidate Facilities and Allocation



Location-Allocation Model



Background and Motivation

The goal of development organizations is broadly to improve the standard of living for their target populations, and they do this in context of limited resources. In essence, development organizations' work is defined by seeking to create maximum possible impact in a resource-constrained setting. However, and unfortunately, the field of development is also known for its inefficient use of resources, as well as duplication of efforts.

In this context, my analysis determines the optimal allocation of primary health care centers in Ecuador, given population demand and density, and the supply of current health centers. Population demand is defined as people's vulnerability, or their risk of being exposed to adverse health outcomes or poverty. Efficiency means reaching the greatest number of people demanding healthcare with the given service (or facility) in the least amount of time (as measured by distance). The ultimate aim is to construct a geospatial model that could help development agencies in using their resources in the most efficient way based on currently available data. This could decrease the waste of resources, and increase the ability of agencies to fill the service provision gaps.

Methodology

I will employ a *Location-Allocation* analysis , which allocates facilities in a way that covers demand points most efficiently. The facilities are assumed to be free of charge so that the only cost of access would be the effort it would take to reach a given facility, and the opportunity cost of going to a clinic. The tool analyzes which potential locations would serve the demand centers in the best way possible given current demand and supply, and distance between demand points and facilities. I used the *Maximize Capacitated Coverage* (MCC) model since it has two main benefits. First, it helps model reality as you can specify the capacity of each facility. This also ensures a modicum of quality. Second, the model allows you to specify if you want to minimize the average distance traveled to a health facility or set the maximum distance anyone will have to travel. I chose the former since I did not want to restrict the model. However, a natural cutoff point would be a nationally defined catchment areas. In summary, the MCC model allocates a pre-determined number of health facilities, with a finite capacity, such that it minimizes the average distance traveled between the vulnerable populations and health facilities.

The vulnerability is determined by several socio-economic factors at a parish level that relate to different factors that could make a person or household vulnerable to adverse health outcomes, such as current health, education, sanitation and employment. The most vulnerable would be at the intersection of people who are at risk of poor health outcomes *and* lack access to health care. After determining the vulnerability index, I weigh it with the population density to emphasize locations that would cover the largest amount of vulnerable people. However, using population weights cuts off some of the most poor people in remote areas, especially in the northern parts.

Results of Analysis

Based on my specifications, a total of ten health centers were allocated, each with a capacity of 100 demand points. The location-allocation model seems to have done a good job in allocating health facilities efficiently, in the sense that they are located in the most suitable area closest to the most vulnerable areas. Analyzing the equity of the allocation, many of the least vulnerable areas are now covered by a health facility. However, the range of distances traveled from demand points vary widely, with the maximum distance being 131 kilometers, and the minimum being 122 meters. The median distance traveled is about 27 kilometers, which in a car or bus is not highly unreasonable. However, a distance of 131 kilometers is highly prohibitive for anyone, let alone poor people. It is not likely that these people would actually utilize those healthcare facilities.

I also calculated the "catchment" area of each of the facilities to provide an estimate of how many people they would actually cover. However, this is not perfectly accurate as the calculation disregards the demand points that did not pass the threshold of vulnerability, which would be close enough to access the facility. A sum total of 824,569 people were covered, with the average number of people per facility being 82,456. Lastly, I conducted a spatial statistical analysis. The goal of this type of analysis is to uncover if there is a persistent geospatial pattern of current supply and demand of healthcare. Both analyses turned out to be statistically significant at the 1% level (positive Z-scores). Tentatively, it seems like the analyses indicate that both supply and demand are clustered, but not necessarily in the same place.

Due to the limited number of healthcare facilities, not every vulnerable population cluster was covered, as is usually the unfortunate reality in development work. However, I believe this model adds insight into where vulnerable populations that lack access to healthcare live, and could improve current practices in the field of development.

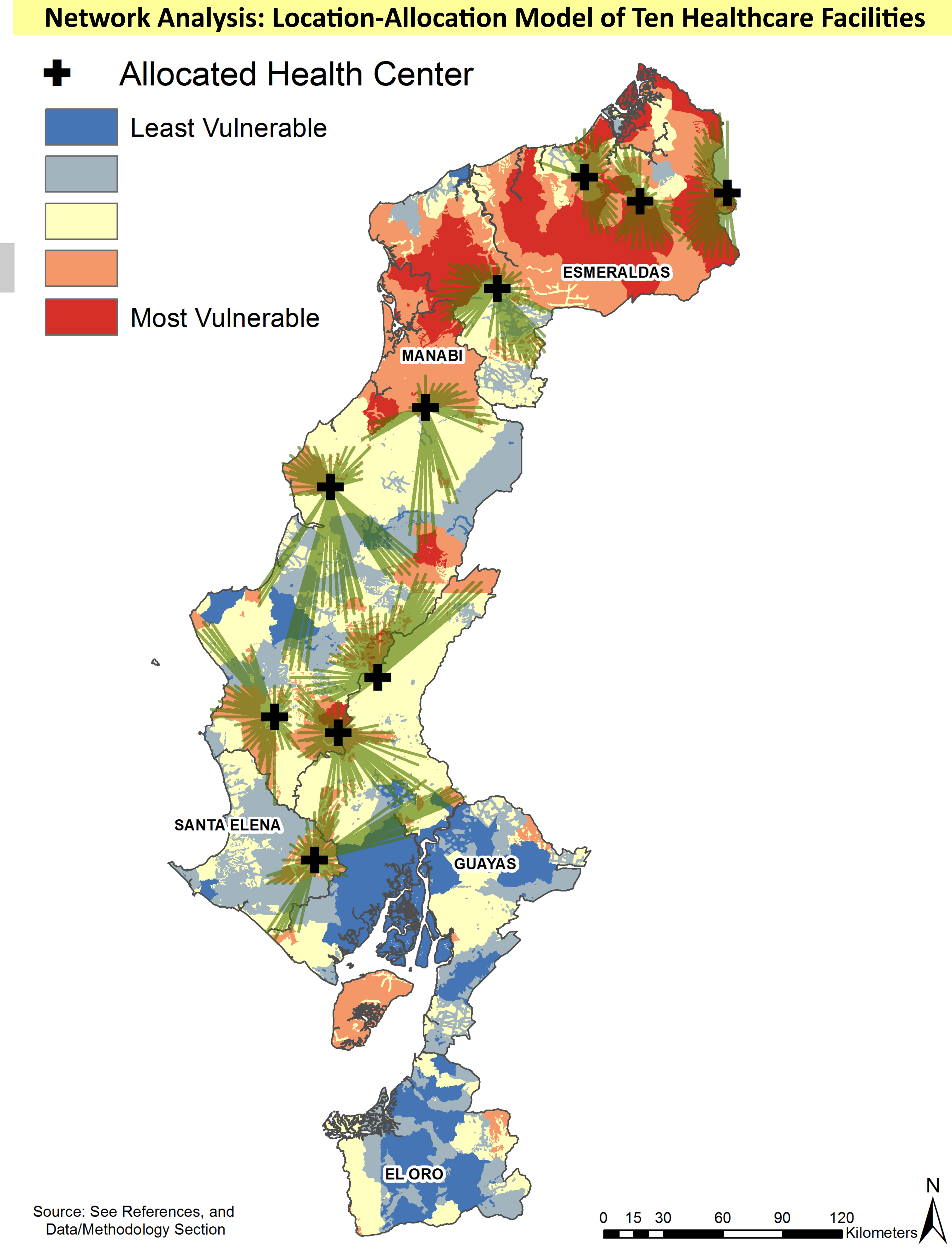
The distance between many demand points and facilities are prohibitively high, but I believe that specifying an impedance cut-off in future models could solve this problem.

Conclusion and Limitations

I was worried that the model would entrench the equity versus efficiency concerns that the literature on location-allocation modelling frequently have mentioned. However, introducing vulnerability analysis helped remedy this problem. The relatively more vulnerable areas got allocated, though one could argue that the cost of getting there would be extremely large for many people. In future iterations of the model, I would hope to include more local knowledge of health conditions, disease patterns, healthcare professionals capacity, and data on local terrain and climatological conditions, which would all affect supply and demand of healthcare. Furthermore, disaggregating the model for different sizes of health facilities would also nuance the analysis, to better determine the amount and types of health facilities are needed to serve the most vulnerable populations.

The first and most important limitation is the missing data for roads. I know that there are several tiles missing in the base scale data, and this impacts all the analyses conducted above. Particularly, the network analysis will suffer as the network dataset is incomplete. Not a major limitation, but interesting improvement, would be to disaggregate the infrastructure data as this would be an additional step to model reality. I also would have liked to include data on access to vehicles and public transportation, but that kind of data are unfortunately not available.

Network Analysis: Location-Allocation Model of Ten Healthcare Facilities



Main Sources

Coordinate System and Projection: WGS_1984_UTM_Zone_17S, Transverse Mercator (Linear Units: Meters)

Course: Advanced GIS | UEP 0294-22 with Professor Zimmerman

Cartography by: Nina A. Skagerlind | December 18, 2013

Sources: Instituto Geografico Militar de Ecuador (IGM), Instituto Nacional de Estadisticas y Censo de Ecuador (INEC), Censo de Poblacion y Vivienda 2010 (Ecuador), Sistema Nacional de Informacion de Ecuador (SNI), CONELEC, MAGAP, Ministries of Health and Education, CIESIN—Gridded Population of the World (v.3—population count and density)

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