Climate Change Vulnerability

Mekong River Delta, Vietnam

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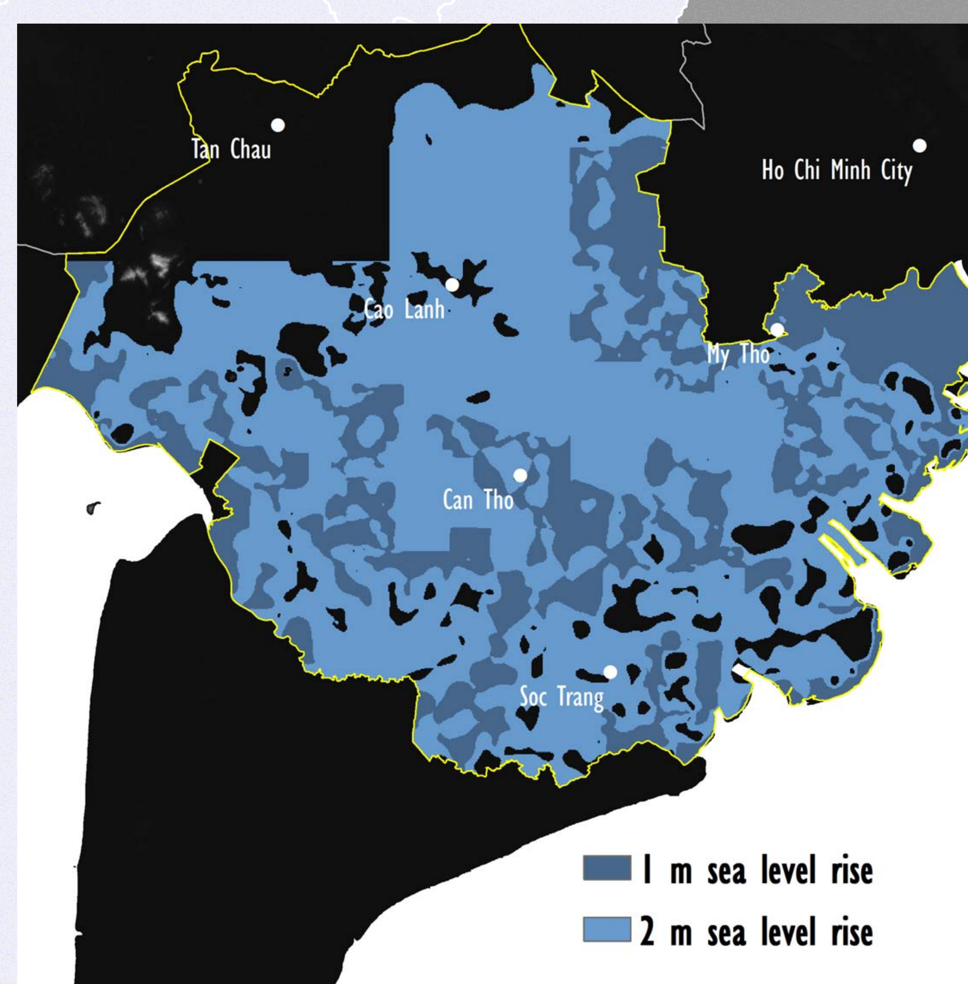
Overview

According to the World Bank, "Vietnam is likely to be one of the most significantly impacted nations in the world from climate change."[1] In the Mekong River delta, one of the most densely populated regions of Vietnam, the effects of climate change are already being felt. Typhoons were once a rarity in the delta, but as they have begun to track farther south they have become more common, buffeting the delta several times since 1997. Sea level has risen as much as 20 cm over the past 50 years. Saltwater has crept farther and farther up the delta, encroaching on farmland as much as 70 km inland. Droughts have become widespread during the dry season, yet flooding has worsened too because of increased precipitation during the rainy season and the more-frequent typhoons. This project will use GIS, remote sensing, and social science to assess the relative vulnerability of 75 districts in the delta to two climate-related hazards: river flooding and sea level rise (SLR).

What is climate change vulnerability?

Vulnerability is the potential to be harmed. The IPCC has defined vulnerability to climate change as a function ***physical exposure***, ***sensitivity***, and *adaptive capacity*.[2] Exposure depends on the likelihood, magnitude, timing, persistence, and reversibility of physical hazards, such as sea level rise. Sensitivity is tied to poverty, lack of access to resources or social services, and dependence on agricultural livelihoods.[3] Adaptive capacity is "the ability or capacity of a system to modify or change its characteristics or behavior so as to cope better with existing or anticipated external stresses."[4]

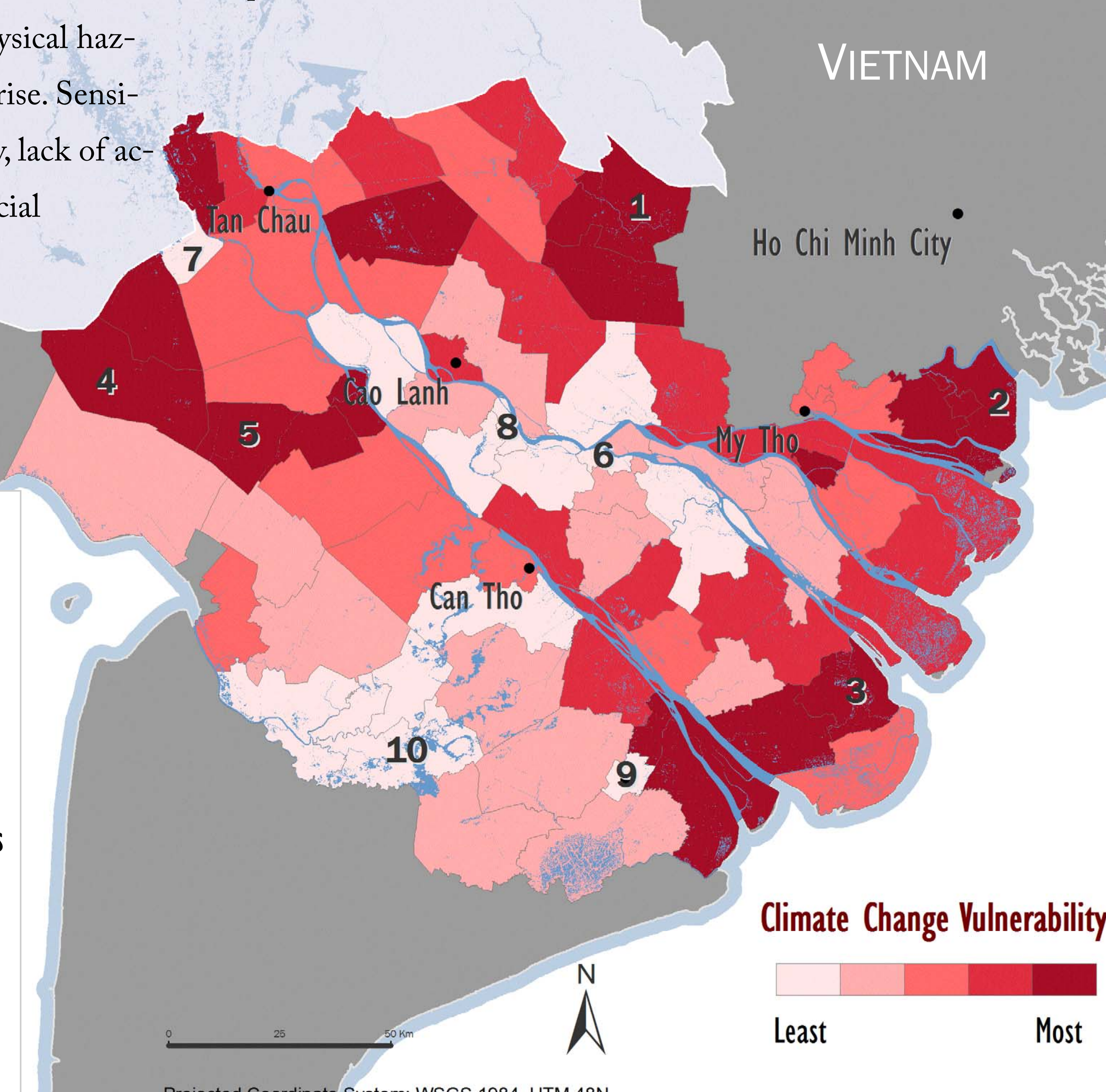


Modeling Sea Level Rise

Much of the Mekong delta is flat, low-laying land. One study estimated that 4.79 million people in the delta are living in areas that would be inundated by a 1 m sea level rise (SLR).[5] As sea level is predicted to rise by 1 m or more over the next century globally, this presents a real threat. To simulate SLR, a digital elevation model (DEM) was obtained from the Mekong River Commission. The Vietnam section of this DEM was derived from a 1:100,000-scale hypsometric contour map. Pixels in the raster data were re-classed as "0" for elevations at or below the "new" sea level. Then, cost-weighted distance was calculated for water to travel up the delta from a source along the coast. Pixels with a cost of "0" were considered inundated. This process was repeated for both a 1m and 2m SLR.

Mapping Flooding Extent

While the annual flooding of the Mekong delta carries sediment from upstream that nourishes the region's agriculture, severe floods can cause extensive damage. From July to October 2002, flooding in the Mekong delta destroyed 85,000 homes and killed more than 130 people. Landsat 7 satellite imagery from October 2002 was used to map the extent of the flooding. Four separate images were calibrated and then combined into a mosaic of the study area. Next, the Modified Normalized Difference Water Index (MNDWI) was calculated to identify water pixels. The MNDWI is the difference in reflectance values for TM bands 2 and 5, divided by the sum of these two bands.[6] The MNDWI score for open water surfaces is positive, with a maximum value of 1. Vegetation and urban areas receive zero or negative scores. Band thresholding was then performed to create a class image of "water" and "non-water" pixels; however, because urban surfaces contain a dense mix of water and non-water, they appeared in the image as being non-flood areas. To correct for this, the image was imported into ArcGIS and the raster calculator was used to fill voids that were surrounded mostly by water pixels and had an elevation above sea level equal to or less than those surrounding pixels. While the results aren't perfect, they are an improvement over other inundation maps of this flooding event created by the MRC using radar imagery.



Most Vulnerable Districts
1. Moc Hoa
2. Go Cong Dong
3. Cau Ngang
4. Tri Ton
5. Thoai Son

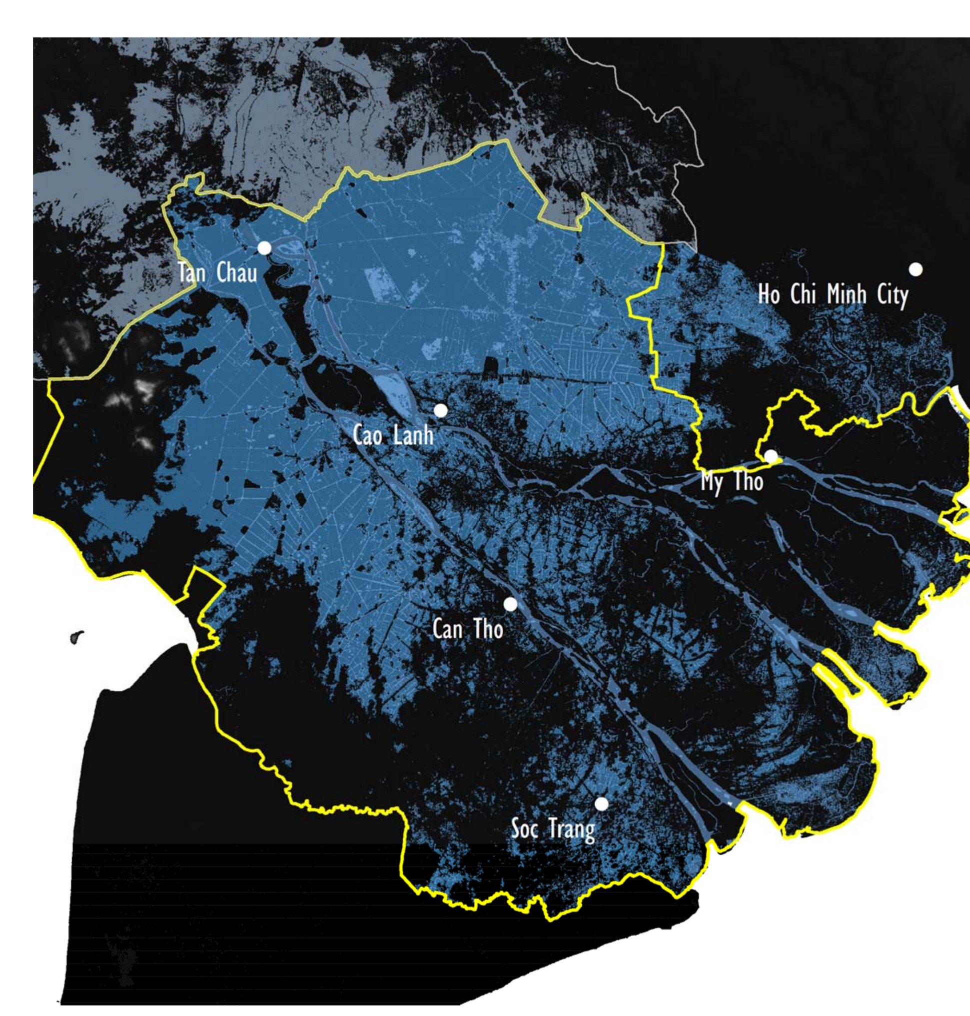
Least Vulnerable Districts
6. Vinh Long Township
7. Chau Doc Township
8. Sa Dec Township
9. Soc Trang Township
10. Long My

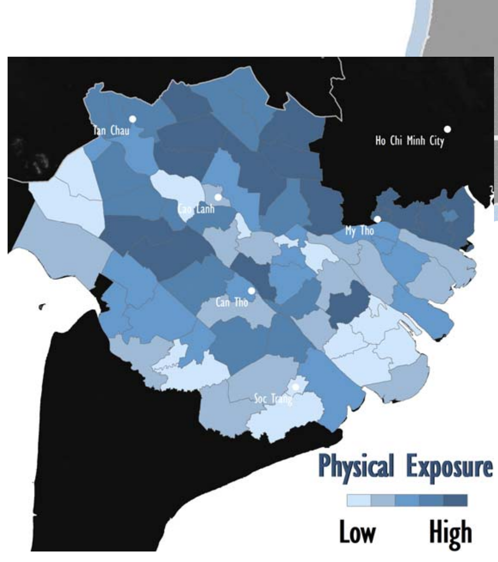
Indicators

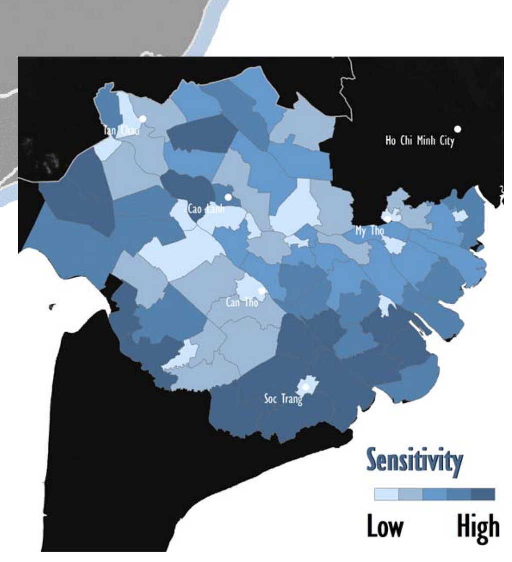
Exposure
- *flo* Percent of district area flooded during Oct 2002
- *slr* Percent of district covered by 2-3m SLR (weighted for 2m)

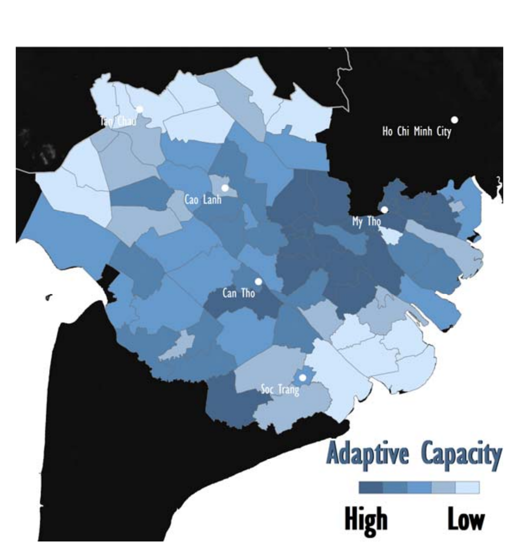
Sensitivity
- *agr* Percent of population over age 15 primarily employed in agriculture
- *min* Percent of population not ethnically Vietnamese or Chinese
- *den* Population density (people per sq km)
- *can* Km of irrigation canals (normalized per sq km)
- *pov* Percent of population living below official poverty line

Adaptive Capacity
- *lit* Percent of population over age 15 that is literate
- *gin* Gini coefficient (measure of income inequality)
- *roa* Km of highways and other paved roads (per sq km)









Building the Vulnerability Index

Once the areas affected by climate change hazards were identified, composite indices were built for exposure (*E*), sensitivity (*S*), and adaptive capacity (*A*) of each affected district. Indicators for each index were normalized as:

$$p_{s_d} = \frac{s_d - s_{min}}{s_{max} - s_{min}}$$

where $p_{s,d}$ is the indicator of *s* measure of *E*, *S* or *A* for district *d*; s_{min} is the minimum *s* value for all the districts in the study area; and s_{max} is the maximum value.[7] Following Iyengar and Sudarshan, *E*, *S*, and *A* were formed as the weighted sum of the respective *p*'s.[8] Weights were assigned such that large variation within a single *p* would not inflate the index scores for any districts. Using the same method, vulnerability scores (*V*) were constructed as the weighted sums of *E, S,* and *A.* Finally, statistical analysis was performed to determine the amount of correlation between individual *p*'s. The results show that, all else being equal, the districts most exposed to river flooding tend to be the poorest, while SLR will affect the more affluent, urban parts of the delta.

Citations: *(1)* P. McElwee, "The Social Dimensions of Adaptation to Climate Change in Vietnam," World Bank Discussion Paper No. 12 (Dec 2010), xiii; *(2)* Martin Parry et al (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2007), 6; *(3)* N. Adger et al, "New Indicators of Vulnerability and Adaptive Capacity," Tyndall Center for Climate Change Research Technical Report No. 7 (Jan 2004), 30; *(4)* Ibid, 34; *(5)* J. Carew-Reid, "Rapid Assessment of the Extent and Impact of Sea Level Rise in Viet Nam," International Centre for Environmental Management (Feb 2008); *(6)* Xu HQ, "Modification of Normalized Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery," *International Journal of Remote Sensing*, Vol. 27 (2006): 3025-3033; *(7)* Note that where an increase in *p* would lower the value of the index (i.e. higher literacy rates *lit15up* would lower sensitivity *S*), then the *p* is normalized as $p_{s,d} = (s_{max} - s_d)/(s_{max} - s_{min})$. Also, measures of adaptive capacity were treated as vulnerability reducing, so higher adaptive capacity led to a lower *A* score when *E, S,* and *A* were summed to get *V;* *(8)* N. Iyengar and P. Sudarshan, "A Method of Classifying Regions from Multivariate Data," *Economic and Political Weekly* vol. 17, no. 51 (Dec 18, 1982): 2047, 2049-2052.

GIS Data Sources: 1999 Vietnam Population and Housing Census, Vietnam General Statistics Office; Lower Mekong Basin Digital Terrain Model, Mekong River Commission; Landsat 7 Imagery, USGS Global Visualization Viewer; Vietnam Poverty Map, International Food Policy Research Institute; administrative boundaries from Global Administrative Areas, www.gadmin.org