The Influence of Urbanization on Climate Adaptive Capacity

Andrea Chu and Pei-Te Chiueh

National Taiwan University

Introduction

In the coming centuries, humanity must adapt or perish. Widespread effects attributed to global climate change are already occurring, with no end in sight for high carbon emissions. Along with this increase in climatic pressures on societies, urbanization is continuing at a breakneck pace. The relationship between urban development and climate change is complex one, with enormous implications for society. Thus, how current land use development affects adaptive capacity at a local level will be an increasingly important consideration. More specifically, areas undergoing massive land use change will have to find methods to measure and predict their adaptive capacity.

Urban changes in land use and land cover (LULC) have complex interactions with atmospheric conditions, which can compound or mitigate climate impacts at a range of scales (Dale 1997). Adaptation specifically is mediated by LULC partly because many determinants of adaptive capacity, both socioeconomic and biophysical, are affected by urbanization. In this study, adaptive capacity means "the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2001) or, more generally, the capacity of response. Adaptive capacity is key because it is a concept that can effectively incorporate concepts of vulnerability and resilience (Engles 2011). When measuring adaptive capacity, it is important to note that it:

- is always positive
- has no upper limit
- is a mutable property

Thus, adaptive capacity is an ideal aspect from which to study the effect of urbanization and LULC change on communities facing climate change. This study aims to create a new index system, particularly for smaller, quickly urbanizing communities to measure the effects of LULC change on the ability of communities to adapt, and to use LULC to predict future adaptive capacities. We have named it the Urbanizing Adaptive Capacity Index (UACI).

Methods

Indicators for the UACI were chosen based on IPCC frameworks and previous literature, and are shown in Tables 1 and 2 (Brooks & Adger 2004, Acosta et al 2013). Indicators were scored for years 2000 and 2010 for two case study sites, using land use percentages to act a baseline, and then this data is used to calculate indicator values at future time slices according to predicted future land use. Data for indicators were sourced from government census data, reports, land use surveys, and historical documents of each site: Tamsui, Taiwan and West Palm Beach, US.

Table 1: Socioeconomic Indicators

j	Determinant	Indicator	Measure
1	Economic Resources	GDP	USD per year
2	Economic Resources	Median Household Income	USD per year
3	Information & Skills	Educational Attainment	Percent with secondary education and above
4	Networks	Occupancy Rate	Percentage of housing
5	Networks	Trust Levels	Percent who answered yes to "can most people be trusted"
6	Equity	Inequality	Gini Coefficient
7	Management & Institutions	Government Preparedness	Existence of Emergency Plans
8	Technology & Infrastructure	Internet Access	Percentage of population

Table 2: Biophysical Indicators

i	Determinant	Indicator	Measure
1	Ecology	Stormwater & Runoff	Percent impervious surface
2	Ecology	Temperature Variance	Temperature difference in Celsius
3	Ecology	Surface Water Stability	Percent mountain forest or wetland

The UACI is calculated using the equation below:

$$\text{UACI} = \sum_{i=1}^{3} B_i + \sum_{j=1}^{8} S_j$$

where i represents the specific biophysical indicator, j represents the specific socioeconomic indicator, B_i is the biophysical indicator score and S_j is the socioeconomic indicator score, and $0 < B_i < 10$ and $0 < S_j < 10$.

The land use change scenarios used in this research are as follows: A) Economically Driven, BAU) Business As Usual, and B) Environmentally/Socially Driven. Each scenario was pushed to year 2030 and 2050 to align with IPCC emission scenario timelines using the planning support system software, *What If?*.

Results & Discussion

Using demographic and economic trends as inputs, as well as environmental factors given as constraints, *What If?* computed the three different land use scenario results for both case study sites, as shown below in Figures 1 and 2.

Figure 1

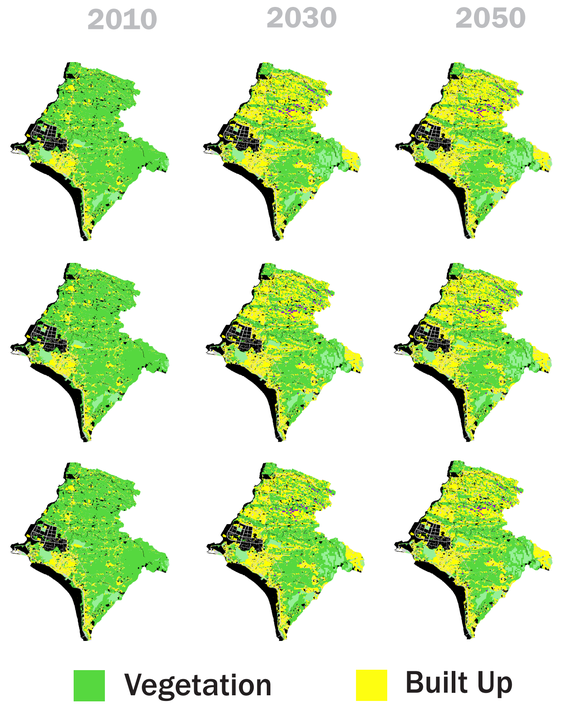
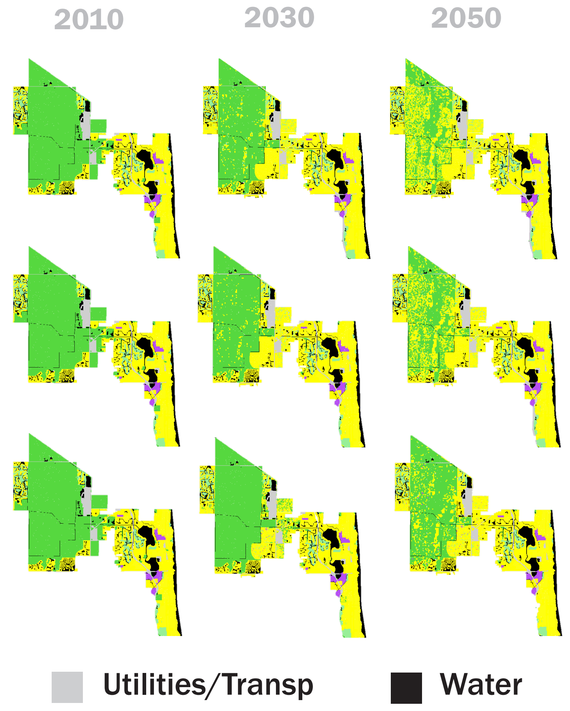
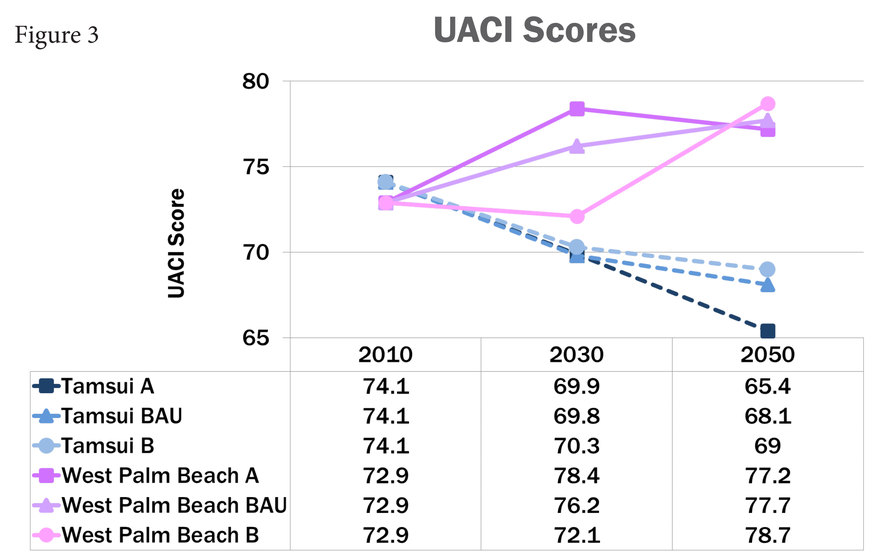


Figure 2



The indicator scores, calculated from the *What If?* results, are shown in Figure 3. They show that Tamsui starts off with a slightly higher adaptive capacity, but West Palm Beach ends up with higher scores regardless of scenario or time slice. These results do reflect, on a larger level, several trends associated with urbanization and land use change. Tamsui gained less in socioeconomic aspects with increased urbanization in comparison to West Palm Beach. Taiwan has seen very clear climatic changes which are more severe than in many other larger or inland countries, and urban sprawl is a major exacerbating factor. West Palm Beach, on the other hand, stands to benefit more from urbanization with internet, GDP, and income indicators. It was also less influenced by temperature changes from the 2000-2010 baseline period, a trend which continued into future time slices. But to rely too heavily on technological or economic for AC would be unwise in the long term.

Figure 3



	2010	2030	2050
Tamsui A	74.1	69.9	65.4
Tamsui BAU	74.1	69.8	68.1
Tamsui B	74.1	70.3	69
West Palm Beach A	72.9	78.4	77.2
West Palm Beach BAU	72.9	76.2	77.7
West Palm Beach B	72.9	72.1	78.7

Conclusion

The UACI results tell a familiar general narrative, that there are increased social and economic benefits as a place urbanizes, such as higher levels of education or income, but at some point the benefits peak and urban drawbacks begin to overtake its benefits, particularly the environmental costs.

Considering the results, we recommend that Tamsui limit urban sprawl and development in the mountainous areas. Preserving the ecosystems of higher altitudes is a high priority in all of Taiwan, and Tamsui should be especially cautious considering its large resident and tourist population. At the same time, maintaining higher population densities can help prevent further land use change. West Palm Beach should take care to prevent ecological degradation to its wetlands. West Palm Beach should also focus on mitigating the social strain of urbanization, as integrating incoming populations justly will be key to lowering inequality and increasing social capital.

The UACI is an easy to use and understand index, ideal for small scale, quickly-urbanizing communities to see different potential trends in their adaptive capacity. This index is well designed to assess districts in a city for comparison and can be easily upgraded as data availability improves. The UACI is an introductory method for measuring adaptive capacity in urbanizing places, but holds great potential for application and refinement in the future.

References

Acosta L, Klein RJT, Reidsma P, et al (2013) A spatially explicit scenario-driven model of adaptive capacity to global change in Europe. Glob Environ Chang 23:1211–1224.

Brooks N, Adger WN, Kelly PM (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang 15:151–163.

Dale VH (1997) The relationship between land-use change and climate change. Ecol Appl 7:753–769.

Engle NL (2011) Adaptive capacity and its assessment. Glob Environ Chang 21:647–656.

Gallopin GC (2006) Linkages between vulnerability, resilience, and adaptive capacity. Glob Environ Chang 16:293–303.

Intergovernmental Panel on Climate Change (2001). Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press.

Acknowledgements

The authors would like to thank the Taiwan Ministry of Science for their support, as well as the help of Penny Liou, Jimmy Liu, Neil Huang, Nick Shen, Laura VanVliet, Stephanie VanVliet and Corinne Swanson.

Contact Information

achu190@gmail.com
ptchueh@ntu.edu.tw