CLIMATE CHANGE ADAPTATION IN DAYTON, OH

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GLAA-C

Great Lakes Adaptation Assessment for Cities

EXECUTIVE SUMMARY

The city of Dayton is likely to experience multiple impacts due to a changing climate, such as increased temperature, severe heat events, flooding, changes in disease vectors, and the introduction of invasive species. Dayton possesses unique capacities and constraints that both enable and inhibit actions needed to prepare for these anticipated changes. In our analysis, dedicated leadership emerged as one key capacity that will likely help Dayton address historical and projected future changes in climate. While strong leadership is key, our research also showed that access to sufficient information regarding climate change and the financial and human resources needed to implement solutions are required to galvanize action. Additionally, our research found that stakeholders find scientific information pertaining to climate change to often be inaccessible and non-usable.

For the city of Dayton, decision-makers view climate change as a threat to existing plans aimed at increasing the economic and social vibrancy of the city. The city government is highly focused making a Dayton a "city of choice' and consequently, attracting new and retaining existing residents and businesses. Adapting to climate change dovetails with this broader city goal. Interviewees frequently framed environmental and social policies as ways to brand Dayton as a place possessing a high quality of life. Adaptation would aid in creating this identity. Climate change will also challenge social and economic goals. As demonstrated through vulnerability mapping, substantial regions of the city remain at risk to climate change impacts, which have the potential to constrain Dayton's economic growth and vibrancy. Developing adaptation strategies which protect Dayton's waterfront, support vulnerable populations, and capitalize on the water resources of the region can help the City to overcome some of the potential challenges which climate change may bring.

During the June 5, 2013 Climate Change Adaptation and Resiliency Workshop a SWOT analysis, vulnerability maps, and an Adaptive Capacity Wheel were presented as tools for Dayton to use to more fully identify key community vulnerabilities, inherent adaptive capacities and ultimately identify strategies to build resilience towards climate change. During this workshop, important strategies for building the resiliency of Dayton were suggested, including the creation of knowledge networks to gather information on adaptation projects taking place in other cities and using regional networks to gather resources for adaptation. Incorporating adaptation into the operations of key city departments, ensuring City infrastructure is updated and climate resilient, and updating codes and ordinances to allow for green infrastructure were also recommended actions.

Dayton was one of four cities studied as part of this project. And while research showed that each study city faces unique challenges there are, nevertheless, capacities within each city to mitigate existing and projected future impacts, so long as each city begins to systematically plan for adaptation. If leaders are able to capitalize on their strengths in order to create long-term and flexible plans, the four study cities of Dayton, Elyria, Toledo, and Avon Lake will make important strides in becoming more resilient to climate change.

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PROJECT BACKGROUND

In the summer of 2012, the city of Dayton accepted an invitation to participate in an interdisciplinary research project conducted by Master's degree students in the University of Michigan School of Natural Resources and Environment. This project was a continuation of research on climate adaptation in Great Lakes cities supported by the Great Lakes Adaptation Assessment for Cities (GLAA-C) project through the Graham Environmental Sustainability Institute. To better understand how the Great Lakes region can adapt to climatic impacts, an Integrated Assessment (IA) of the adaptive capacity of four cities in Ohio (Avon Lake, Dayton, Elyria, and Toledo) was conducted. This assessment included an analysis of the various capitals, capacities and constraints in these four cities to respond to climatic impacts.

To support the IA, a total of sixty-two interviews with city decision-makers were conducted between August and November 2012. In interviews, participants were asked scripted questions, designed to elicit responses elucidating each city's ability to cope and adapt to climate change. Broadly, the questions asked centered on the following:

- What are opportunities and challenges for Great Lakes cities to respond to climate change?
- What are the main drivers building adaptive capacity across the four research sites?
- What has each community done to build adaptive capacity?
- What policies and projects are being implemented in each community to adapt to climate change?

Using qualitative data coding software, the data from interviews was organized and analyzed to identify leverage points, synergistic projects, and partnerships. The adaptive capacity wheel (Gupta et al., 2010) was utilized to identify current institutional strengths and weaknesses constraining potential adaptation activities. Additionally, preliminary Global Information System (GIS) maps displaying the spatial distribution of climate change exposure and sensitivity in each city were created. By bringing together mixed methods and analytical frames, the assessment sought to provide decision-makers and stakeholders in participating cities with information and tools necessary to better adapt to climate change while also recognizing the current successes and strengths of each city.

What is GLAA-C?

The Great Lakes Adaptation Assessment for Cities is an Integrated Assessment (IA) supported by the Kresge Foundation and the Graham Environmental Sustainability Institute. The IA is being led by six university of Michigan (U-M) faculty and regional partners with the aim to "strengthen the science and decision making necessary for more effective urban climate adaptation in the Great Lakes Region." The project seeks to engage experts to:

- Work with cities to develop climate adaptation plans or strategies
- Integrate the collection of social and climate science data to further inform the field
- Create a tool that can be used by stakeholders to prepare for resiliency under different climate scenarios
- Establish a council to create greater awareness of likely urban impacts of climate change

More details about GLAA-C as well as this project can be at: www.graham.umich.edu/glaac

ADAPTIVE CAPACITY

Adaptive capacity refers to the ability of a system to respond to an outside perturbation. Often, there are three steps to adaptive capacity research:

1. Identifying a set of factors or determinants of adaptive capacity
2. Conducting an evaluation of the relative adaptive capacity of countries, regions, or municipalities, and
3. Identifying areas with the greatest vulnerability or least adaptive capacity.

This type of study assumes that decision-makers will apply this information to improve response to the impacts of climate change (Smit & Wandel, 2006). In their review of how adaptive capacity relates to efforts to respond to climate impacts and reduce system vulnerability, Nelson et al. (2007) argue that adaptive capacity describes the preconditions for a system to adapt to outside disturbances. Ideally, these preconditions reflect the goals of managers and stakeholders.

Climate Change Adaptation refers to adjustments in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC, 2007)

Adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with consequences. (USGCRP, 2008)

Assessing adaptive capacity is difficult. Most scholars argue that adaptive capacity is a latent quality of a system and observable only when individuals call upon it to actually adapt to a stress (Engle, 2011). Because of this, researchers have identified determinants of adaptive capacity, which describe the assumed preconditions likely to increase the potential of any system to adapt to climate change. Broadly defined, these determinants include: social capital; human capital; financial capital; political capital; institutions and entitlements; and technology and communication (Table 1).

TABLE 1: DETERMINANTS OF ADAPTIVE CAPACITY (EAKIN AND LEMOS, 2006)

Determinant	**Encompasses**
Human capital	Knowledge (scientific, "local", technical, political), education levels, health, individual risk perception, labor
Information and technology	Communication networks, freedom of expression, technology transfer and data exchange, innovation capacity, early warning systems, technological relevance
Material resources and infrastructure	Transport, water infrastructure, buildings, sanitation, energy supply and management, environmental quality
Organization and social capital	State-civil society relations, local coping networks, social mobilization, density of institutional relationships
Political capital	Modes of governance, leadership legitimacy, participation, decentralization, decision and management capacity, sovereignty
Wealth and financial capital	Income and wealth distribution, economic marginalization, accessibility and availability of financial instruments (insurance, credit), fiscal incentives for risk management

Institutions and entitlements	Informal and formal rules for resource conservation, risk management, regional planning, participation, information dissemination, technological innovation, property rights and risk sharing mechanisms

CLIMATE CHANGE IMPACTS

The IPCC Fourth Assessment Report predicts that, depending on the quantities of greenhouse gas emissions, the temperature will increase 3-5°C in the Great Lakes region by the end of the 21st century compared to the 1961-1990 mean (Pryor, 2013). The Canadian Regional Climate Model projects increasing temperatures in the winter and summer, with variability around the mean remaining relatively constant (Pryor, 2013). Moreover, these projected changes will not likely be uniform over space or time. The CRUTEM3 dataset shows that while the average mean temperature has increased by roughly 0.067°C per decade from 1900 to 2010, decadal increase for 1950-2010 is roughly 0.12°C, increasing to 0.23°C per decade for 1979-2010 (Pryor, 2013). Jones et al (1999) show that the Midwest region has also experienced reduced diurnal temperature range, that is, the minimum temperature at night has increased more than daytime maximum temperatures (Pryor, 2013).

Climate change and its effects on the environment will present particular challenges to the urban areas of the Great Lakes Region. Higher temperatures may lead to dangerous conditions in cities due to the heat island effect, during which residents will face health risks from heat stress and air quality deterioration (Bulkeley et al, 2012). In the US, extreme heat events are one of the largest causes of weather related mortality, responsible for over 3,442 deaths between 1999 and 2003 (Luber and McGeehin, 2008; Pryor, 2013). On July 20, 2011, the majority of the Midwest experienced temperatures over 100°F (Pryor, 2013) and several studies (Meehl and Tebaldi, 2004, Tebaldi et al, 2006, Battisti and Naylor, 2009; cited in Pryor, 2013) project that there will likely be future increases in heat wave occurrence and intensity in the region. Higher temperatures will also affect the generation and transmission of energy through efficiency losses and damage to transmission infrastructure, a crucial process when air conditioners must function to protect human health (IJC, 2003). Extreme precipitation events may lead to damage from flooding and water contamination from sewer overflows (IJC, 2003). More information about historic and projected climate change impacts for the Dayton area can be found in the *Climate Resources – City of Dayton* file.

TABLE 2 PROJECTED CLIMATE CHANGES AND POTENTIAL IMPACTS

Change in Climate	Possible Impact	Potential urban planning related impacts
Increase in temperature	• Increased frequency of heat wave occurrences and intensities • Deteriorated air quality • Damage to energy efficiency and transmission structure	• Increased urban heat island effect • Health impacts on vulnerable population (increased heat mortality, heat stress, disease outbreaks etc.) • Food security access (high food prices) • Increase in energy prices and demand
Changes in Precipitation	• Heavy rainfall • Ground water depletion and possible water shortages	• Flooding and erosion • Damage to food production and supply • Water shortages

Projections adopted from Pryor 2013; GLRA 2000; Bulkeley et al. 2010; and Hinderer 2010

DAYTON CAPACITIES & CONSTRAINTS

The City of Dayton, located in Montgomery County, Ohio, is positioned along the Miami River and has approximately 141,500 residents. Dayton has developed a significant service economy with legal, insurance and healthcare sectors after the regional decline in manufacturing. As the location of Wright-Patterson Air Force Base, the city also hosts numerous institutions involved in research into astronautical, aeronautical, and advanced materials technology. The city is considering environmental issues by pursing sustainability through its adoption of the Sustainable Practices Policy and incorporating sustainability into its plan for the revitalization of downtown Dayton.

Through a series of stakeholder interviews, a number of concerns relevant to the anticipated impacts of climate change were identified in Dayton:

- ***Flooding*** -Dayton has historically faced flood threats due to its location. After the Great Dayton Flood of 1913, flood infrastructure was significantly improved but concerns are still present
- ***Invasive species*** such as the emerald ash borer
- ***Vulnerability*** of population living in poverty

CAPACITIES

In terms of capacities, Dayton possesses a variety of assets and capitals that should aid in adapting to climate change. City employees, decision makers, and elected officials often use the frame of economic and social vibrancy to discuss sustainability and, to a lesser extent, adaptation. Many city employees consider being a 'sustainable city' as a way to distinguish Dayton from other Midwest localities and attract young professionals, small businesses, and even immigrant communities.

Leaders are able to connect environmental and climate policy to the identity of their city. In these cases, leaders argue that taking action on climate mitigation and adaptation makes sense as an extension of the sense of place the city possesses. Respondents often stated that high-level decision-makers in their city supported their efforts to address sustainability concerns. A city employee reported that "the idea of environmentalism has now mainstreamed [within the city government]." However, this employee also mentioned the need to apply appropriate "political pressure" to gain interest from decision makers. This demonstrates that leaders often are acting as policy entrepreneurs, in that they are utilizing their political and social capital to connect policy solutions to problems. While so far this ability has not been applied to adaptation, the potential to do so is there.

> *"We think that that's a way to differentiate ourselves from other Midwest cities. I don't like using the 'green' term but a sustainable city; all those things combine to make it—at least we think, it elevates us to a place of an even playing field, if not an elevated playing field."*
>
> -Dayton Public Official

Beyond individual leadership, there are also examples of collective leadership. City officials referenced the sustainability task force, an organization composed of volunteers that span city departments and brings together officials who care about sustainability in Dayton, as one of the places where leadership lies. Moreover, various individuals from across the city government have collaborated to collectively enact change that moves beyond their job descriptions. In many ways, these groups are acting as collective entrepreneurs in that they make use of their shared and combined social capital—namely the connections they have formed through the city government—to push for changes as a group.

Dayton has a long record of incorporating community and county input into city governance. For example, priority boards, though falling out of use recently, have historically offered a medium for neighborhoods to directly express their concerns. Seven priority boards have historically acted as a link between local citizens and the city government. In theory, each priority board consists of representatives from a defined region. City government employees and officials then seek input from these boards on how to best conduct government business. Multiple interviewees stated that the city is working to reorganize these boards to increase their efficacy.

Interviewees in Dayton reported participation in many partnerships of mutual benefit. These partnerships are often driven by initiatives for sustainability and economic development. They also may aid in increasing adaptive capacity by building social capital among city staff, the public, and partners. While sustainability and adaptation are not the same things, as processes, they have many overlapping aspects and can build off one another. Interestingly, many interviewees referenced partnerships and outreach efforts of other departments and entities, often referring to them as being integral to the city's plan for moving forward. This level of buy-in and integration can aid in the transfer of information and facilitates institutionalization of these undertakings.

> *"If it's something that we can do some cross-collaborations on, not just internal to the city, we partner with folks outside of the city as well to get grants."*
>
> -Dayton Public Official

At times, these linkages also span political levels and jurisdictions. For example, the city works with the regional Miami Conservancy District, which preserves the watershed on which Dayton and other nearby municipalities rely. Interviewees reported strategizing with the Conservancy District on efforts to protect the watershed from the potential impacts hydraulic fracturing fluid disposal might have on water quality. By coordinating with the Conservancy District, the city has been able to protect its interests in the region—including areas outside its jurisdiction—without attracting controversy or conflict with other local governments. Dayton also collaborates with the Miami Valley Regional Planning Commission to develop large transportation, environmental, and economic projects—including an air pollution reduction campaign. These networks demonstrate institutional arrangements and civic relations that can aid in adaptation.

Some infrastructure in Dayton also increases the city's ability to make steady progress towards resiliency and building adaptive capacity, such as green infrastructure. City officials are taking steps to plan geothermal infrastructure that will serve as an economic development tool, along with innovative low-interest financing for buildings and homeowners for energy improvements that reduce energy consumption. Another effort towards green energy has been the installation of the largest solar facility in southwest Ohio by the Dayton Power & Light Company. The city is looking into building energy efficiency and has entered into a 10-year performance contract with Honeywell for city-owned buildings. Additionally Dayton has invested in equipment to capture methane gas from the wastewater treatment plant to sell and to use as a fuel source. The ability to leverage existing physical resources for adaptation is a strength for Dayton.

CONSTRAINTS

A major factor constraining adaptation in Dayton is the low rate of inclusion/consideration of climate change issues in the everyday functioning of the city. Officials noted that Dayton is in the early stages of considering adaptation and reaching out for more information from credible sources on tying adaptation in with sustainability plans. Therefore, while it is likely that adaptation may eventually become a focus of the city government, current lack of widespread support in the city government hinders building and utilizing adaptive capacity.

Another critical constraint working against Dayton adapting to climate change is a lack of financial resources and competition from many different needs. Budgets are likely to continue to decrease during the next few years as federal stimulus funding phases out. One effect of current financial constraints is that Dayton has been unable to properly staff its departments. For two decades now, staff numbers have fallen substantially, though this is largely due to hiring freezes once people quit or retire. With less staff covering basic city services and functions, more people are wearing more hats, straining this crucial resource. As a result, less human capital is available to mobilize adaptive initiatives.

Additionally, Dayton has limited access to usable climate knowledge, especially concerning potential impacts on the city. Often, city employees described being unsure where to find credible and usable climate information. Other interviewees expressed a need for information in the short term from sources that can be trusted. This limitation in terms of access to technical knowledge hinders the city's ability to plan for long-term climate impacts.

Distributing information and gaining public support were also pointed out as challenges. Some respondents questioned the types of communication methods the city has typically used, based on actual readership and the challenges associated with having constant contact through social media and the internet. The amount of time required to continuously release information that is useful, relevant, and timely through social media as opposed to traditional press releases was identified as a challenge. The majority of interviewees reported being very confident in their existing plans and processes, however there were references to gaining new momentum being difficult at times. Integrating new information into a set system, such as is present in Dayton, may prove to be a challenge.

> *"In a city such as Dayton, an urban city, funding is a big issue right now because there's a battle between protecting the environment, managing climate initiatives—which is important—and sustaining city services."*
>
> -Dayton Public Official

ASSESSMENT TOOLS

SWOT ANALYSIS

Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis is a tool used to identify both internal and external forces that may impact proposed actions. SWOT is used to encourage awareness of factors, positive and negative, that may affect planning and decision-making (Goodrich, 2013). Strengths are internal characteristics of the institution that put it in an advantageous position for adaptation. Weaknesses are those internal characteristics that place the institution at a relatively disadvantageous position for adaptation. Opportunities are external elements that the institution can exploit for its advantage towards adaptation. Threats are external elements that can provide obstacles to the institution in its efforts toward adaptation.

Based on identified climate change concerns, constraints and capacities, a SWOT analysis for climate change adaptation was performed for the city of Dayton as a whole, as it pertains to climate adaptation, informed by our interviews in 2012.

TABLE 3 SWOT ANALYSIS FOR DAYTON, OH

	STRENGTHS	**WEAKNESSES**
Internal Attributes	Employees passionate and dedicated to the success of the city	Communicating information, particularly using newer technologies
	Regionalism through a number of partnerships	Gaining public support and momentum
	Collaboration across departments	Staff (numbers)
	Connecting policy, particularly environmental, to city identity	Funding
	Entrepreneurial leadership	Consideration of climate in policies
	OPPORTUNITIES	**THREATS**
External Attributes	Framing adaptation as a way to differentiate from other cities	Climate change as incremental change rather than an emergency situation
	Restructuring feedback mechanisms (i.e. priority boards)	Lack of usable climate information
	Leveraging existing physical resources (i.e. methane waste, solar energy, geothermal potential)	Funding
	Leveraging entrepreneurial strength and vision towards adaptation	

ADAPTIVE CAPACITY WHEEL

To further assess the city's adaptive capacity, an analytical framework was developed and applied in Dayton that builds upon and synthesizes institutional adaptive capacity determinants and urban adaptation planning research. The adaptive capacity wheel (Gupta et al., 2010) constitutes the heart of the research framework. The wheel serves as a heuristic analytical tool to assess the capacity of institutions to adapt to climate change (Gupta et al., 2010). Researchers rate institutions according to the wheel dimensions using a five-point scale ranging from 'very negative' (-2/dark red) to 'very positive' (+2/dark green) (see figure 1). The outputs of the adaptive capacity wheel are achieved through interpretation and judgment— and rather than being objective, the wheel reflects the knowledge, experience, values, and beliefs of whoever is doing the evaluation (Gupta et al., 2010).

For each city in the study, the adaptive capacity wheel was adapted to reflect both the specific variables relevant to each city and the data collected. Because evaluations are based on the experience and knowledge of different actors, cities can use the wheel to self-assess adaptive capacity. Thus, cities can use the framework both to modify/enhance this assessment, creating a more detailed picture of adaptive capacity or as a tool to reassess capacity over time.

Specific elements of the wheel and their definitions are summarized in Table 4.

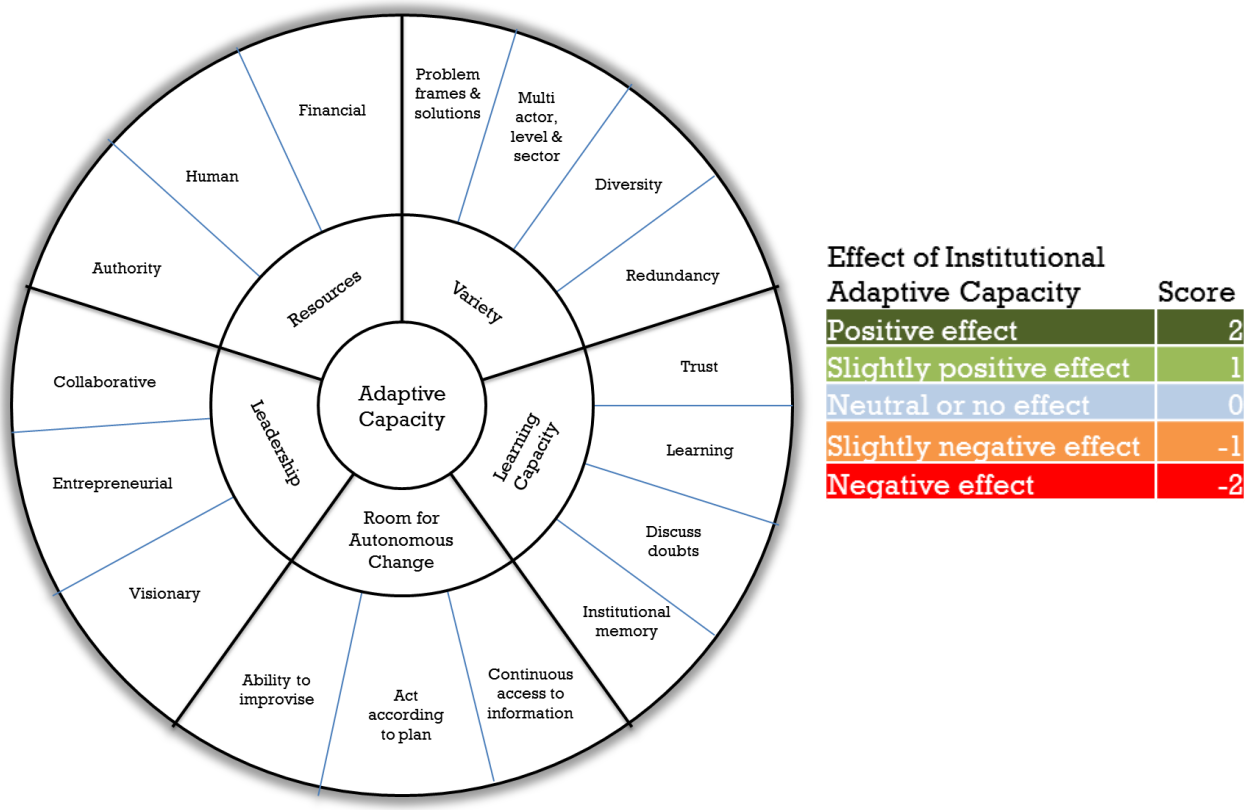

FIGURE 1 ADAPTIVE CAPACITY WHEEL (GUPTA ET AL, 2010)

TABLE 4 ADAPTIVE CAPACITY DEFINITION (GUPTA ET AL, 2010

Variety	*Variety of problem frames*—room for multiple frames of references, opinions, and problem definitions
	Multi-actor, multi-level, multi-sector—involvement of different actors, levels, and sectors in the governance process
	Diversity of solutions—availability of a wide range of different policy options to tackle a problem
	Redundancy (duplication)—presence of over-lapping measures and back-up systems; not cost effective
Learning Capacity	*Trust*—presence of institutional patterns that promote mutual respect and trust
	Learning—ability of institutional patterns to learn from past experiences and improve their routines
	Discuss doubts—institutional openness towards uncertainties
	Institutional memory—institutional provision of monitoring and evaluation processes of policy experiences
Room for Autonomous Change	*Continuous access to information*—accessibility of data within institutional memory and early warning systems to individuals
	Act according to plan—increasing the ability of individuals to act by providing plans and scripts, especially in case of disasters
	Capacity to improvise—increasing the capacity of individuals to self-organize and innovate; foster social capital
Leadership	*Visionary*—room for long-term visions and reformist leaders
	Entrepreneurial—room for leaders that stimulate actions and undertakings; leadership by example
	Collaborative—room for leaders who encourage collaboration between different actors; adaptive co-management
Resources	*Authority*—provision of accepted or legitimate forms of power; whether or not institutional rules are embedded in constitutional law
	Human resources—availability of expertise, knowledge and human labor
	Financial resources—availability of financial resources to support policy measures and financial incentives

While these criteria are organized in discrete categories, in a real life context, they overlap and complement each other. Although these criteria were kept separate for analytical and heuristic purposes, in practice they are intrinsically connected—both regarding who city officials are and what they do. Evaluations of capacities (positively or negatively) were based on the peer-reviewed literature as well as what was observed in the cities and on what the existing literature suggests and/or shows are important. A number of key findings in the literature were used to add weight to evaluation criteria.

Both the urban planning and adaptive capacity literature highlight the critical role of policy entrepreneurs, social learning, and incorporating adaptation in facilitating adaptation to climate change. Therefore, we gave weight to the criterion of entrepreneurial and visionary leadership and learning.

The literature demonstrates that even well-intentioned adaptation efforts can lead to negative outcomes—either by inadvertently increasing vulnerability or by conflicting with other policy objectives. Accordingly, the criterions listed under "Variety," as well as the ability to discuss doubts, are important for avoiding mal-adaptations and maximizing synergies between adaptation and other policy goals.

APPLYING THE ADAPTIVE CAPACITY WHEEL

We find Dayton to possess both strong political leadership and policy entrepreneurship. The urban adaptation literature describes the ability of entrepreneurial leaders to connect policy solutions to problems and politics as being a key attribute for facilitating adaptation. Various leaders both identified themselves and were identified by others as taking initiative to push for sustainability and, to a lesser extent, adaptation policies in city governance. These efforts have helped integrate these concerns into the broader discourse of vibrancy that permeates city decisions. Further, the city has exhibited a history of collaboration—particularly around environmental protection, such as the Miami Valley Conservancy District and the city 'Green Team'. This ability to collaborate is particularly important in light of human resource constraints.

Collaboration is likely facilitated by, and facilitates the city's strengths in trust, multi-level governance networks, and bringing together multiple problem frames. The city works to integrate both community and regional stakeholders into governance by collaborating with community priority boards and regional partners. These efforts have contributed to trust building, as stakeholders are likely to feel governance that incorporates their input is more legitimate.

Dayton's visionary leadership was rated as neutral—at least in regards to climate change adaptation. Adaptation remains largely a short-term, reactive consideration, as it is not fully integrated into the long-term thinking of the city. On the other hand, the city has shown the ability to think in creative and long-term ways about development in general, which prevents the rating of this criterion as negative. If the city is able to harness its visionary leadership and apply it to the realm of climate change adaptation,, Dayton would greatly increase its overall adaptive capacity.

However, to accomplish this task, Dayton must increase its access to resources. Financial resources were the most significant constraint the city was facing in regards to climate adaptation—and likely in nearly every other major effort. The city did not have enough financial capital to invest in adaptation efforts. Additionally, the lack of financial resources influenced Dayton's deficit of human capital. Though the city has many dedicated, talented employees, it does not have enough of them.

Finally, lack of access to usable climate information (as well as other kinds of information necessary to inform adaptation decisions) represents a limitation to the integration of adaptation into everyday governance. This is partially due to the lack of participation in formalized information-sharing networks. Interviewees with high social capital reported being able to navigate informal networks to access information regarding city

operations, but without more formalized information sharing, Dayton's efforts to address the impacts of climate change will likely be constrained. Perhaps more significant is the reported difficulty many interviewees expressed regarding accessing credible and locally relevant climate change information. Though many interviewees showed detailed knowledge of past and current changes in weather and climate patterns, they consistently lamented they did not sufficiently know about likely future impacts.

The assessment done through the adaptive capacity wheel is based on one interpretation of the information given by interviewees and can be modified according to city priorities. Its greatest use is as a tool for Dayton and other cities to begin discussions related to capacities needed to adapt to climate change.

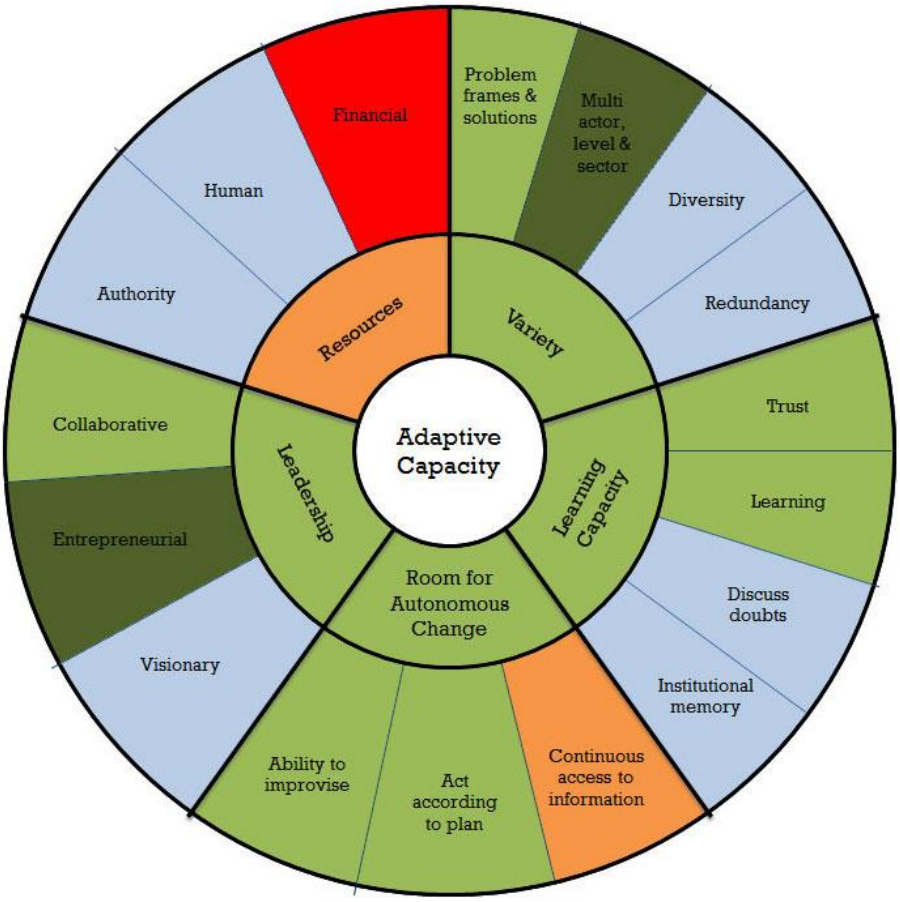

FIGURE 2: DAYTON ADAPTIVE CAPACITY WHEEL

DAYTON PRELIMINARY VULNERABILITY ANALYSIS

Note: These maps should serve as a tool, or starting point, for the city. They do not indicate definite patterns and they are not predictions.

Risk index (vulnerability) maps were created for Dayton and the other three research cities using geographic information system (GIS). GIS is a tool that enables data to be visualized and analyzed for the purposes of examining spatial relationships, patterns and trends (ESRI, n.d.). In this study, GIS was used to augment the city interview analysis by delving into data to identify areas within the city where populations may be more

vulnerable to anticipated climate change impacts and could be targeted for program and policy intervention. The maps can serve as a starting point for expanding decision-maker knowledge and streamlining resource allocation to areas that may be most at risk.

Data used for this analysis included:

- Block group demographic information from the 2010 U.S. Census and 2006-2010 American Community Survey
- 100-year flood hazard data from FEMA
- A variety of city specific data including boundaries, roadways, rivers, and land use

The demographic data included percentage of the population below 2010 poverty level, percentage under 5 years of age, percentage over 65 years of age, and percentage minority. These demographics were of particular interest as research has shown these groups may be most vulnerable to climate change impacts, particularly heat events (USGCRP, 2008). Localized flooding due to increased storm intensity, access to green space, and proximity to high concentrations of vacant land, were expressed as concerns by interviewees. Green spaces help mitigate urban heat island effect, a projected climate impact on urban areas that will likely affect vulnerable populations (Altman, 2012). Citizens living near 100-year flood plains will likely be affected by a greater incidence of flooding events (NOAA, 2012). Distance to areas with high vacancy was included in these risk indices because a few public officials in Dayton expressed concern about the spread of disease vectors due to waste dumping on vacant property. Block groups and neighborhood boundaries were overlaid to allow for visual reference.

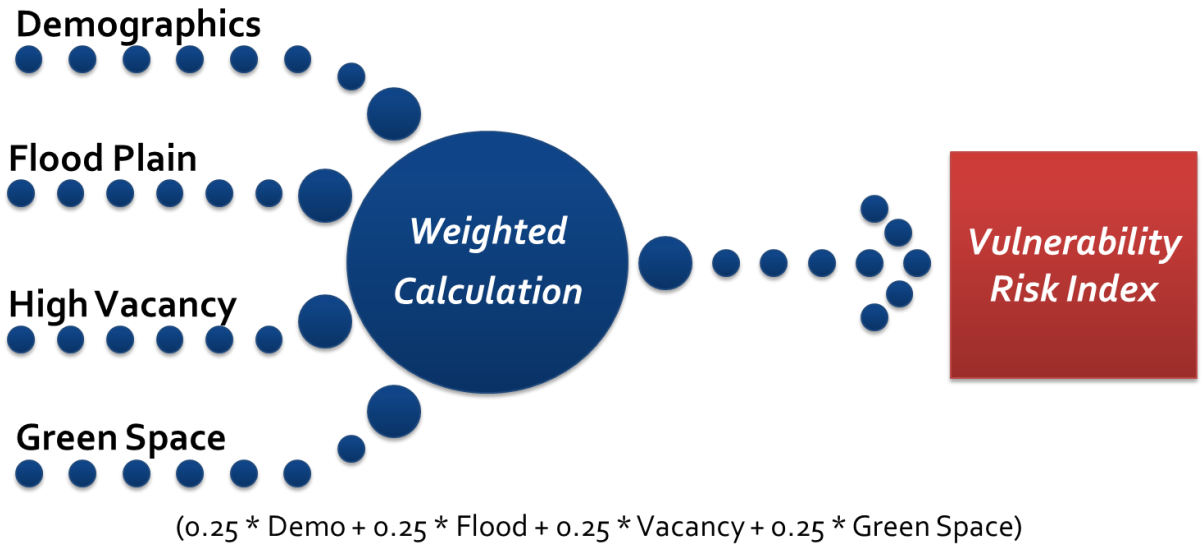

FIGURE 3 REPRESENTATION OF INPUTS INTO GIS WEIGHTED CALCULATION

These data were combined in a weighted calculation to identify areas where the combination of these variables may increase risk relative to the rest of the city. The weights of individual variables can be adjusted, depending on the primary concern of the city or department using the information.

While no neighborhood in Dayton was considered at highest risk in all five weighted calculations, two were considered at highest risk in four and another was considered high risk in three.

- ***Southern Dayton View***: Considered high risk in Equal Weight and calculations weighted for proximity to flood plain, proximity to green space, and population demographics.

- ***Riverdale***: Considered high risk in Equal Weight and calculations weighted for proximity to flood plain, proximity to green space, and population demographics.
- ***Miami Chapel***: Considered high risk in Equal Weight and calculations weighted for proximity to vacancy and population demographics.

While these areas possess a number of risk factors that have been associated with climate change impacts, their actual vulnerability needs to be further examined. As described throughout this report, opportunities for taking advantage of neighborhood adaptive capacities can be explored. For example, as Dayton looks to implement and expand their urban forestry and street tree replacement program in an effort to counter recent losses due to pest infestation and increase community engagement, targeting areas potentially most vulnerable due to heat and distance from green space may make sense. Interestingly, one of the two neighborhoods where this program is being piloted, Five Oaks, was considered to be at high risk due to distance from recreation space.

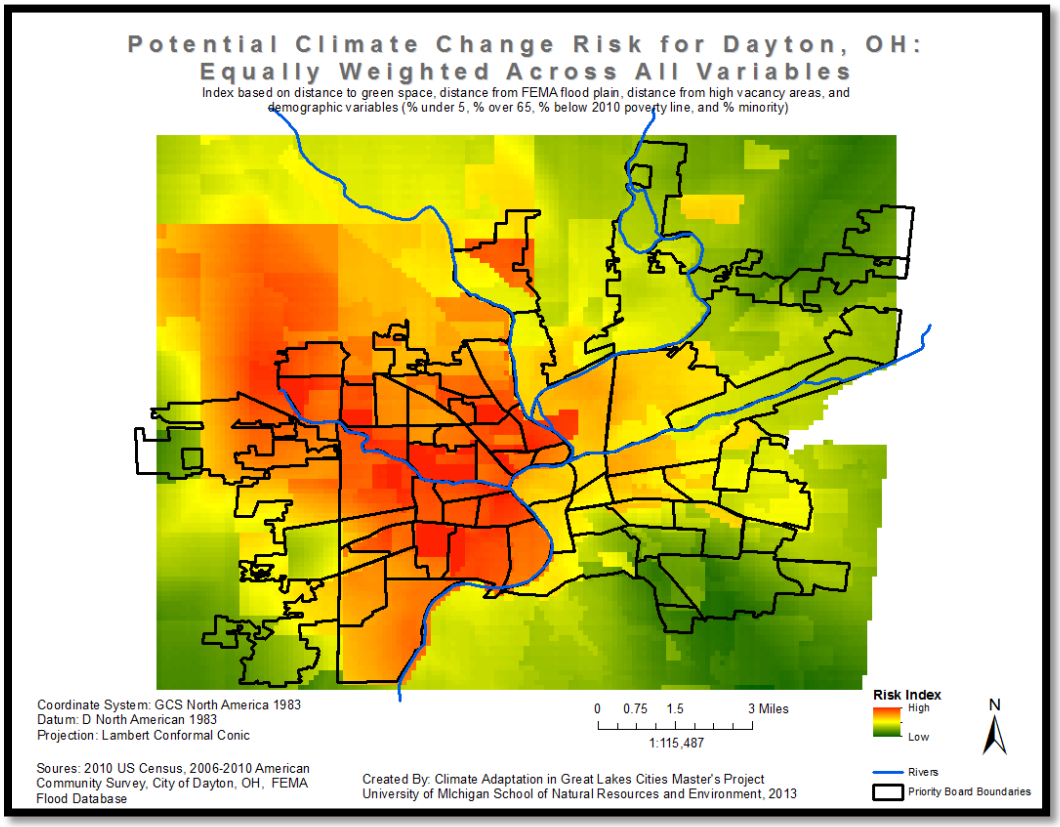

FIGURE 4 POTENTIAL CLIMATE RISK FOR DAYTON, OH

BEST PRACTICES & RECOMMENDATIONS

Adaptation is a dynamic process, involving multiple stakeholders from different sectors tackling complex issues. Adaptation processes and strategies can be challenging to implement as resources and collaboration from across a city are necessary. Most adaptive processes in cities are currently in nascent stages or more broadly defined as sustainability. Yet there is growing consensus in the scientific literature and some political circles that it is best to anticipate projected impacts and implement adaptive processes in a preparatory rather and responsive fashion (NRC, 2010). Many believe that feeling at risk from extreme weather events could provide the impetus or a "window of opportunity" to implement adaptive measures (Penning-Roswell et al, 2006).

Many adaptation initiatives also have the potential to provide co-benefits to quality of life of the city's citizens. For example, near-term benefits of adaptive processes can reduce emergency response costs, building future resilience and adaptive capacity (Rosenzweig, 2010). The literature offers many examples of best practices and strategies cities can deploy to increase their adaptive capacity and/or implement effective adaptation options. Many scholars and planners suggest adopting decision-making frameworks that favor robustness and can handle uncertainty (Hallegatte, 2008; Quay, 2010). A robust strategy is most insensitive to future climate conditions, rather than being the best strategy in a particular climate future. Uncertainty refers to embracing the fact that future climate conditions are unknowable and potentially novel, yet identifying alternative scenarios to capture as many possibilities as possible. It is important to identify quantitative signals to help decision-makers recognize when a potential scenario is becoming more likely (Hallegatte, 2008). Below, are specific recommendations on adaptation activities that best practices for Dayton using Hallegatte's criteria (Table 5).

TABLE 5 BEST PRACTICES RELEVANT TO DAYTON, OH

Sector	Potential Adaptation Options
Ecosystem Services	A multilevel governance framework for adaptation responses, setting goals, regulations and financial support given to local governments by national government
	Share knowledge and best practices with nearby cities to achieve outcomes towards regional adaptation
Regional Networks and Knowledge	Improving social care networks/social safety nets
	Institutionalize risk/vulnerability analysis in long term plans
	Emergency back-up systems/infrastructure
	Restrictive land use management
Public Health	Utilize urban forestry to reduce heat island effects and improve air quality
	Increase the amount of green infrastructure throughout the city
Infrastructure	Invest in wetland restoration and rain gardens for storm water management
	Determine critical infrastructure and assess climate impact vulnerabilities in the short and long term
	Develop robust disaster management plans to resume critical services during emergencies
	Implement green building codes for new building projects

KNOWLEDGE NETWORKS & REGIONAL PARTNERSHIPS

Networks and partnerships are tools that can aid in enhancing the tangible and intangible resources available to a city. Associations of existing knowledge are crucial to promote networks of knowledge across cities that can translate to actionable outcomes within geographic regions. These networks of knowledge ideally amalgamate different kinds of knowledge (i.e. scientific, local and indigenous knowledge, practical and experiential knowledge) that inform action and build resilience of socio-ecological systems (Adger et al, 2005). They may also encourage participation and buy-in from stakeholders (Lemos, Kirchhoff and Ramprasad, 2012). Additionally, formalized partnerships enable action on climate knowledge through the sharing of resources and expertise. Several resources for beginning or strengthening networking and partnership formation are detailed below.

- Great Lakes Adaptation Assessment for Cities works with cities in the Great Lakes region to develop and implement climate adaptation. After development, adaptation reports will be available on GLAA-C's website. http://graham.umich.edu/glaac/)
- Climate Adaptation Knowledge Exchange (CAKE) aims to build a shared knowledge base for managing natural and built systems in the face of rapid climate change. Case studies, a library of tools, and community forums are available for knowledge and strategy sharing. (http://www.cakex.org/)
- ICLEI-Local Governments for Sustainability is a national and international network of local governments working on issues pertaining to climate change and sustainable development (www.icleiusa.org)
- Great Lakes Integrated Sciences & Assessments (GLISA) works to bridge the gap between the produces and users of climate science information. A number of resources including educational events, research, grants, and decision tools are available on the GLISA web site. (http://glisa.msu.edu/index.php)
- The Southeast Florida Regional Climate Change Compact is a multi-county effort to mitigate the causes and adapt to the challenges of climate change. The compact was officially executed in January 2010. (http://southeastfloridaclimatecompact.org/)
- The Georgetown Climate Center is a resource for state and federal policy. As a part of its mission, the Center shares best practices and success stories. (http://www.georgetownclimate.org/adaptation/state-and-local-plans)

IDENTIFYING AND RETAINING ADAPTATION FUNDING

As Eakin and Lemos (2006) propose, building adaptive capacity relies upon governments having both administrative and policy capacities, which depend upon having access to required resources. Financial resources are particularly significant for cities' ability to adapt. Possessing a sufficient amount of financial capital allows cities to move beyond short-term 'core' functions, such as police, fire, water, and so on, to incorporating long-term considerations—such as built infrastructure, sustainability and adaptation. Further, human resources depend upon being able to hire and retain talented individuals within city government. Similarly, infrastructure and technology monitoring and maintenance require significant capital investment. Included below are a number of funding resources for climate change adaptation.

- ICLEI-Local Governments for Sustainability has created a fact sheet regarding financing climate change adaption. (http://www.icleiusa.org/action-center/financing-staffing/ICLEI_Adaptation%20Financing%20Fact%20Sheet.pdf)

- The U.S. Department of Housing and Urban Development (HUD) has a series of sustainability focused grants that can be applied to advance local adaptation efforts (http://portal.hud.gov/hudportal/HUD?src=/program_offices/sustainable_housing_communities)

CLIMATE ADAPTATION PLANNING STRATEGIES

As the built environment is a primary contributor to greenhouse gas emissions and land use decisions play an important role in how and where the impacts of climate change will be felt, there are great opportunities to implement adaptation strategies through the planning process (American Planning Association, 2011). While some cities elect to draft a separate climate action plan, while others choose to integrate considerations of climate change into already existing policies, practices, and plans. With either option, understanding the cross-cutting impacts of climate change is important to understanding potential trade-offs and opportunities.

- The American Planning Association has developed a policy guide for planning and climate change. The guide includes information on the role of planning in climate action as well as policy recommendations for a number of sectors, including land use, natural resources, economic development, and public health. (http://www.planning.org/policy/guides/pdf/climatechange.pdf)
- California developed a Climate Adaptation Planning Guide that was made available to the public in April 2012. The guide discusses vulnerability assessment, strategy development, climate change impacts and adaptation strategies. (http://resources.ca.gov/climate_adaptation/local_government/adaptation_policy_guide.html)
- EPA has compiled links to information clearinghouses, sector and region specific tools, and guidebooks. (http://www.epa.gov/climatechange/impacts-adaptation/adapt-tools.html)
- Through the ICLEI web site, there are a number of trainings, educational resources, and tools for climate adaptation available. (http://www.icleiusa.org/climate_and_energy/Climate_Adaptation_Guidance)

PROJECT CITIES COMPARISON

In the following section, the SWOT Analysis for each city studied is provided for comparison. Table 6 provides demographics information for each city and the state of Ohio. The cities included in the project include two small cities (Avon Lake and Elyria), two large cities (Dayton and Toledo), two coastal cities (Avon Lake and Toledo), and two inland cities (Elyria and Dayton). Based on interviews within each city, these SWOT assessments can serve as a point of comparison across study cities. This comparison can aid in identifying common weaknesses and threats as well as opportunities to connect based on strengths and opportunities. Based on these analyses, a number of trends emerged:

- The availability of funding and financial capital was a threat in all four cities.
- Networks and partnerships were consistently seen as a priority for respondents, though some efforts were just beginning.
- Usable information regarding climate change and adaptation was frequently seen as a constraint by respondents in all cities.
- Framing adaptation to meet the needs of city development and identity is a strategy that is used or could be used by all study cities.

TABLE 6 2010 CENSUS DATA

	Dayton	**Toledo**	**Elyria**	**Avon Lake**	**State of Ohio**
Population	**141,527**	**287,208**	**54,533**	**22,581**	**11,536,504**
Population under 5 years	6.9%	7.4%	6.9%	5.7%	6.2%
Population 65 years and over	11.8%	12.1%	14.3%	14.5%	14.1%
Median household income	$ 28,843	$ 34,170	$ 42,383	$ 81,635	$ 48,071
Persons below poverty line	32.5%	25.6%	16.5%	4.5%	14.8%
Racial make-up					
White	51.7%	64.8%	78.1%	95.7%	82.7%
Black	42.9%	27.2%	15.5%	1.1%	12.2%
Other	4.2%	8.9%	6%	3.8%	5%

	DAYTON, OH SWOT ANALYSIS	
	STRENGTHS	**WEAKNESSES**
Internal Attributes	Employees passionate and dedicated to the success of the city	Communicating information, particularly using newer technologies
	Regionalism through a number of partnerships	Gaining public support and momentum
	Collaboration across departments	Staff (numbers)
	Connecting policy, particularly environmental, to city identity	Funding
	Entrepreneurial leadership	Consideration of climate in policies
	OPPORTUNITIES	**THREATS**
External Attributes	Adaptation as a way to differentiate from other cities	Climate change as incremental change rather than an emergency response
	Restructuring feedback mechanisms (i.e. priority boards)	Lack of usable climate information
	Leveraging existing physical resources (i.e. methane waste, solar energy, and geothermal potential)	Funding
	Leveraging entrepreneurial strength towards adaptation	

	TOLEDO, OH SWOT ANALYSIS	
	STRENGTHS	**WEAKNESSES**
Internal Attributes	Innovative approaches to shifting economic base to improve financial capital	Departmental silos inhibit integration of goals across departments
	Increasing collaboration across departments	Lack of financial capital
	Willingness to implement green infrastructure solutions	Extending collaborations beyond city departments and programs
	Ability to learn from past events/experiences	Transferring knowledge
	Participation in networks for information and resource sharing	Human capital (Staff numbers)
	OPPORTUNITIES	**THREATS**
External Attributes	Infrastructure replacement, particularly with storm water management	Interstate and international regionalism challenges
	Increasing trust through partnerships with the public and industry	Coastal climate challenges
	Utilizing sustainability to encourage resiliency through revitalization	Lack of accessible and usable climate information
	Capitalizing on an engaged population/community	Gaps in expertise as it related to climate change/adaptation
		Narrow understanding of climate impacts (environmental concerns only) and adaptation (same thing as sustainability)

	AVON LAKE, OH SWOT ANALYSIS	
	STRENGTHS	**WEAKNESSES**
Internal Attributes	Good personal communication	Mistrust of climate information
	Focus on sustainability initiatives	No formalized communication networks
	Human capital	Short term reactive decision making
	Accessibility of city officials	Lack of climate knowledge
		Human Capital
	OPPORTUNITIES	**THREATS**
External Attributes	Forming Regional Networks	Changing Climate
	Promoting collaborations with scientist/ entrepreneurs	Financial Capital is not flexible or increasing
	Population increase due to highway opening	

	ELYRIA, OH SWOT ANALYSIS	
	STRENGTHS	**WEAKNESSES**
Internal Attributes	Social capital and informal relationships among city officials allows for resource and information sharing, as well as collaboration	Shortage in number of staffers among institutions
	Consistent communication and informal relationships with the public	Overburdening of current staff members
	Membership of regional sustainability networks	Little integration of sustainability and adaptation in city governance
	Resourceful staff members that obtain grants and maximize opportunities	Low comprehension of climate science, adaptation, or sustainability among staffers
	Relative flexibility to allocate funding within departments	Inconsistent or a lack of accessing climate information for use in planning
	OPPORTUNITIES	**THREATS**
External Attributes	Regional leaders in sustainability willing to share best practices and collaborate	Reduction in federal grants
	Renewable energy projects in Northern Ohio likely to create new green jobs in Elyria	Projected increase in precipitation will increase soil erosion in Cascade Park
	Industrial infrastructure of Elyria attractive to national green industry	Invasive species to threaten biodiversity of local flora and fauna
	Sustainable storm water management on regional brownfields, i.e. rain gardens, green roofs, etc. can be emulated in Elyria	Political silos at interstate and interregional levels prevent collaborative solutions
	Regional leaders in sustainability willing to share best practices and collaborate	Reduction in federal grants

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APPENDICES

GLOSSARY OF TERMS

The following list is based on definitions from the IPCC AR4, USGCRP 2012, Ontario Expert Panel on Climate Change Adaptation (2009), whenever possible. Other references include NOAA, and US EPA as noted.

Climate Change

Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/ or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC Fourth Assessment Report)

Adaptation

a) Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature shock-resistant plants for sensitive ones, etc. (IPCC Fourth Assessment Report)
b) Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities and moderates negative impacts. (USGCRP 2012)

Adaptive Capacity

a) The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures. (IPCC Fourth Assessment Report)
b) The ability of a system to adjust to climate change (including climate variability and extremes) in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (Ontario Expert Panel on Climate Change Adaptation 2009)

Capacity building

In the context of climate change, capacity building is developing technical skills and institutional capabilities in developing countries and economies in transition to enable their participation in all aspects of adaptation to, mitigation of, and research on climate change, and in the implementation of the Kyoto Mechanisms, etc. (IPCC Fourth Assessment Report)

Climate prediction

A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate – including weather variations – in the future, for example, at seasonal, interannual, or long-term timescales. (USGCRP 2012)

Climate projection

A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases or aerosols, or radiative-forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend

upon the emission/concentration/radiative forcing scenarios used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty. (USGCRP 2012)

Coping Range/Capacity

The capacity of systems to accommodate variations in climatic conditions. (IPCC Fourth Assessment Report)

Effects

Changes in the physical characteristics of climate that are driven by forcings. These usually describe indicators from a management or status perspective.

Exposure

The severity and frequency that a system experiences a given type of event.

Extreme weather event

An event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density of weather events. (USGCRP 2012)

Impacts

Changes in the engineered or natural environment that affect human or ecosystem behavior and can be altered or avoided by direct action. They are often the result of climate effects coupled with existing conditions in built or natural the environment. For example, severe storms and paved surfaces can lead to channeled storm water and flooding. This, in turn, can lead to further cascading impacts, such as water supply contamination and property damage. Reducing the amount of paved surface, or changing storm water management practices can avoid this particular impact. Climate impacts are generally problems that can be solved through action.

Indicators

Observables that are unambiguously affected by natural or anthropogenic climate change. Precipitation, temperature, sea level rise, extreme weather, snow cover, snowfall, and glacial melt are some examples. NOAA limits this definition to observable physical changes. Ecological and environmental changes are often included in a broader definition of indicators used by many organizations.

Integrated assessment

A method of bringing together knowledge of ecosystems, people, and policy in order to find solutions for particularly challenging or "wicked" problems. Assessments summarize scientific knowledge to build consensus and guide decision making around a particular resource management, environmental or sustainability issue. (Vaccaro, 2009).

Mitigation

a) Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. (IPCC Fourth Assessment Report)

b) An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. (Ontario Expert Panel on Climate Change Adaptation 2009)

Resilience

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. (Ontario Expert Panel on Climate Change Adaptation 2009)

Risk

The probability of an event occurring multiplied by the severity of the consequence.

Sensitivity

The susceptibility of a system is to a particular type of impact.

Uncertainty

An expression of the degree to which a value is unknown (e.g. the future state of the climate system). Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts). (IPCC Fourth Assessment Report)

Urban heat Island

The elevated temperatures in developed areas compared to more rural surroundings. (US EPA)

Vulnerability

a) The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate and global change, including climate variability and extremes, as well as climate change in conjunction with other stressors. (USGCRP 2012)
b) The degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (Ontario Expert Panel on Climate Change Adaptation 2009)

Sustainability Projects and Programs in our Project Cities

Projects in Dayton	*Dayton*	• Geothermal energy project for downtown area (in planning phases) • Recycling program • Construction and expansion of bike trails • Well-field protection (aquifer protection program) • Urban forestry program with the help of volunteering community groups to grow seedlings in city-owned green houses and planted in specific locations; • Riverfront development as a part of Downtown plan 20/20 in collaboration with Miami Conservancy District, County Metro Parks etc.
	Montgomery County	• Dayton Region Green-3 (DRG3) program offered by the County and local utility for green certification of downtown businesses • Biodiversity conservation and habitat restoration by Five Rivers Metro parks • Urban reforestation • River front development • Bike program • Recycling Program • Wetland bank
	State/Fed	• Nutrient -reduction credits offered to farmers by Miami Conservancy District • Water trail protection and development (MCD) • Bike program • Renewable energy grants for solar, wind, geothermal etc. by DOE • Habitat/biodiversity conservation programs by Ohio Department of Natural Resources
Projects in Toledo	*Toledo*	• Separation of Combined sewer system under Waterways initiatives program by 2020 due to USEPA Consent Decree • Community gardens including rain and kitchen gardens constructed as storm water best management practices; • Energy Special improvement district (ESID) in collaboration with Port Authority investing in solar energy manufacturing and installations; • Newly initiated Recycling program to reduce transport of recyclables to the city of Ann Arbor;
	Lucas County	• Great Lakes Coastal Resilience Planning Guide –an online guide for best management practices in coastal areas • Energy audit program in collaboration with the University of Toledo, Lucas County Soil and Water Conservation District; • Rain Garden initiatives spearheaded by County Soil and Water Conservation District • "Healthy Homes" program providing grants to the city for lead and asbestos abatement; • Biodiversity conservation and restoration projects, i.e. species habitat corridor etc. Supervised by the Country Metro parks
	State/Fed	• Coastal Wetland Climate Vulnerability Assessment for Lake Erie coastal wetlands (for construction of wind farms) • Adaptation plan for coastal wetlands and wild life by ODNR • Regional storm water project assessing the best management practices for the

		State of Ohio- by ODNR • Renewable energy grants offered by the Department of Energy (DOE)
Projects in small cities (pop. <60,000)	*Elyria*	• Separation of Combined sewer system by 2020 under USEPA Consent Decree • 50-year long leasing of Cascade Park to County Metro Park for management and maintenance • Emergency management plan of 2006 • Energy efficiency and rebate programs • Regional bike trail ultimately connecting Indiana State to Pennsylvania through northern Ohio; • (Voluntary) Recycling program and construction of a recycling center • Community gardens program utilizing the empty property lots the construction of rain or food gardens;
	Avon	• Separation of Combined sewer system by 2020 under USEPA Consent Decree • Sanitary sewer awareness and education program • Renewable energy projects for solar and wind energy; • Energy efficiency program for residential building by offering energy audits • Expansion of bike trail connecting the city with neighboring cities; • Recreation
	Lorain County	• Offshore fresh water wind project including several other countries- first of its kind project in the State of Ohio • Combined Regional Sewer authority system including Avon Lake and Elyria; • Solid waste management program with recycling center in the city of Elyria • Regional bikeway program run by County Metro Park and city of Elyria connecting Ohio state with other neighboring states

DAYTON PRELIMINARY VULNERABILITY ANALYSIS (MAPS & METHODS)

The GIS maps were created by combining data from a number of sources using a series of steps designed to allow users to prioritize issues of concern for their city.

Identify data of interest

For each city in the study, a number of types of information were of interest including city boundaries, land use, particularly green space, areas prone to flooding, and demographic information (age, race, and wealth). Based on research, these characteristics are indicative of areas that are more vulnerable to the impacts of climate change. Additionally, as expressed in several Dayton interviews, areas of high vacancy were also included. Data found was publicly available online or via request.

- City Boundaries: digitized from priority board maps provided by the city
- Land Use: 2009 Adopted Land Use Plans, Miami Valley Regional Planning Commission (http://www.arcgis.com/home/item.html?id=1e1baf29ac474901980083017eea22ca)
- Flood Data: FEMA Flood Plain data, can be obtained by request from FEMA
- Demographic Information and Vacancy: US Census and American Communities Survey (Social Explorer and TIGER shapefiles)

Import Data Layers into ARCGIS programs

Ensure that the layers are all using the same projection to minimize distortion and allow for the data layers to overlay.

Process Data Layers

Clip layers to appropriate spatial extent using city, regional, or county boundary layers of interest. Identify and isolate variables of interest (i.e. green space, flood hazard areas) from data sets. Join demographic data tables with corresponding shapefiles.

Perform Risk Analysis

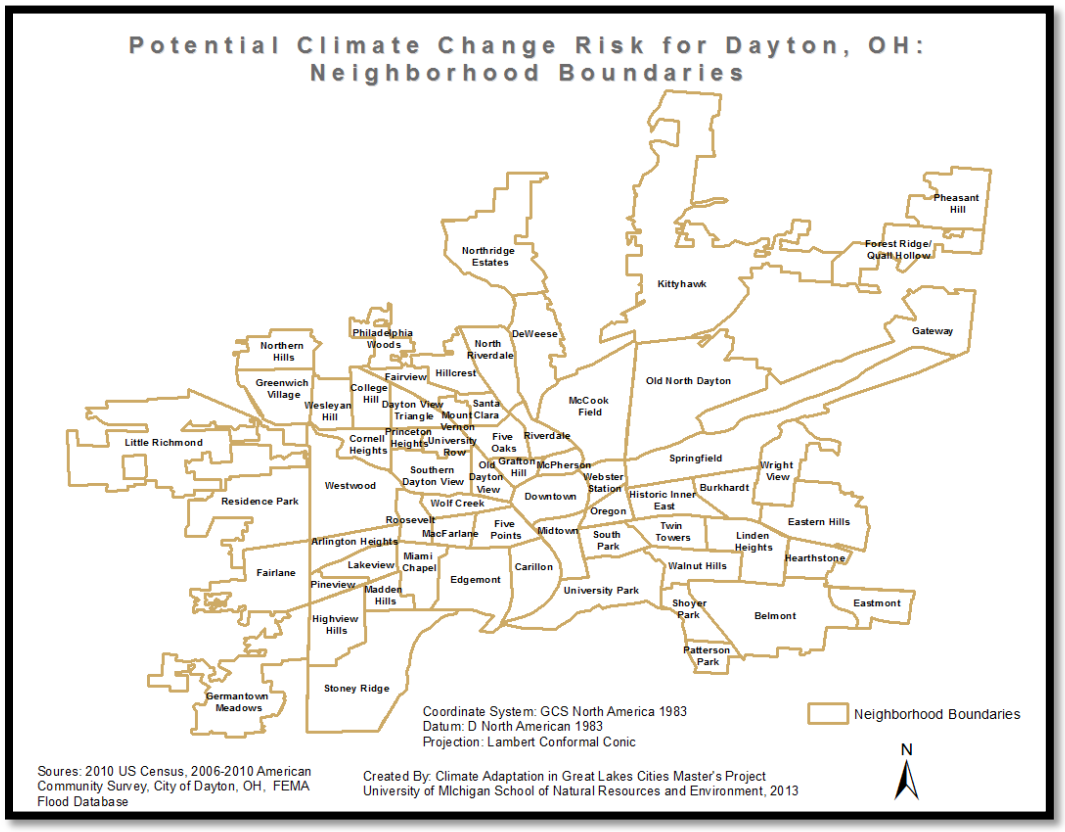
To perform the combined risk analysis, the data layers of interest need to be converted from shapefiles to raster. Demographic layers (% over 65, % under 5, % minority, and % under poverty line) were combined in a weighted calculation to create a demographic risk index. The calculation for giving each demographic variable equal weight is as follows:

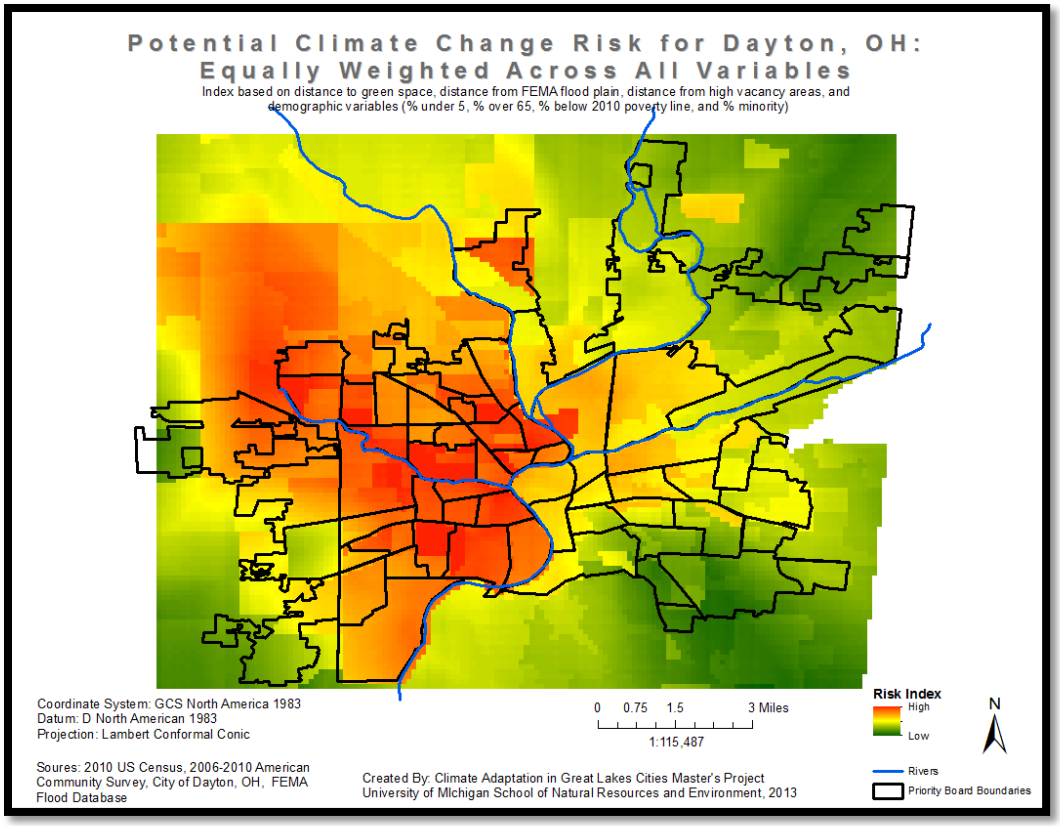
- (.25 * over_65 + .25 * under_5 + .25 * min_pop + .25 * pov_stat)

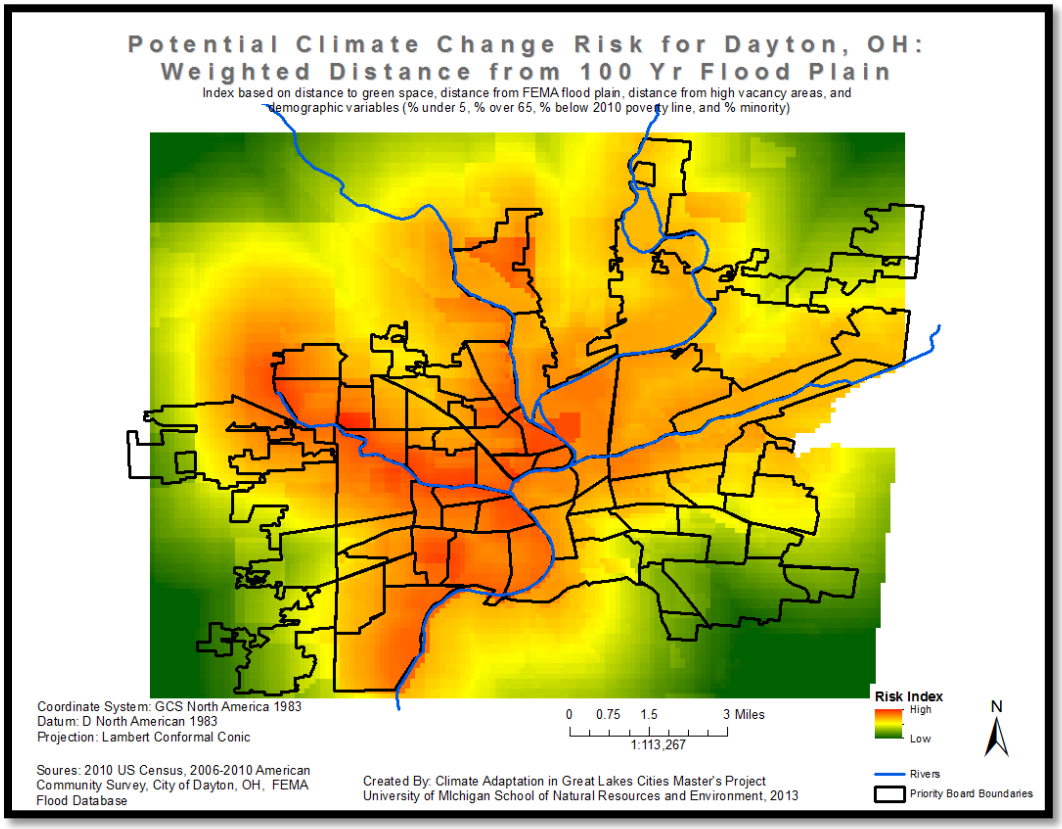
Euclidean distance can then be utilized to determine distance from features of interest (i.e. flood hazard, high vacancy areas, green space). The values for these variables need to be stretched so they are on the same scale (i.e. 0-100) so they can be combined. When Euclidean distance is calculated, it is assumed that closer to the variable interest is better, so proximity to flood hazard and high vacancy were then inversed so that closer proximity indicated higher risk. Proximity to high vacancy areas, the demographic risk index, proximity to flood plains, and proximity to green/recreation space were then combined in a weighted calculation. The weights attributed to each variable can be adjusted depending on primary issue of concern of the city. This calculation is as follows:

- Equally weighted: (.25 * vacancy + .25 * demographics + .25 * flood + .25 * green_space)
- Vacancy Weighted: (.55 * vacancy + .15 * demographics + .15 * flood + .15 * green_space)

- Demographics Weighted: (.15 * vacancy + .55 * demographics + .15 * flood + .15 * green_space)
- Flood Plain Weighted: (.15 * vacancy + .15 * demographics + .55 * flood + .15 * green_space)
- Green Space Weighted: (.15 * vacancy + .15 * demographics + .15 * flood + .55 * green_space)




Potential Climate Change Risk for Dayton, OH:
Equally Weighted Across All Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:115,487
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from 100 Yr Flood Plain
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
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Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
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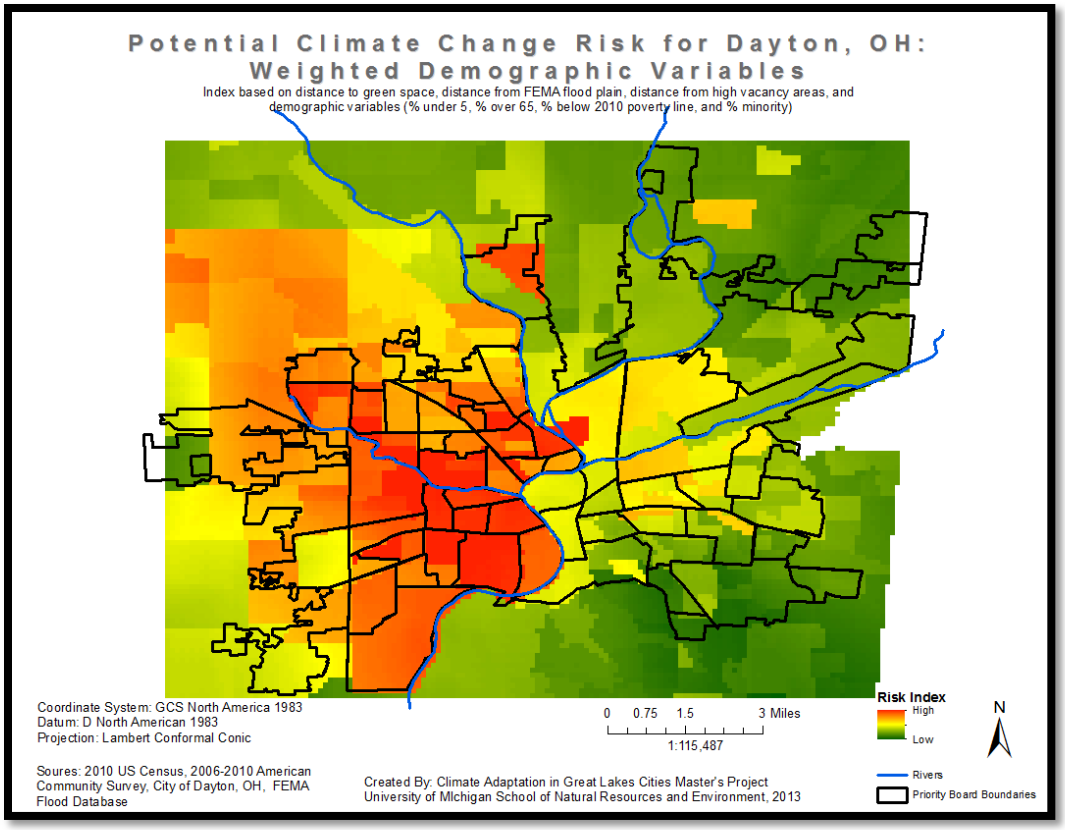
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Demographic Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
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Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of MIchigan School of Natural Resources and Environment, 2013
Risk Index
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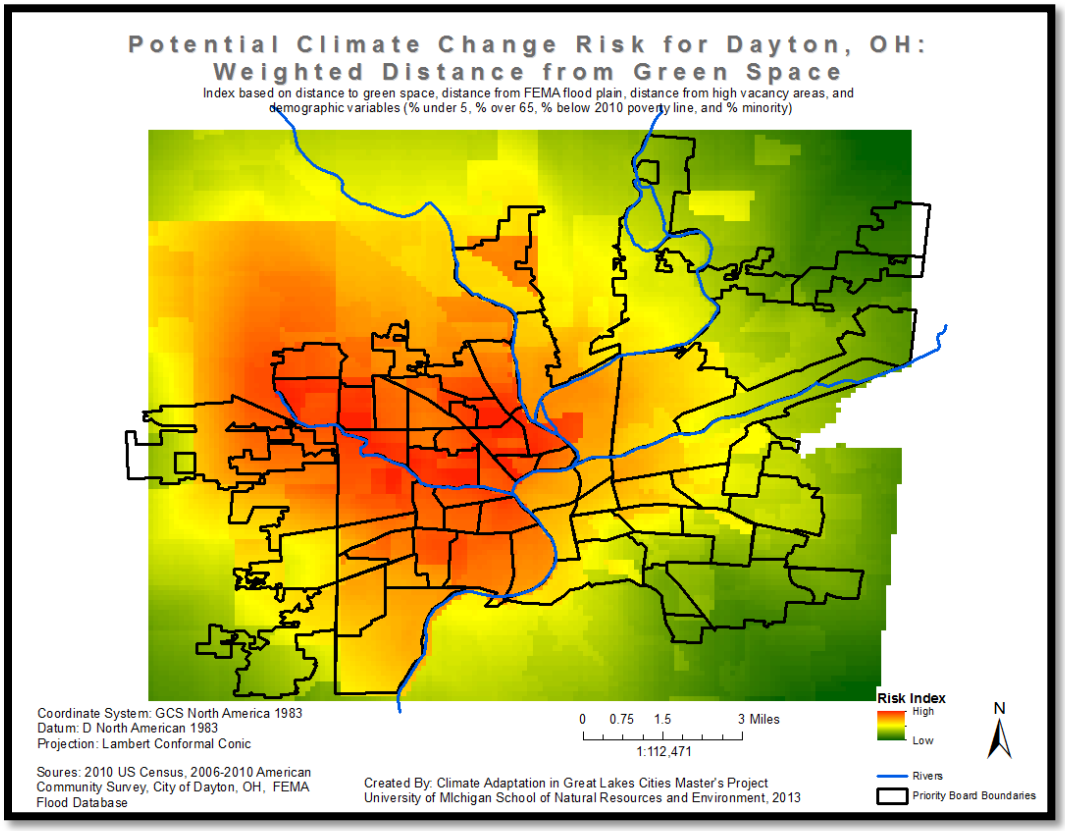
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from Green Space
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
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Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of MIchigan School of Natural Resources and Environment, 2013
Risk Index
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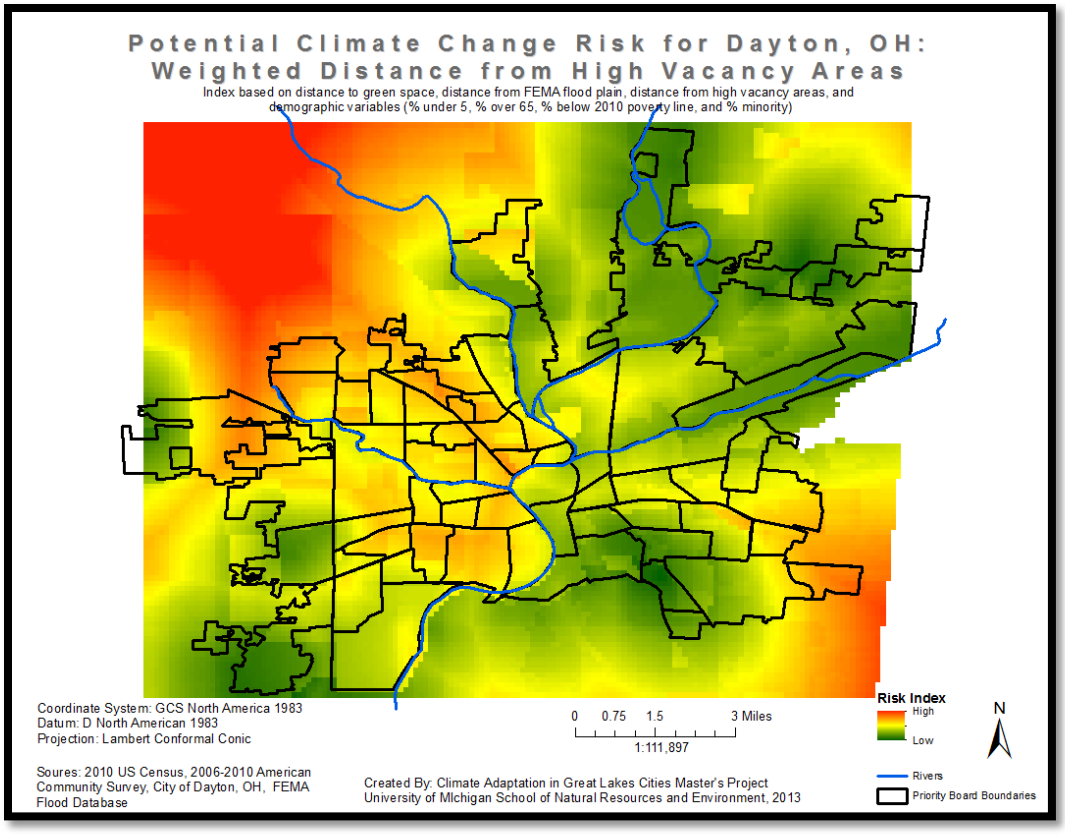
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from High Vacancy Areas
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
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Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of MIchigan School of Natural Resources and Environment, 2013
Risk Index
High
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Rivers
Priority Board Boundaries

Sector	*Examples of adaptation options/Best practices*	*No regret' strategy*	*Reversible/Flexible*	*Existence of cheap safety margins*	*Soft strategies*	*Reduced decision horizons*	*Synergies with mitigation*
Ecosystem services	Strategic wetland restoration	++	+				+
	Create and manage buffer zones around ecological reserves	++	-		+		+
	Mitigate air, water, and soil pollution	++					+
	Intensive management of climate-sensitive species	+	+		+		
	Promote landscape connectivity to facilitate species adaptation	+	-				+
Regional networks & knowledge	Facilitating scientist-stakeholder information sharing addressing adaptation needs and uncertainties	++	+		++		
	A multilevel governance framework for adaptation responses, setting goals, regulations and financial support given to local governments by national government	++	+		+		
	Inter-agency, regional coordination to protect ecosystems and vulnerable species	++			+		+
	Share knowledge and best practices with nearby cities to achieve outcomes towards regional adaptation	++	++		+		
Emergency preparedness	Insurance, early warning and evacuation schemes	++	+	+	+		
	Improving social care networks/social safety nets	++	++				
	Institutionalize risk/vulnerability analysis in long term plans	+	+		+		
	Emergency back-up systems/infrastructure	+	-	+			
	Restrictive land use management	+	+	+	+		
	Adopt portfolio of actions to reduce and transfer risk	+	+	+	+		

Public Health	Research & development on vector control and vaccines	+					
	Reevaluate and revise maps detailing populations at risk for climate impacts	++					
	Utilize urban forestry to reduce heat island effects and improve air quality	+	++		+		++
	Improve communication of climate risks and resources to vulnerable populations	+	+		+		
	Assess coping capacity of health care system in extreme weather events	+			+		
Infrastructure	Invest in wetland restoration and rain gardens for storm water management	++	+		+	+	+
	Determine critical infrastructure and assess climate impact vulnerabilities in the short and long term	++					
	Prioritize building a climate resilient energy sector by investing in alternative forms of energy generation and distribution	+					++
	Develop robust disaster management plans to resume critical services during emergencies	++			+		
	Implement green building codes for new building projects						++

No regret options are actions with socially beneficial outcomes in all projected climate change scenarios (Heltberg, Siegel, & Jorgensen, 2008). For example, climate-proofing new buildings through creating new building codes requiring efficiency and insulation is beneficial in any future scenario because the decrease in energy needs will save money and mitigate further climate change (Hallegatte, 2008). By using computer simulations, Pyke et al (2011) concluded that low impact development that decreases impervious surface area while maintaining high-density levels is a positive planning strategy for storm water management in all climate scenarios.

Reversible and flexible strategies aim to keep the costs of being wrong as low as possible so plans can be terminated with minimal cost. For cities, this may entail taking short-term actions that can be adapted over time as impacts become more evident (Quay, 2010). For example, cities can implement restrictive land use planning then alter restrictions through time as information changes (Hallegatte, 2008).

Including safety margins into infrastructure and the built environment at low- and no-cost increases the robustness of a city to withstand climate impacts. For example, Copenhagen uses run-off figures that are 70% larger than current levels of need (Hallegatte, 2008). Such margins allow for continued population growth and increased rainfall intensity. Including safety margins now is more efficient than retrofitting run-off infrastructure in the future. A similar strategy to 'no regrets' options is planning for the 'worst case' scenario in which the worst outcomes are planned for so that all potential scenarios are covered (Quay, 2010).

Soft strategies refers to institutional and financial tools for addressing climate impacts. Forcing planners to think ahead several decades or creating suitable insurance policies to extreme weather events can increase the flexibility and robustness of urban areas to climate change (Hallegatte, 2008). Creating formal, dedicated climate units in city governments that monitor implementation and effectiveness of climate adaptation plans can increase the legitimacy, coordination, and support for such policies (Anguelovski & Carmin, 2011). To mitigate the effects of urban heat effects, Katzschner (2011) argues that planners must incorporate building design and open spaces that create diverse microclimates and cooling effects, while ventilation should be considered at the city level. Similarly, Mathey et al (2011) found that a 'richly structured system of many parcels of interconnected green spaces, supported by unrestricted cold air corridors from outlying areas, can positively influence the entire urban micro-climate" (p. 434). Creating the institutional tools for implementing such strategies requires altering the scale at which such considerations take place and increasing coordination between regional and levels of governance.

Reducing the time horizon for decision-making means that some planning decisions may be best served if long-term commitments are avoided. For example, if there is a great deal of uncertainty regarding climate conditions in fifty to one hundred years, it might be most efficient to build cheaper buildings with shorter lifespans (Hallegatte, 2008). Though this may seem to contradict taking a long view in climate adaptation planning, these types of decisions can make the most sense when the long-term outcomes are uncertain.