A Review of Management Options for Improving Climate Resiliency in the Huron River Watershed's Forest and Tree Resources

HURON RIVER WATERSHED COUNCIL

Climate Resilient Communities
Natural Infrastructure

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Executive Summary

Climate change can have many implications for overall forest health within the Huron River Watershed. With drastically different climate conditions, tree species that evolved to tolerate the historic temperature and precipitation ranges of this area may no longer be suited to live here or may experience a change in abundance. Despite these predictions, it is possible to improve the resiliency of forests of the Huron River Watershed to the impacts of climate change if key decision makers and environmental managers take action. Ecological resilience is the capacity for an ecosystem to absorb disturbance without shifting into a qualitatively different state.

Given the nature of climate change and environmental variability, the inevitability of novelty and surprise, and the range of management objectives and situations, it is important to remember that no single approach will fit all solutions. A toolbox approach recognizes this and arms managers with a range of options. It is up to the manager to decide which combination of these options makes the most sense based on their unique understanding of their forest resources and the associated vulnerabilities to climate change.

This report presents a summary of climate adaptation strategies emerging for forest and tree management. Summaries are intended to introduce the array of possible approaches being discussed in the literature to improve the resilience of forests impacted by climate change. The paper does not attempt to recommend particular strategies as most lack significant supporting evidence due to the long-term nature of climate change as a stressor. The following is a summary of the management options discussed in the full report.

Long-term planning and policy formulation

(see page 12 for additional information)

LAND PLANNING

Reserve planning: The ecologically informed acquisition of land for conservation management.
Protecting refugia: The preservation of natural areas known to be resistant to the climatic changes affecting surrounding regions.
Improving landscape connectivity: Creating and maintaining habitat linkages between natural areas to reduce the negative impacts of fragmentation.
Inventory urban forest resources: The inventory and mapping of urban trees by a municipality to allow for more informed management practices of their tree resources.
Balanced approach to urban forest planning: Planning for both “wild” forested areas and more intensively managed forest areas (i.e. street trees) in urban settings.
Long-term seed banks: The creation of a long-term seed bank to re-establish populations in new and more appropriate locations.

POLICY

Anticipate future constraints to the timely establishment of resiliency-based management strategies following disturbances: A strategy for municipalities and land management organizations who may feel that the uncertainties related to climate change impacts make immediate investment in climate resiliency measures for forests too risky. They choose to react once the problem is evident.
Development ordinances that promote resiliency: Ordinances could include a climate resilient tree species list for new plantings, minimum tree canopy standards in new developments, protection of natural areas, etc.
Protection of existing trees: The development of a planning program and policy to protect urban trees from removal during new development and from indiscriminant removal.

MODELS AND TOOLS

Be wary of relying on historical tree species ranges in planning efforts: This does not allow one to account for climate change and associated changes in weather.
Cross-scale integration of ecosystem models and data: The coupling of forest inventory with maps and data at different scales to better understand and predict tree species distributions.
Establish an organizational framework for management decisions: The use of a framework/methodology for making management decisions a less overwhelming ordeal.

COMMUNICATION AND EDUCATION

Improving stakeholder communication: Good communication is important for insuring that all stakeholders are operating with common goals and objectives, while also increasing support for climate resilient forestry programs.
Community engagement: Working with the public to educate and advocate for the preservation of ecologically valuable natural areas on private land.
Development of open-access information systems: Open-access information systems can help decision makers learn and share lessons in forest management and climate changes.

Site Scale Recommendations for Natural Areas

(see page 17 for additional information)

PROMOTING DIVERSITY

Increase tree species diversity: This can help maintain resilience to mortality and reduction in growth rates of trees in response to diseases and other climate change impacts like drought stress.
Use of multi-aged management systems: A multi-aged forest management program can buffer against stressors that might affect trees differently based on size and age. This also balances a higher carbon stores in retained mature trees with higher sequestration rates in younger trees.
Increasing genetic diversity: Increasing the genetic diversity of tree types used for local restoration projects to enhance forest disease resistance and tolerance to environmental stresses.

ESTABLISHING NEW TREES

Natural regeneration: Allowing an ecosystem to follow a successional pathway back to its original stable state following a disturbance. This is more often used in highly resilient systems.
Enrichment planting: The planting of seedlings within a forest where natural regeneration is poor or non-existent.
Assisted migration: The intentional, human-assisted range expansion of selected biota to avoid decline and extinction.

MAINTENANCE

Thinning and pruning: These practices can lessen the risks posed by disturbances associated with climate change such as pests and diseases (lower stand density decreases spread and increases resources available for tree defenses) and drought stress (less competition for water).
Minimizing thinning: This allows for the maximization of aboveground carbon stores.
Increasing canopy cover: Increased canopy cover in forests can create microclimates favorable for species at risk to stressors related to climate change.

PROCESSES

Manage for processes instead of species and manage for ecosystem redundancy: Management goals and approaches should not focus on the health of specific tree species, but instead determine the ecological role that the species and encourage additional species that fulfill a similar niche.

MISCELLANEOUS

Controlled burns: The use of human induced and controlled fires to promote forest health.
Irrigation systems: The installation of irrigation systems for particularly drought-intolerant tree species.
Hunting seasons for troublesome game populations: Changes in game population may be required for sustainable forest management.

Site scale recommendation for urban areas

(see page 21 for additional information)

PROMOTING DIVERSITY

Increase the biodiversity of urban forests: Increasing the diversity of tree family, genus, and species raises the odds that at least some of the tree species will thrive in future climates and protects against disease or pest outbreaks targeting specific types of trees.
Ensure that there are a healthy distribution of age classes and growth rates: This helps to maintain a relatively constant canopy cover over time and safeguards against high proportions of trees reaching the end of their lifespan simultaneously.

TREE SPECIES SELECTION

“Right tree, right place”: Matching tree type to the appropriate urban planting site based on conditions such as underground and overhead utilities, above and below ground space, light, soil and drainage conditions, and existing right-of-way infrastructure. Trees are planted to achieve the maximum benefit.
Maximize benefits: Choosing large trees over small trees will provide the most benefits. Some trees are also disproportionately valuable for biodiversity.
Plant native species: Some experts argue that because native plants are adapted to the local climate and site conditions they will be more resistant to drought and will require less nutrient inputs. In addition, natural wildlife habitats will be preserved.
Plant drought resistant species: This practice can allow communities to anticipate increased summer drought likely to be associated with climate change and to reduce irrigation needs.

PESTS, DISEASES, & INVASIVES

Prepare for high incidences of pests and disease: Proactive measures and monitoring can help mitigate the impacts of climate change and associated increases in pest insect populations and added stress on trees that makes them more susceptible to pathogens.
Proper pruning technique and sanitation to prevent disease spread: Most pathogens need some way of entering the tree to cause disease, and fresh wounds offer an ideal opportunity for infections to begin.
Be wary of planting invasive species: If trees are not native to the area, consider before planting if they exhibit any characteristics that give them the potential to become invasive.
Planting cultivars: If an invasive species must be planted, a cultivar of that species could be used because it may lack invasive potential, as many tree cultivars do not produce viable seed.

EXPERT OPINION

Seek expert opinion: Collaborating with experts on the creation of urban forest management plans aimed at resiliency is an ideal option for municipalities with ample financial resources.

Evaluating and adapting existing conservation plans

(see page 25 for additional information)

ACTNG WHEN WE DON’T HAVE ALL THE ANSWERS

Incorporate climate data and models into conservation plans: This allows for better understanding of the types and ranges of climate change impacts predicted for an area. It helps identify ranges of potential management options to reduce vulnerability risk from uncertainty.
Use adaptive management framework for planning: A systematic and iterative approach for improving resource management by emphasizing learning from management outcomes.

PRIORITIZING RESOURCES

Prioritize management responses in situation of resource scarcity – the triage approach: An approach to forest management that sorts management situations into categories according to urgency, sensitivity, and capacity of available resources to achieve desired goals (i.e. survival).
Management plan audits: utilized by land managers as a means of quickly prioritizing what aspects of current management plans need to be updated to increase climate resiliency.

MANAGEMENT PLANS FOR PRIVATE LANDOWNERS

Federally assisted establishment of forest management plans: Federally subsidized assistance for writing conservation management plans is available to private landowners.

A Review of Management Options for Improving Climate Resiliency in the Huron River Watershed's Forest and Tree Resources

Introduction

Climate change can have many implications for overall forest health within the Huron River Watershed. Scientists generally agree that Michigan will be warmer by the end of the century by upwards of 10 degrees F with precipitation patterns creating more drought prone summers and shifts in the seasonal distribution of rainfall. With drastically different climate conditions, tree species that evolved to tolerate the historic temperature and precipitation ranges of this area may no longer be suited to live here or may experience a change in abundance. A migration of tree species north is expected as range envelopes shift to accommodate for a changing climate (Weubbles & Hayhoe 2008; Barnes 2009; HRWC 2009; HRWC 2012).

An average 700 km shift northward is foreseen by the end of the 21st century. However, it is generally agreed that this long distance shift in the projected potential distribution of native trees will not be realized. The reasons include relatively slow migration rate, lack of suitable establishment sites, forest fragmentation, natural disturbance dysfunction and uncertainty, aggressive competition from non-native species, silvicultural activities, threats from non-native insects and pathogens, and genetic maladaptation. Thus, community composition is expected to be markedly different than that of today (Barnes 2009).

It is possible to improve the resiliency of forests of the Huron River Watershed to the impacts of climate change if action is taken by key decision makers and environmental managers. Ecological resilience is the capacity for an ecosystem to absorb disturbance without shifting into a qualitatively different state (Sturrock et al. 2011). In practice, planners and managers could apply strategies in at least three ways to help safeguard against the impacts of climate change. At the broadest scale, *long-term planning and policy formulation* should tackle adaptation for whole landscapes and regions, with tools like reserve selection, ecosystem management, and land use zoning schemes. Second, managers of individual reserves might want to know *what to do at the individual site scale or in concert with other sites*. Third, rather than initially pursuing an idealized regional, landscape, or site-scale plan, the first practical step for many managers and stakeholders is to *evaluate and adapt existing conservation plans* (Heller and Zavaleta 2008).

The landscape that characterizes the Huron River Watershed ranges from urban to relatively undeveloped wild areas. The forests of the watershed also share this range (urban to wild). Actions taken by local land managers to improve the resilience of forests and will be different in urban areas and natural areas.

This report presents a summary of climate adaptation strategies emerging for forest and tree management. Summaries are intended to introduce the array of possible approaches being discussed in the literature to improve the resilience of forests impacted by climate change. The paper does not attempt to recommend particular strategies as most lack significant supporting evidence due to the long-term nature of climate change as a stressor. Strategies are organized by the three recommendations outlined by Heller and Zavaleta (italicized above), with individual site scale action being further broken down in urban-based strategies and "natural area" strategies.

Long-term planning and policy formulation

LAND PLANNING

Reserve planning: Nature reserves are protected areas of ecological importance and managed for conservation. Reserve planning is the ecologically informed acquisition of these lands. In order to make informed decisions about land acquisitions, reserve managers must develop an inventory of both their reserve land and potential land for acquisition in near vicinity of their property. This allows for more prudent land purchases that can result in better landscape connectivity (see section below titled "Improving Landscape Connectivity") and the increased protection of highly valuable natural areas. For instance, reserves should be planned around areas predicted to be hotspots for biodiversity in the future or to provide/expand habitat for species of high conservation value (Heller and Zavaleta 2008). Planning and inventory could allow managers to recognize these areas and target them when resources allow for further land acquisition. Despite a lack of agreement in the literature regarding the optimal area, distribution, and location of reserve lands, there is consensus in the idea that more land should be protected rapidly (Heller and Zavaleta 2008).

The HRWC Bioreserve Project provides a local example of reserve planning through which HRWC and local governments work to prioritize and protect remaining natural areas in the watershed. Visit the Bioreserve webpage at: http://www.hrwc.org/our-work/programs/bioreserve/

Protecting refugia: Closely tied to reserve planning, reserve managers and planners are encouraged to identify past climate refugia and protect these areas so that they can again function as life-boats in the present and future climate. Refugia are areas that have remained resistant to climatic changes affecting surrounding regions and that therefore form a haven for relict fauna and flora. This helps persisting populations to recolonize the surrounding landscape when conditions favorable for their survival and reproduction return (Julius et al. 2008; Singh 2008).

Improving landscape connectivity: Fragmentation may threaten biodiversity during climate change through several mechanisms, most notably through edge effects and patches. Under a rapidly changing climate, survival may be difficult for species with poor dispersion abilities, especially in fragmented and degraded habitats. Maintaining habitat linkages parallel to climate gradients and minimizing artificial barriers is a forward-thinking management strategy under any climate change scenario (Singh 2008). Land level linkages to maintain biodiversity and corridors can be done by aggregating individual sites' management plans to better increase landscape connectivity (Singh 2008). This would require improving communication between reserve and other land managers. Enlisting people and human communities to "soften" land use through sustainable or less damaging practices (innovative landscaping and natural areas preservation on private lands) will facilitate species movement and persistence in the future (Heller and Zavaleta 2008). The HRWC Bioreserve Project has been working with various townships throughout the watershed to determine possible connections between already existing reserve lands. Resources mapping these potential connections can be found on the Bioreserve webpage and can serve as a planning tool for decision makers to prioritize new reserve land acquisitions.

"You can't manage what you can't measure" – Inventory forest resources: Inventory and map urban forests to better manage the resource and know what is at risk. Even smaller communities without a lot of financial resources will benefit from a simple inventory (British Columbia: Ministry of Community, Sport, and Cultural Development 2010). There are several tools, many of them free, which allow for cost-effective tree measurement and management (Nowack 2010). i-Tree is a suite of urban forestry analysis tools for collecting and analyzing information on urban forests. i-Tree uses local data to statistically assess urban forest composition and its effects and values related to air pollution removal; carbon storage and sequestration; building energy use; and urban runoff, stream flow, and water quality. Software, training, and technical support are free. Specialized versions of forestry analysis tools such as i-Tree are also available to assist urban foresters with management regarding specific concerns. For instance, i-Ped is a specialized i-Tree tool for establishing a long-term, large-scale, urban pest detection and reporting system (Nowack 2010). Visit the i-Tree Web site above for this and other tools (www.itreetools.org). Provide a tree inventory to assess age distribution is also critical for preventing high numbers of municipal trees reaching the end of their life spans simultaneously and creating a financial burden on the city to replace them all at once (Brosius 2007).

Balanced approach to urban forest planning: For urban forests as a whole, there is a need to balance order with chaos. Cities need to have areas that are "wild," or less intensively managed, in addition to some orderly trees along streets. Native trees, shrubs, and flowers encourage ecological relationships between insects, mammals and birds that are important to a city's ecosystem (Ramstad 2009). Where remnant forests exist, planning efforts should seek to preserve these areas and their biological integrity should be actively maintained. This includes not planting invasive species near these areas (prevents "escape") and possibly engaging in an active control program to eliminate and control exotic invasive plants (Brosius 2007). Less intensively managed wild areas can also serve as key linkages between larger reserve areas outside of city limits to increase forest connectivity.

Long-term seed banks: Establishment of a long-term seed bank is one available option to cope with the inability to maintain ecosystems that currently exist. Seed banks can be used for re-establishing populations in new and more appropriate locations (Palmer & Peterson 2008).

POLICY

Anticipate future constraints to the timely establishment of resiliency-based management strategies following disturbances: Many municipalities and land management organizations might feel that the uncertainties related to the ultimate impacts of climate change make immediate investments in climate resiliency measures for forests too risky. For these governing bodies, a choice could be made not to act now, but rather to react once the problem is evident. Their rationale is that due to the uncertainty, the best time for action from a scientific as well as organizational efficiency standpoint may be post-disturbance. These groups might see disturbances as windows for opportunity to establish climate resilient forests. However, governing bodies must be prudent to anticipate future constraints when these windows open in order to plan for and possibly remove them in advance for timely adaptation to be able to occur when opportunity arises. For example, if a planned management alternative was to replant disturbed areas with a climate resilient mixed tree species, managers could ensure that genetic nursery stocks are available for wider areas, or they could re-examine regulations restricting practices so that, immediately after a disturbance, management can act rapidly to re-vegetate and manage the site (Palmer & Peterson 2008).

Development ordinances that promote resiliency: New development in urban areas can be viewed as an opportunity for increasing the climate resiliency of the tree species planted within a municipality. Ordinances can be established that require tree plantings in new developments to be selected from a list of climate resilient species. Additionally, tree canopy goals can be aided by requiring new developments meet minimum standards (Brosius 2007). Likewise, ordinances protecting natural areas can increase resilience such as buffers.

Protection of existing trees: New development and construction in urban environments should take care not to remove existing tree resources in order to insure maximum function and ecosystem services of urban forests. Trees are often slow growing and take several years to become well established in developed urban environments. Thus, it could take years for a newly planted tree to reach a size where it matches the ecosystem services provided by the removed specimen (DiSalvo 2011). Replacing lost trees really isn't as simple as planting another specimen in turn. Similarly, designated trees of high ecological value on private property should be protected against indiscriminate removal and damage. In order to safeguard existing tree resources, municipalities should provide an integrated planning program for conservation and development including the development and enforcement of a tree preservation ordinance. Municipalities could also require tree preservation plans for all projects (public, private, commercial, residential) (Brosius 2007).

MODELS AND TOOLS

Be wary of relying on historical tree species ranges in planning efforts: Many quantitative tools currently used to manage forests currently do not account for climate change and associated changes in weather. Consequently, most management strategies or practices (for example, natural regeneration) assume a relatively constant climate or weather pattern that predict current tree species ranges based on historical coverages. Historical conditions can be a useful reference point. However, predicted future conditions should be considered as well. Adaptive management should be used where possible to reflect the uncertainty of climate change and their impacts to natural community (Palmer & Peterson 2008).

Cross-scale integration of ecosystem models and data: Coupling your forest inventory with maps and data at different scales can provide the ecological framework for monitoring and understanding the site-specific pattern of tree migration. A broad scale model showing tree species ranges across the Great Lakes region might be a good resource for understanding general trends in the ranges where trees are likely to grow, however tree populations are unlikely to sweep over the landscape smoothly as these maps might indicate. A map at finer scale might better help forest managers predict the likely stand compositions based on more nuanced details like soil moisture and landform (Palmer & Peterson 2008; Barnes 2009).

Establish an organizational framework for management decisions: Using a set framework from which to make management decisions provides a methodology with which to narrow the scope of a planning process into a set of manageable tasks. Nitschke and Innes (2008) describes such a framework:

1. Identify and demarcate the various forested ecosystems within a reserve.
2. Allocate different areas of the landscape into zones where fundamentally different management objectives need to be achieved (i.e. intensive use land vs. limited access conservation land).
3. Identify key stressors and vulnerabilities.
4. Assess vulnerabilities in relation to the defined forested ecosystem types and land uses and determine management options and goals.

Another example comes from The U.S. Climate Change Science Program (Palmer & Peterson 2008):

1. Define the issue (management situation, goals, and environmental and institutional contexts)
2. Evaluate vulnerabilities under changing conditions
3. Identify suitable adaptive actions that can be taken at present or in the short term
4. Develop suitable adaptive actions that could be taken in the longer term

COMMUNICATION AND EDUCATION

Improving stakeholder communication: Optimizing the climate resiliency of the Huron River Watershed's forests will require communication across stakeholders to establish unified and cohesive forest management strategies. Cross-jurisdictional communication is important for the coordination of land management plans across reserves and to ensure departments within a municipality operate with common goals and objectives. The same principles hold true for the area's regional planning groups, private institutional landowners, residents, etc. (Brosius 2007). This improved communication can also aid in creating support for city-wide funding and staffing for climate resilient forestry programs. Additionally, the establishment of active relationships between reserve areas/municipal planning agencies and community organizations can help decrease potential contentions between these groups by building trust (Palmer & Peterson 2008).

Community engagement: Action in lands outside of reserves must also be a part of climate change strategies for biodiversity conservation (Heller and Zavaleta 2008). Some of the most sought-after residential properties within the Huron River watershed are areas rich in natural outdoor amenities along the edges of public reserve lands that also tend to be wildlife hotspots with highly favorable growing conditions for tree species (Kerr and Deguise 2004; Hansen et al.

2005). Innovative landscaping strategies by these residents (i.e. the planting of a diverse array of climate resilient tree species) could help ensure the persistence of a healthy forest edge for the adjacent reserve lands and limit edge effects caused by more conventional (i.e. lawn-dominated) residential landscaping strategies. Challenges regarding this strategy lie in overcoming long-held cultural preferences for lawn-dominated conventional landscaping tendencies (Jenkins 1994). This strategy could be facilitated by establishing incentive programs for private property owners to increase tree canopy cover, by establishing municipal program that provides small climate resilient trees for individuals to plant on their properties free of charge, or by providing a community-oriented cost-share program of moderate sized trees to be planted on private properties (Brosius 2007).

Development of open-access information systems: There is a need for better access to policy advice and information regarding forest management efforts for climate resiliency. Open-access information systems can help decision makers learn and share lessons in forest management and climate changes (Keskitalo 2011). Another challenge faced by forest managers is the need to keep up with the rapidly changing science of climate change and it's implications for forest health. This suggests the need to build on and strengthen current relationships between researchers and foresters (Julius 2008).
Two open-access information systems useful for climate adaptation work are the Climate Collaboratory (https://adapt.nd.edu/) and the Climate Adaptation Knowledge Exchange (cakex.org).

Site scale recommendations for natural areas

PROMOTING DIVERSITY

Increase tree species diversity: Incorporate a broader range of species and genotypes in restoration and forestry. This may include utilizing species not native to the forested area being managed (Heller and Zavaleta 2008). Locally native species that are well adapted to the planting site should be chosen, augmented by non-local material where this is needed (Keskilato 2011). The establishment and maintenance of forests with diverse species and age classes can help maintain resilience to mortality and reduction in growth rates of trees in response to diseases and other impacts from climate change such as increased drought stress (Sturrock 2011). Although there is strong advocacy for intensive management actions to protect historical species in their ranges, this approach can become increasingly costly and difficult to continue as climate change shifts continue. Relying solely on a "natives only" type of resistance approach is also risky in that it can leave systems threatened by total collapse if interventions are not maintained or compromise other system components (Heller and Zavaleta 2008).

Use of multi-aged management systems: Stand diversity can be achieved through the use of multi-aged forest management systems such as irregular shelterwood and selection systems. These practices maintain a large proportion of carbon stores in retained mature trees while using thinning to create spatial heterogeneity that promotes higher sequestration rates in smaller, younger trees and simultaneously enhance structural and compositional complexity (D'Amato et al. 2011; Keskilato 2011).

Increasing genetic diversity: Breeding programs for forest trees can promote genetic diversity, disease resistance and tolerance to environmental stresses (Sturrock 2011). Existing guidelines for genetic management of restoration projects typically limit plantings to a very localized germplasm in order to avoid contamination of populations with genotypes not adapted to the local site. However, these guideline were developed without considering impacts from a changing climate. Relaxing these guidelines could allow for the planting of more resilient species (Palmer & Peterson 2008).

ESTABLISHING NEW TREES

Natural regeneration: Following a disturbance (either natural or anthropogenic), natural regeneration may allow an ecosystem to follow a successional pathway back to its original stable state if the system is highly resilient. In ecosystems with low resilience to climate change, the use of natural regeneration alone may not guarantee that the ecosystem will develop along a traditional pathway, as a new stable state may develop (Nitschke and Innes 2008; Keskilato 2011). Low resilience or vulnerable communities might be where communities are currently at the southern edge of their range, rely on very specific hydrologic conditions or tend to occur in small isolated patches (Lee et al, 2012).

Enrichment planting: Enrichment planting involves the planting of seedlings within a forest where natural regeneration is poor or non-existent. Mixed-species plantings can be used to improve resilience to vulnerabilities and lessen the risks posed by disturbance and biodiversity loss (Nitschke and Innes 2008). Mixed stands can be used to counter the risk of drought by increasing variation and distributing risk (Keskilato 2011). These stands can also be augmented by non-local trees when it is necessary to fill an ecological niche left empty by a tree species being lost to climate change (Keskilato 2011). Compared to mixed species plantations, monoculture plantations are markedly less resistant to disturbances such as fire and more subject to pest outbreaks (Singh 2008). Enrichment planting could also be used to establish late successional species that are vulnerable to climate change in the understory of established forests where temperatures are lower, humidity is higher, and wetter edaphic conditions may persist over the summer season (Nitschke and Innes 2008).

Assisted migration: Assisted migration is the intentional range expansion of selected biota to avoid decline and extinction. It is a strategy used to: 1) preserve biodiversity, and 2) manage species of concern (i.e. species with narrow resource requirements or poor dispersal ability) (Nitschke and Innes 2008; Barnes 2009; Sturrock 2011). Assisted migration should be done with great care paid to the diverse array of components that affects a tree's ability to become established. This includes not only climate (temperature and precipitation), but also geology, physiography, soil, hydrology, and biota (Barnes 2009). It should also be noted that facilitated migration can have unintended consequences. For example, new pathogens may be introduced along with the target species. Likewise, the introduced trees may have little immunity against disease in the areas into which they are moved (Tubby & Webber 2010; Sturrock 2011).

MAINTENANCE

Thinning and pruning: Thinning and pruning can lessen the risk posed by multiple disturbances associated with climate change. For instance, these practices have been found to be effective in reducing the susceptibility of stands to certain diseases and pests by lowering stand density. This creates less competition for resources thereby allowing trees to boost their natural defenses. Reduced competition also lowers the vulnerability of trees, particularly understory seedlings, to drought stress (Nitschke and Innes 2008; Palmer & Peterson 2008). The resiliency tree species that will likely be vulnerable to the increased drought stressed associated with climate change might be improved in dense stand areas by thinning to reduce water competition.

Minimizing thinning: Opposite thinning practices to create climate resilient forests, studies have shown that minimizing thinning is critical to maximizing aboveground carbon stores. However, this approach can also lead to a simplification of forest composition, particularly in systems dominated by shade-tolerant species, in which low levels of canopy disturbance tend to favor shade-tolerant species at the expense of others (D'Amato et al. 2011). This is a common phenomenon associated with red maples throughout the watershed (Barnes 2009). Particular care is needed to ensure that short-term incentives to achieve carbon sequestration objectives do not result in future forests with low resilience (Nitschke and Innes 2008).

Increasing canopy cover: Microclimate is a very important factor related to the ability of a tree to successfully establish itself. An increasing size of canopy opening proportionately increases the light levels and temperatures and decreases the humidity in forested areas. Forests that provide higher humidity, cooler temperatures, and wetter edaphic conditions are important for maintaining intolerant species of sites that are exposed and have lower humidity, high temperature, and drier edaphic conditions. Enrichment planting could be used to establish late successional species that are vulnerable to climate change in the understory of established forests where temperatures are lower, humidity is higher, and wetter edaphic conditions may persist over the summer season (Nitschke and Innes 2008).

PROCESSES

Manage for processes instead of species and manage for ecosystem redundancy: Management goals and approaches will be most successful when they emphasize ecological processes, rather than focusing primarily on structure and composition. Rather than concentrating on the health of a specific vulnerable tree species, management plan efforts would be better spent by determining the ecological roles that the species of interest provides. Managers could then determine what other tree species can carry out these processes and ensure that these species are also encouraged. This exemplifies the concept of ecosystem redundancy, which assumes that more than one species performs a given role within an ecosystem.

Increasing ecosystem redundancy in both natural environments and planted populations spreads the risk of catastrophic disturbances related to climate change. For instance, having more than one tree species in a stand that can serve as a food source for wildlife can prevent a complete system collapse if a species-specific pest or disease outbreak decimates one of these food-providing tree populations. Similarly, ensuring the presence of different species with different soil moisture tolerance ranges can help protect against differing levels of drought stress to a system. Mixed species plantings and planting species over a variety of ranges is built on the concept of ecosystem redundancy (Palmer & Peterson 2008).

MISCILLENEOUS

Controlled burns: Fuel reduction fires can be used to decrease the potential of crown fires and to reduce surface fire intensity. Burning is only suitable for stands dominated by fire tolerant species, however, when fire is appropriate in ecosystems adapted to fire, burned sites often will have more native plant and animal species (Singh 2008). These areas can also serve as an opportunity to establish fire-dependent species in the area whose projected future ranges indicate that they would be climate resilient species (i.e. oaks). In stands dominated by fire-intolerant species, fire is best avoided (Barnes 2009).

Irrigation systems: Land managers can add irrigation systems for particularly at-risk species if precipitation continues to decline or drought periods become more severe. With this strategy land managers are attempting to resist biotic change rather than trying to build resilience. (Heller and Zavaleta 2008; Keskilato 2011).

Hunting seasons for troublesome game populations: Changes in game population may be required for sustainable forest management (Keskilato 2011).

<u>Site scale recommendations for urban areas</u>

PROMOTING DIVERSITY

Increase the biodiversity of urban forests. Increasing the biodiversity of urban forests raises the odds that at least some of the tree species will thrive in future climates and protects against disease or pest outbreaks targeting specific species (Raup et al. 2006; Sturrock et al. 2011). A popular guideline is to follow the "10/20/30 rule". It recommends that an urban tree inventory should contain no more than 10% of one species or cultivar, 20% of one genus, or 30% of one family (British Columbia: Ministry of Community, Sport, and Cultural Development 2010; Columbus Recreation & Parks Department 2010). Some argue that street tree diversity should instead be related to the range of conditions and objectives in a community (i.e. the "right tree, right place" rule), rather than simple numerical standards. Species adaptation to local conditions might be more critical than promoting diversity for the sake of diversity. Simple percentage limits on species do not safeguard a population from poor species choices (Bell 2006; Brosius 2007). Species diversity must also be addressed on a smaller scale within neighborhoods and subdivisions. For uniformity, streets are generally planted with the same species. To achieve diversity, intersecting streets should be planted with different species and a different tree species should be selected on a block-by-block basis. On long streets and blocks, the alternation of species every other tree is recommended (Columbus Recreation & Parks Department).

Ensure that there are a healthy distribution of age classes and growth rates: It is important for urban foresters to provide for an uneven age distribution of young and mature trees to maintain canopy cover relatively constant over time. It is also important to establish an on-going planting program hand in hand with the removal of dead and dying trees (DiSalvo 2011). An inventory of tree age distribution should be included in any monitoring program conducted by municipalities (Brosius 2007; British Columbia: Ministry of Community, Sport, and Cultural Development 2010). This safeguards against high numbers of trees reaching the end of their lifespans simultaneously and subsequently requiring large financial investments to replace them all at once.

TREE SPECIES SELECTION

Think "right tree, right place": Criteria used in matching trees to the appropriate urban planting site include underground and overhead utilities, above and below ground space, light, soil and drainage conditions, and existing right-of-way infrastructure (sidewalks, curbs, fire hydrants, signs and lights) (Columbus Recreation & Parks Department 2010). Trees should be planted to achieve the maximum benefit. In general, the benefits trees provide increase proportionally with the ultimate size of the tree, therefore it is preferable to plant the largest class tree suitable to the available planting site (Columbus Recreation & Parks Department 2010). Replacement of underperforming species (especially undersized trees in large rights-of-way), in favor of high functioning, appropriately sized trees, could be encouraged (DiSalvo 2011). Urban areas create many challenging growing conditions and the selecting the right tree may mean choosing a tree with its historic range lying outside the region to accommodate the unique growing conditions or requirements necessitated by the urban area. For example, trees that have evolved in swampy areas without much air around their roots (like red maples), also tolerate the compacted soil conditions found in cities. Another example of the right tree, right place principle stems from the concept that many understory species adapted to this geographic area might not survive in an urban environment in their native range. For instance, understory species accustomed to lower light levels or shade under taller forest trees suffer in a hot, concrete city environment (Ramstad 2009). It should also be noted that bringing in novel tree species that do not share their historic ranges with the municipality can have unintended consequences. For example, new pathogens may be introduced along with the target species. Likewise, the introduced trees may have little immunity against disease in the areas into which they are moved (Tubby & Webber 2010; Sturrock 2011). When selecting these trees, urban foresters must also take care to prevent the spread of invasive tree species.

Maximize benefits: Choose large trees over small trees since they will provide the most benefits over the long term. Large trees provide greater energy savings, air and water pollution mitigation, runoff reduction, visual impact, traffic calming, increase in property values, and carbon sequestration (Bell 2006). Also recognize that some native tree species are disproportionately valuable for biodiversity because they provide resources such as mast, fruit, nectar, or cavities for wildlife (Singh 2008).

Plant native species: Some sources argue that because native plants are adapted to the local climate and site conditions they will be more resistant to drought and will require less nutrient inputs. In addition, natural wildlife habitats will be preserved (Bell 2006). However, some literature questions the relevance of the concept of native species in highly developed areas. For instance, Ramstad (2009) writes: "How do you define what species are native to an urban area where the built environment has erased the native soil, understory plants, and wildlife that characterize a native ecosystem?" Perhaps native tree species plantings are better encouraged in less developed residential and parkland areas of the city vs. the highly ecologically altered urban core. These less developed urban areas could be used to preserve regionally viable native trees when they might otherwise be stressed and die off in the more developed surrounding urban areas. These areas could also maintain the character of our region by planting and preserving its native trees as the more urbanized areas shift their planting lists hardier non-natives (Ramstad 2009).

Plant drought resistant species: Planting drought tolerant species can provide the double benefit of allowing communities to safeguard their street trees in anticipation of increased summer droughts likely to be associated with climate change impacts of the 21st century and to reduce water consumption needed for tree irrigation in times of drought (Bell 2006; Huron River Watershed Council 2012). The use of mulch also helps trees to resist drought (Ramstad 2009).

PESTS, DISEASES, & INVASIVES

Prepare for higher incidences of pests and disease. Shorter winters and longer periods of drought have been connected to higher pest insect populations. Tree diseases caused by fungi and bacteria are becoming more prevalent, and expected to get worse as trees already stressed by changes in local climate are more susceptible to pathogens (British Columbia: Ministry of Community, Sport, and Cultural Development 2010). Establish a process for early detection and treatment of pests and disease. Remove sick or damaged trees to reduce risks from tree failure or spread of insects and diseases (British Columbia: Ministry of Community, Sport, and Cultural Development 2010). Diversifying the tree species selected for planting can help avoid catastrophic outcomes from the risks associated with species-specific pests (Raup et al. 2006; Brosius 2007; Sturrock 2011). Improved monitoring and research can help to track and reduce the risk of threats likely exacerbated by climate change (Keskilato 2011). The following can serve as valuable local resources for identifying tree pests and diseases and providing recommendations for their management:
www.michigan.gov/dnr/0,1607,7-153-30301_30505_30830-36661--,00.html
www.a2gov.org/government/publicservices/fieldoperations/forestry/Pages/tree%20care.aspx
www.ipm.msu.edu.

Proper pruning technique and sanitation to prevent disease spread: Proper pruning techniques should be used to protect the longevity of trees. Improper pruning cuts may cause unnecessary injury that could even lead to tree death. Poor cutting techniques can result in tissue decay, delayed wound closure, and increased opportunity for pathogen entry. Tools should be clean and sanitized as well as sharp to help prevent the spread of disease from infected to healthy trees on contaminated tools. Tools become contaminated when they come into contact with fungi, bacteria, viruses, and other microorganisms that cause disease in trees. Most pathogens need some way of entering the tree to cause disease, and fresh wounds offer an ideal opportunity for infections to begin. Sanitization can be done with either 70% denatured alcohol or with liquid household bleach diluted 1 to 9 with water (United States Forest Service 2012). The need for sanitizing tools can be greatly reduced by pruning during the dormant season. For more info on proper pruning technique, please see the USDA's guide on "How to Prune Trees" at: http://na.fs.fed.us/spfo/pubs/howtos/ht_prune/htprune-rev-2012-screen.pdf.

Be wary of planting invasive species: Some popular and well-growing urban trees exhibit invasive tendencies. It needs to be considered whether these trees should be completely banned from use in cities or just restricted to sites where they can be monitored and spread limited (Ramstad 2009). If trees are not native to the area, consider before planting if they exhibit any of the characteristics of species that have the potential to become invasive:

- Ability to reproduce themselves both asexually and sexually
- Fast growth
- Rapid reproduction
- High dispersal ability
- Phenotypic plasticity (ability to alter one's growth form to suit current conditions)
- Tolerance of a wide range of environmental conditions
- Ability to live off of a wide range of food types
- Other successful invasions

Use sites like www.invasive.org to determine if a tree being considered for planting could be invasive. If it could be invasive but it will still be planted anyway, don't plant it near natural areas, stream corridors, or near roadways where the chances of "escape" are higher (Ramstad 2009).

Planting cultivars: If an invasive species is to be used as an urban street tree, consider planting a cultivar of that species. Invasiveness is usually more of a tendency with tree species than with tree cultivars. Many tree cultivars – especially newer introductions – do not produce viable seed. Also, many cultivars are grafted or budded onto rootstocks, which limits their ability to spread by root suckers (Ramstad 2009).

EXPERT OPPINION

Seek expert opinion: Collaborating with experts to assist in the creation of urban forest management plans aimed at resiliency is an ideal option for municipalities with the funding and resources to do so. Cities can hire a full International Society of Arboculture (ISA) certified arborist to help inform tree management decisions, or they can reach out to private consulting firms. Davey Tree Expert Company (www.Davey.com) is a national and highly respected tree care and consulting firm that has been used extensively by the city of Ann Arbor on past tree inventory and management projects (Kerry Gray, City of Ann Arbor, personal communication). Another possibility for more cash-strapped townships could be an attempt involve local academic institutions (Brosius 2007).

<u>Evaluating and adapting existing conservation plans</u>

ACTING WHEN WE DON'T HAVE ALL THE ANSWERS

Incorporate Climate Data and Models into Conservation Plans: In order to develop adaptation strategies for a changing climate it is important to understand the types of changes predicted for the area and the confidence of the model projections being considered. Bringing in multiple projection models and focusing on results that are similar across diverse models may indicate results of greater likelihood. However, no model is perfect and a degree of uncertainty can still be expected when comparing differences between models. Uncertainty displayed across models can help identify ranges of potential management options to reduce vulnerability risk from uncertainty. Uncertainty doesn't imply a complete lack of understanding, but rather that management will best involve a suite of approaches aimed at preventing the full range of plausible vulnerability. When using models, it is important to understanding that different modeling approaches contain different underlying assumptions about ecological processes. By understanding these assumptions and their implicit impacts on the strengths and weaknesses of the available models, managers can better use these tools to address their planning and analysis needs. Assistance and consultation on interpreting models is also encouraged if the manager believes it to be necessary (Palmer & Peterson 2008). Recommended sources for climate change models include:
The USDA Tree Species Atlas (www.nrs.fs.fed.us/atlas/tree/)
Local climatologies on the GLISA website (www.glisa.umich.edu)
The Nature Conservancy's Climate Wizard (www.climatewizard.org)

The use of the tree species range maps being provided by the HRWC (www.hrwc.org/wp-content/uploads/2013/03/Natural%20Infastructure.pdf) can provide a good starting point from which to consider how current tree communities in the area's reserve lands might look in the long-term and where management efforts should be prioritized first.

Use adaptive management framework for planning: Adaptive management can be defined as a systematic and iterative approach for improving resource management by emphasizing learning from management outcomes (Julius 2008). The adaptive management process generally involves setting goals, developing strategies, taking action, measuring results, and adapting actions if the original efforts are not working to achieve the set goals. This allows managers to alter courses of action based on monitoring data. The adaptive management process also underscores the importance of avoiding rigid adherence to a single objective in forest management (Julius 2008; D'Amato 2011). Adaptive management additionally allows for the adjustment of specific management targets (such as maintenance of a particular species or habitat) over time, as the opportunities for those ecosystem services diminish under a changing climate and new opportunities for other services may have a greater chance of being met (Palmer & Peterson 2008). Given the uncertain nature of climate change and associated environmental variability, the inevitability of novelty, and surprise, it is important to take a flexible approach to natural resource management in the face of climate change and make changes to our efforts as we learn more. Model examples of adaptive management frameworks that display this flexibility include The Nature Conservancy's Conservation Action Planning (www.conservationgateway.org/cap).

PRIORITIZING RESOURCES

Prioritize management responses in situations of resource scarcity – The Triage approach: Different tree species and forest communities will respond to a changing climate individualistically. This results in some species and ecosystems requiring aggressive treatment to maintain viability while others require less intensive management. Management goals for a particular species or community will also vary depending on the perceived importance of the ecosystem services they provide. The triage approach in a natural resource context sorts management situations into categories according to urgency, sensitivity, and capacity of available resources to achieve desired goals (i.e. survival). Cases are rapidly assessed and sorted into three to five major categories that determine further action. Examples of categories include highest priority ("significant ongoing emergency: immediate action required"), moderate priority ("strong to medium potential for emergency: marginally stable with action needed eventually"), low priority ("low likelihood for emergency: little to no action required"), and zero priority ("conditions are already altered beyond hope of treatment: no action to be taken"). The prioritization of management responses helps land managers to efficiently allocate limited available resources where they are most needed (Palmer & Peterson 2008).

Management plan audits: Management plan audits can be utilized by land managers as a means of quickly prioritizing what aspects of current management plans need to be updated to increase climate resiliency and decrease the chances of catastrophic disturbances fundamentally altering their forest resources. Audits would be performed by teams of climate experts that visit the reserves. Teams would rapidly review planning documents, interview staff, and visit representative field sties. They would conclude their visits with a set of recommendations on what aspects of the overall local forest management practices and plans are in (1) immediate need of significant revision, (2) need of revision in a longer time frame, and (3) no need of revision; already climate-savvy (Palmer & Peterson 2008).

MANAGEMENT PLANS FOR PRIVATE LANDOWNERS

Federally Assisted Establishment of Forest Management Plans: Federally subsidized assistance for writing conservation management plans is available to private landowners who own large tracts of forested property. The Washtenaw County Conservation District's stated mission is "to assist landowners with, and provide leadership in, the conservation, management and wise use of natural resources of Washtenaw County." This organization will work with property owners to match them with a federally subsidized management plan writer or forester to assist in creating a management program. The Conservation District seeks to get property owners in touch with programs such as National Resource Conservation Service with the USDA (www.mi.nrcs.usda.gov), or the DNR's Forest Stewardship Program (www. michigan.gov/dnr/0,1607,7-153-30301_30505_34240-107504--,00.html). For example, the DNR Forest Stewardship Program will pay a portion of the total costs of creating a forest management plan to a Michigan Certified Plan Writer. The program pays approximately 50% of the costs and the property must be a minimum of 12 contiguous acres with five currently wooded.

Conclusion

Given the nature of climate change and environmental variability, the inevitability of novelty and surprise, and the range of management objectives and situations, it is important to remember that no single approach will fit all solutions. A toolbox approach recognizes this and arms managers with a range of options. It is up to the manager to decide which combination of these options makes the most sense based on their unique understanding of their forest resources and the associated vulnerabilities to climate change. The range of options outlined in this literature review will provide environmental leaders throughout the Huron River Watershed with the tools they need to start planning for climate resiliency in the area's forests.

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