Regional Climate Change Adaptation Strategies for Biodiversity Conservation in Minnesota

Susan Galatowitsch, Lee Frelich, and Laura Phillips

University of Minnesota

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Climate change adaptation planning for biodiversity involves planning for actions that may help ecosystems and species accommodate to climate change. Adaptation planning for biodiversity has received relatively little attention, despite the high likelihood of significant ecosystem change, even with mitigation to avoid further increases in greenhouse gas emissions. Using down-scaled climate projections from an ensemble of 16 models*, we conducted scenario planning for wetland, forest, and prairie ecosystems within the state of Minnesota (USA).

Situated at the intersection of three major biomes (boreal forest, temperate deciduous forest, and Great Plains grasslands), Minnesota is likely to face significant challenges for sustaining biodiversity during climate transition. We divided Minnesota into eight landscape regions and for each, developed climate change projections, assessed likely impacts, and proposed adaptation options. Climate change projections suggest that by 2069, average annual temperatures will increase approximately 5.8° F; annual precipitation will increase 6-8%, but summer precipitation will decline. Places with analogous climates currently prevail 310-440 miles to the SSW.

Although the effects of climate change may be resisted through intensive management of invasive species, herbivores, disturbance regimes, and even water supplies, eventually conservation practices must shift to facilitation and resilience strategies. Facilitation strategies help ecosystems move from current to new conditions and resilience strategies improve the capacity of ecosystems to rebound from disturbance. Key resilience strategies for Minnesota landscape regions include providing buffers for small reserves, expanding reserves that lack ad-

*We created climate change projection maps for Minnesota at a grid square resolution of 1/8° (degree latitude and longitude, approximately 8 miles on a side) for precipitation and temperature in the years 2030-2039 and 2060-2069. These were produced by downscaling the 2° grid square resolution predictions of Global Circulation Models to take into account local differences in historical temperature and precipitation as measured by weather stations throughout Minnesota. Thus, spatial patterns of precipitation and temperature (for example the effect of Lake Superior on temperature) that have occurred in Minnesota during the reference period of 1950-1999 are also assumed to persist into the future. To reduce the biases and take advantage of strengths that occur in individual Global Circulation Models, we averaged together the predictions from 16 models that were produced for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).

equate environmental heterogeneity, prioritizing protection of likely climate refuges, and managing forests for multi-species and multi-aged stands. Modifying practices of current restoration programs to rely on seeding (not plants), enlarge seed zones (especially in a southerly direction), and include common species from nearby southerly or drier locales is a logical low-risk facilitation strategy. Monitoring "trailing edge" populations of rare species should be a high conservation priority, to support decision-making related to assisted colonization. Despite uncertainties in climate projections and ecological responses, comprehensive climate change adaptation planning is needed for Minnesota that coordinates with adjacent states/provinces, considers the full array of organisms and their interactions, and is linked to research to fill key knowledge gaps.

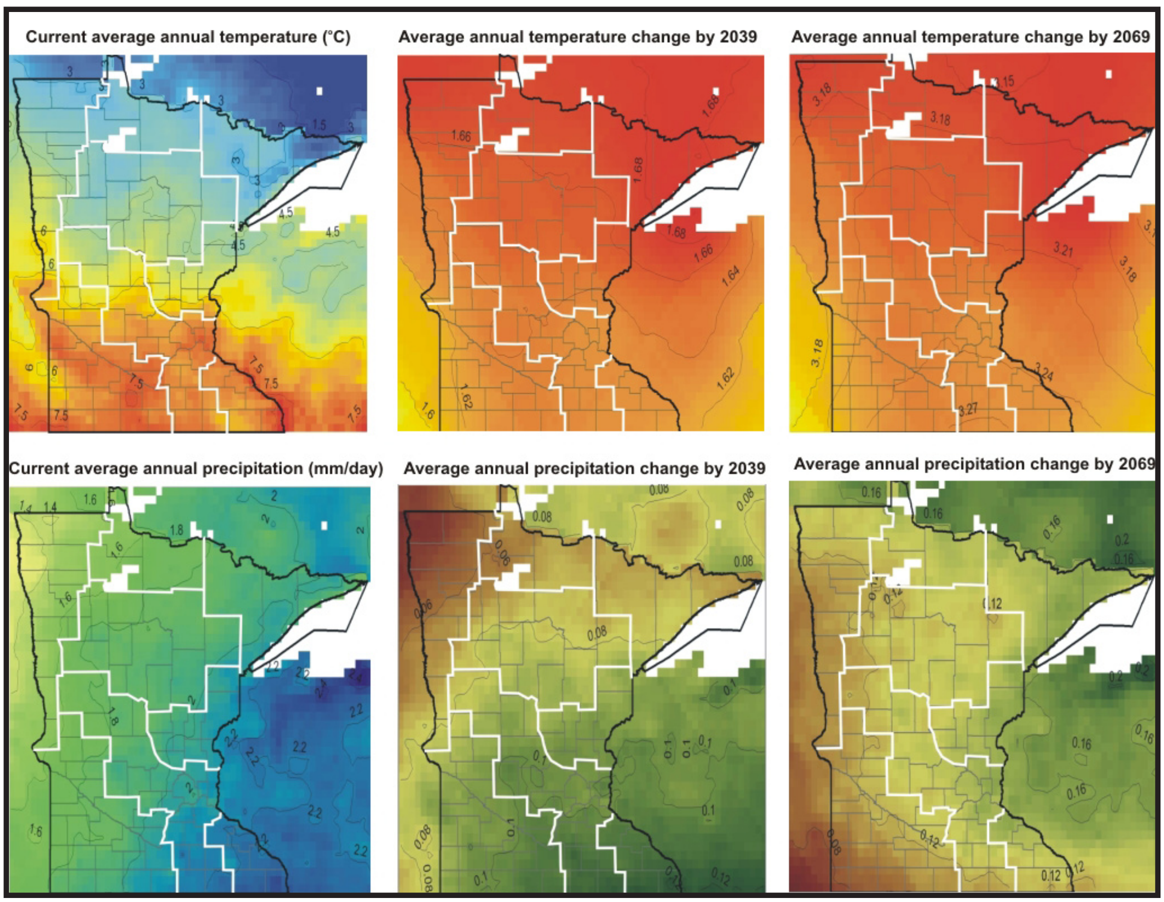

Figure 1. Predicted changes in average annual temperature and precipitation by 2039 and 2069 as compared to the 1950-1999 reference period. Mean annual temperature currently varies from 34 o F (1.5 o C) in northeastern MN to 46 o F (7.5 o C) in the southwest. These temperatures are predicted to increase by 2.9-3.0 o F (1.60-1.68 o C) and 5.7-5.9 o F (3.15-3.17 o C) by 2039 and 2069, respectively. Mean annual precipitation currently varies from 20 inches (1.4 mm/day) in the northwest to 35 inches (2.3 mm/day) in the southeast, and is predicted to increase by 0.9-1.7 inches by 2039 and 1.1-2.3 inches by 2069.For temperature change maps (first row, right two columns), the color scale indicates relative degree of predicted temperature change from yellow (less change compared to current temperatures) to red (more change). For precipitation change maps (second row, right two columns), the color scale indicates relative degree of predicted increases in precipitation from brown (little increase) to green (areas with larger increases).

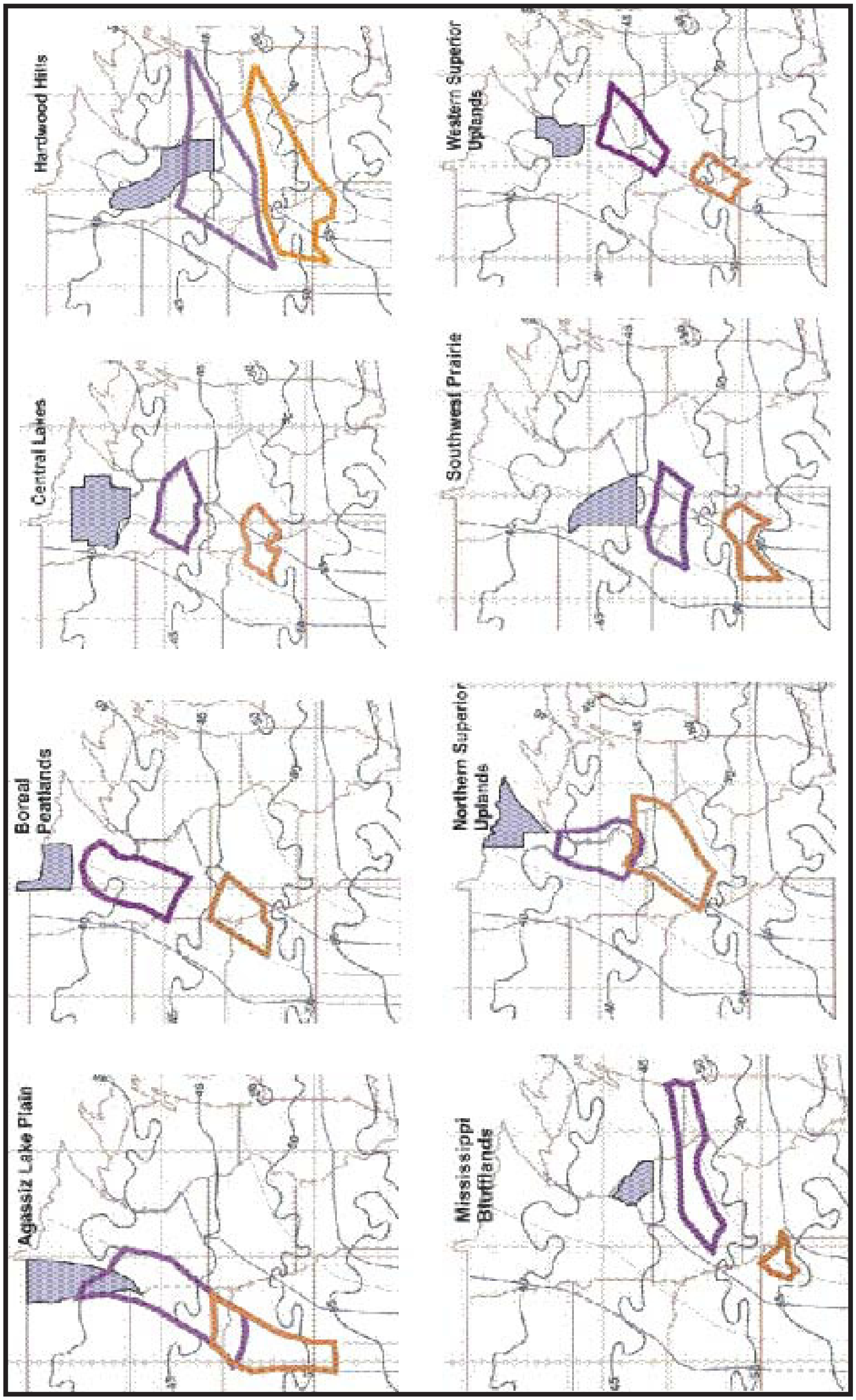

Figure 2. Migrating climate analogs for eight Minnesota landscape regions (shaded). The predicted climate analog for 2030-2039 is outlined in purple and that for 2060-2069 in brown. The migrating climate analogs are shown on a base map of mean annual precipitation (inches/year) and temperature (o F) for 1961-1990 (National Climate Data Center- Owenby et al. 1992).

Landscape Region	Conservation Context	Most Significant Ecosystem Impacts Anticipated	Key Adaptation Strategies
Agassiz Lake Plain	This region consists of extensive prairies on sandy glacial lake deposits and on heavy clays of the Red River Valley. Although there are extensive protected areas on the lake plain, the river valley is mostly converted to drained, agricultural land.	Reduced extent of wet prairies and meadows; shorter hydroperiods in wetlands; increased brackish and alkaline conditions in wetlands; reduced groundwater flow to calcareous fens.	Prohibit agricultural drainage improvements in vicinity of protected wetlands; Prohibit groundwater withdrawals in recharge areas of calcareous fens; Restore agricultural lands to expand small reserves using facilitation practices.
Boreal Peatlands	Flat, poorly drained landscape dominated by peatland vegetation, including bogs, tamarack swamps, and fens. Protected areas include several large Scientific and Natural Areas.	Lower water table in peatlands; increase in peat fires; increased shrub growth in bogs; increased tree mortality from drought, disease, insects and disturbances.	Prohibit drainage improvements in vicinity of peatlands; Control peat fires.
Central Lakes	Maple-basswood forests, oak woodlands, mixed with jack and red pine forests and woodlands on complex glacial deposits (including numerous lakes). Region includes large lake plains with extensive peatlands of bogs, tamarack swamps, and sedge meadows. Many sizeable protected areas (state parks, wildlife refuges).	Increase in large-scale tree mortality; loss of boreal forests; expansion of weedy grassland species; influx of exotic submersed aquatics in lakes; lower water table in peatlands; increase in peat fires.	Manage forests to reduce water stress; Facilitate transition from forests to grasslands (rather than invasive species) on shallow and sandy soils; Facilitate expansion of oaks on loamy soils; Remove exotic submersed aquatics from lakes.
Hardwood Hills	Hardwood forests and oak woodlands and savannas were interspersed with prairies along this 'prairie-forest border' region. This region includes the Minneapolis-St. Paul metropolitan area and extensive agricultural land. Most of the protected areas network are small wildlife management areas.	Increased tree mortality from drought, pests, disturbances; influx of exotic submersed aquatics in lakes; shorter hydroperiods in wetlands; expansion of weedy grassland species.	Manage forests for reduced water stress; Use fire to reduce dominance by weedy grassland species; Monitor changes in community composition to detect species' declines.

Table 1. Each landscape region's primary ecosystems and the extent of protected areas is summarized along with 3-6 of the most significant ecosystem impacts predicted to occur as a result of global climate change, and several key adaptation strategies that may be important for climate change adaptation during the next 50-60 years.

Mississippi Blufflands	Hardwood forests covered steep bluffs along the Mississippi River and in tributary valleys. Prairies and oak woodlands occurred on glacial river deposits in the main valley. A large state forest and National Wildlife Refuge are the most significant protected areas in this region.	Increased tree mortality from drought, pests, disturbance; reduced groundwater flow to calcareous fens.	Protect potential refugial habitats; manage forests for reduced water stress; Prohibit groundwater withdrawals in recharge areas of calcareous fens.
Northern Superior Uplands	Red and white pine forests were historically widespread, mixed with aspen, paper birch, spruce and balsam fir. Glacially scoured bedrock terrain, often rugged and with numerous lakes. Protected areas include BWCA Wilderness, Voyageur's National Park, Superior National Forest.	Increase in large-scale tree-mortality; reduced regeneration from increased deer herbivory; loss of boreal forests.	Minimize deer herbivory in white cedar and pine forests; Protect potential refugial habitats; Monitor community changes to detect species' declines; Facilitate transition from forests to grasslands (rather than invasive species) on shallow and sandy soils.
Southwestern Prairie	Bisected by the Minnesota River valley, this landscape was once a mosaic of tallgrass prairie and emergent wetlands. More than 90% is now drained agricultural land. Many small wildlife management areas comprise most of the protected areas network in this region.	Increased exotic invasions in small protected areas; loss of rare wet prairie species; reduced extent of wet prairies and meadows; shorter hydroperiods in wetlands; brackish and alkaline conditions increase in wetlands; reduced groundwater flow to calcareous fens.	Restore agricultural lands to expand small reserves using facilitation practices; Intensify invasive species removal; Prohibit agricultural drainage improvements in vicinity of protected wetlands; Prohibit groundwater withdrawals in recharge areas of calcareous fens.
Western Superior Uplands	Oak woodlands and hardwood forests on non-calcareous glacial tills, ranging from clayey to sandy. Protected areas with high quality vegetation are of minor extent, although several large state parks and wildlife areas are in this region.	Increased tree mortality from drought, pests, disturbances; shorter hydroperiods in wetlands, influx of exotic submersed aquatics in lakes.	Facilitate transition from forests to grasslands (rather than invasive species) on shallow and sandy soils; Facilitate expansion of oaks on loamy soils; Manage forests for reduced water stress: Prohibit drainage improvements in vicinity of protected wetlands; Intensify invasive species removal.

Table 1 Continued.