Wisconsin Initiative on Climate Change Impacts

Forestry Working Group Report

This report provided content for the Wisconsin Initiative on Climate Change Impacts first report, Wisconsin’s Changing Climate: Impacts and Adaptation, released in February 2011.
Executive Summary

Over the next 100 years, Wisconsin’s climate is expected to undergo significant changes that may include rising average temperatures, longer growing seasons, shorter winters, and more severe storm events, floods, and droughts. Significant impacts to forest communities across the state are expected. Climate change will probably impact all forest communities, but certain forest ecosystems may be more sensitive to change than others. With diverse forest types within the State it is important to identify types of forests and trees which are potentially most sensitive to climate change and to develop strategies to assess and manage changes within the forest matrix.

Climate Change's impacts on forests are important to the State of Wisconsin. 46% of Wisconsin's 35 million acres are forested. Wisconsin’s forest resources can be divided into two broad categories, the Northern Mixed Forest and the Southern Broadleaf Forest. These two forest types exist in Wisconsin because they have adapted to different climatic conditions. This differentiation between Northern and Southern Forests follows the Tension Zone, which is a zone of vegetative change that generally follows a gradient in temperature and moisture across the state from northwest to southeast. Wisconsin's forests occur on a variety of soils and landscapes which will be impacted differently by climate change. This report uses a system of landscape classification called Ecological Landscapes, to further divide southern Wisconsin into areas such as the Western Coulees and Ridges, Central Sands and Lake Michigan Coast so that potential local climate impacts can be better examined.

Wisconsin's forests can adapt naturally to climate fluctuations; climates have changed in the past, and types, severity, and rates of change have been variable (e.g. forests responded and re-established after glaciation). However, the expected rate and severity (magnitude) of climate change will probably be greater than in the past. These potential changes need to be examined in order to estimate the magnitude of changes and how the forests may adapt. However, the types, severity, rates, and pattern of climate changes over the next 50 to 100 years and beyond are extremely difficult to forecast, and the actual response of forests to climate change is highly uncertain. The Forestry Working Group (FWG) is investigating these potential impacts by working closely with climate scientists, biologists, foresters, and stakeholders to better understand Wisconsin’s changing climate and its potential effects on native and urban forests. The FWG used models which attempt to simulate future forest site suitability, the WICCI downscaled climate data, Climate Analogs and regional expert panels to estimate the impacts of potential late summer drought, decreased snowcover, reduced soil moisture, winter rain, invasive species, insect pests and diseases in the context of forests. Each of these scenarios are hypothetical and would potentially occur at a given period of time, some scenarios are more likely than others, and actual climate and forest ecosystem responses 50-100 years in the future are unknown. The results of these investigations led the working group to recommend actions that would monitor changes in forests, increase the probabilities of impacts assessment, improve adaptive management, and maintain and increase diversity and connectivity across spatial scales.

In order to assess the potential impacts to forests, natural resource professionals worked with climate scientists to project hypothetical forest impacts based on new climate and forest models that cover the state. Forest site suitability models (also referred to as climate envelope models) are
available from the USDA Forest Service, Canadian Forest Service and University of Wisconsin and were used to in the vulnerability assessment. These models show where the ideal conditions to grow Wisconsin tree species might change as climate changes 100 years into the future. This information was combined with climate analog models which show where climates in the United States exist now, which might be similar to what Wisconsin would experience 50 and 100 years into the future. Furthermore, the working group had the benefit of cooperation with the USDA Forest Service vulnerability assessment drafted for northern Wisconsin forests to provide a parallel integration of similar forest models and expert assessments. Lastly, The WICCI Forestry working group solicited the expertise of foresters, planners and biologists throughout the state to gain a local perspective on how the projections of both climate and forest models may affect the significant forest features which they provide stewardship for across the state.

For the first iteration of the Forest Vulnerability Assessment the FWG adopted a scale and scope that was consistent with existing resources and information. In scale, the group examined forest vulnerability at the scale of northern and southern sections of the state separated by the tension zone. The south was further divided into Ecological Landscapes. The north will be assessed at Ecological Landscape scale for the second assessment. The vulnerability assessment covers points in time centering around 2050 and 2100 for impacts. These time frames are consistent with information that is readily available from climate and forest models, further subdivisions of time would have required additional model runs. The scope of the assessment covered climate change vulnerabilities and adaptation as is consistent with definitions used by other WICCI groups. These vulnerabilities were confined to ecosystem attributes such as forest establishment, pest interactions, disease interactions, species migration, biodiversity, soils, species moisture and temperature tolerances. Impacts on forest based economies, communities and recreation were outside the scope of this assessment but are planned for the second assessment.

Key findings

- **Young forests may be vulnerable:** Young forest saplings and seedlings could be at risk of stress and mortality from changing temperature and precipitation patterns. Mature trees have large root systems and sugar reserves which allow them to endure shorter droughts and moderate pest and disease attacks while small seedlings will often die off under a short drought or heavy competition from other plants. This trend could lead to more forest sites being difficult to regenerate through natural seeding and sprouting.

- **Forests are vulnerable to changes in soil moisture:** Soil moisture has a strong link to the types of forest species which grow on a particular site and changes in precipitation, hydrology and rate of evaporation will impact the types of forest species in a forest. However, what changes in moisture availability will occur across the state are unknown.

- **Central Hardwoods may increase:** Central Hardwood species such as Hickory, Black Oak and Black Walnut might expand their range in Wisconsin under a warmer climate. However, it is uncertain how this forest type will be affected by much wetter or much drier conditions

- **Boreal species are at risk:** Warmer winter temperatures and possible late summer droughts would increase stress in species which are currently at the southern edge of their natural range limits such as; aspen, white birch, white spruce, black spruce, balsam fir and jack pine and red pine. Those species with increased stress will be more susceptible to damage from insects and diseases.

  - **Jack Pine could be resilient:** Jack Pine barrens and forests are primarily adapted to extremely dry sandy sites and are not so dependent on climate. If these dry
sandy sites persist jack pine may prove more resilient than other boreal species. However, as a boreal species at the southern edge of its range there are concerns about jack pine, and it could be replaced by scrubby oaks on dry sites. - Conifer Lowlands are vulnerable: Black spruce and tamarack lowland forests are sensitive to changes in water tables and snow cover. Less snow or shorter durations of snow cover could lead to freezing damage in fine root systems. In addition, changes in the water table could flood or dry out the moist wetland surface needed to establish seedlings on these sites.

- Invasive species will become more aggressive: Many of the invasive species in Wisconsin are habitat generalists, and will probably be well adapted to grow in warmer temperatures and a carbon dioxide enriched atmosphere. Furthermore, their ability to rapidly colonize disturbed sites will afford these plants an advantage in areas where floods, droughts, tree mortality etc. opens up growing space. New invasive species may colonize sites in WI.

- Insect and pathogens: Pests and pathogens are likely to experience changes in population cycles and competitive relationships. Some could be a greater problem than currently.

- Urban forests can respond well: The forests which grow in the streets and parks of Wisconsin's towns and cities can respond well to climate change impacts. Cities can replant urban trees with species that are more suited to warmer temperatures and expanding these forests will help to shade and cool the urban heat island effects which are projected to increase. However, resources to implement this response remain limited across municipalities in the state.

Key Adaptation Strategies

- Monitor Vegetation for Impacts Caused by Climate Change: Forest Ecosystems are complex communities and monitoring sites will provide a means to track the pace and extent of change, tree species responses, and associated changes in forest shrubs, wildlife and herbs.

- Increase model certainty of long-term climate forecasts: If opportunities arise to improve confidence in long-term future climate trend prediction, particularly precipitation, it could be valuable to support these endeavors to then provide better inputs into future forest condition modeling, however, long-term climate prediction will probably continue to have a high degree of uncertainty.

- Adaptive Management: Forest managers already use a number of tools, policies and practices to ensure that the forests of Wisconsin are sustained into the future. An assessment of the usefulness of these forest management tools and policies, such as invasive species management and assisted regeneration, can be valuable in reducing climate change impacts through resource investment rather than re-invention. Adaptive responses that identify, slow, and constructively manage change will be important tools in helping forest managers cope with changing forest conditions.

- Manage for diversity across scales; particularly species diversity

- Create and maintain landscape connectivity
Working Group Participation

The membership of the WICCI Forestry Working group varies by participating function. Group members fluctuate depending on the task to be addressed and are outlined in this section.

Sponsorship

The initial formation of the Forestry Working Group occurred in August 2008 with group sponsorship by Darrell Zastrow of the Department of Natural Resources (DNR), and WICCI Science Council; and Dr. Raymond Guries of the University of Wisconsin. Avery Dorland of the DNR is the current chair of the working group; acting as a Liaison to the WICCI Science Council.

Researchers

With the support of the Forestry Working Group Dr. Jack Williams and Dr. Sam Veloz were able to develop climate analogs for the ecological landscapes of Wisconsin. Dr. Adena Rissman, Dr. Eunice Padley and Dr. Chadwick Rittenhouse are investigating the links between land use changes and adaptation.

Editors

The Vulnerability Assessment was compiled using information from published research, expert opinion collected at the Southern Forests Workshop and the USFS Climate Change Response Framework's Vulnerability Assessment. This information was synthesized and edited by Dr. Jack Williams of the University of Wisconsin; Dr. Eunice Padley, Carmen Wagner, Sarah Herrick and Avery Dorland of the DNR.

USFS CNNF Climate Change Response Framework

The Vulnerability Assessment within the Chequamegon Nicolet National Forest's Climate Change Response Framework was created in partnership with Dr. David Mladenoff of the University of Wisconsin; Dr. Louis Iverson, Linda Parker and Matthew St. Pierre of the United States Forest Service and Dr. Chris Swanston, Maria Janowiak, Dr. Leslie Brandt and Patricia Butler of the Northern Institute of Applied Carbon Science.

Reviewers

Eunice Padley, Carmen Wagner, Joe Kovach

Southern Forests Workshop

The panel of natural resource professionals assembled to evaluate the climate impacts on the forest components of the ecological landscapes in southern Wisconsin were: Owen Boyle, Bill Carlson, Jane Cummings Carlson, Avery Dorland, Sarah Herrick, Brad Hutnik, Karl Martin, Mike Mossman, John Nielsen, Ryan O'Connor, Dr. Eunice Padley, Julie Peltier, Jeff Roe and Carmen Wagner of the DNR; Dr. Sarah Gagne, Dr. Adena Rissman, Dr. Chadwick Rittenhouse, Dr. Janet Silbernagel, Dr. Sam Veloz and Dr. Jack Williams of the University of Wisconsin - Madison; Linda Parker of the United States Forest Service and Dr. Les Werner of the University of Wisconsin - Stevens Point.
Description of Topic Area and Geographic Region

Over the next 100 years, Wisconsin’s climate is expected to undergo significant changes that may include rising average temperatures, longer growing seasons, shorter winters, and more severe storm events, floods, and droughts. Significant impacts on forest communities and the species that depend on them are expected. The Forestry Working Group is investigating these potential impacts by working closely with climate scientists, biologists, foresters, and stakeholders to better understand Wisconsin’s changing climate and its effect on native and urban forests.

To understand how climate change may impact Wisconsin’s valuable forest resources coordinated research must be conducted over a broad range of subject areas. The WICCI Forestry Working Group aims to facilitate this multi-disciplinary research to produce a body of work, including adaptation strategies, that can be used by policy makers, stakeholders and citizens to support management and policy decisions that encourage the persistence of sustainable forests in the future.

This analysis of climate change vulnerabilities is for all Wisconsin forests—rural and urban, public and privately owned. Forest benefits and services (clean water, forest products, wildlife habitat, etc.) are produced by all forests, statewide, and impacts to forests from climate change will occur statewide.

This report is focused on assessing the features of forest communities in northern and southern Wisconsin that are vulnerable to climate change. For this report, assessment of vulnerabilities in Southern Wisconsin will be discussed with respect to the seven Ecological Landscapes found there. Northern Wisconsin will be discussed as a whole, however, for future reports the working group hopes to expand the analysis to the Ecological Landscape level for the entire state.

Statewide Forest Resources

Of Wisconsin’s 35 million acres of land, approximately 16 million are forested – about 46%. Forested area has been increasing since 1968 largely due to the conversion of marginal agricultural land. The most abundant forest types in Wisconsin are hardwood forest types, which account for 84% of Wisconsin’s forest communities. Maple-basswood, aspen-birch and oak-hickory are the most common. There are also significant softwood forest types occupying large areas, especially in northern Wisconsin. Red pine, jack pine, black spruce, northern white cedar, and tamarack are the most common types.

Area and relative proportion of various forest types have changed significantly over the last 70 years. Hardwood succession is very apparent. Since the first official statewide forest inventory in 1936, aspen-birch forest area has decreased steadily, although it is still much more common than at the beginning of the Cutover. The Cutover was the period of intense timber harvest that followed Euro-American settlement in the Lake States, lasting about 40 years, from 1880 to 1920. Since 1936, maple-basswood, soft maple-ash, and oak-hickory forests have increased, while hemlock and yellow birch remain at levels far below those that preceded cutover. Conifer forest area has remained roughly constant over the last 70 years.

Wisconsin’s forest resources can be divided into two broad categories, the Northern Mixed Forest and the Southern Broadleaf Forest. These two forest types exist in Wisconsin because they have adapted to changing climatic conditions over several thousand years.
Northern Forest Communities
Wisconsin’s northern forest communities occupy about 64% (11.4 million acres) of Province 212, the area north of the Tension Zone, a zone of vegetative change where many plant species reach their range limits, bisecting the state from the southeast to the northwest, as described by community ecologist John Curtis (1959) (see Figure 1). Before Euro-American settlement, this was the area where the forests, prairies and oak savannas of the south transitioned into the mixed deciduous-coniferous forests of the north. Today, agricultural uses predominate in the south, and there is more continuous forest cover in the north.

Figure 1. Approximate location of the Tension Zone in Wisconsin (WDNR 1995, modified from Curtis (1959)).

Away from Lake Michigan, the shorter growing season in northern Wisconsin makes this area less suitable for agriculture and contributes to forest to predominate. Data from the Forest Inventory and Analysis (FIA), indicate that the area is 58% timberland (10.9 million acres) and 42% non-forested or marginally productive (7.9 million acres). The northern forests represent 69% of forested area statewide. The area is less populated than the southern part of the state, and less developed, although vacation homes have become common in the past 20 years.

Northern forests are characterized by broadleaf deciduous tree species, with a lesser proportion of conifers. About 30 native tree species occur in the northern forest. In general terms, site level tree species composition varies depending in part on characteristics of the glacial landform providing the substrate, and on past human activities and natural disturbance.

Southern Forest Communities
Wisconsin’s southern forest communities cover approximately 5.4 million acres south and west of the climatic Tension Zone (Fig. 1). While the landscape in northern Wisconsin was largely forested prior to EuroAmerican settlement, the southern forests were interspersed with extensive prairie and savanna communities. Although a number of species range across both the northern and southern forests, there are floristic elements specific to each. Also, species abundances may differ - oaks are less common in the north - and species may occur in different assemblages.
Historically, southern Wisconsin's communities included, in order of relative abundance, broad-leaved deciduous forest, oak savanna, conifer forest, prairie, and open wetland. Estimates of the extent of these communities vary depending on classification scheme and mapping methods (Curtis 1959, Finley 1976, Schulte et al. 2002).

Southern Wisconsin’s fertile soils and milder climate make it suitable for many agricultural uses, which led to dramatic changes in the composition and extent of native vegetation. The fertile prairies, savannas, and forests were quickly cleared and converted to cropland or pasture by EuroAmerican immigrants during the 19th century. The greatest loss of forest occurred in the gentler terrain of the glaciated southeastern and south central portions of the state. In the unglaciated Driftless Area of southwestern Wisconsin, the steep side slopes have generally remained forested, though the broader ridgetops and flat valley bottoms were converted to farmland wherever possible. The slope forests were often used by local landowners as sources of lumber and firewood, and many of them were also pastured. The infertile, coarse-textured soils and extensive wetlands of central Wisconsin made that region less suitable for agriculture than other areas in the south. Extensive forests occur there today, in part because of fire suppression that has allowed the pine and oak forests, barrens and savannas complex to succeed to predominantly oak and pine forests along with development and some agriculture.

For this discussion, southern Wisconsin will be divided into seven Ecological Landscapes: Central Sand Hills, Central Sand Plains, Southeast Glacial Plains, Southern Lake Michigan Coastal, Southwest Savanna, Western Coulee & Ridges, and the Western Prairie. Of these landscapes, the Western Coulee & Ridges, Central Sand Plains, Central Sand Hills, and Southwest Savanna are most important with respect to vulnerable forest resources.

What is an Ecological Landscape?

Wisconsin was divided into 16 ecoregions based on ecological characteristics (e.g. climate, geology, soil, vegetation, disturbance regime) Each of these ecoregions is called an Ecological Landscape. A map entitled the “Ecological Landscapes of Wisconsin” has been in use since 2000. This map was derived from the National Hierarchical Framework of Ecological Units (NHFEU; Cleland et al. 1997). the “Ecological Landscapes of Wisconsin” map (see map right), with Ecological Landscapes in the state.

Below is a very brief characterization of the seven Ecological Landscapes found in southern Wisconsin that will be discussed in this report. More detailed information about each Ecological Landscape is published in the Ecological Landscapes Handbook.

Central Sand Hills: rolling, hilly topography with sandy soils on outwash and lake plains interspersed with loamy sand moraines; a mixture of agriculture, oak and pine forests, and wetlands, with many coldwater streams.

Central Sand Plains: flat topography with sandstone buttes and sandy soils; primarily oak and pine forests with extensive wetlands.
Southeast Glacial Plains: rolling topography with silt loam soils; primarily agriculture with small wetlands and mixed hardwood forests.

Southern Lake Michigan Coastal: Lake Michigan climate influence; rolling topography with clay and loam soils; primarily urban and agriculture.

Southwest Savanna: ridge and valley topography with shallow soils; a mixture of agriculture, grasslands, and scattered hardwood woodlots, with some streams.

Western Coulee and Ridges: Pronounced ridge and valley topography, with shallow soils over sandstone and dolomite bedrock; generally agriculture on hilltops and valleys with hardwood forests on slopes; high gradient streams; three major rivers: Wisconsin, Chippewa, and Black.

Western Prairie: gently rolling to flat topography with many small depressions forming small lakes and wetlands; silt loam soils; uplands primarily agriculture.
Future Climate Impacts

Climate change will impact entire forest ecosystems and individual tree species. Projected increases in annual mean temperature, changes in precipitation and soil moisture balance, and increases in atmospheric CO$_2$ will have direct and indirect effects on multiple, interconnected ecosystem components and drivers. In Wisconsin and the Midwest, climate change is expected to lead to increased likelihood of periodic drought conditions, flash flooding, and extreme weather events. Within forests, changes in climate will interact with natural processes to increase stress on trees and forest communities. In addition, soil processes, such as nitrogen deposition, nutrient cycling, carbon storage, decomposition, and water storage and recharge, could be altered. New stresses will be added to stress that forests already experience. Combined interactions in these systems may increase, damage, or change productivity as stressed trees become less vigorous. Tree mortality may rise due to these combined impacts, and it may be difficult to attribute the changes directly to a changing climate.

While it is impossible to predict exactly how species and ecosystems will respond to increased atmospheric CO$_2$ and changing climatic conditions, scientific models can help us understand some possible impacts of climate change on forests in Wisconsin. The Climate Change Tree Atlas is one of two models used by the Forestry Working Group to explore potential changes to forest communities. The Tree Atlas is a species distribution model that examines the features that contribute to a tree species’ current habitat and then projects where similar habitat conditions are likely to occur in the future. Model results show that climate change may lead to changes in the suitable habitat of many common tree species. Many conifer species such as black spruce and balsam fir are predicted to have declines in suitable habitat. The model also predicts that a number of important hardwood species such as quaking aspen, and sugar maple will probably persist, but that habitat quality may decline. In addition, the model predicts that some oak and hickory species may experience an increase in suitable habitat under some climate change emission scenarios. The ways in which tree species will actually respond to climate change is unknown and may be influenced by a number of factors, including site conditions, competition from other species, landscape connectivity, the degree of disturbance, and the ability of species to disperse. Suitable habitats in the future may not be fully occupied by forest species.

Climate analog analysis is model that uses a spatial representation of projected climate for a given location. For this report, climate analog analysis was used to identify a US location where the current climate is similar to the future projected climate for a location in Wisconsin. Analogs for Wisconsin’s future climate are found primarily 200-500 km to the southwest of their reference locations, in areas that tend to have lower overall forest cover or with forest communities comprised of species with more southerly distributions. In general, models that project drier and warmer climates result in analogs that are further from reference locations than models that project increased precipitation. Precipitation projections tend to have more uncertainty than temperature projections, because precipitation is controlled by local-scale processes that operate at spatial scales too small to be resolved the General Circulation Models (GCMs) used for this analysis.
Climate Analogs

Overview
Climate-analog analyses offer a place-based method for assessing the local impacts of climate-change. The analog method takes the projected future climate for a specific location in Wisconsin, and identifies the US location with the most similar current climate (i.e. the analog). The location of the closest modern analog can then be mapped (Fig. 2), using a spatial shift to represent projected future climate changes for a location. Although there is a high degree of uncertainty inherent in this type of analysis, especially surrounding precipitation predictions, climate analog analyses are an attractive method for communicating and exploring potential impacts due to climate change because they carry no assumptions about the biology of species, they provide easily interpreted visualizations, and they can be applied across different regions and scales.

Wisconsin climate analog analysis
In the climate analog analyses shown here, each grid cell from the downscaled future WI climate data was compared to each grid cell of an observational dataset of North American climate from 1950-1999 {Maurer, 2002 #1}, using eight variables (average temperature and precipitation for the four seasons). The grid cell from the North American dataset with lowest standardized Euclidean distance (i.e. greatest similarity) was recorded as the closest climatic analog for each WI grid cell {Williams, 2007 #1731, Veloz et al. in prep.}. Larger projected climate changes result in more distant climate analogs. We conducted analog analyses for three greenhouse gas emission scenarios, and two time periods (2046-2065 and 2081-2100). Results were averaged across general circulation models (GCM), with up to 14 GCMs used.

The climate analog analysis indicates that analogs for Wisconsin’s future climate are found primarily 200-500 km to the southwest of their reference locations (Figure 1). The closest analogs for northern Wisconsin locations from the middle of the 21st-century future climate projections are generally found in southern Wisconsin while the closest analogs for southern Wisconsin are found in Illinois, Iowa and Kansas. By the end of the 21st century, nearly all of the closest climatic analogs for Wisconsin are found outside of the state’s boundaries, especially under models using the high greenhouse gas emission scenarios.

There are significant differences in future climate projections among the GCMs, emission scenarios and time windows analyzed and the corresponding locations of closest analogs for Wisconsin reference locations. GCMs that project a drier and warmer future Wisconsin climate have closest analogs farther from their reference locations, while GCMS that project increasing precipitation indicate closest analogs more constrained to locations nearer to reference locations. Spatial gradients of precipitation and projected interannual variability of precipitation within Wisconsin are large relative to the projected change in precipitation which results in precipitation constraining the location of closest analogs to areas within closer proximity of reference locations. Temperature, on the other hand, has the largest effect on the choice of analog with warmer temperatures resulting in closest analogs at greater distance from their reference location. Likewise, greenhouse gas emission scenarios which project greater emissions also project higher temperatures and greater distances to closest analogs. The difference in the locations of closest analogs among greenhouse gas scenarios are more extreme at the end of the 21st-century vs. the middle of the 21st-century which suggests that the choice of emission scenario is not as great of a source of uncertainty when developing adaptation strategies for the middle of the 21st-century.

There is considerable variability in the location of closest analogs within Wisconsin. For example many of the GCMs project that northern and eastern Wisconsin will experience both increased temperature and precipitation, so the closest analogs for these areas are located to the southeast
within distances of 200-500 km (Figure 2A). By the end of the 21st-century, a clear band bisecting northern and southern Wisconsin becomes apparent (Figure 2B). The closest analogs to sites in the northern half of the state are found at distances of 0-600km from their reference locations while analogs for sites in southern Wisconsin are found at distances greater than 600km and almost exclusively to the southwest (Figure 2B). Closest analogs for southwest Wisconsin, which is projected to experience increases in temperature and small increases or decreases in precipitation, are found at the greatest distances from their reference locations and are located predominantly to the southwest.

Potential forest cover change

The climate analog analysis provides a first pass indication of potential ecological impacts of climate change. For example, by comparing the dominant vegetation cover of reference sites to their closest analogs, we can get a general sense for how vegetation might change in response to changing climate. The climates of closest analog locations for southern Wisconsin are characteristic of areas dominated by herbaceous cover within Kansas, Oklahoma, Missouri, and Iowa. On the other hand, northern sites tend to have their analogs located within southern Wisconsin or northern Illinois, areas with lower overall forest cover, often due to landuse, and with forest communities comprised of species with more southerly distributions. The climate analog analyses suggest that forest cover across the state could decline with the southern half of the state becoming increasingly dominated by herbaceous vegetation while sites in the north may experience compositional turnover with decreasing abundances of northerly distributed species and increasing abundances of southerly distributed species. However, these results should be interpreted cautiously as other non-climatic factors including soil type, landscape fragmentation and the dispersal abilities of species may prevent species from closely matching their distributions to changing climate {Webb, 1986 #73}.

Conclusion

Based on this analysis, many assumptions, and many uncertainties, the closest late 20th-century climate analogs for future Wisconsin climate are located hundreds of kilometers away and frequently across the state’s borders. Identifying reference conditions for Wisconsin’s future climate will require decision makers to look beyond the state when developing adaptation strategies. The climate analog analyses provide a first pass indication of where we can turn to understand what types of ecosystems may occur under Wisconsin’s future climate. It will probably continue to get warmer, and change will impact forests, and there will be changes in forest community ecology. Managing for diversity and connectivity could help forest ecosystems respond and maintain management options if climate changes are not too drastic.
Figure 2. Maps of the location of the closest late-20th-century climatic analog for future Wisconsin climates. Each dot represents the closest analog for a single WI grid cell for a single model, and the set of dots includes all models and grid cells for a particular scenario and time period. These analog analyses use both temperature and precipitation variables. The left column shows the climate analogs for Wisconsin climates for the middle 21st-century (2046-2065 AD) while the right column shows the climate analogs for Wisconsin climates for the middle 21st-century (2081-2100 AD). Rows represent different greenhouse gas emission scenario, with scenarios ordered for increasing greenhouse emissions from top to bottom.
Figure 3. Maps showing the distance and direction between modeled future Wisconsin climate and their closest late 20th century climatic analogs. Arrows indicate direction, while colors indicate distance.

Forest Community Impacts

CO2 Enrichment
Understanding how forests will respond to elevated CO2 is critical for making predictions about the biological composition of forested ecosystems in the coming century but also for understanding how forests will interact in the future global carbon cycle. Currently, temperate and boreal forests account for 22% of global carbon sequestration. If net primary productivity (NPP) increases, then forest could store more carbon. If increases in forest NPP are transient or carbon is assimilated in fine roots, forests could have no effect or be a carbon source. Currently we have limited understanding of the physiological responses to elevated CO2 as well as these responses will relate to changes in the forest/soil carbon cycle.

Physiological responses to elevated CO2
Much of our knowledge about the physiological response of forest species to elevated CO2 come from long term Free-air CO2 enrichment (FACE) experiments which have shown some consistent responses among forest types to elevated CO2 but have also revealed key uncertainties for future responses. Forests have consistently shown a direct response of increasing NPP to elevated CO2 levels (Norby et al., 2005). Increases in NPP have mainly been attributed to increased leaf production (Ainsworth and Long, 2005) which results in a greater photosynthetic rate. However changes in NPP can be species specific, for example, the trees in loblolly pine (Pinus taeda) plantations exposed to elevated CO2 allocated carbon to woody tissues, while the trees in sweet gum (Liquidambar styraciflua) plantations allocated carbon to fine roots (DeLucia and Moore, 2006).

The positive relationship between NPP and CO2 enrichment may be sensitive to nitrogen (N) in the soil. As NPP increases in response to elevated CO2 the demand for N also increases resulting in an increase in N utilization in the soil and subsequent depletion of soil N. If soil N levels are not replenished, the increased levels of NPP cannot be sustained (Ellsworth et al., 2004). Soil water can have a similar interaction with CO2 in that initial increases in NPP can lead to greater water demand and a subsequent decline in NPP if soil water continues to diminish.
Soil Moisture/Precipitation
Physiological tolerances to different levels of soil moisture represent one of the most critical constraints on the geographic distributions to forest species. Species have fundamental tolerances to available soil moisture that can determine where populations may persist on the landscape (Iverson et al., 2008). Species have adapted to optimum hydrological levels and thus large scale changes in precipitation can lead to large scale changes in the distribution of species across the landscape. For example, eastern Hemlock (Tsuga canadensis) is thought to have declined in abundance across North America around 5500 years ago, at least in part due to large scale drought (Foster et al. 2006) or increased variability in precipitation with persistent droughts occurring through time (Shuman et al., 2009).

Understanding how Wisconsin’s forests respond to future climate change is complicated by the uncertainty in future precipitation projections. However there is agreement among some models that precipitation may increase somewhat during the fall, winter and spring but decrease during the summer months. Additionally, more winter precipitation is projected to fall as rainfall. Increases in winter rainfall can affect forest growth as more of the water is lost to runoff leading to drier soils earlier in the summer (Huntington et al., 2009).

Changes in CO2 levels, precipitation and temperature could result in substantial changes in soil moisture availability during the summer. Greater plant productivity in response to elevated CO2 in conjunction with longer growing season could lead to increases in evapotranspiration which may result in decreases of soil moisture in the summer (Hayhoe et al., 2007). Even though CO2 enrichment leads to more efficient water use in plants, vegetation grown on soils with prolonged water limitation have been shown to have less of a positive I response in terms of productivity (Oren et al., 2001). Thus projected changes in hydrology may lead to changes in species composition or the adaptation of existing species.

Temperature/Frost
The increases in temperature projected for Wisconsin during the 21st-century will increase the growing season length. The changes in growing season will lead to changes in phenology of species that respond to temperature as a cue to initiate growth (Schwartz et al., 2006). Additionally, increases in the growing season may also result in increased plant productivity. However, temperature induced increases in plant productivity may be limited by the availability of soil water or soil nitrogen (Oren et al., 2001), or the impacts of ozone, or changes in insect/disease susceptibility.

Changes in temperature could have conflicting effects on the stress tolerance of plants. For example, increasing temperatures could alleviate the stress of freezing for cold intolerant species. However, warming could reduce the snowpack which could expose species to the freezing temperatures that would have been insulated due to the snow. Increasing summer temperatures, in conjunction with increased evapotranspiration due to higher net primary productivity (NPP) could lead to increased drought stress especially late in the summer. Species that persist under Wisconsin’s future climate may need to be able to adapt to greater weather variability.

Climate change may differentially affect different age-classes of forest species. The increases in temperatures projected for the 21st-century within Wisconsin may be within the physiological tolerances of adults of many forest species, however, juveniles and older trees already under stress may not be able to persist. Recent forest inventory surveys in the eastern United States have found that density of northerly distributed tree seedlings was found to be 10 times higher in northern latitudes vs. southern latitudes possibly indicating the start of a northward migration for these species (Woodall et al., 2009). If northerly distributed species migrate out of Wisconsin, the
question remains whether remaining species will increase in abundance or whether more southerly distributed species move in to replace vacated space. Alternatively, changes in temperature, precipitation and fire regimes may lead to conditions conducive to the expansion of the prairie/forest boundary northward into Wisconsin (Freligh and Reich, 2009), or lead to novel forest ecosystems that may differ considerably from current forests in composition, density, and shrub/brush components.
Climate Change Vulnerability Assessment

Wisconsin's forested ecosystems vary considerably across the state. This variability means that specific climate impacts also vary by location and this assessment is structured in such a way that those trends are captured at both the broad, statewide, scale and finer, ecological landscape scale. It is also important to note that at the time of this report, only the Ecological Landscapes of Southern Wisconsin have been examined with the intent that the Northern Ecological Landscapes will be examined in the next assessment report.

State Wide Forest Vulnerability and Impacts

The potential impacts to forests from climate change that are common across the entire state are few. The makeup of the forests between northern and southern Wisconsin are different due to land use patterns, soils and current and past climate which have influenced their establishment. A major division is the Tension Zone which runs through the middle of the state. The impacts specific to northern and southern Wisconsin are further examined in later sections of this assessment but there are still some trends and vulnerabilities which are common across the state.

Forest ecosystems and the species which comprise them are dependent on moisture conditions related to soil moisture and precipitation. Changes in soil moisture from either changing precipitation or increasing evapo-transpiration will most certainly have an impact on the composition of forest types but the uncertainty around modeled precipitation makes it difficult to fully assess these potential changes.

It is likely that those forest systems which contain a range of both species and genetic diversity will be better positioned to respond to climate change impacts. While the species which make up these forests may change, the certainty that they will remain as forest ecosystem is higher than more specialized, low diversity forest systems that could be pushed beyond their limits of adaptability.

Throughout the fine scale assessments there is a common trend around forest vulnerability which supports current issues with forests being pushed to further extremes. Those issues around diseases, pests and invasive species which are difficult to manage are likely to become more difficult to manage under a changing climate. The same elements which limit certain forest species now are projected to become more limiting in the future.

Northern Forest Vulnerability and Impacts

The assessment of impacts outlined for northern Wisconsin were undertaken by the members of the Climate Change Response Framework for the Chequamegon-Nicolet National Forest and the United States Forest Service. The extent of this assessment covers the section of Province 212 which covers Northern Wisconsin. These assessments are summarized in the section below.

In northern Wisconsin, suitable habitat for many tree species will move northwards as temperature and precipitation patterns change. In general, warmer temperatures will be more favorable to species that are currently more common in southern Wisconsin. Habitat fragmentation and the limited dispersal ability of more southerly tree species seeds could hinder the movement of these species northward despite the increase in habitat suitability. According to the modeling results presented in the USFS Climate Change Tree Atlas most species are projected
to decline, especially boreal species like aspen, jack pine, red pine, paper birch, and balsam fir at
the southern extent of their range.

This movement of species will not be immediate. A change in the existing species is dependent
on colonization of sites following disturbance. These disturbances include fire, wind throw and
harvesting and it is unknown if these disturbances will change in the future. Furthermore, it is
unlikely that a decline in northern species will result in a large mortality of mature trees within a
forested system. Temperature and moisture stress will likely cause mortality in young
regeneration but mature trees will persist unless mortality is caused through disturbance, pests or
disease.

The specific future forest composition is currently unclear, complex interactions between tree
species and uncertainties around future precipitation creates a range of possible forest ecosystems
including ecosystem assemblages which are not observable today.

Interactions of multiple stressors may change overall forest productivity. The combination of
changes in climate, increased intensity of disturbances, slowed arrival of better adapted southern
species, and changes in hydrology could lead to declines in growth rates and forest yield. The
combination of these stressors may also make existing forests less resilient and more susceptible
to pests and disease which cause mortality in stressed trees.

In terms of varied susceptibility, those forest ecosystems which are low in diversity will be more
at risk. Low diversity systems are usually occupied by specialist species and if a changing climate
alters the environment to which they are specialized the ability of the system to adapt is limited.
Examples of such forest ecosystems in Northern Wisconsin include Aspen dominated forests,
Red Pine plantations, Black Spruce lowlands and Jack Pine forests.

Climate change will likely exacerbate problems for some species already in decline. Many
species such as hemlock, white cedar, yellow birch, and white spruce have been documented to
be in decline through forest inventories. Modeling results from two projects in Northern
Wisconsin indicate that climate change is projected to reduce the habitat suitability for these
species, which will accelerate their decline.

Resilience may of forests be weakened in fragmented ecosystems. Smaller and more isolated
forest fragments may not be able to adapt as easily as larger continuous areas of forest. Smaller
patch sizes support less species and genetic diversity, reducing their ability to adapt to a changing
climate. Habitat fragmentation might also hinder species’ ability to migrate to more suitable
habitat on the landscape, especially if the surrounding area is non-forested. Modeling results in
the USFS Climate Response Framework and elsewhere indicate that trees would need migrate at
a rate of hundred of meters up to several kilometers per year in order to track the changes in
climate that are projected to occur over the next 100 years.

Altered hydrology may jeopardize lowland forests. Lowland forests rely on saturated soils. If
precipitation regimes result in drought periods later in the growing season, the altered hydrology
could leave these sites vulnerable to drying out and extreme stress. Lowland conifer sites often
have peaty organic soils. If these sites dry out, they may be vulnerable to catastrophic wildfires.
Lowland hardwoods also rely on spring discharge, which may be altered if peak discharge comes
earlier in the year. These sites are also dominated by black ash, which is at risk for being
eradicated by the emerald ash borer.
Southern Ecological Landscapes Forest Vulnerability

An assessment of vulnerabilities within southern ecological landscapes was conducted using a panel of natural resource professionals who outlined potential impacts on forests within these landscapes given downscaled climate models from the WICCI climate group and existing forest climate models available through researchers and the USFS. Analysis of vulnerabilities at the
ecological landscape level is expected to be undertaken in the second WICCI assessment.

**Southwest Savanna**

Forests in the Southwest Savanna ecological landscape are extremely fragmented largely due to agricultural land use. The proportion of forests in this landscape compared to grasslands and agricultural lands is also low, so the existing forests here take on a role as an important ecosystem niches. This fragmentation creates an impediment to species movement, which isolates these systems from invasion but also limits the ability of the system to adapt through the migration of new, more southern, forest species.

The landscape also contains unique pine and hemlock relicts that exist on sheltered coldwater streams. These relicts are significant as they contain forest species that are much further south of their typical range. The microclimate of sheltered cliffs and coldwater streams on these sites allow these systems to persist, regenerate and be resilient to a changing regional climate. While forest cover in these systems may persist, the species composition may change to favor pine over hemlock as the latter species is very sensitive to moisture stress, disturbance and possibly warmer temperatures.

The dominant soils of the Southwest Savanna are also a feature that can aid in the resilience of forest systems in a changing climate where changing precipitation and increasing evapotranspiration could lead to decreasing soil moisture. The rich silt loam soils hold water well and can buffer soil moisture loss during short drying periods.

This landscape is also on the southern edge of the state and could see both new tree species and invasive species. Current minor component species such as Kentucky Coffee Tree, Sycamore, Pignut Hickory, Box Elder and Yellow Poplar may increase in abundance as temperature and precipitation change to create an environment to which they are more suited.

As implied by the name, Oak savanna is a significant component in this ecological landscape. These savanna ecosystems are heavily managed for to control woody vegetation through prescribed fire. This management system gives the savanna ecosystem a high degree of resilience; however, this management system is dependent on having an available season to conduct safe and feasible prescribed burns. The factors that affect the feasibility of conducting a prescribed burn are moderate temperatures, light winds, moderate humidity and dry, dead vegetation. It is possible that prescribed burn opportunities will increase. However, a warming spring could shorten the time from thawing to first vegetative flush and increasing precipitation could compress the time available to land managers to conduct spring prescribed burns.

**Western Coulees and Ridges**

The forests of this ecological landscape are characterized by ecosystems existing on side slopes and bottomlands with a trend on the upland forests that is seeing Oak dominated forests converting to northern and central hardwood dominance. This loss of Oak is not perceived to be climate change related but to pressures from deer browsing and changing natural disturbance and harvest regimes that favor natural succession to more shade tolerant species.

This landscape also contains some Jack Pine forests on dry sandy sites. The occupation of Jack Pine on these sites is related to the soil conditions that persist here as there is little competition otherwise. Under a warming climate these sites may persist as Jack Pine. However, jack pine is a boreal species at the southern extent of its range, and could be at risk for replacement by scrubby oaks on drier sites.
Upland forests in this landscape occur predominantly on side slopes that were unsuitable for agriculture and are composed mainly of Oak, often succeeding to Central and Northern Hardwood species such as Sugar Maple, Red Maple, Black Cherry, Shagbark Hickory, Hackberry, White Ash, Basswood and Yellow Birch but an increasing average temperature will allow for the integration and survival of more central hardwood species such as Hickory and Black Oak.

Unique to this landscape is a geologic feature referred to as Algific talus slopes. These slopes are shallow fractured bedrock slopes where cool air drainage keeps soil 40° to 50° all year. This cold driven system could be very vulnerable to climate change and the pine and hemlock relics that they support would be put at risk.

Another important forest type within this region is the floodplain forest. These forests are comprised of Ash, River Birch, Oak, and Silver Maple and are found along major river ways such as the Wisconsin and Mississippi Rivers. These river corridors have mostly intact forests and provide a pathway for species movement. Heavier precipitation events along these riverways may increase flooding and disturbance of floodplain forests, but these forest types are adapted to these disturbances. However, invasive species may complicate the floodplain forest response to increased flood events. Reed Canary Grass is currently invading these forest types and increasing the rate of disturbance could also increase the rate of Reed Canary Grass spread. Furthermore, the spread of Emerald Ash Borer in Wisconsin will impact the significant Ash component of these lowland forests. This loss of these species and increased flood events could exacerbate the Reed Canary Grass issue.

**Western Prairie**

The Western Prairie Ecological Landscape lies along the floristic tension zone which makes it an ideal area to monitor for changes in species assemblages. Furthermore, urban expansion of the Minneapolis/St. Paul suburbs which leads to fragmentation of the forests in this region.

Oak composition in this region could be compromised due to two factors. First, modeled summer drying in the northwestern part of the state could create an environment in which drought stress leads to an expansion of oak and/or possibly jack pine. Second, on sites with higher moisture capacity Red Maple is out competing Oak regeneration. The US Forest Service Tree Atlas shows Red Maple becoming a more competitive species under all future emission scenarios.

**Central Sand Plains**

The Central Sand Plains are located on an extinct glacial lake which drained catastrophically and formed the dells of the Wisconsin River. This system is dominated by dry and wet sandy soils; the hydrology is dominated by groundwater movement. Changes in water tables can be pronounced and quickly impact forests, facilitating shifting dominance by species adapted to very dry or very wet drainage conditions.

This landscape, located in central Wisconsin and bordering the Tension Zone, contains the highest proportion of conifers in Southern Wisconsin, which creates a significant risk for impact as dominant conifers such as Tamarack, Red Pine, Jack Pine, and Eastern White Pine have modeled risk according to projections in the USFS Tree Atlas.

Red Pine in this area could be subjected to stress from longer growing seasons, which increase respiration and can be linked to pocket decline and topping off.
White Pine is projected only to be put under stress under higher emissions scenarios, but could decline on sites which are currently marginal in terms of soil suitability. These marginal sites may become dominated by Oak if they are susceptible to drought.

Jack Pine is a boreal species at the southern edge of its range and could be outcompeted by oak in this landscape. However, this species persists on dry sandy sites and though some marginal sites may change in soil moisture, it is possible that a large component of Jack Pine dominated sands could persist in this landscape.

Wetlands in this landscape are dominated by peatlands, some of which are forested with Tamarack. Peatlands are sensitive to changes in water table, which is a risk if the groundwater systems in the Central Sand Plains increase due to heavier rainfall or decrease due to prolonged summer drying. As drying occurs in these systems the dried peat surface becomes unsuitable for regeneration and the system becomes disrupted and conversion to alder or red maple is likely.

**Central Sand Hills**
The Central Sand Hills are primarily moraines and outwash with a silt cap in the southeastern part of the landscape. In general, soils are dry to dry-mesic and nutrient poor to medium. Conifers in this landscape are primarily red pine, scrub oaks are common with higher quality oaks on the moraines. Unlike the Central Sand Plains differences in elevation in this landscape can result in large differences in moisture regime. Abandoned farms planted to pine are characteristic of this landscape. This heterogeneous landscape creates a resilience in the forests as not all types are likely to decline or increase simultaneously under a variable climate.

Current wetlands that could experience drying would likely be invaded by red maple, a species which is well adapted to warmer climates.

In this region, hickory can be found on forested sites which have been susceptible to drought. On these sites there is an increased incidence of hickory bark beetle and associated fungus which could limit the spread of this forest species even if precipitation and temperature become more suitable to its growth.

**Southeast Glacial Plains**
The Southeast Glacial Plains contain relatively low amounts of forest in comparison to the other land uses in the landscape but those that remain can be considered important to the makeup of the landscape. Also unique to this landscape in terms of current precipitation trends and projected trends is an increase in overall precipitation while the rest of the state is predicted to get drier.

The soils are rich in this area and are more suited to the growth of Oak but current management practices enable these forests to persist as northern hardwoods. Disturbance based management practices would favors oak in this landscape, while succession, especially on rich soils, favors maple-basswood.

Existing forests are fragmented and scattered into small woodlots which limits the opportunities for species migration, encourages the establishment of invasive species on the edges and concentrates herbivores which feed on the forest understory in these areas. Forests under these pressures are currently difficult to manage and will become increasingly difficult to manage under a changing climate which induces more stress on existing forests.
Also unique to this landscape are lowland cedar and tamarack forests which reach their southern extent in this landscape. One example is the cedarburg bog; its lowland tamarack sites are currently difficult to regenerate and could become more difficult in the future as tamarack may be very sensitive to changes in climate. Possible impacts that could affect tamarack bogs include warming and more penetrating freezes if snow cover is reduced.

This landscape also contains the Kettle Moraine State Forest, which is a north/south oriented property which contains a large component of the forests within this landscape. Within this forest, central hardwood species in the south are currently migrating to the northern sections of the forest and could continue to be a forest species migration route in the landscape. However, within this forest, invasives continue to present challenges to forest establishment in the Kettle Moraine and invasive species are projected to become a larger problem as the plants are adapted to take advantage of warmer temperatures, increased disturbance and carbon dioxide enrichment.

This landscape also contains floodplain forest along river bottoms. These areas could provide migration routes to new southern species but they are currently heavily disturbed and invaded by reed canary grass; making the establishment of new forests unlikely.

**Southern Lake Michigan Coastal**
This landscape is highly urbanized and contains relatively little forest. Most forests that do remain are heavily managed to deal with invasive species.

The proximity of this landscape to the Lake Michigan coast indicates that any projected temperature increases will be moderated, indicating that there may be less stress put on the forests in this region. This landscape may have persistent forests but its connection to the urban corridor of Chicago includes it as a likely introduction route for new forest pests and diseases.

This landscape also contains a population of Blue Ash, a species which could experience more favorable conditions under climate change but is currently at risk to the Emerald Ash Borer.

**Urban Forests**
On the surface, Wisconsin’s urban forests and their management will be affected in three fundamental ways: tree growth, pressure from pests, and species selection.

To compensate for the increase in annual growth associated with warming temperatures and carbon dioxide enrichment communities would be forced to shorten their pruning cycles so as to maximize the benefits derived from trees in urban environments and to reduce public risk from limb failure resulting from a lack of timely pruning. Additionally, there is a potential for an increase in the frequency of immediate response activities, such as removing tree limbs that are obstructing visibility at road intersections, resulting from accelerated growth/longer growing seasons. In all likelihood, municipal urban forestry budgets would need to reflect the increased demand for management resulting from the combination of these two outcomes.

A changing climate, a warming one in particular, could result in the introduction of new tree pests and pathogens into Wisconsin. An aggressive pest that attacks a commonly planted tree within urban areas could have devastating effects on both the existing urban forest and future urban forests. Aggressive pests would force communities to allocate the precious few resources they currently have to remove standing trees that have succumbed to the pest and now represent a structural liability. Significant canopy loss, especially if it is sustained for a long period of time, could negatively affect the quality of life within Wisconsin’s communities.
A changing climate would influence the species of trees we plant in our communities. Trees that currently exist in our urban areas may not be able to thrive or survive under a new set of climatic conditions. Undoubtedly, there will be a few species of trees that will not tolerate the changes in climate. These species would eventually need to be eliminated from the urban forest and not replanted. If the primary urban forestry management objective is to maintain or increase the environmental benefits derived from the urban canopy, those species that could not survive in the new climatic conditions must be replaced by a species of tree that is capable of surviving.

Perhaps under a lower emissions scenario would result in a situation where a tree species thrived under the old climatic conditions, but merely hangs on under the new conditions. Under this scenario, the affected tree species would undoubtedly require additional resources, financial and physical, to maintain their health and vitality so as to remain a valued component of the urban forest. Another, more practical concern, is the availability and acquisition of the new tree species that will be planted in Wisconsin’s communities. Acquiring new tree species will require nurseries that are currently providing trees to Wisconsin’s communities to start planting a yet to be determined suite of trees well ahead of the replacement demand.
Sensitivity Analysis and Uncertainty

Sensitivity Analysis
The sensitivity of forest response to climate change follows a smooth gradient along temperatures but results in more drastic changes along varying precipitation. It is also important to note that the sensitivities are distinct between northern and southern Wisconsin.

Variability in Precipitation
Precipitation projections tend to have more uncertainty than temperature projections, because precipitation is controlled by local-scale processes and mechanisms operating at spatial scales too small to be resolved by GCMs. For example, a thunderstorm on a summer day may result in intense rainfall, yet have a spatial footprint that is on the order of kilometers to tens of kilometers – much smaller than the 1°x1° (~100km) resolution available from the highest-resolution GCM’s. Nevertheless, at a global scale, GCM’s consistently indicate that the tropics and high latitudes will get wetter during the 21st-century (if atmospheric greenhouse gas concentrations are not stabilized) while the subtropics will get dryer. For North America, most GCMs indicate that Canada and parts of the northern US will have increased rainfall during the 21st-century, while the southern US and Mexico will experience reduced rainfall {Fig. 3, IPCC, 2007 #2443}.

Wisconsin and other areas in the central US are in an intermediate zone, in which models differ widely in their projections of precipitation (Fig. 3). Most models project an increase in winter and annual precipitation, but models are evenly split between whether Wisconsin will receive more or less rainfall during the summer months (Fig. 3).

This uncertainty in precipitation is reflected in the climate-analog analyses, and in particular in the wide spread of analogs from east to west (Fig. 1). Among the 14 GCMs used in the climate-analog analyses, two indicate that Wisconsin will become hotter and dryer than present, while the others indicate either no change or somewhat wetter conditions. For the dryer-than-present future simulations, the closest modern analogs to the future climates of Wisconsin tend to be found to the southwest (e.g. Oklahoma, Kansas, Nebraska), while the wetter-than-present future simulations tend to find closest modern analogs to the east (e.g. New York, Pennsylvania, Virginia). Uncertainty in precipitation projections thus is a major issue for planning forest adaptation strategies.
Figure 3: Projected precipitation changes for North America, for the SRES A1B greenhouse gas emission scenario. The top row of maps indicates differences between 2080-2099 and 1980-1999, averaged over 21 models. The bottom row of maps indicates the number of models (out of the 21 considered) that indicate that precipitation will increase over the 21st century. Left column: annual precipitation. Middle: winter precipitation (averaged for December/January/February). Right: summer precipitation (averaged for June/July/August). Source: {IPCC, 2007 #2443, Figure 11.12} Climate Analog models produced by Dr. Jack Williams and Dr. Sam Veloz of the University of Wisconsin show southern Wisconsin Temperature Analogs consistently occurring in mid-latitude Illinois through 2050 in either the Sres B1 or Sres A2 emissions scenarios. However, through 2050, Sres B1 analogs for northern Wisconsin occur in mid-latitude Wisconsin; while Sres A2 temperature analogs occur in southern Wisconsin. This sensitivity to emissions scenarios in northern Wisconsin versus southern Wisconsin remain pronounced through simulations to 2100. In terms of forests, this climate sensitivity is compounded by expert analysis around the vulnerability of northern forests which target typically boreal species to be less resilient to climate change. As a result of both forest species analysis by the USFS Climate Change Framework and climate analog models, northern Wisconsin forests will be sensitive to temperature variability while southern Wisconsin forests may be better adapted.

Precipitation sensitivity is also shown through a comparison of forest modeling work in northern Wisconsin done by Dr. Louis Iverson's USFS Tree Atlas team and Dr. David Mladenoff. Dr. Mladenoff's model inputs used a Hadley Center climate model with consistently wetter climates while Dr. Iverson's model used drier inputs. The two models project similar changes in forests but a tradeoff between Sugar Maple and Red Oak respectively. The differences in moisture inputs between the two models was not large but the sensitivity was enough to trigger a tipping point in dominance between the two species across sites. This supports that the forest models used in this assessment are sensitive to moisture inputs.

Uncertainty
Uncertainty is a common issue that is well documented in climate model downscaling done by the WICCI Climate Working group. These models form the basis for the Forestry Vulnerability assessment and as such compound the uncertainties within this assessment. Forest Ecosystems
are sensitive to water inputs and so variability within Global Circulation Models limits the accuracy of projections within Forest modeling. However, these models are consistent along two trends which have implications for forests. The first consistency is an increased probability of late summer drought, which increases forest stress. The second consistency is that of increased spring precipitation which relates to flood and fire risk in forest ecosystems.

There are a range of uncertainties specific to forests that relate to unknowns in both climate science and silvicultural science. These uncertainties include: future ecosystem assemblages, spinoff land use impacts, silvicultural effectiveness and forest fire risk. Ecosystem assemblages are uncertain due to the fact that species migration may create interactions between species which have not previously been observed in Wisconsin. Another uncertainty relates to the impact on forest vulnerability that may be created by changing forest land uses in terms of fragmentation; bioenergy incentives and voluntary carbon offsets. A further uncertainty lies within silvicultural effectiveness; current forest models assume either no harvest or management with forest regeneration results consistent with present day systems. Future climate impacts on the success of these silvicultural techniques is unknown and so their interaction with future forest conditions is uncertain. Finally, Forest fire risk will certainly change under a future climate but the models currently in use in Wisconsin have not been run with modeled climate variables so this interaction on the landscape remains uncertain.

Adaptation Strategies

Introduction
In spite of the vulnerabilities listed in the previous sections of this assessment there are adaptation strategies available to policy makers and land managers which might reduce or slow or facilitate rational adaptation to the eventual impacts of climate change. Those strategies are tied to the certainty of available information gathered and might become more specific as outcomes become more distinct. For the scope of this document, forest adaptation strategies will remain broad with the intent of providing managers with tools to respond to climate change while ensuring that resources are well used and provide least harm in implementation.

Strategy 1. Support Increasing Certainty of Long-term Climate Forecasts
Soil moisture and Precipitation are important factors which determine the presence and type of forest ecosystem which may develop at a geographic location. These factors along with fire disturbance and anthropogenic influence are also important in determining the forest/prairie boundary in the state. Given that current climate models are relatively consistent in modeling temperature but more uncertain in modeling precipitation it is difficult to predict specific ecosystem changes that may result from changing climate. If opportunities arise to improve confidence in long-term future climate trend prediction it would be valuable to support these endeavors to then provide better inputs into future forest condition modeling, however, long-term climate prediction will probably continue to have a very high degree of uncertainty.

Strategy 2. Monitor Vegetation for Impacts Caused by Climate Change
The vulnerability assessment indicates forest types which are likely to change as well as imputing the likelihood that new regeneration will decline in northern species with southern species moving outside of their typical ranges. The rate, timing and mechanisms for these changes are unknown and monitoring of at risk and sensitive sites would help to test these projections. Monitoring of typical forest sites could help identify potential long-term impacts to the forested matrix of the state. Monitoring would need to be intensive and carefully designed in order to
determine causes for observed effects.

Sensitive sites that would be ideal for monitoring would include: sites prone to disturbance, riverbottom migration routes, abandoned agricultural lands, conifer lowlands and existing forest relics outside of their typical ranges. Sites which are at risk, which would be ideal for monitoring could include: forest sites currently experiencing regeneration failures, forest or savannah sites on the prairie transition and sites experiencing mortality from forest pest pressures.

In the short term, being able to inventory what exists on these sites in terms of both understory and over story would be valuable to establish trends in forest establishment and regeneration in each subsequent decade.

**Strategy 3. Adaptive Management**

Many of the impacts hypothesized in the vulnerability assessment project the intensification of negative pressures impacting forests caused by multiple interacting stressors. In order to help forests adapt to increasing pressures, adaptive management strategies may be needed to evaluate change, slow change where necessary and constructively manage change that is bound to occur. Adaptive responses that work with change rather than opposing and conquering will likely be more effective and less costly. In some cases intensive management may not be feasible and passively managed reserves may be the best option for managing change. The challenge in the future will be identifying change and efficient management tools and prioritizing resources to apply adaptive management techniques to a changing forest landscape.

Significant management activities that should be encouraged and pursued now, that might help ameliorate impacts:

- Manage for diversity across scales; particularly species diversity.
- Create and maintain landscape connectivity.
References


http://files.dnr.state.mn.us/natural_resources/ecs/nhfeu.pdf


Appendix A – Supporting Documents

THE CENTRAL SAND HILLS ECOLOGICAL LANDSCAPE

General Description and Overview

The Central Sand Hills Ecological Landscape is located in central Wisconsin at the eastern edge of what was once Glacial Lake Wisconsin. The landforms in this Ecological Landscape are a series of glacial moraines that were later partially covered by glacial outwash. The area is characterized by a mixture of farmland, woodlots, wetlands, small kettle lakes, and cold water streams, all on sandy soils. The mosaic of glacial moraine and pitted outwash throughout this Ecological Landscape has given rise to extensive wetlands in the outwash areas, and the headwaters of coldwater streams that originate in glacial moraines. The growing season is long enough for agriculture but the sandy soils limit agricultural productivity somewhat.

Historic upland vegetation consisted of oak-forest, oak savanna, and tallgrass prairie. Fens were common in this Ecological Landscape and occurred along with wet-mesic prairie, wet prairie, and rare coastal plain marshes. Current vegetation is composed of more than one-third agricultural crops, and almost 20% grasslands with smaller amounts of open wetland, open water, shrubs, barren, and urban areas. The major forested type is oak-hickory, with smaller amounts of white-red-jack pine, maple-basswood, lowland hardwoods, aspen-birch, and spruce-fir. Black spruce is a component of a wetland complex in the northwestern corner of Columbia County - Corning-Weeting lakes. This is one of the southernmost locations for black spruce in the Upper Midwest.

There are numerous small kettle lakes and ponds associated with the glacial outwash. There are many softwater lakes with sand bottoms that have been or are being developed for recreational uses. Green Lake is found here and is the deepest natural lake in the state. Large, shallow impoundments include Lake Wisconsin on the Wisconsin River and Buffalo Lake and Lake Puckaway on the Fox River. Important rivers are a segment of the Wisconsin River, the lower Baraboo River, and the upper Fox River. Water quality in free-flowing rivers and streams is generally good. Water quality in these streams is enhanced by spring flows, the absence of point source discharges, and either minimal agricultural activity or well-maintained stream buffers. Urban non-point runoff, sedimentation, excess nutrients, and heavy recreational boating use impact lake water quality and habitat.
The total land area for the Central Sand Hills Ecological Landscape is approximately 1.4 million acres, of which 28% is classified as timberland. Only about 4% of the Ecological Landscape is in public ownership.

Although soils are predominantly dry and sandy, the Central Sand Hills Counties are primarily agricultural. Agriculture is successful in this sandy area with use of irrigation mostly in the production of potatoes, sweet corn, peas, and snap beans but there is a considerable amount of marginal and idle agricultural land. There is one State Park (Hartman Creek) in the Ecological Landscape, as well as 26 State Natural Areas, and 24 State Fishery and State Wildlife Areas. Federal lands include: Fox River National Wildlife Refuge, Waterfowl Production Areas of the Leopold Wetland Management District including the Lower Baraboo River Waterfowl Production Area, as well as several segments of the Ice Age Trail.

The Central Sand Hills Counties are nearly average for most socioeconomic indicators. The population density (59 persons/sq. mile) is slightly more than half that of the state as a whole (96 persons/sq. mile). The region has shown an above average population growth rate since 1970, especially for the elderly (over 65). The number of minorities is quite low. Although average wage and per capita income are well below the state average, these indicators are intermediate compared to other landscape approximations. In addition, the rates of poverty and unemployment are well below average when compared to the other regions. The agricultural and government sectors have a more influential role in the number of employees in the Central Sand Hills Counties, whereas manufacturing and the service sector are less important than elsewhere in the state.

<table>
<thead>
<tr>
<th>Physical and Biotic Environment:</th>
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<tbody>
<tr>
<td><strong>Size</strong></td>
<td>1,388,705 acres (2,170 square miles), representing 3.9 % of the land area of the State of Wisconsin</td>
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<tr>
<td><strong>Climate</strong></td>
<td>Typical of south central Wisconsin; mean growing season of 144 days, mean annual temperature is 44.8 °F, average January minimum temperature is 4°F, average August maximum temperature is 81°F, mean annual precipitation is 33, mean annual snowfall is 44 inches. Although the climate is suitable for agricultural row crops, small grains, and pastures, the sandy soil may limit agriculture.</td>
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<tr>
<td><strong>Bedrock</strong></td>
<td>Bedrock exposures are limited but include Precambrian rhyolite bluffs, and a vertical exposure of Ordovician St. Peter sandstone with a thin dolomite cap at Gibraltar Rock in Columbia County.</td>
</tr>
<tr>
<td><strong>Geology and Landforms</strong></td>
<td>The landforms in this Ecological Landscape include a series of glacial moraines (the Johnstown Moraine is the terminal moraine of the Green Bay lobe; the Arnott Moraine is older, and has more subdued topography. Pitted outwash is extensive in some areas. Glacial tunnel channels occur here, e.g., in Waushara County, just east of I-39.</td>
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<tr>
<td><strong>Soils</strong></td>
<td>Primarily sands. Organic soils underlie wetlands such as tamarack swamps and sedge meadows. Muck farming still occurs in some areas.</td>
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<tr>
<td><strong>Hydrology</strong></td>
<td>Mosaic of extensive wetlands and small kettle lakes in the outwash areas, and the headwaters of coldwater streams originating in glacial moraines. Some seepage lakes and ponds exhibit dramatic natural water level fluctuations which create important Inland Beach and Coastal Plain Marsh habitats. The Wisconsin River and a short but ecologically important stretch of the lower Baraboo River flow through this Landscape. Other important rivers include the Fox, Grand, Mecan, Montello, and White. Large impoundments occur on the Wisconsin (Lake</td>
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Wisconsin), Fox (Buffalo and Puckaway lakes) and Grand (Grand River Marsh) rivers.

Current Landcover: Current vegetation is more than one-third agricultural crops, one third forest, and almost 20% grasslands with smaller amounts of open wetland, open water, shrubs, barren, and urban areas. Large contiguous areas of any of the major natural or “surrogate” vegetation types are generally uncommon.

Socioeconomic Conditions (The counties included in this socioeconomic region are: Portage, Waushara, Marquette, Green Lake, and Columbia.)

- Population: 182,035; 3.2% of the state total
- Population Density: 59 persons/ mi²
- Per Capita Income: $30,777

Important Economic Sectors: The largest employment sectors are: government (13.2%); tourism-related (12.6%), manufacturing (non-wood) (12.0%) and health care & social services (9.4%) sectors in 2007. Although forestry, agriculture, and development do not have a large impact on the economy or in the number of jobs they produce, they are the sectors that have the largest impact on the natural resources in the Ecological Landscape.

Public Ownership: Scattered Federal Waterfowl Production Areas, Fox River National Wildlife Refuge, scattered state-owned and managed lands, including Hartman Creek State Park, several State Wildlife and Fisheries Areas, and State Natural Areas. A map showing public land ownership (county, state, and federal) and private lands enrolled in the Forest Tax Programs in this Ecological Landscape can be found at the end of this chapter.

Other Notable Ownerships: The Nature Conservancy has been active in this Ecological Landscape, for example at Summerton Bog and Page Creek Marsh.

Considerations for Planning and Management

Habitat fragmentation and isolation, groundwater withdrawals and contamination, hydrologic disruption, fire suppression, shoreline development, spread of invasive species are concerns in this Ecological Landscape. Poor water quality exists in some lakes and impoundments. Ground water contamination is also an issue in this Ecological Landscape. Excessive groundwater withdrawals could have serious negative consequences in areas supporting coldwater streams, and within the recharge areas of groundwater-dependent natural communities such as Coastal Plain Marsh, Calcareous Fen, Tamarack Swamp, and Southern Sedge Meadow. Fire suppression has altered successional pathways that maintained barrens and other fire adapted vegetation.

Management Opportunities

- Oak savanna remnants (barrens and oak openings) occurring on dry and dry-mesic sites, are scattered throughout the Ecological Landscape.
- Excellent opportunities to manage for fire-adapted communities, including oak forest and woodland, oak savanna, prairies, and wetland types such as sedge meadows and fens.
- Dry forests of white, black, and bur oak are still common.
- Mixed forests of pine and oak are locally common. The Central Sand Hills represents one of the better Landscapes in which to manage for the Central Sands Pine-Oak Forest community.
- Large wetland complexes contain good examples of communities such as fen, sedge meadow, low prairie, shrub swamps, and tamarack swamp (e.g., Germania Marsh, Comstock Marsh, Grand River Marsh, Fountain Creek Prairie).
- Floodplain forest is well-developed along the Wisconsin, Baraboo, and Montello rivers, among others.
- Numerous springs and coldwater streams emanate from the end moraine that forms the western
boundary of the Central Sand Hills. Wetlands associated with these landforms, some of them quite alkaline, include fen, sedge meadow, low prairie, shrub swamp, and tamarack swamp.

- Significant savanna and grassland remnants.

Current and Historic Vegetation of the Central Sand Hills

Historic Vegetation
Several sources were used to characterize the historic vegetation of the Central Sand Hills, including data from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866 and Finley’s (1976) map of historic land cover based on his interpretation of PLS data. Additional inferences about vegetative cover were sometimes drawn from information on land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives.

Figure 1. Vegetation of the Central Sand Hills Ecological Landscape during the mid-1800's, as interpreted by Finley (1976) from Public Land Survey information.

According to Finley’s map and data interpretation, in the mid-1800s the Central Sand Hills Ecological Landscape was dominated by either oak forest or oak opening, with interspersed wetlands (mostly marsh and sedge meadow) (Figure 1). Only 8,700 acres of the Ecological Landscape was covered by mesic upland forest, the least amount of this forest type in any Ecological Landscape (also see “Finley’s Presettlement Vegetation” in the Statewide Maps section of this Handbook).

Current Vegetation
There are several data sets available to help assess current vegetation on a broad scale in Wisconsin. Each was developed for different purposes and has its own strengths and limitations in describing vegetation. WISCLAND, the Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’s Forest Inventory and Analysis (FIA) and the National Land Cover Dataset (NLCD) were used for this analysis. Results among these data sets often differ, as they are the products of different methodologies for classifying land cover, and each dataset was compiled
based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales.

Figure 2. WISCLAND Land Use/Land Cover data showing categories of land use classified from LANDSAT satellite imagery (1992) for the Central Sand Hills Ecological Landscape.

The Central Sand Hills Ecological Landscape is approximately 1,389,000 acres in size, of which approximately 33% was forested, and 34% was in agricultural use (WISCLAND, 1992). WISCLAND land use/land cover data from 1992 also indicates that 19.2% of the Ecological Landscape was classified as grassland, which is the highest percentage of grassland of all of the Ecological Landscapes south of the tension zone, and second only to the Western Prairie Ecological Landscape in the State (Figure 2). The Wisconsin Wetlands Inventory (WDNR 2007) offers a more specific assessment of wetlands than is available with WISCLAND data, but is limited to those areas identified from satellite imagery as wetland. According to the Wisconsin Wetlands Inventory (WDNR 2007), wetlands occupy a relatively large portion of the Central Sand Hills, comprising 18.3%, (approximately 254,000 acres) of this Ecological Landscape’s vegetation. Forested wetlands make up over 107,000 acres of the Ecological Landscape, making these the most abundant wetlands in the Central Sand Hills. Wet meadows (including emergent marsh and sedge meadow) occupy approximately 81,000 acres. Shrub/scrub wetlands occur across approximately 56,000 acres (See the Glossary of this Handbook). Forest Inventory and Analysis (FIA) data from 2004 is a USDA Forest Service program which compiles point samples of forested lands to assess the timber resources of the country. According to FIA data summarized in 2004, approximately 66% of land area in the Central Sand Hills Ecological Landscape is non-forested, and about 34% is forested. The predominant forest cover type group is oak-hickory (47.0% of the forested area). All other forest types occupy less than 10% of the forested area (Figure 3).

Figure 3. Forest Inventory and Analysis data (2004) showing forest type as a percent of forested land area (greater than 17% crown cover) for the Central Sand Hills Ecological Landscape.
Major Significant Features of the Central Sand Hills Ecological Landscape

The Central Sand Hills Ecological Landscape in central Wisconsin is characterized by a mixture of farmland, woodlots, wetlands, small kettle lakes, and cold water streams, all on sandy soils. The mosaic of glacial moraine and pitted outwash throughout this Ecological Landscape has given rise to extensive wetlands in the outwash areas, and the headwaters of coldwater streams that originate in glacial moraines. The growing season is long enough for agriculture but the sandy soils limit agricultural productivity somewhat. Historic vegetation consisted of oak-forest, oak savanna, and tallgrass prairie. Current vegetation is composed of more than one-third agricultural crops, and almost 20% grasslands with smaller amounts of open wetland, open water, shrubs, barren, and urban areas. The major forested type is oak-hickory, with smaller amounts of white-red-jack pine, maple-basswood, lowland hardwoods, aspen-birch, and spruce-fir. Black spruce is a component of a wetland complex in the northwestern corner of Columbia County - Corning-Weeting lakes. This is one of the southernmost locations for black spruce in the Upper Midwest.

Ecological Opportunities of the Central Sand Hills Ecological Landscape include:

- Fire-adapted ecosystems such as prairies, sedge meadows, fens, savannas, woodlands, and forests constitute a major management opportunity in the Central Sand Hills.
- Alkaline wetlands, such as tamarack swamps, are well-represented here and harbor many sensitive plant and animal species.
- Miscellaneous opportunities include scattered forests, savannas, prairies, wetlands, surrogate grasslands, and populations of rare species.
- The lack of large blocks of public or private land in the Central Sand Hills make it necessary to create and rely on partnerships for many projects.
- In developed areas with little public ownership work across administrative and ecological boundaries to reduce problems associated with small stand size and population or habitat isolation.
- Oak woodland, oak savanna, and grassland wildlife (e.g., bullsnake, ornate box turtle, western slender glass lizard, Red-headed Woodpecker, Blue-winged Warbler, Brown Thrasher, Black-billed Cuckoo, Bobolink, Eastern Meadowlark, Field Sparrow, Grasshopper Sparrow, Henslow’s Sparrow, Lark Sparrow, Upland Sandpiper, Vesper Sparrow, Western
Meadowlark, Whip-poor-will, Franklin’s ground squirrel, gorgone checkerspot, and Leonard’s skipper.

Citation:
THE CENTRAL SAND PLAINS ECOLOGICAL LANDSCAPE

General Description and Overview

The Central Sand Plains Ecological Landscape, located in central Wisconsin, is centered on a flat, sandy lake plain, and supports agriculture, forestry, recreation, and wildlife management. The Ecological Landscape formed in and around what was once Glacial Lake Wisconsin, which contained glacial meltwater that covered over 1.1 million acres at its highest stage. Soils are primarily sands, including lacustrine deposits, outwash, and material eroded from the sandstone bedrock. Organic soils are characteristic of the poorly drained peatlands. Sandstone buttes, pinnacles and cliffs were created by wave action, and the catastrophic drainage of the glacial lake carved spectacular gorges in some parts of the Landscape. No other Wisconsin landscape has geological features such as these.

The historic vegetation of the area included extensive wetlands, especially in the bed of extinct Glacial Lake Wisconsin where large peatlands of open bog, poor fen, sedge meadow, and conifer were the dominant vegetation. Uplands were vegetated with forests of oak or pine, pine barrens, oak barrens, and small areas of prairie. Very limited areas of more mesic hemlock hardwood forest were present. A major pinery occurred in eastern Jackson County. The northwestern part of the Landscape supported mixed forests of white pine, oak, and other hardwoods. Mixed barrens occurred in eastern Eau Claire County.

Today, the western portion of the Landscape contains extensive forests of oak and pine, abundant peatlands, and large public ownerships. Human population density is low and associated infrastructure limited. Attempts were made early in the 20th century to drain many of the wetlands west of the Wisconsin River for agriculture, but, with the notable exception of commercial cranberry production, many of these failed. Widespread wetland drainage occurred at about the same time in the eastern part of the Landscape and many of these lands are now used mostly for agricultural purposes, including the production of row crops, small grains, vegetables, and pasture. Recently, commercial cranberry bed development has occurred on uplands east of the Wisconsin River. Public lands are less extensive east of the Wisconsin River than to the west, but include significant areas of dominated by non-native grass that are managed to benefit rare grassland birds such as the Greater Prairie Chicken.

The Wisconsin, which has been dammed at several locations, is the largest river flowing across this Ecological Landscape. Other significant rivers include the Black, East Fork of the Black, Yellow, and Lemonweir. All of the larger rivers (and some of the smaller streams) are associated with significant floodplains, which are mostly forested with lowland hardwoods. There are no
large natural lakes here, though there are few small lakes and ponds. Most natural lakes are associated with the large river floodplains. The rivers and lakes and rivers of the Ecological Landscape are relatively unpolluted, with some exceptions. However, non-point pollution rankings by the Wisconsin DNR indicate that watersheds in the more agricultural eastern half of this Ecological Landscape are quite susceptible to groundwater contamination from non-point sources, compared with other areas of Wisconsin. Only the Central Sand Hills has a more severe non-point groundwater pollution susceptibility ranking.

The principal land uses within the Central Sand Plains Counties are agriculture, recreation, timber production, and cranberry production. Some of these counties are top producers of several crops including potatoes (these counties combined produce half the state’s potatoes) and cranberries. Jackson and Wood counties are the top cranberry producers in the state. The forest products and processing industries are also significant here, accounting for 17% of the region’s industrial output compared to 8% of statewide output. The pulp and paper industry are primary contributors to the forest products and processing industries in the CSP Counties.

In the Central Sand Plains Ecological Landscape, there is a 31% higher percentage of forestland and a 25% lower proportion of agricultural land compared to the rest of the state. The percentage of surface area in water is 4th highest in the state. The Central Sand Plains Ecological Landscape has far more public land in general. The density of campgrounds is higher than average as is the number of visitors to state lands. Trail density, however, is quite low compared to other Ecological Landscapes. Acreage in natural areas is much higher than average but the number of heritage sites with high recreation potential is low. These counties rank 12th out of 16 Ecological Landscapes in trail density (miles per 100 mi²). There is a lower density of hiking, road biking, ATV, and snowmobiling trails compared to the rest of the state.

The Central Sand Plains Counties are rural in character, with many small cities and towns. The mean population density of the CSP counties (46 persons per mi²) is less than half that of the state as a whole (98.8). Property values are among the lowest on average among all Ecological Landscape County Approximations in the state. In general, the region is homogenous in racial structure, and exhibits an age distribution only slightly skewed towards an aging population. Education attainment in CSP counties is lower than statewide averages.

**Central Sand Plains Ecological Landscape at a Glance:**

<table>
<thead>
<tr>
<th>Physical and Biotic Environment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>3,420 square miles (2,188,861 acres), representing 6.1% of the land area of the State of Wisconsin.</td>
</tr>
<tr>
<td><strong>Climate</strong></td>
<td>This Ecological Landscape has a continental climate, with cold winters and warm summers. The growing season length is average among Ecological Landscapes; however, summer temperatures can drop below freezing at night in the lower-lying areas, limiting agricultural uses and the occurrence of some flora.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
<td>Late Cambrian sandstone that contains strata of dolomite and shale. Precambrian igneous (granite) and metamorphic rocks (gneiss) lie beneath the sandstone and are exposed in only a few places.</td>
</tr>
<tr>
<td>Geology and Landforms</td>
<td>An extensive, nearly level expanse of lacustrine and outwash sand, that originated from a huge glacial lake. Sand was deposited in Glacial Lake Wisconsin by outwash sand derived from glaciers to the north. Sandstone ridges, buttes, mounds, and pinnacles occur here.</td>
</tr>
<tr>
<td>Soils</td>
<td>Most soils formed from deep sand deposits of glacial lacustrine or outwash origin or in materials eroded from sandstone hillslopes and sometimes with a surface of wind-deposited (aeolian) sand. These soils are excessively drained, with very rapid permeability, very low available water capacity, and low nutrient status. In lower-lying places where silty lacustrine material impedes drainage, the water table is very close to the surface. Such areas are extensive in the western part of the Ecological Landscape, where soils may be poorly drained with surfaces of muck or mucky peat. Thickness of peat deposits in places ranges from a few inches to more than 15 feet.</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Large areas of wetlands and a number of generally low-gradient streams that range from small coldwater streams to large warmwater rivers. Major rivers include the Wisconsin, Black, East Fork of the Black, Yellow, and Lemonweir. Headwaters streams originating in extensive acid peatlands. Natural lakes are rare, limited to river floodplains, and a few scattered ponds. Hydrologic alterations (ditches and impoundments) are frequent and occur throughout the Landscape.</td>
</tr>
<tr>
<td>Current Landcover</td>
<td>The eastern portion of the Landscape is primarily agricultural crops, grasslands and woodlots. Many of the historic wetlands in the eastern portion were drained early in the 1900s and are now used for agricultural purposes. Most of the western portion of the Landscape is forested or wetland. The forested portion is mostly oak-dominated followed by aspen and pines. Most attempts to practice agriculture west of the Wisconsin River failed due to poor soils, poor drainage, and growing season frosts.</td>
</tr>
<tr>
<td><strong>Socioeconomic Conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>285,897; 5.2% of the state total.</td>
</tr>
<tr>
<td>Population Density</td>
<td>46 persons/ mi²</td>
</tr>
<tr>
<td>Per Capita Income</td>
<td>$29,022</td>
</tr>
<tr>
<td>Important Economic Sectors</td>
<td>The largest employment sectors in 2007 were: health care &amp; social services (13.5%); government (13.4%); tourism-related (10.8%), retail trade (8.9%). Forestry and agriculture have the largest impacts on natural resources in this Landscape.</td>
</tr>
<tr>
<td>Public Ownership</td>
<td>Approximately one-quarter of the Ecological Landscape is publicly owned, very high for a Landscape this far south. Most of these lands are in federal, state, or county ownership, and include Necedah National Wildlife Refuge, Black River State Forest, Sandhill State Wildlife Area, Buckhorn State Park, and Jackson County Forest. A map showing public land ownership (county, state, and federal) and private lands enrolled in the Forest Tax Programs in this Ecological Landscape can be found at the end of this chapter.</td>
</tr>
<tr>
<td>Other Notable Ownership</td>
<td>The Nature Conservancy has partnered with WDNR and others to develop a large conservation project at Quincy Bluff in southern Adams County.</td>
</tr>
<tr>
<td><strong>Considerations for Planning and Management</strong></td>
<td>The extensive acreage of public lands, especially in the western part of Landscape, provides unique opportunities for management at large scales. A small number of large private ownerships rather</td>
</tr>
</tbody>
</table>
than numerous small private ownerships may also facilitate management at large scales, including coordination with management of public lands. Integration of forest and barrens management is possible and desirable because of the type, capability, and condition of the habitats present, the extensive public lands, and relatively low levels of development. Hydrologic restoration is possible by restoring meanders, removing dams, plugging ditches, and improving management of uplands. Groundwater withdrawals and contamination are a concern, due to sandy soils and at some locations, the high water table. Use of prescribed fire as a management tool may be more feasible here than elsewhere in southern WI, and is appropriate for many forest, barrens, grasslands, and wetlands. The spread of invasive plants threatens many natural communities and species habitats and is a significant and growing management challenge. Commercial cranberry farming is currently expanding, including on some upland sites in the eastern part of the Landscape. Opportunities to identify and integrate areas of mutual interests agricultural and wildlife interest should be pursued.

**Management Opportunities**

Extensive forests of oak and pine west of the Yellow River create opportunities for management at all scales and age classes, and to manage successfully for edge- and area-sensitive species. Remnant pine and oak barrens communities support many rare and declining plants and animals and should be protected, and where feasible, expanded and connected. Major rivers and their floodplains (Wisconsin, Black, East Fork of the Black, Yellow, Lemonweir rivers) provide extensive, contiguous habitats for many species of management concern, and as travel corridors. Major river corridors are a means of maintaining or establishing connectivity with Ecological Landscapes to the north, south, and west of the Central Sand Plains. Headwaters streams often originate in extensive peatlands, offering an opportunity to restore, protect, and manage entire stream systems, their aquatic biota, and adjoining habitats. Streams with these attributes are rare in southern WI. Extensive “surrogate grasslands” east of the Wisconsin River support and are managed for sensitive grassland birds, including our best populations of the WI Threatened Greater Prairie Chicken and the WI Endangered regal fritillary. There is an opportunity to use prescribed fire here to manage forest, barren, grassland, and wetland habitats. Unusual exposures of bedrock (sandstone buttes, mounds, pinnacles, cliffs, gorges) are present, and some of these support rare habitat specialists. Rare natural communities are present (e.g., Pine and Oak Barrens, Coastal Plain Marsh; White Pine-Red Maple Swamp), as are large and unfragmented examples of more common communities. Landscape context here offers better opportunities for long-term population and habitat viability than almost any other location in southern WI. The Central Sand Plains is a major concentration area for rare species, contains globally imperiled species, unusual disjuncts, and many species that are at or near their southern or northern range limits.

**Current and Historic Vegetation of the Central Sand Plains**

**Historic Vegetation**

Several sources were used to characterize the historic vegetation of the Central Sand Plains, including data from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866 and Finley’s (1976) map of historic land cover based on his interpretation of PLS data. Additional inferences about vegetative cover were sometimes drawn from information on land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives. According to Finley’s map and data interpretation, in the mid-1800s the Central Sand Plains Ecological Landscape contained a mixture of dry types (forest, savanna and prairie) combined with wetland types (forested and non-forested). Only 6% (135,000 out of 2,189,000 acres) of the Ecological Landscape was covered by mesic upland forest (Figure 1). Jack pine, scrub oak and barrens covered 26% of the area, with oak forest the next largest cover type (20%).
Figure 1. Vegetation of the Central Sand Plains Ecological Landscape during the mid-1800's, as interpreted by Finley (1976) from Public Land Survey information.

Current Vegetation
There are several data sets available to help assess current vegetation on a broad scale in Wisconsin. For the most part, we have used WISCLAND, the Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’s Forest Inventory and Analysis (FIA) and the National Land Cover Dataset (NLCD). Results among these data sets often differ, as they are the products of different methodologies for classifying land cover, and each dataset was compiled based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales.

Figure 2. WISCLAND Land Use/Land Cover data showing categories of land use classified from LANDSAT satellite imagery (1992) for the Central Sand Plains Ecological Landscape.
WISCLAND land use/land cover data from 1992 classifies general land cover attributes, and can be useful in characterizing large-scale land use features and attributes. It is based on satellite imagery from 1992, so it does not represent present day information. We use it here to offer a general view of land use and land cover in a given Landscape. The Central Sand Plains Ecological Landscape is approximately 2,189,000 acres in size, of which approximately 52% is forested (WISCLAND, 1992). This is the highest percentage of forested land cover of all of the Ecological Landscapes south of the tension zone. WISCLAND land use/land cover data from 1992 also indicates that 16% of the Ecological Landscape was in agricultural use, which is the lowest percentage of agricultural use of all of the Ecological Landscapes south of the tension zone (Figure 2).

The Wisconsin Wetlands Inventory (WDNR 2007) offers a more specific assessment of wetlands than is available with WISCLAND data, but is limited to those areas identified from satellite imagery as wetland. According to the Wisconsin Wetlands Inventory (WDNR 2007), wetlands occupy a relatively large portion of the Central Sand Plains, comprising 24.4%, (approximately 436,000 acres) of this Ecological Landscape’s vegetation (there is currently no data available for Eau Claire or Jackson Counties). Forested wetlands make up over 220,000 acres of the Ecological Landscape, making these the most abundant wetlands in the Central Sand Plains. Shrub/scrub wetlands occur across approximately 120,000 acres. Wet meadows (including emergent marsh and sedge meadow) occupy approximately 90,000 acres.

Forest Inventory and Analysis (FIA) data from 2004 is a USDA Forest Service program which compiles point samples of forested lands to assess the timber resources of the country. According to FIA data summarized in 2004, approximately 43% of land area in the Central Sand Plains Ecological Landscape is nonforested, and about 57% is forested. The predominant forest cover type group is oak-hickory (25.3% of the forested area) followed by aspen-birch (12.7%), mixed pine-oak (12.6%), northern hardwoods (10.9%), and jack pine (10.8%). All other forest types occupy less than 10% of the forested area.

Figure 3. Forest Inventory and Analysis data (2004) showing forest type as a percent of forested land area (greater than 17% crown cover) for the Central Sand Plains Ecological Landscape.

Major Significant Features of the Central Sand Plains Ecological Landscape
The Central Sand Plains Ecological Landscape in central Wisconsin, is centered on a flat, sandy lake plain, and supports agriculture, forestry, recreation, and wildlife management. Soils are primarily sands, including lacustrine deposits, outwash, and material eroded from the sandstone bedrock. Organic soils are characteristic of the poorly drained peatlands. The historic vegetation of the area included extensive wetlands. Uplands were vegetated with forests of oak or pine, pine barrens, oak barrens, and small areas of prairie. Very limited areas of more mesic hemlock hardwood forest were present. The northwestern part of the Landscape supported mixed forests of white pine, oak, and other hardwoods. Today, the western portion of the Landscape contains extensive forests of oak and pine, abundant peatlands, and large public ownerships.

Ecological Opportunities of the Central Sand Plains Ecological Landscape include:

- Extensive forests of oak and pine occur west of the Yellow River.
- There are excellent opportunities to protect rare natural communities such as White pine-Red Maple Swamp and Coastal Plain Marsh.
- Characteristic geological features include sandstone buttes, pinnacles, and gorges, which support habitat specialists and distinctive assemblages of plants and animals.
- A large public land base and relatively little development west of the Yellow River offer opportunities to manage at large scales.
- Some of the vegetation types and patterns are unlike those in any other part of southern Wisconsin.
- Restoration of (prescribed) fire as a natural disturbance factor and management tool is possible in some areas, and would have many benefits – including increased public safety.
- Species using extensive pine-oak forest, floodplain forest, large acid peatlands, sedge meadows, surrogate grasslands, sand prairie, and barrens remnants.

Citation:
THE SOUTHEAST GLACIAL PLAINS ECOLOGICAL LANDSCAPE

The Southeast Glacial Plains Ecological Landscape makes up the bulk of the non-coastal land area in southeast Wisconsin. This Ecological Landscape is situated on glacial till plains, outwash landforms, as well as rolling, ground, and interlobate moraines. Most of this Ecological Landscape is composed of glacial materials deposited during the Wisconsin Ice Age, but the southwest portion consists of older, pre-Wisconsin till with a more dissected topography. Soils are lime-rich tills overlain in most areas by a silt-loam loess cap. Agricultural and residential interests throughout the landscape have significantly altered the historical vegetation and the hydrology. Most of the rare natural communities that remain are associated with large moraines or in areas where the Niagara Escarpment occurs close to the surface.

Historically, vegetation in the Southeast Glacial Plains consisted of a mix of prairie, oak forests and savanna, and maple-basswood forests. Wet-mesic prairies, southern sedge meadows, emergent marshes, calcareous fens, and tamarack swamps were found in poorly drained, wetter portions of the Landscape. End moraines and drumlins supported savannas and forests. Agricultural and urban land use practices have drastically changed the land cover of the Southeast Glacial Plains since Euro-American settlement. The current vegetation is primarily agricultural cropland. Remaining forests occupy only about 10% of the land area and important covertypes include oak, maple-basswood, and lowland hardwoods. No large areas of contiguous forest exist today except on the Kettle Interlobate Moraine, which has relatively rugged topography that is often ill-suited for agricultural uses. In the southern Kettle Moraine, much of the historic oak savanna cover has succeeded to dense hardwood forests due to fire suppression. The total land area for the Ecological Landscape is approximately 4.9 million acres, of which only 10% is classified as timberland. Only about 4% of the area of this Ecological Landscape is publicly owned.

The Southeast Glacial Plains has the highest aquatic productivity for plants, insects, invertebrates, and fish, of any Ecological Landscape in the state. Significant river systems include the Mukwonago, Bark, Wolf, Sheboygan, Milwaukee, Rock, Sugar, Illinois Fox and Green Bay Fox. Most riparian zones have been degraded through forest clearing, urban development, and intensive agricultural practices. The Ecological Landscape contains several large lakes, including those in the Madison area and in the Lake Winnebago Pool system. These lakes are important to many aquatic species including the lake sturgeon. Kettle lakes are common on end moraines and in outwash channels. In addition to Horicon Marsh, this Ecological Landscape contains other important marshes, as well as fens, tamarack swamps, wet prairies, and wet-mesic prairies, many of which support rare plants and animals. However, many wetlands have experienced ditching, tiling, grazing, and infestation by invasive plants. Widespread fire suppression has facilitated the spread and increase of woody plants into oak-dominated savannas and forests, and into rare herb-dominated communities such as fens, prairies, and sedge meadows. The large percentage of
impermeable land cover and the increasing problems with groundwater drawdown contribute to this ranking. Impermeable land cover tends to collect and concentrate pollutants that can eventually filter into the soil. Groundwater drawdown caused by high pumping rates is correlated with increasing concentrations of naturally occurring radium and other radionuclides in deep aquifer formations.

Although the Southeast Glacial Plains Counties are densely populated compared to other areas of the state, agriculture is very important. Among the regions it ranks third in percent of acreage in farmland, market value of agricultural products per acre, and milk production per acre; and it ranks second in corn production. (Farmland includes all land under farm ownership such as cropland, pastureland, and woodland.) The percentage of agricultural land sold and diverted to other uses is below average. Recreation is also important in this region. It has the highest number of fishery and wildlife areas, the second highest number of state parks and forests, and one of the highest ratios of water to land surface area. Per capita water use is near average. The Southeast Glacial Plains Region is economically prosperous with a well-educated and racially diverse population. The population density (188 persons/ sq. mile) is about twice that of the state as a whole (96 persons/ sq. mile), the second highest population density among the regions. This region has the third lowest population of elderly (over 65) while the proportion of nonwhites, especially Hispanics and African Americans, is one of the highest. The per capita income, average wage, and number of high school and college graduates are all third highest, while the rates of poverty and unemployment are both third lowest among the regions. The manufacturing sector is relatively strong, whereas farming, though very productive, does not provide a large percentage of jobs.

**Southeast Glacial Plains Ecological Landscape at a Glance**

<table>
<thead>
<tr>
<th>Physical and Biotic Environment:</th>
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</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>4,943,731 acres (7,725 square miles), representing 13.8% of the land area of the State of Wisconsin.</td>
</tr>
<tr>
<td><strong>Climate</strong></td>
<td>The growing season averages 155 days somewhat longer compared to other Ecological Landscapes. Annual precipitation averages 33 inches, an average value as compared with the rest of the state. Annual snowfall averages 41 inches, a snowfall typical of southern Wisconsin.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
<td>Primarily underlain by limestone and dolomite but with some sandstone, and shale. Generally covered by a thick layer of soils of glacial origin (&gt;50 feet). The southernmost exposures of the dolomite ‘Niagara Escarpment’ occur east and south of Lake Winnebago.</td>
</tr>
<tr>
<td><strong>Geology and Landforms</strong></td>
<td>Made up of glacial till plains and moraines. Most is composed of glacial materials deposited during the Wisconsin Ice Age, but the southwest portion consists of older, pre-Wisconsin till with a more dissected topography. Other glacial landforms are also well-represented, e.g., within the Kettle Moraine region.</td>
</tr>
<tr>
<td><strong>Soils</strong></td>
<td>Soils are lime-rich tills overlain in most areas by a silt-loam loess cap.</td>
</tr>
<tr>
<td><strong>Hydrology</strong></td>
<td>Has the highest aquatic productivity for plants, insects, invertebrates, and fish, of any Ecological Landscape in the state. Significant river systems include the Wolf, Bark, Rock, Fox, Milwaukee, Sugar, Mukwonago, and Sheboygan. Most riparian zones have been degraded. Several large lakes exist, including the Madison lakes and the Lake Winnebago Pool system. Kettle lakes occur within end moraines, in outwash channels, and in ancient riverbeds. The Landscape contains some huge marshes, as well as important fens, sedge meadows, low prairies, and tamarack swamps. Most wetlands here have been affected by hydrologic modifications (ditching, diking,</td>
</tr>
</tbody>
</table>
tiling), grazing, infestations of invasive plants, and sediment/nutrient-laden runoff from croplands.

Current Landcover

Primarily agricultural cropland (58% of Landscape). Remaining forests occupy only 11% of the land area and consist of maple-basswood, oak, and lowland hardwoods. No large areas of upland forest exist except on the Kettle Interlobate Moraine, which has topography too rugged for agriculture. Wetlands are extensive (12% of Landscape, 593,248 acres) and include a large area of forested lowlands within the Wolf River floodplain.


Population 1,519,000 (28.5% of Wisconsin’s population). Half of Wisconsin’s residents live within 50 miles of this Landscape.

Population Density
Per Capita Income

Important Economic Sectors

Public Ownership

Four percent is in public ownership (226,230 acres) of which 58% is wetland and 42% is upland. Major public lands include Horicon National Wildlife Refuge and Horicon State Wildlife Area and the North and South Units of the Kettle Moraine State Forest. Many other state lands are present and managed for fish, wildlife, natural areas, and recreation. The University of Wisconsin system has a significant holding here, the Cedarburg Bog Field Station. County-owned lands are not extensive but include ecologically significant features, including several stretches of the Niagara Escarpment.

Other Notable Ownerships

The Wisconsin Chapter of The Nature Conservancy in cooperation with WDNR has a major project designed to protect the Mukwonago River watershed, which includes Lulu Lake. The Waukesha County Land Conservancy has several active projects that protect lands of high ecological significance as does a number of other counties and Madison Audubon Society.

Considerations for Planning and Management

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has conducted biological inventories of the seven counties in which they have jurisdiction; all of which are wholly or partially within the Southeast Glacial Plains Ecological Landscape. Some of this information was recently updated and is available for use by both public and private planners and managers. Many invasive species are now widespread and well established.

Management Opportunities

- The Kettle Moraine region features this Landscape’s largest areas of contiguous forest and relatively undeveloped uplands.
- The southern Kettle Moraine is a major repository of rare and diminished natural communities such as Oak Opening, Oak Woodland, Calcareous Fen, Wet-mesic Prairie, Southern Sedge Meadow, and ‘Bog Relicts’, and is the site of one of Wisconsin’s largest native grassland protection and restoration projects - the Scuppernong Basin.
- The northern Kettle Moraine borders or straddles the eco-climatic Tension Zone and features extensive forests, conifer and ash swamps, lakes, springs, and marshes, and a significant stretch of the Milwaukee River. This area is a major refuge for forest interior species in southeastern Wisconsin.
- The southern extremities of the Niagara Escarpment occur here providing habitat for rare invertebrates and plants, and supporting a large bat hibernaculum.
- The Mukwonago River features a spring-fed river with a significant diversity of fishes and aquatic macroinvertebrates, extensive wetlands of emergent marsh and southern sedge meadow, calcareous fens,
bog relicts, remnant oak openings and prairies, and many rare species.

- Numerous wetlands support large populations of many species of breeding and migratory waterfowl.
- The Lower Wolf River corridor features the most extensive forested floodplain in eastern Wisconsin.

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**Current and Historic Vegetation of the Southeast Glacial Plains**

**Historic Vegetation**

Information on historic vegetation comes primarily from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866 and Finley’s (1976) map of historic land cover based on the interpretation of PLS data. Additional inferences about vegetative cover can be drawn from information on land capability, climate, disturbance regimes, and the activities of native people.

According to Finley’s map and data interpretation, in the mid-1800s the Southeast Glacial Plains Ecological Landscape contained a mixture of upland forest, oak openings, prairie, and wetlands. Oak and northern hardwood (mesic maple-basswood, or rarely, maple-beech) forest covered nearly 50% of the area, however there was little or no coniferous forest, other than tamarack in the lowlands (Figure 1). Wetlands covered approximately 17% of the area.

![Figure 1. Vegetation of the Southeast Glacial Plains Ecological Landscape during the mid-1800s, as interpreted by Finley (1976) from Public Land Survey information.](image)

**Current Vegetation**

There are several data sets available to help assess current vegetation on a large scale in Wisconsin. Each was developed for slightly different purposes and has its own strengths and weaknesses in providing a complete picture of vegetative composition. WISCLAND, Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’ Forest Inventory and Analysis (FIA), and National Land Cover Dataset (NLCD) data were used for this analysis. On occasion, these data offer slightly differing numbers about vegetation and land cover that may be interpreted in
different ways. This is the result of each data set being derived using different methodologies to classify land cover, and each data set was compiled based on sampling or imagery collected in different years.

The Southeast Glacial Plains Ecological Landscape is approximately 4,943,000 acres in size, of which approximately 11% is forested (WISCLAND, 1992). WISCLAND land use/land cover data from 1992 also indicates that 58% of the Ecological Landscape was in agricultural use (Figure 2). While this is only the third highest percentage of agricultural use of all of the Ecological Landscapes, the land area (2,844,000 acres) in agricultural use represents the most area in agriculture of any Ecological Landscape. Nearly 26% of all of the agricultural lands in Wisconsin are in the Southeast Glacial Plains Ecological Landscape.

The Wisconsin Wetlands Inventory (WDNR 2007) offers a more specific assessment of wetlands than is available with WISCLAND data, but is limited to those areas identified from air photo interpretation as wetland. According to the Wisconsin Wetlands Inventory (WDNR 2007), wetlands occupy a relatively large portion of the Southeast Glacial Plains, comprising 14.5%, (approximately 714,000 acres) of this Ecological Landscape’s vegetation. Emergent/wet meadow is the most abundant wetland category (encompassing marshes, sedge meadows, and disturbed areas dominated by reed canary grass or common reed), covering more than 330,000 acres, followed by forested wetlands (both hardwood and coniferous), covering approximately 246,000 acres of the Ecological Landscape. Shrub/scrub wetlands occur across approximately 126,000 acres. Aquatic beds also occupy approximately 11,000 acres.

Forest Inventory and Analysis (FIA) data from 2004 is a USDA Forest Service program which compiles point samples of forested lands to assess the timber resources of the country. According to FIA data summarized in 2004, approximately 88% of land area in the Southeast Glacial Plains Ecological Landscape is nonforested, and about 12% is forested. The predominant forest cover type group is northern hardwood (28.1% of the forested area) followed by lowland hardwood (26.5%), and oak-hickory (25.1%). All other forest types occupy less than 10% of the forested land area (Figure 3).

Figure 2. WISCLAND Land Use/Land Cover data showing categories of land use classified from LANDSAT satellite imagery (1992) for the Southeast Glacial Plains Ecological Landscape.
Major Significant Features of the Southeast Glacial Plain Ecological Landscape

The Southeast Glacial Plains Ecological Landscape makes up the bulk of the non-coastal land area in southeast Wisconsin. Agricultural and residential interests throughout the landscape have significantly altered the historical vegetation and the hydrology. Most of the rare natural communities that remain are associated with large moraines or in areas where the Niagara Escarpment occurs close to the surface. The current vegetation is primarily agricultural cropland. Remaining forests occupy only about 10% of the land area and important covertypes include oak,
maple-basswood, and lowland hardwoods. No large areas of contiguous forest exist today except on the Kettle Interlobate Moraine, which has relatively rugged topography that is often ill-suited for agricultural uses. In the southern Kettle Moraine, much of the historic oak savanna cover has succeeded to dense hardwood forests due to fire suppression.

Ecological Opportunities of the Southeast Glacial Plain Ecological Landscape include:

- The Kettle Moraine, one of southern Wisconsin’s major repositories of biodiversity, including natural communities, aquatic features, and rare species.
- The Kettle Moraine State Forest offers a regionally rare opportunity to manage uplands with wetlands at a large scale.
- The North Kettle features extensive upland hardwood forests, hardwood swamps, conifer swamps, open wetlands, and ephemeral ponds.
- The South Kettle contains some of Wisconsin’s best examples of oak savanna, oak forest, prairie, fen, and marsh.
- This Landscape features some of the Upper Midwest’s best opportunities to restore and manage globally rare natural communities such as Oak Openings, Calcareous Fen, and Wet-mesic Prairie.
- The Mukwonago River system supports exceptional diversity and occurs within a mosaic of highly significant wetlands, oak savanna, and oak forest.
- Birds and other fauna found in oak savanna.
- “Southern” forest interior birds: Kettle Moraine State Forests and Wolf River Bottoms.
- “Northern birds and fauna” found in conifer swamps.
- Oak Openings and upland prairies supply critical habitat for rare plants, including kittentails, yellow gentian, pale purple coneflower, prairie parsley, rough rattlesnake root, and yellow giant hyssop.
- Recent research has shown that forests in southern WI are demonstrating increases in exotic species and habitat generalists at the expense of more sensitive native plants.

Citation:
The Southern Lake Michigan Coastal Ecological Landscape is located in the southeastern corner of Wisconsin along Lake Michigan. Along Lake Michigan, the landforms are characteristic of those produced by past glacial lakes, such as lake dunes and beaches, ridge and swale topography, clay bluffs, and level lakeplain. Further inland, ground moraine is the dominant landform. Soils typically have a silt-loam surface overlying loamy and clayey tills.

The land surface of the northern and eastern parts of the Ecological Landscape is dominated by urban and industrial development, which has included clearing of forests, extensive drainage and filling of wetlands, grading and construction of an extensive grid of railways and roads, and leveling for construction. There is a large extent (16.5%) of impermeable surface in this Landscape, where the land is covered with structures, asphalt, or concrete; the highest of any Ecological Landscape in the state. Not much of the natural landscape remains evident here. In the southern and western parts of the Ecological Landscape, developed areas are interspersed with agricultural land. There is a great emphasis on urban forestry here, due to the large proportion of urban and suburban areas. Only 1.1% of the land area is in public ownership.

Lake Michigan is the dominant aquatic feature in this Ecological Landscape. The lake and its associated shoreline features provide essential support for a wide range of aquatic, upland and avian species. Most of the rivers and streams here have been altered by historic human activities, some of which are still occurring. Channelization, dam construction, excessive inputs of sediments, nutrients, and pollutants, and loss of adjoining wetlands have all contributed to the ecological degradation of flowing waters. There are only 26 named inland lakes here, which total over 5,000 acres, but there are nearly 1,500 unnamed lakes, totaling only about 1,800 acres. The vast majority of lakes in this Landscape are shallow ponds.

Historic vegetation in the northern and eastern parts of this Ecological Landscape was dominated by sugar maple-basswood-beech forest with some oak. The southern and western parts were dominated by oak forest, oak savanna, and prairie. In the southeastern corner of the Landscape, along Lake Michigan, a mosaic of native grasslands - prairie, meadow, marsh, fen, and dune - was associated with and partially maintained by post-glacial dynamics that created unusual landforms and topography. The largest remnant of these historic grasslands is Chiwaukee Prairie.

Currently, most of the natural communities remaining in this Ecological Landscape are small, isolated and somewhat degraded. WISCLAND land use/land cover data from 1992 indicate that 39% of the land area was agricultural, 16% grassland, 24% was urban, 12% forested (10% upland
forest and 2% lowland forest), and 4% open wetland. Due in part to the scale, extent, and types of human development and disturbance now prevalent here, there are many non-native invasive species that are a major problem in this Ecological Landscape. There are, however, places that are still of high ecological significance, that support rare and relatively undisturbed natural communities and rare species, and constitute important reservoirs for many native plants and animals.

Socio-economic information is summarized based on county boundaries that approximate Ecological Landscapes. The counties included in this summary are Kenosha, Milwaukee, and Racine - the Southern Lake Michigan Coastal (SLMC) Counties. These counties are highly urbanized, and stand out from other parts of the state in several socioeconomic indicators, especially population attributes and income. Compared with other county approximations of Ecological Landscapes in the state, this one has the highest population density (1,655 persons/ sq. mile), much higher than that of the state as a whole (96 persons/ sq. mile). The percentage of the state population in these counties has declined since 1970. These counties have the highest percentage of people who are less than 18 years of age, and the second lowest median age. The population of nonwhites, especially African American and Hispanic, is higher here than elsewhere in the state. Economically, the SLMC Counties have an average wage that is the highest in the state and the per capita income is second highest. However, the unemployment rates are high and the rates of poverty, especially for children, are quite high.

Almost a quarter of the people in the state live here and almost 20% of the jobs in the state are here. The economy has changed from a strong manufacturing base to a service-based economy. Although natural resources are used for some economic activities (e.g., agriculture, forestry), they are less important as an economic base here than in other parts of the state. Major socioeconomic activities are the service based sectors, some resource based sectors, education services, ecological restoration, and land use planning. Five of the 11 largest water technology companies in the world (e.g., manufacture of water meters, water heaters, sewage treatment equipment) have significant operations in the Milwaukee area.

Farmland in the SLMC Counties has the highest market value per acre compared with the rest of the state, and the amount of farmland is decreasing rapidly. These counties have the highest percentage of farmland sold and diverted to other uses, primarily to residential construction. Agricultural production on the remaining farms is high, and the counties rank fourth in the total market value of agricultural products. As with agricultural lands, a fairly high percentage of forested land (though only 12% of the SLMC Ecological Landscape is forested) is sold and diverted to other uses each year. The counties have small acreages in inland water bodies, and the number of fishery and wildlife areas is second lowest in the state. Per capita water use figures are very high due to the high water usage by electrical generating plants.

**Southern Lake Michigan Coastal Ecological Landscape at a Glance**

<table>
<thead>
<tr>
<th>Physical Environment:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>843 square miles (539,830 acres). 1.5% of the land area of the state.</td>
</tr>
<tr>
<td>Climate</td>
<td>Continental climate moderated by Lake Michigan, with warmer temperatures in the fall and early winter, and slightly cooler temperatures during spring and early summer. SLMC has the longest growing season of all the Ecological Landscapes in Wisconsin.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
<td>Predominately Silurian dolomite, generally covered by deposits of glacial drift from 50 to well over 100 feet in depth.</td>
</tr>
<tr>
<td><strong>Geology and Landforms</strong></td>
<td>Inland, the primary landform is level to gently rolling ground moraine. Near Lake Michigan, landforms include subdued ridge and swale topography, beach and dune complexes, and wave-cut clay bluffs.</td>
</tr>
<tr>
<td><strong>Soils</strong></td>
<td>In the uplands, soils are primarily moderately well drained brown calcareous silty clay loam till. In the lowlands, soils are primarily very poorly drained non-acid muck or silty and clayey lacustrine.</td>
</tr>
<tr>
<td><strong>Aquatic Features</strong></td>
<td>Lake Michigan is the dominant feature; 26 named lakes (&gt;5,000 total acres); ~1,500 unnamed lakes (~1,800 total acres). Important rivers include the Milwaukee, Menomonee, Kinnickinnic, Root, Des Plaines, the Southeast Fox, and Pike. 4% of Landscape is open wetland.</td>
</tr>
<tr>
<td><strong>Current Landcover</strong></td>
<td>Most urbanized Ecological Landscape in state. Primarily agricultural (39%) and urban (24%) with 16% grassland and 12% upland and lowland forest.</td>
</tr>
</tbody>
</table>

**Socio Economic Conditions** (by county approximation, US Census Bureau, 2000):

| Population | 1,278,572; 23.8% of the state total. |
| Population Density | 1,655 persons/ mi² |
| Per Capita Income | $27,837 |
| Important Economic Sectors | Service based sectors (education services, administration and support services, health care and social services, transportation, and arts, entertainment, and recreation) and some resource based sectors (manufacturing, utilities, agriculture, and secondary wood products). |
| Public Ownership | 1.1% of Landscape. A map showing public land ownership (county, state, and federal) and private lands enrolled in the Forest Tax Programs in this Ecological Landscape can be found at the end of this chapter. |
| Other Notable Ownerships | Chiwaukee Prairie Nature Preserve; Silver Lake Bog SNA; Des Plains River Lowlands; Pike River Low Woods; St. Francis Seminary Woods; Carity Prairie; Fitzsimmons Woods; Monastery Lake Wetlands; Renak-Polak Maple-Beech Woods SNA; Harris Marsh and Oak Woods; Petrifying Springs Woods; Benedict Prairie; Downer Woods. |

**Considerations for Planning and Management**

- Densely populated and developed.
- Severe fragmentation and disturbance of natural areas by widespread, intensive agricultural, industrial, and residential development.
- Plant communities - forests, savannas, prairies, and wetlands - are greatly reduced from their historical abundance.
- Natural community remnants are mostly small and isolated.
- Invasive species are a major problem.
- Degraded wetland and aquatic systems leading to serious water management issues.
- Rare and declining species and communities that occur at few other locations.
- Protection of natural resources in the face of high urban expansion.
- Protection of drinking water quality.
- Local interest in conservation
- Urban forestry may help sequester carbon and improve human habitat.

**Opportunities for Management**

- Lake Michigan, Great Lakes shoreline habitats, and near-shore waters support a unique complex of natural features and are of especially high significance to migratory birds and fish.
- Management and protection of the lake and its surroundings is an economic and recreational priority.
- The coastal prairies and other wetlands in the southeastern corner of the Landscape are irreplaceable,
exceptionally diverse, and offer unique opportunities for management and protection.
- The large surrogate grasslands and embedded natural community remnants at sites such as Bong State Recreation Area.
- Opportunities to re-vegetate areas (e.g. brownfields) as surrogate habitats for wildlife.
- The restoration and management of major river and stream corridors is a major ecological and socio-economic priority. Important rivers and streams include the Milwaukee, Menomonee, Kinnickinnic, Des Plaines, and Root.

Current and Historic Vegetation of the Southern Lake Michigan Coastal Ecological Landscape

Historic Vegetation
Several sources were used to characterize the historic vegetation of the Southern Lake Michigan Coastal, including data from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866 and Finley’s (1976) map of historic land cover based on his interpretation of PLS data. Additional inferences about vegetative cover were sometimes drawn from information on land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives.

Historic vegetation in the northern part of this Ecological Landscape was dominated by sugar maple-basswood-beech forest with some oak, while the southern part was dominated by oak forest, oak savanna and prairie (Figure 1). In the southeast corner of the Ecological Landscape near Lake Michigan, a mosaic of native grasslands was associated with post glacial influences along the shoreline of the Great Lakes. Mesic, Wet-mesic and Wet prairies were included, as were Southern Sedge Meadows and Calcareous Fens. Great Lakes beach and dune complexes were prominent at several locations along Lake Michigan. Black ash (Fraxinus nigra) and relict conifer swamps were found in northern portions of this Ecological Landscape, in ravines along Lake Michigan and at a few inland locations. In total, in the mid-1800s about 65% of the Ecological Landscape was forested, with over 25% in prairie and oak savanna. The remainder was mostly open wetland of marsh and meadow.
Current Vegetation

There are several data sets available to help assess current vegetation on a broad scale in Wisconsin. WISCLAND, the Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’s Forest Inventory and Analysis (FIA) and the National Land Cover Dataset (NLCD) were used for this analysis. Results among these data sets often differ, as they are the products of different methodologies for classifying land cover, and each dataset was compiled based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales.

WISCLAND land use/land cover data from 1992 indicate that most of the land area (65%, or 350,000 out of 540,000 acres) was classified as agricultural, urban or bare land, with a relatively low percentage in grassland, forests or wetlands (Figure 2). Very little of the Ecological Landscape is publicly owned; one estimate indicates that only about 1% is public land designated primarily for conservation purposes.
Forest Inventory and Analysis (FIA) data calculated from sample plot data from 2004 show that the vast majority (94%) of this Ecological Landscape is non-forested (Figure 3). This generally agrees with the satellite imagery based WISCLAND estimate of 88% of the Landscape being non-forested. Within the small percentage of land that is still forested, based on FIA data, 29% of the relative importance value (RIV) of tree species is oaks (*Quercus* spp.), 26% green ash (*Fraxinus pennsylvanica*) and white ash (*Fraxinus americana*), while 9% is American basswood (*Tilia americana*), 5% each willow (*Salix* spp.), cherry (*Prunus* spp.), and elm (*Ulmus* spp.).

Figure 6. Forest Inventory and Analysis data (USDA FS 2004) showing forest type groups and nonforested land (less than 17% crown cover) as a percent of land area for the Southern Lake Michigan Coastal Ecological Landscape.
Major Significant Features of the Southern Lake Michigan Coastal Ecological Landscape

Lake Michigan is the dominant feature in this Ecological Landscape. The lake and its associated shoreline features provide habitat for a wide range of aquatic, upland and avian species. Most of the landscape has been altered by historic human activities, some of which are still occurring. Agriculture is a major landuse (39%), as is urban development (24%); only 12% of the SLMC is forested. The landscape is densely population and heavily developed for residential and industrial use. Forest communities in the Southern Lake Michigan Coastal Ecological Landscape are almost entirely composed of hardwoods. The remnants are restricted to parks, riparian corridors, and farm woodlots. Currently, most of the natural communities remaining in this Ecological Landscape are small, isolated and somewhat degraded. There are, however, places that are still of high ecological significance, that support rare and relatively undisturbed natural communities and rare species, and constitute important reservoirs for many native plants and animals.

Ecological opportunities for the Southern Lake Michigan Coastal Ecological Landscape:

- The poorly drained ridge and swale topography along Lake Michigan in the southeastern corner of Kenosha County is arguably the single most important site to conserve in the entire Landscape. It harbors a floristically diverse complex of Wet-mesic Prairie, Calcareous Fen, Southern Sedge Meadow, and Emergent Marsh; many rare species occur here. There is no similar site in Wisconsin.

- Lake Michigan is the most important natural feature of the Southern Lake Michigan Coastal Ecological Landscape due to its size and depth, its heavy use by birds and fish, and the dependence of millions of citizens upon it for a wide array of ecosystem services, economic uses, and social amenities.

- The state’s only tree with statutory protection, the State Threatened blue ash (*Fraxinus quadrantrangulata*), is represented here by the largest of its 2 extant populations. Both Wisconsin populations of the extremely rare State Endangered heart-leaved plantain (*Plantago cordata*) occur here, as do all 3 known occurrences of the State Endangered ravenfoot sedge (*Carex crus-corvi*).

- Relatively undisturbed hardwood forests support rare plants that occur nowhere else in the state.

Citation:
The Southwest Savanna Ecological Landscape is located in the southwestern part of Wisconsin. It is characterized by rolling topography with broad open ridges and narrow river valleys. Forests are often associated with steeper slopes. The Southwest Savanna has been unglaciated for at least the last 2.4 million years. The climate is favorable for agriculture but the steep slopes limit it to the hilltops and valley bottoms. The soils are underlain by sedimentary bedrock, calcareous dolomites and sandstones. Soils on ridgetops are loess-derived silt loams of varying depths. In some areas these soils form a shallow layer over bedrock and stony red clay subsoil. Valley soils include alluvial sands, loams, and peats. Some hilltops are almost treeless due to the thin soils, the historical disturbance regime of periodic fire, and present land uses, while others have a deep silt loam cap which is now very productive for agricultural crops.

Historic vegetation consisted of tallgrass prairie and oak savanna, with some slopes and draws supporting oak forest. Almost three-quarters of the current landcover is agricultural crops with lesser amounts of grasslands, barrens, and urban areas. Where forests occur, the most common forest types are oak-hickory and maple-basswood. This Ecological Landscape has the largest acreage of pasture of any in Wisconsin. High-quality prairie remnants occur on rocky hilltops and slopes that are not farmed. Some prairie pastures and oak savannas still exist. Over 2,000 acres of unplowed prairie sod exists in York Township, Green County alone. The grassland areas harbor many rare grassland birds, invertebrates, and other grassland species. Relict stands of pine, and rarely, hemlock, occur in association with some bedrock outcroppings undercut by streams.

The Southwest Savanna contains both warmwater and coldwater resources. Warmwater streams support rare aquatic species, including fish, herptiles, and invertebrates. While streams are common features in this Ecological Landscape, few natural lakes occur here. Most “lakes” here are the result of impounding streams.

The total land area for the Southwest Savanna Ecological Landscape is approximately 1.2 million acres. Less than 1% of the Ecological Landscape is in public ownership.

The economy of the SWS Counties (Grant, Lafayette, Iowa, and Green) is highly dependent on agriculture (70% of the landcover is agricultural cropland). These counties have a greater percentage of farmland than any other Ecological Landscape (“farmland” includes all land under
farm ownership, such as cropland, pastureland, and woodland). The Southwest Savanna Counties rank second in milk production per acre and first in corn production per acre. Although much of the land is farmed, some parts of this Ecological Landscape are farmed less intensively than in other parts of the state, as evidenced by large pastures and the many lands enrolled in the Conservation Reserve Program. Contour strip cropping is widespread on slopes throughout this Ecological Landscape.

Compared to other Ecological Landscape County approximations, the number of fisheries and wildlife areas are low. The percentage of “timberland” (see glossary) being sold and diverted to other uses is higher here than in any other Ecological Landscape County approximation.

The population of the Southwest Savanna is primarily Caucasian and has, on average, a lower level of education than for the state as a whole. The population density (39 persons/sq. mile) is much lower than for the state as a whole (99 persons/sq. mile). The percentage of elderly (over 65) is higher than the statewide percentage. There is a relatively low per capita income; however, both poverty and unemployment rates are also low. SWS Counties jobs are concentrated in retail trade, government, and agriculture-related jobs.

**Southwest Savanna Ecological Landscape at a Glance**

<table>
<thead>
<tr>
<th>Physical and Biotic Environment:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
</tr>
<tr>
<td>This Landscape encompasses 1,248,126 acres (1,950 square miles); 3.5% of the land area of Wisconsin.</td>
</tr>
<tr>
<td><strong>Climate</strong></td>
</tr>
<tr>
<td>The climate of the Southwest Savanna is similar to other Landscapes south of the Tension Zone but has the fourth longest growing season, the most precipitation, the lowest snowfall, and second warmest January low temperature among Ecological Landscapes in the state.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
</tr>
<tr>
<td>This Landscape is underlain with calcareous bedrock.</td>
</tr>
<tr>
<td><strong>Geology and Landforms</strong></td>
</tr>
<tr>
<td>Dolomites and sandstones</td>
</tr>
<tr>
<td>Characterized by deeply dissected topography, unglaciated for the last 2.4 million years, with broad open hilltops and river valleys, and steep wooded slopes.</td>
</tr>
<tr>
<td><strong>Soils</strong></td>
</tr>
<tr>
<td>Soils on hilltops are silty loams, sometimes of shallow depth over exposed bedrock and stony red clay subsoil while others have a deep silt loam cap. Some valley soils are alluvial sands, loams, and peats.</td>
</tr>
<tr>
<td><strong>Hydrology</strong></td>
</tr>
<tr>
<td>Dendritic drainage patterns, characteristic of Driftless terrain. Warmwater rivers, some coldwater streams, springs. There are very few natural lakes, but a few occur in the floodplain of the Pecatonica River; there are impoundments and reservoirs where dams have been constructed on rivers and streams.</td>
</tr>
<tr>
<td><strong>Current Landcover</strong></td>
</tr>
<tr>
<td>Seventy percent is agricultural crops (corn, soybeans, hay, and pasture) with lesser amounts of grasslands, forests, and urban areas. The major forest types are oak-hickory and maple-basswood. High-quality prairie remnants occur on rocky hilltops and slopes that are not farmed. Some prairie pastures and oak savannas still exist.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Socioeconomic Conditions (based on data from Iowa, Grant, Lafayette, and Green Counties).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
</tr>
<tr>
<td>123,899; 2.2% of the state total.</td>
</tr>
<tr>
<td><strong>Population Density</strong></td>
</tr>
<tr>
<td>39 persons/ mi²</td>
</tr>
</tbody>
</table>
Per Capita Income $28,795

Important Economic Sectors Retail trade (15.2% vs. rest of state: 9.0%); Government (14.0% vs. 12.1%); Agriculture, Fishing & Hunting (13.8% vs. 3.1%); and Manufacturing (non-wood) (9.1% vs. 11.7%) sectors in 2007 reflecting high retail trade, government and agriculture dependence.

Public Ownership State-owned lands include several Parks, Wildlife Areas, Fisheries Areas, State Natural Areas, and a Recreation Area including Belmont Mound State Park, New Glarus Woods State Park, Yellowstone Lake State Park, part of Blue Mound State Park, Browntown-Cadiz Springs State Recreation Area, Hardscrabble Prairie State Natural Area, Mount Vernon Creek State Fishery Area, and Yellowstone Lake State Wildlife Area. About 96.5% of all land is privately owned while 3.5% belongs to the state, counties or municipalities. A map showing public land ownership (county, state, and federal) and private lands enrolled in the Forest Tax Programs in this Ecological Landscape can be found at the end of this chapter.

Other Notable Ownerships Several projects of the Wisconsin Chapter of The Nature Conservancy occur here, including Thomson Memorial Prairie and Barneveld. The Prairie Enthusiasts (Southwest Wisconsin, Empire-Sauk, and Prairie Bluff chapters) have also been very active and have at least 10 active projects in the Southwest Savanna Ecological Landscape. Pheasants for Forever and the National Wild Turkey Federation are also very active in this Ecological Landscape.

Considerations for Planning and Management
Need for partnerships between government agencies, NGOs, and private individuals are critical as less than 1% of the Ecological Landscape is publicly owned.

Management Opportunities
Large grassland landscapes, prairie remnants, and surrogate grasslands; oak savanna restoration; restoration of the continuum of fire-adapted communities, including prairie-oak savanna-oak woodland-oak forest; grassland birds and other rare taxa associated with grassland habitats, including plants, invertebrates, and herptiles; warmwater and coldwater rivers and streams; miscellaneous opportunities including hardwood forests, conifer relicts, springs and spring runs, scattered populations of rare species.

Current and Historic Vegetation of the Southwest Savanna

Historic Vegetation
Several sources were used to characterize the historic vegetation of the Southwest Savanna, including data from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866, and Finley’s (1976) map of historic land cover based on his interpretation of PLS data. Additional inferences about vegetative cover were sometimes drawn from information on land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives.

Figure 1. Vegetation of the Southwest Savanna Ecological Landscape during the mid-1800's, as interpreted by Finley (1976) from General Land Office survey information.
According to Finley’s map and data interpretation, in the mid-1800s the Southwest Savanna Ecological Landscape was almost entirely vegetated by a continuum of fire-adapted natural communities that included prairie, oak savanna, and oak forest. An unknown but probably significant proportion of the lands considered to have supported “oak forest” would have been classified today as “oak woodland”, a community with relatively high canopy cover (50-95%) that was affected by frequent fires of low intensity. In aggregate, these communities covered nearly 95% of the Ecological Landscape (Figure 1). This is by far the largest percentage of land occupied collectively by these communities in any Ecological Landscape (also see “Finley’s Presettlement Vegetation” in the Statewide Maps section of this Handbook). The amount of land occupied by shrubs, and especially by oak “grubs” (sprouts from trees top-killed by periodic wildfire), is impossible to determine by examining the PLS notes. It’s likely, though, that shrubs and grubs were widespread, and at least locally important.

**Current Vegetation**

There are several data sets available to help assess current vegetation on a broad scale in Wisconsin. Each was developed for different purposes and has its own strengths and limitations in describing vegetation. WISCLAND, the Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’s Forest Inventory and Analysis (FIA) and the National Land Cover Dataset (NLCD) were used for this analysis. Results among these data sets often differ, as they are the products of different methodologies for classifying land cover, and each dataset was compiled based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales.

Figure 2. WISCLAND Land Use/Land Cover data showing categories of land use classified from LANDSAT satellite imagery (1992) for the Southwest Savanna Ecological Landscape.
The Southwest Savanna Ecological Landscape is approximately 1,248,000 acres in size, of which approximately 17% was forested and 83% was non-forested in 1992 (WISCLAND, 1992). WISCLAND land use/land cover data from 1992 also indicates that 69.8% of the Ecological Landscape was classified as in agricultural use, which is the highest percentage of land in agricultural use of all of Wisconsin’s Ecological Landscapes (Figure 2). According to the Wisconsin Wetlands Inventory (WDNR 2007), wetlands occupy a very low portion of the Southwest Savanna Ecological Landscape, comprising less than 1% (approximately 9,000 acres) of this Ecological Landscape’s vegetation. This is by far the smallest amount of wetlands, both by acreage and by percent of land area, of any Ecological Landscape. Emergent/wet meadow wetlands make up the majority of wetland vegetation here (6,600 acres).

2004 Forest Inventory and Analysis (FIA) data is from a USDA Forest Service program which compiles point samples of forested lands to assess the timber resources of the country. According to FIA data summarized in 2004, the predominant forest cover type group is oak-hickory (55.1% of the forested area), followed by central hardwoods (31.8%). All other forest types occupy less than 10% of the forested area. Keep in mind that overall forest cover is low here, and that extensive areas dominated by forests are virtually absent.

Major Significant Features of the Southwest Savanna Ecological Landscape

Historically, most of the vegetation of the Southwest Savanna Ecological Landscape was fire-driven, resulting in a vast areas of tallgrass prairie and oak savanna, often arranged as a mosaic on the landscape. Smaller areas of oak woodland and forest were also present. Existing prairie remnants are all small and often somewhat degraded, but some are embedded within larger areas of ‘prairie pasture’, or occur in association with “surrogate savannas” (an incomplete canopy of scattered open-grown oaks over an understory that has been altered by prolonged grazing) that had never been cleared and plowed. Forests occurred most often on slopes and in draws that were afforded some protection from frequent, hot fires. Most of the remnant hardwood forests are dry to dry-mesic, and dominated by oaks, but in a few locations there are stands of mesic maple-basswood forest. These mesic hardwood forests tend to occur as isolated islands, and none of them are extensive. The hardwood forests provide habitat for several herbs that reach their northernmost range limits in this Ecological Landscape.
Ecological Opportunities of the Southeast Glacial Plain Ecological Landscape include:

- The Southwest Savanna offers one of the best opportunities in the state to manage grasslands and their associated biota at large scales.
- Oak savannas that have been pastured but never plowed have high restoration potential.
- This is one of the few locations in Wisconsin where there are opportunities to manage for the entire continuum of fire-driven terrestrial plant communities (prairie, oak opening, oak woodland, and oak forest).
- Many rare and declining grassland species have been documented here.
- Forests are not extensive here. Oak forests are best represented, but mesic hardwoods and conifer relicts are also present.
- Oak savanna and oak opening wildlife such as Red-headed Woodpecker, Eastern Bluebird, Orchard Oriole, Whip-poore-will, eastern pipistrelle bat, bull snake, and western fox snake.
- This Ecological Landscape is especially important for rare plants associated with prairie and savanna habitats.
- Hardwood forests in the Southwest Savanna support several plants that reach their northern range limits here, and which are rare in or absent from other Landscapes.
- Native conifers such as white pine and hemlock, along with several “northern” understory associates, reach their southern range limits here; eastern hemlock does not occur naturally farther south or west.

Citation:
THE WESTERN PRAIRIE ECOLOGICAL LANDSCAPE

General Description and Overview

This Western Prairie Ecological Landscape is located on the far western edge of the state just south of the Tension Zone; it contains extensive grasslands, which include Wisconsin’s only prairie pothole region. It is characterized by rolling, glaciated topography and much of the land is open, with rich prairie soils, pothole lakes and ponds, and scattered wet depressions. Forests occur mostly in the larger river valleys, and in areas historically protected from fire by stream corridors, lakes, and wetlands. The climate and growing season are favorable for agricultural crops. Sandstones and dolomites underlie the Landscape. Bedrock exposures occur as cliffs and talus slopes along some of the larger rivers. Soils are predominantly loamy till glacial deposits, while some are in outwash. A loess cap of aeolian silt is 6 to 48 inches thick over the surface. The dominant soil is well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity. Alluvial sands and gravels are found in stream valleys.

Historic vegetation included extensive tallgrass prairie on the rolling uplands areas, with wet prairie and marsh in the depressions. Oak Openings were common in some areas, and hardwood forests occurred in areas protected from fire by waterbodies and wetlands. Extensive forests were limited to some of the larger river valleys. Prairie pothole type wetlands were mainly found in St. Croix and Polk counties. Almost half of the current vegetation is agricultural crops and almost a third of the area is grasslands, with smaller areas of open water, open wetlands, and urban areas. The major forest types are maple-basswood and oak-hickory, with lesser amounts of lowland hardwoods. Coniferous forests are rare, generally limited to a few tamarack swamps and small scattered stands of pine on steep rocky slopes.

The St. Croix is the largest and most important river flowing through this Landscape. The Lower St. Croix is part of the St. Croix-Namekagon National Scenic Riverway, which is administered by the National Park Service. The Willow, Kinnickinnic, and Apple rivers are the major secondary streams. Water quality is relatively poor here compared with the rest of the state.

The total land area for the Western Prairie Ecological Landscape is approximately 698,000 acres, of which half is agriculture and a third grassland. Less than 3% of the land is in public ownership.

Agriculture is a fairly important part of the economy of the Western Prairie Counties. The Western Prairie Counties have the second highest percentage of farmland compared with the other Ecological Landscape approximations (Farmland includes all land under farm ownership such as cropland, pastureland, and woodland). Compared to the other landscape approximations, these counties are third highest in corn production per acre and fourth in milk production per acre.
It has the highest percentage of both agricultural and forest land acreage sold, and the second highest percentage diverted to nonagricultural and non-forest uses.

Overall acreage in lakes is low in this Ecological Landscape. Per capita water usage in the Western Prairie Counties is the lowest of all landscape approximations in the state. Although the population density is not high, it does have the fastest growth rate since 1970 and the lowest median age. The population density (77 persons/sq. mile) is slightly lower than that of the state as a whole (99 persons/sq. mile). The population is fairly young, not racially diverse, and very well educated, on average. Economically, people in the Western Prairie Counties are quite prosperous with a high per capita income and the lowest rates of child and adult poverty and unemployment. Agriculture is important with a higher percentage of jobs in agriculture than any other landscape approximation.

**Western Prairie Ecological Landscape at a Glance**

<table>
<thead>
<tr>
<th>Physical and Biotic Environment:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
</tr>
<tr>
<td>The Western Prairie Ecological Landscape encompasses 697,633 acres, (1,090 square miles), representing 1.9% of the land area of the State of Wisconsin. It is the third smallest Ecological Landscape in the state; however, this Ecological Landscape is part of a larger ecological region extended west into Minnesota.</td>
</tr>
<tr>
<td><strong>Climate</strong></td>
</tr>
<tr>
<td>Typical of southern Wisconsin; mean growing season of 145 days, mean annual temperature is 43.7 °F, mean annual precipitation is 32.1, and mean annual snowfall is 45.4 inches. The climate and topography was favorable to frequent fires that resulted in prairie vegetation occurring in almost a third of the area prior to Euro-American times. The length of the growing season, adequate precipitation, and favorable temperatures make the climate favorable for agriculture, which is prevalent here.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
</tr>
<tr>
<td>Bedrock was deposited during the Paleozoic Era (including the Cambrian and Ordovician Periods), and is dominantly marine sandstone and dolomite. Precambrian igneous and metamorphic bedrock lies below the Paleozoic deposits. The walls of the Apple River Canyon feature exposures of Cambrian sandstone, Cambrian shale, and Cambrian and Ordovician dolomites. Similar exposures occur along the lower Kinnickinnic River, near its confluence with the St. Croix.</td>
</tr>
<tr>
<td><strong>Geology and Landforms</strong></td>
</tr>
<tr>
<td>The Landscape is entirely glaciated. Major landforms are rolling till plain, with end moraine in the northwest and small areas of outwash.</td>
</tr>
<tr>
<td><strong>Soils</strong></td>
</tr>
<tr>
<td>Soils are predominantly formed in loamy till glacial deposits, while some are in outwash. A loess cap of aeolian silt is 6 to 48 inches thick over the surface. The dominant soil is well drained and loamy with a silt loam surface, moderate permeability, and moderate available water capacity.</td>
</tr>
<tr>
<td><strong>Hydrology</strong></td>
</tr>
<tr>
<td>The Lower St. Croix River forms the western boundary of this Ecological Landscape. Other important though much smaller rivers include the Apple, Kinnickinnic, and Willow. Most of the rivers drain westward to the St. Croix, with others draining south into the Mississippi, and a few flow southeast to the Chippewa. Inland lakes, mostly seepage lakes and ponds, are most common in the northwestern part of the Landscape, in an area known informally as the “Prairie Pothole Region”. There are multiple dams on the Willow River, and the Kinnickinnic has been dammed at River Falls. Many wetlands have been lost or severely altered by agricultural activities, which have been widespread and intensive in this productive Landscape.</td>
</tr>
<tr>
<td><strong>Current Landcover</strong></td>
</tr>
<tr>
<td>Almost half of the current land cover is agricultural crops and almost a third of the area is grasslands, with smaller areas of open water, open wetlands, and urban areas.</td>
</tr>
</tbody>
</table>
The major forest types are maple-basswood and oak-hickory, with lesser amounts of lowland hardwoods. Native coniferous forests are rare, generally limited to a few tamarack swamps and small scattered stands of pine on steep rocky slopes.

**Socioeconomic Conditions** *(The counties included in this socioeconomic region are: St. Croix and Pierce.)*

<table>
<thead>
<tr>
<th>Population</th>
<th>120,708; 2.2% of the state total.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Density</td>
<td>77 persons/ mi²</td>
</tr>
<tr>
<td>Per Capita Income</td>
<td>$26,853</td>
</tr>
<tr>
<td>Important Economic Sectors</td>
<td>Government (14.6%); tourism-related (12.6%); manufacturing (non-wood) (11.6%); and retail trade (10.2%) sectors provided the most jobs in 2007. Agriculture and urban development affect the natural resources of this Ecological Landscape most.</td>
</tr>
<tr>
<td>Public Ownership</td>
<td>Only three percent is in public ownership, much of it associated with the St. Croix, Kinnickinnic, and Willow Rivers. Federal lands include the southern end of the St. Croix National Scenic Riverway and several Federal Waterfowl Production Areas. State-owned lands include Wildlife Areas, Parks, and Natural Areas. A map showing public land ownership (county, state, and federal) and private lands enrolled in the Forest Tax Programs in this Ecological Landscape can be found at the end of this chapter.</td>
</tr>
</tbody>
</table>

**Other Notable Ownerships**

The Kinnickinnic River Land Trust has been actively protecting lands in northwestern Pierce County. Several other NGOs have been protecting lands along the St. Croix River, in Polk and St. Croix counties.

**Considerations for Planning and Management**

Public lands are limited, making management at large scales difficult. Agriculture is the dominant land use, but in recent years residential development has increased dramatically in the western part of the Landscape along and near the St. Croix River.

**Management Opportunities**

Grassland management is a major opportunity here, encompassing a group of prairie remnants and extensive areas of “surrogate grassland”. The largest grassland management project in this Ecological Landscape is the Western Prairie Habitat Restoration Area in St. Croix and Polk counties. The Lower St. Croix River supports an exceptionally high diversity of aquatic organisms, and the river’s floodplain contains good examples of emergent marsh, wet prairie, and floodplain forest. The forested slopes of the St. Croix Valley contain rich mesic hardwood forests, dry oak forests, and a few stands of natural white pine. The upper slopes above the St. Croix River also support remnant prairies and oak openings. Other important management opportunities include the Kinnickinnic River Corridor; scattered prairie, savanna, and forest remnants (including mesic, dry-mesic and dry forests); coldwater and coolwater streams; and miscellaneous opportunities to protect scattered populations of rare species and features not covered by the categories previously mentioned. Most of the public lands occur along the St. Croix, Kinnickinnic, and Willow rivers. Others are associated with the Landscape’s interior grasslands.

**Current and Historic Vegetation of the Western Prairie**

**Historic Vegetation**

Several sources were used to characterize the historic vegetation of the Western Prairie, including data from the General Land Office’s Public Land Survey (PLS), conducted in Wisconsin between 1832 and 1866 and Finley’s (1976) map of historic land cover based on his interpretation of PLS data. Additional inferences about vegetative cover were sometimes drawn from information on
land capability, climate, disturbance regimes, the activities of native peoples, and from various descriptive narratives.

According to Finley’s map and data interpretation, in the mid-1800s the Western Prairie Ecological Landscape was a mixture of different forested and open communities (Figure 1). The Western Prairie Ecological Landscape had the largest percentage of prairie and brush combined (34.3%), as classified by Finley, of all the Ecological Landscapes. PLS information has been converted to a database format, and relative importance values (RIV) for tree species were calculated based on the average of tree species density and basal area. This analysis indicates that there was a high degree of heterogeneity in tree species in this Ecological Landscape. Sugar maple had the highest RIV (18.3%), followed by aspen (14.8%), white oak (12.9%) and burr oak (11.6%). The RIV for aspen (14.8%) was the highest RIV for aspen of all of the Ecological Landscapes.

**Current Vegetation**

Several data sets were used for this analysis including WISCLAND, the Wisconsin Wetlands Inventory (WWI), the USDA Forest Service’s Forest Inventory and Analysis (FIA) and the National Land Cover Dataset (NLCD). Results among these data sets often differ, as they are the products of different methodologies for classifying land cover, and each dataset was compiled based on sampling or imagery collected in different years, sometimes at different seasons, and at different scales.
WISCLAND land use/land cover data from 1992 classifies general land cover attributes, and can be useful in characterizing large-scale land use features and attributes. It is based on satellite imagery from 1992, so it does not represent present day information. We use it here to offer a general view of the broad patterns of land use and land cover in a given Landscape.

The Western Prairie Ecological Landscape is approximately 697,000 acres in size, of which approximately 19% was forested, and 81% was non-forested (WISCLAND, 1992). WISCLAND land use/land cover data from 1992 also indicates that 29% of the Ecological Landscape was classified as grassland, which is the highest percentage of grasslands of all of the Ecological Landscapes (Figure 2). According to the Wisconsin Wetlands Inventory, wetlands occupy a very low portion of the Western Prairie Ecological Landscape, comprising only 3.7%, (approximately 26,000 acres) of this Ecological Landscape’s land cover. Forested wetlands make up approximately 12,000 acres of the Ecological Landscape, making these the most abundant wetlands in the Western Prairie.

Forest Inventory and Analysis (FIA) data from 2004 is a USDA Forest Service program which compiles point samples of forested lands to assess the timber resources of the country. According to FIA data summarized in 2004, approximately 80% of the land area in the Western Prairie Ecological Landscape is nonforested, and about 20% is forested. The predominant forest cover type group is Northern hardwood (29.6% of the forested area), followed by Oak (21.9%). All other forest types occupy less than 20% of the forested area (Figure 3).

Figure 3. Forest Inventory and Analysis data (2004) showing forest type as a percent of forested land area (greater than 17% crown cover) for the Western Prairie Ecological Landscape.
Major Significant Features of the Western Prairie Ecological Landscape

Most of the native forests in this Landscape are deciduous. Oaks dominate the drier sites; maples, ashes, and basswood the more mesic sites; and bottomland hardwoods the lowland sites. Large blocks of forest are scarce or absent, but the extensive corridor of forest along the St. Croix River is important to many migratory and resident animals, most notably, birds. Natural Coniferous forests are scarce, but white (rarely red) pine occurs on dry, often, rocky sites on the upper slopes of some of the river valleys, including the Kinnickinnic and St. Croix. Eastern red cedar has increased and formed dense thickets on some hill prairies from which fire has been excluded.

Oak Openings were formerly common here. The few remnants persisting today occur mostly on the drier, steeper sites, which were not converted to intensive agricultural uses. Savanna restoration opportunities may also occur on the upper slopes of south- or west-facing bluffs along rivers, often in association with dry prairie remnants and oak forests. ‘Cedar Glades’, which Curtis (1959) considered a type of savanna in which eastern red cedar was the dominant “tree”, occur in association with dolomite bluffs along the St. Croix and elsewhere, but these are at least in part an artifact of fire suppression. The semi-open glades may succeed to dense thickets in some areas.

Ecological Opportunities of the Western Prairie Ecological Landscape include:

- The St. Croix River and its associated corridor of wetlands and forested bluffs, represent an exceptionally important complex of natural features.
- The Kinnickinnic River Valley from River Falls to the St. Croix River stands out for its diverse array of natural communities, bedrock and aquatic features, and numerous rare species populations.
- Scattered prairie, savanna, and forest remnants of high ecological value need to be identified and protected where possible.
- Miscellaneous Opportunities include scattered rare species populations, natural communities, and habitats not covered by the other opportunities.
Rare plants associated with savanna remnants of the Western Prairie include the Midwestern endemic, kitten tails.

Mesic hardwood forests, remnant wetlands associated with prairie potholes, and bedrock habitats.

**Citation:**
The Climate Change Tree Atlas is one model that was used to understand the potential impacts of climate change on Wisconsin’s forests. The Tree Atlas is a species distribution model, which means that it examines the features that contribute to a tree species’ current habitat and then projects where similar habitat conditions are likely to occur in the future. The Tree Atlas does not predict where species will be present in the future, but rather where suitable habitat for individual tree species may be present. A description of the Tree Atlas including background and methods used can be found at http://www.nrs.fs.fed.us/atlas/tree/tree_atlas.html# and also in Iverson et al. (2008).

The USFS Climate Change Tree Atlas assesses the current status and potential future status following climate change, of 134 tree species in the eastern United States, using US Forest Service inventory data with 38 environmental variables to generate models of current suitable habitat for each species. The climate is changed according to three climate models (HADCM3, PCM & GFDL) and two emissions scenarios (A1FI (Hi) = little conservation efforts to mitigate CO2 emissions, B1 (Lo) = significant conservation effort). These two emissions scenarios bracket most of the emission futures as outlined by the Intergovernmental Panel on Climate Change’s evaluation of emission scenarios (Nakicenovic et al., 2000), and end the 21st century at roughly double (550 ppm-B1) and triple (970 ppm-A1fi) the pre-industrial levels of CO2.

The results of this analysis show that climate change will likely lead to changes in the suitable habitat of many common tree species. Of course, the ways in which tree species will actually respond to climate change is influenced by a number of factors, including site conditions, competition from other species, landscape connectivity, the degree of disturbance, and the ability of species to disperse. Many of these factors can not be modeled directly by the Tree Atlas, and additional information from both the research literature and examination of the individual models was used to assess the ways in which individual species may respond uniquely to climate change. When possible, the contributions of these “modifying factors” have been included.
Evidence for tree species migration – Sally Dahir

There is some evidence in the FIA (Forest Inventory and Analysis) data that certain species have migrated north between 1983 and 2007. For this analysis, I used only saplings (1-4.9” dbh) of commercial species on natural stands (excluding plantations). FIA data is based on data sampled on plots which is then expanded to represent the entire population and there is therefore some error inherent in the method.

Some facts

Although 60% of all forestland and 68% of all trees are located in northwest and northeast Wisconsin, the highest rate of increase between 1983 and 2007 in forestland and the number of trees has occurred in the southeast and southwest units. It comes as no surprise then to see the latitude of the average tree has decreased from 45.26 to 45.22 in this time period as more trees invade abandoned agricultural land in southern Wisconsin. This decrease is greatest for pole-sized timber (5-8.9 inches dbh for softwoods, 5-10.9 inches for hardwoods). The number of large trees has increased slightly in the north as forests have aged.

Methods

Two methods were used to test the change in average latitude by species from 1983 to 2007. The first is a population estimate based on expanding each sampled tree by a specific expansion factor. The average latitude per sapling was multiplied by the number of trees the sapling represented in the database. This value was summed and divided by the total number of saplings both by region and statewide. The advantage of this method was that it accounts for the different sampling schemes of the two inventories. For instance, in 1983, not only were fewer plots and trees sampled, but a ten-subplot design was used whereas in 2007, a four-subplot design was used. The disadvantage was there was no means of testing statistical significance.

The second method used each tree as the sampling unit (without referring to the entire population). A means comparison using the two-sample t-test was used to compare mean latitude for each sapling by species. This has the advantage of permitting significance testing but does not deal with the differing sampling techniques between the two inventories.

Only sapling numbers were compared because of a lower degree of discrepancy in numbers sampled and the ratio of sampled trees to total population. For instance there were 24,000 saplings tallied in 1983 and 34,000 in 2007, for a sampling to population ratio of 1 to 225,000 for 1983 and 1 to 235,400 for 2007. This is quite comparable. The ratio for poles on the other hand, was much different: 1 to 40,000 in 1983 and 1 to 17,200 for 2007. Because of this, I limited the t-test analysis to saplings. Since the difference in latitude between 1983 and 2007 is consistently more conservative for the second method, the t-test results will be conservative as well.

Table 1 shows the results that were significant. Only species with at least 30 saplings in each inventory are displayed. The average latitude presented in the table is based on method 1 or population estimates and the t-test results are based on method 2. Several species showed a northerly shift in latitude that was not significant using this method.

<table>
<thead>
<tr>
<th>Species</th>
<th>1983</th>
<th>2007</th>
<th>Difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Pin Oak</td>
<td>44.785</td>
<td>45.352</td>
<td>0.57</td>
<td>0.000</td>
</tr>
<tr>
<td>White Ash</td>
<td>44.577</td>
<td>44.929</td>
<td>0.35</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Wisconsin ranges in latitude from 42.5 to 47 degrees north. The average latitude of saplings was 45.277 in 1983 and 45.147 in 2007, a decrease of about 0.13. Species that experienced a significant decrease in latitude include red and sugar maple, American and rock elm, white and red pine, black ash and basswood.