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Climate Change Trends and Impacts at Martin Van Buren National Historic Site

Focused Condition Assessment Report

Natural Resource Report NPS/MAVA/NRR—2021/2344

ON THE COVER
An aerial view of the park landscape, 2011.
NPS / MICHAEL FREDERICK

Climate Change Trends and Impacts at Martin Van Buren National Historic Site

Focused Condition Assessment Report

Natural Resource Report NPS/MAVA/NRR—2021/2344

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Executive Summary

This assessment synthesizes information about current and projected climate and related impacts at Martin Van Buren National Historic Park (MAVA) in order to help park stewards understand, plan, and manage for climate change. MAVA is dedicated to interpreting the life and career of the eighth President of the United States and the issues facing the nation in the turbulent decades leading up to the Civil War. Located in Columbia County, in the Hudson River Valley Region of New York State (NYS), the park also seeks to showcase and interpret historical and modern progressive farming, as practiced by Van Buren in the mid-nineteenth century, and by modern farmers working this land today.

Working with a group of park managers, scientists, and local stake-holders, six key park resources were identified for assessment herein: Climate, Water quantity, Phenology, Agriculture, Trees, and Cultural resources. Where data was available, this analysis assessed current condition and considered mid-century (2030–2060) and end-of-century (2100) impacts based on a range of projected future climate conditions, including reduced, low, high and highest emission pathways.

Climate change stressors identified for MAVA include: Increased temperature, increased hot days, increased precipitation, increased extreme precipitation events, increased flooding and erosion, shifting ranges of both native species and pest, pathogen and weed species, and phenological shifts and mismatches. Key findings are summarized below.

Climate

The park's climate has become warmer and wetter over the last century, and these trends are projected to continue over the coming century. Average temperature at the park has increased by 0.7 (± 0.4) °F, and total yearly precipitation has increased by 13 (±4) %. Continued increases in mean annual temperature of 3.4–9.7 °F and in total annual precipitation of 7–15 % are projected at the park by 2100. The largest increases in both temperature and precipitation are predicted for the winter months, with spring thaw occurring earlier in the year (Gonzalez et al. 2018).

The growing season in Columbia County, NY has lengthened by about 20 days since 1950, to about 160 days, and is projected to continue lengthening throughout the coming century. Future projections for low and highest emission pathways show further increases resulting in a growing season length up to 170 to 200 days by 2100 (CSF 2020).

Projections for low and highest emission pathways show large increases in the number of hot (> 90 °F) days in Columbia County by 2100, which may increase both heat stress and temporary drought stress (CSF 2020, Horton et al. 2014). At the same time, precipitation events have become more variable and intense in the northeast United States (US) in recent decades (Hayhoe et al. 2018). In Columbia County, the average number of days of extreme (> 1 inch) precipitation has doubled since 1950 (CSF 2020). Increases in the intensity or frequency of extreme precipitation events can increase flooding and soil erosion, impacting agriculture and the management of both natural and cultural resources.

The level of confidence in current climate trends is high, while projections for future conditions and impacts contain considerable uncertainty. By considering the range of projections for future change, park managers can use the best available science as they plan for managing and adapting to the unprecedented challenges posed by climate change. Detailed climate averages, trends and projections for the park are included in Appendix A.

Water quantity

Climate is a primary driver of hydrology, and variation in the timing and magnitude of precipitation and snowmelt are important drivers of change in water quantity. Regionally, streamflow in the northeast US has increased over recent decades, with peak flow occurring earlier in the season, and flooding events along rivers and streams have increased (Tamuddun et al. 2016, Dudley et al. 2017). At MAVA, recent stream discharge data for Kinderhook Creek showed elevated low-flow and mid-flow discharge compared to the historical record; these low and medium flow conditions are regulated by upstream power plants.

Projected increases in temperature and precipitation at MAVA by 2030 are expected to drive moderate increases in runoff from January to March, decreased runoff from April to June, and possibly small decreases in runoff for the rest of the year, including in late summer when runoff is lowest (Battaglin et al. 2020). Future flood-risk modeling predicts a 40% increased risk of flood damage at the park for 2035–2050 under a low emission pathway (First Street Foundation 2020a). Model visualizations show the projected 5-year flood encroaching on the edges of fields on the park’s lower terrace, while the projected 100-year flood shows substantial encroachment into fields on the lower terrace as well as flooding in the park’s Southern Swamp and the ravine connecting Upper Pond to other park ponds and the lower terrace (First Street Foundation 2020a).

Phenology

Climate is a primary driver of recurrent natural events which are tied to seasonal cycles. such as flower blooming and insect emergence. Climate change is altering the timing of these events, which are fundamental to both natural and agricultural systems (IPCC 2014). In temperate fruit trees, bud break and bloom dates are dependent upon overwinter temperatures to meet chilling requirements, and are driven by spring temperatures with some influence from solar radiation, moisture availability and other factors. This is relevant at MAVA, where the park plans to restore a historic orchard.

Analysis of a 40-year record of McIntosh apple bloom phenology at the Cornell University Hudson Valley Laboratory farm in Ulster County, NY did not show a significant temporal trend. However, a modeling effort projected apple bloom dates in central NYS to shift 15 days earlier by 2100 (Wolfe et al. 2018). Such a shift could leave trees more susceptible to damage from early spring cold temperature events, and to potential mismatch between emergence times of flowers and key pollinators. Early season weather-damage to apple crops has been the leading cause of crop insurance payments in Columbia County NY over the past two decades (Reyes and Elias 2019).

Agriculture

Climate change is causing many direct and indirect impacts to agriculture, creating both unprecedented challenges and new opportunities in New York State. Increases in heavy precipitation events can delay planting, cause physical and flood-related damage to crops, and increase soil erosion. Hotter summers increase summer heat stress and can cause temporary drought stress, while warmer night-time temperatures can increase carbon loss from respiration, limiting crop growth and decreasing yields. Increased temperature and moisture create conditions for increased agricultural pathogen and fungal infection. Warmer winters can complicate chill-requirements for fruit tree growers, and increase overwinter survival of plant pests and pathogens. Climate change is also altering ranges and intensities of agricultural pest and weed species, which will affect agricultural practices and production in ways that are difficult to predict (Wolfe et al. 2018).

However, a longer growing season may offer opportunities to increase yields if other factors are not limiting (Rosenzweig et al. 2011). Crops that could benefit from continued warming in this region include peaches, plums, cherries, watermelon and tomato (Wolfe et al. 2018). Yields can be increased by selection of crop varieties that are resistant to frost or drought stress, or that can optimize yield over the longer growing season. Many of the strategies already in use at Roxbury Farm, such as diversifying crops, careful improvement of soil health, and managing water availability, will help the farm adapt to climate change.

To better understand climate change impacts to agriculture at the park, this analysis considered occurrence of insect pest species, pollinators, and weed ranges. The state has been identified as a potential hotspot for invasive species under climate change scenarios (Bellard et al. 2013, Allen and Bradley 2016).

Climate change will increase some pest populations while decreasing others, in ways that are hard to predict due to complex interactions between insects, hosts and predators. These changes will be complicated further by the simultaneous effects of other stressors, including changes in land use and agricultural practices. As climate change progresses in NYS, migratory insects are likely to arrive earlier in the season and may expand their ranges northward, and many insect species may increase the number of generations per year (Skendzic et al. 2021). Analysis of a long-term dataset of insect pests of sweet corn across the state showed no annual trend for two species (migratory corn earworm and fall armyworm), while prevalence of a third species (European corn borer) declined since the 1990s and early 2000s, perhaps due to land use change such as the adoption of Bt field corn (Walter et al. 2018).

Bees and other insect pollinators are vital to the reproduction of wild plants and to the production of a wide range of agricultural crops. Climate change is currently affecting the distribution and abundance of insect species (Kerr et al. 2015). Future climate change is expected to seriously impact plant-insect interactions in agricultural systems, causing both geographical and phenological mismatches between pollinators and native plant and crop species (Gerard et al. 2020). Climate changes predicted for the northeast US (warmer winters, more intense precipitation in winter and spring, and longer growing seasons with higher temperatures) are associated with lower wild bee abundance (Kammerer et al. 2021). A study of buzz-pollinating native bees associated with tomato crop production predicted a small decrease in bee species richness in Columbia County, NY under future climate scenarios (Carrasco et al. 2020).

A watch list of non-native plant species potentially capable of invading agricultural and natural systems in Columbia County by mid-century is included in Appendix B.

Trees

Changes in climate will impact the suitability of habitat for park trees. A US Forest Service (USFS) model of the capability of tree species to adapt to changing climate projected that roughly 1/3 of tree species currently occurring in MAVA are capable of adapting to projected regional climate change by 2100, while another 1/3 of park tree species have poor capability to adapt. Some key park species (including American sycamore, red maple, and black locust) are expected to possess the capability to adapt to projected changes, while other key species (Eastern white pine, slippery elm, and green ash) are expected to have poor capability (USFS 2021).

Cultural resources

The park contains many important cultural resources impacted by climate change, including the Lindenwald mansion and two additional historic structures, archeological resources, vegetation features, agricultural areas, historic views, circulation features, ponds, and other features. Key climate-related impacts to cultural resources include physical damage, loss, cracking, deterioration, decay, mold, flooding, erosion, loss of historic or significant vegetation, loss of species, loss of synchrony between species, loss of pollinators, and altered views.

Monitoring of the actual interior microclimate of the main hall in the Lindenwald Mansion shows that relative humidity in the summer reaches the upper limits recommended for protection from mold and decay (Appendix C). Thus, there is little additional capacity for maintaining acceptable interior microclimate as climate change continues, and increased costs for upkeep, drainage and air-conditioning for historic park structures are expected.

The Stockbridge-Munsee Mohican Tribe considers the entire park site to be a Native American archeological site, and noted that the tribal preference is for artifacts to be left to decay in place from the natural processes of weathering and erosion (N. Allison, personal communication, 10/21/20).

Recommendations

Understanding climate change and incorporating this information into park planning and management will be essential for preserving the natural and cultural resources at MAVA in the 21st century. Key recommendations for MAVA include:

- **Tell the story of climate change at the park**. Using information from this report and on-site monitoring, help the public understand the impacts of climate change on park natural and cultural resources.
- Installation of an on-site **weather station** would provide site-specific data to inform management of natural and cultural resources, including the Lindenwald Mansion, as well as agricultural operations.
- An annual detection survey for key **invasive species** in all habitats, including agricultural systems, would provide essential information to enable rapid response before new species become established.

- Periodic monitoring of **tree health** in cultural landscape areas, the restored orchard, and the southern swamp would detect emerging tree health issues.
- Monitoring **phenology** of key park species would provide a concrete record of change at the park to engage visitors and volunteers.
- **Photo-monitoring** of key views would provide a visual record and baseline to document change within the park viewshed.
- Areas at-risk for flooding (see Figure 9) should be prioritized for regular **archeological monitoring**.
- Maintaining or enhancing **shade trees** in key locations can provide shaded areas to enhance the comfort of park visitors.
- Selection of **crop and livestock species, cultivars and breeds** that can tolerate increased summer heat, or that can benefit from a longer growing season, will increase adaptive capacity of agriculture in the park.
- For new plantings, choosing tree species that have **capacity to adapt** to changing climate at the park (see Section 3.4), while also maintaining cultural and historical aesthetics, can enhance the cultural landscape.
- Incorporating **future climate scenarios** into mid- and long-term park planning and management documents, including maintenance of interior micro-climate in historic buildings and land management for areas at-risk for flooding, will help the park adapt to the unprecedented challenge of climate change.

Additional recommendations are included in Chapter 3, and additional resources for understanding climate change and related impacts are included in Appendix D.

Acknowledgments

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Focused Condition Assessments – Introduction

The National Park Service's (NPS) Natural Resource Condition Assessment (NRCA) Program evaluates natural resource conditions in park units and delivers the results to park staff, scientists, strategic planners, and the general public through reports and associated products. All NRCA efforts strive to report resource condition information in a way that informs multiple levels of park stewardship activities. Stewardship activities may include partnerships, resource stewardship plans, and park management plans, and may inform on-the-ground actions that park management can readily implement.

As part of the NRCA program, Focused Condition Assessments (FCAs) are short-term projects where a pressing issue or critical data or knowledge gap exists, prompting the need to assess the current conditions of one, or a few park natural resources. FCAs are intended to address specific natural resource conditions that lend important information for management and decision-making. As short-term projects, FCAs primarily rely on utilization and synthesis of existing science and data. FCAs are intended to strengthen our understanding of current resource conditions and their relation to environmental processes across the landscape and improve the delivery of best available science for park management.

Standard products from FCA projects include a detailed project report and associated products. Associated products may be data summaries, resource briefs, geospatial maps and information, story maps, and others. All reports and associated products are available via the NPS Datastore (https://irma.nps.gov/DataStore/).

Chapter 1. Purpose and Approach

This study assessed climate trends and projected impacts for Martin Van Buren National Historic Site (MAVA), in the Hudson Valley Region of New York State (NYS).

1.1 Purpose

Anthropogenic emissions of greenhouse gases (carbon dioxide, methane, and other gases) since the Industrial Revolution have increased atmospheric absorption of radiated heat from the earth's surface and increased global surface temperatures, causing a cascade of impacts to natural and human systems (IPCC 2014). The National Park Service (NPS) has recognized climate change as a major threat to national park units, and has developed a coordinated Climate Change Response Strategy (CCRS) to increase understanding of climate change through science, mitigate climate change with high standards for energy efficiency and greenhouse gas reduction, adapt to climate change with planning and management strategies, and to communicate broadly about the issue (NPS 2010). Recently, NPS has published guidance to help park planners and managers incorporate climate adaptation into all facets of park planning and management (NPS 2021). That guidance provides a structured, six-step process for assessing how current and future climate change may affect park resources, and for developing strategies that reduce climate-related vulnerabilities and risks in park planning and management.

The goal of this assessment was to synthesize existing information on current and projected climate and related impacts at MAVA, in order to help park stewards understand, plan and manage for climate change. This is a key component of the NPS adaptation planning process (NPS 2021). Key questions considered in this assessment include:

- How have patterns of temperature and precipitation at MAVA changed over the historical record?
- How are temperature and precipitation likely to continue to change over the 21st century?
- How is changing climate affecting Kinderhook Creek streamflow and seasonal flooding in the park?
- How is changing climate impacting key phenological events, such as fruit tree budbreak?
- How are key agricultural and natural resource weed and insect pests responding to changing climate?
- How is climate change affecting agriculture in the region?
- How are park cultural resources, including archeological resources, impacted by changing climate?
- What resources are available to park managers and stake-holders to continue to improve understanding of climate change and associated impacts?

1.2 Park Background

MAVA is located in Columbia County, in the Town of Kinderhook, New York. The park is dedicated to interpreting the life and career of the eighth President of the United States and the issues facing the nation in the turbulent decades leading up to the Civil War. The park also seeks to showcase and interpret historical and modern progressive farming, as practiced by Van Buren in the mid-nineteenth century, and by modern farmers working this land today.

The property lies 30 km (20 miles) south of Albany and six km (four miles) east of the Hudson River, on a terraced landscape along Kinderhook Creek, within the Hudson River Valley Natural Heritage Area. The park landscape is complex (Figure 1). The park boundary includes an organic farm (Roxbury Farm), which lies on the lower terrace adjacent to Kinderhook Creek, as well as several privately-owned parcels under conservation or agricultural easement. The park boundary excludes three “cut-out” parcels which are private residences.

Park resources include the Lindenwald mansion and outbuildings, an archival and museum collection, the cultural landscape, archeological sites, and impressive views to the west, across the agrarian landscape towards the distant Catskill Mountains. Natural resources lying within the park’s 120-ha (296-ac) authorized legislative boundary include prime agricultural soils, a vegetated escarpment, a historic woodlot/orchard, wetlands, and habitat for many species of conservation interest. Park water resources includes six ponds, a section of Kinderhook Creek, and a channelized creek (Muddy Brook). Kinderhook Creek runs along the park’s northwest boundary and is used by Roxbury Farm for irrigation water. It is a cool, medium river with average depth 0.6 m (2 feet) and average width 14 m (45 feet). It is rated a class C stream by the NYS Department of Environmental Conservation (DEC) and suitable for fishing (NPS 2015). Historic and modern ditches and Muddy Brook connect agricultural fields on the lower terrace to Kinderhook Creek.

Climate change is a key stressor of concern acting on park natural and cultural resources. Additional stressors acting upon park ecosystems include atmospheric deposition, nutrient enrichment, habitat fragmentation, and invasive species, while cultural resources are subject to deterioration from wind, fire, floods, humidity and visitor use.

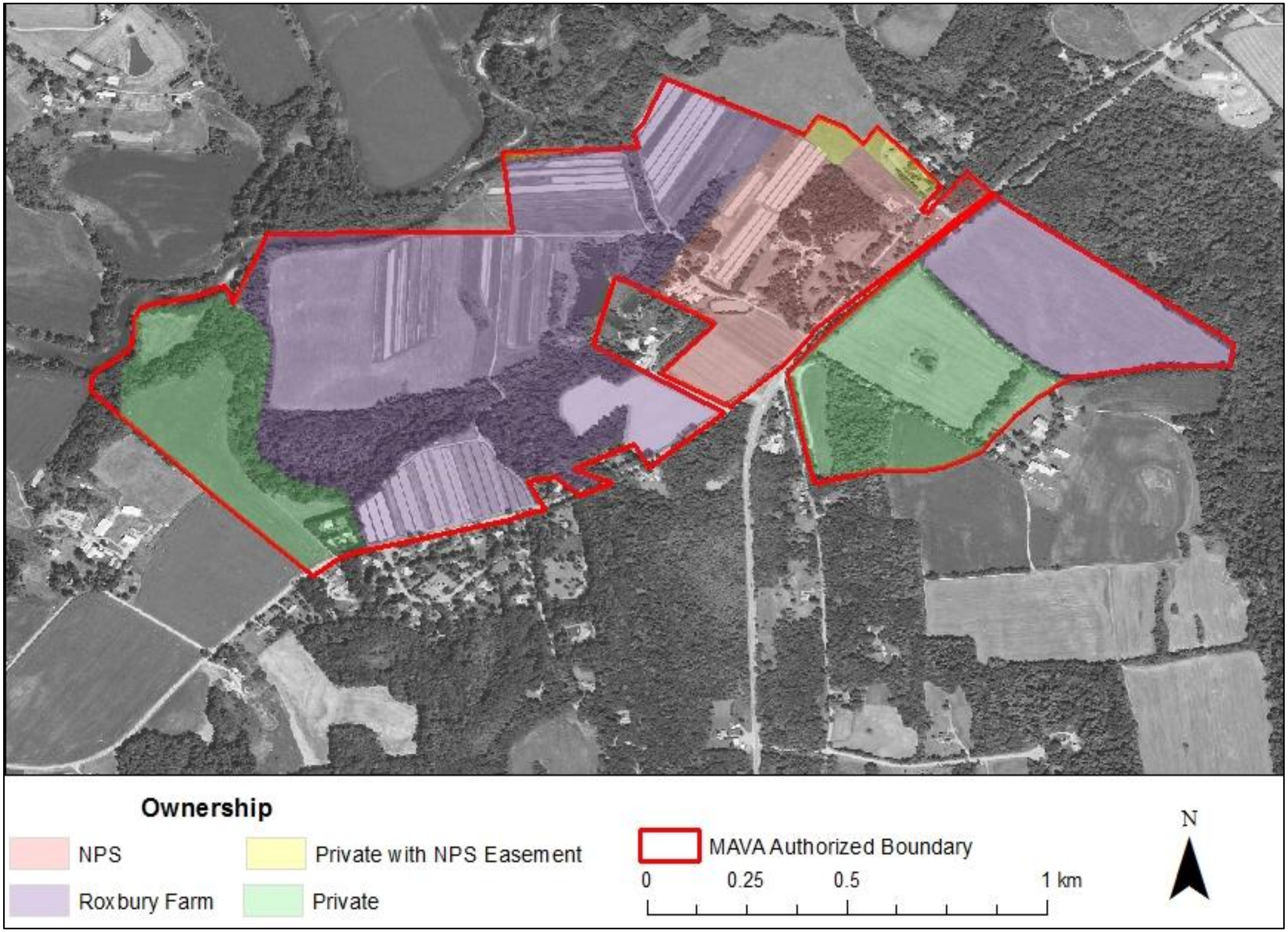

Figure 1. Ownership of land within the authorized boundary of Martin Van Buren National Historic Site (NHS).

1.2.1 Data Sources

Sources of existing data available for use in this assessment are shown in Table 1.

Table 1. Data for assessment of climate change trends and impacts at Martin Van Buren NHS.

Data Type	Description	Time period	Source
Climate trends and projections	Monthly temperature and precipitation at MAVA	1895–2017, 2071–2100	National Park Service (Gonzalez et al. 2018)
Climate trends	Temperature and precipitation at national parks	1901–2012	National Park Service (Monahan and Fisichelli 2014)
Climate trends and projections	Regional temperature and precipitation, including extreme events	1900–2012, 2100	NYS ClimAID (Horton et al. 2014, Rosenzweig et al. 2011)
Climate trends and projections	County-level temperature and precipitation, including extreme events	1950–2100	Cornell Climate Smart Farming (CSF 2020)
Actual interior microclimate	Humidity ratio in main hall of Lindenwald Mansion	June 2017–May 2018	Breuker and Bittermann, HACE (Appendix C)
Phenology	Columbia County (and NYS)	1826–1872	Hudson Valley Farmscape Ecology Program
Phenology	Apple tree budbreak at Hudson Valley Farm, Ulster County, NY	1980–ongoing	Jentsch Lab (2021), Cornell University
Discharge – Kinderhook Creek	At Rossman, downstream from park	1906–ongoing (with gaps)	US Geologic Survey
Hydrology	Projected runoff	2030	Battaglin et al. 2020
Species ranges	Projected future distribution of tree and bird species	2100	USFS Climate Change Atlas
Pest and pathogen response	Projections for pest and weed response in eastern US	2100	National Park Service (Fisichelli et al. 2014)
Invasive species occurrence, and projected ranges	Reported occurrence data, projected ranges for mid-century	Ongoing, mid-century	Univ. of Georgia, Early Detection and Distribution Mapping System
Invasive plants projected ranges	Prioritized list of invasive plants projected to invade NYS and southern New England	Mid-century	Rockwell-Postel et al. 2020
Key insect pest trap captures	Captures of key insect pests of sweet corn at network of sites across NYS	1994–ongoing	Sweet Corn Pheromone Trap Network 2020
Crop insurance payments	County-level crop loss payments	1989–ongoing	USDA Risk Management Agency

1.3 Study Approach

A group of park managers, scientists, and other stakeholders was assembled to define park needs relative to climate and to steer this project. The working group included a resident farmer (Jody Bolluyt) and a representative of the Stockbridge-Munsee Mohican Tribal Preservation Office

(THPO; Nathan Allison). National and regional datasets were analyzed to determine condition and trends, and to provide a range of climate change projections for the park over the next century. The project also sought to identify data gaps for further study, and to document available resources to help park managers continue to understand, plan and manage for climate change.

1.3.1 Selection of Key Resources, Indicators, and Reference Criteria

The project working group identified six key park resources for assessment: Climate, Water quantity, Phenology, Agriculture, Trees, and Cultural resources.

Climate was assessed using four indicators (temperature, extreme temperature days, precipitation, and extreme precipitation events). Temperature and precipitation are fundamental drivers of ecological and agricultural processes, and extreme temperature events can create adverse conditions for natural resources and agriculture. For Phenology, impacts on apple tree blooming were considered. This is relevant at MAVA, where NPS plans to restore a historic orchard (von Bieberstein and Coffin Brown 2016).

For Water quantity, this analysis considered streamflow in Kinderhook Creek, as well as projected changes in flooding which could substantially impact agricultural operations and park management.

For Agriculture, this analysis considered climate impacts on occurrence of insect pest species, pollinators, and weed ranges. For Trees, the analysis considered projected changes in tree ranges at the park. Trees are important natural and cultural resources at MAVA, providing habitat for a myriad of species, performing vital ecosystem services, and comprising a key part of the cultural landscape.

The park contains many important cultural resources impacted by climate change, including the Lindenwald mansion and two historic outbuildings, archeological resources, vegetation features, agricultural areas, historic views, circulation features, ponds, and other features. Key climate-related impacts to cultural resources include physical damage, disruption, loss, cracking, deterioration, decay, mold, flooding, erosion, loss of historic or significant vegetation, loss of species, loss of synchrony between species, loss of pollinators, and altered views. The Stockbridge-Munsee Mohican tribe considers the entire park site to be a Native American archeological site, and noted that the tribal preference is for artifacts to be left to decay in place due to natural processes of weathering and erosion (N. Allison, personal communication, 10/21/20).

1.3.2 Methodology/Analysis

This analysis assessed current condition for climate, and considered climate change projections and impacts for the coming century. For current condition, assessment points (also known as reference values) were used to distinguish expected or acceptable condition (i.e., *good condition*) from undesired conditions that warrant concern, further evaluation or management action (Bennetts et al. 2007). Unless otherwise specified, assessment points were defined in relation to the historical or established baseline, with an undesired change of more than 30% considered *significant concern*, and an undesired change up to 30% considered *moderate concern*. Trends were determined by linear regression using an alpha value of 0.10 to determine statistical significance.

Projected climate change and impacts for mid-century (2030–2060) and end-of-century (2100) were based on future climate scenarios representing a range of representative concentration pathways (RCPs). RCPs are scenarios for future atmospheric composition that represent a trajectory of climate-forcing emissions over time. Under RCP2.6, a reduced emission pathway, radiative forcing peaks at about 3 W m^{-2} before 2100 and then declines. Under low (RCP4.5) and high (RCP6.0) pathways, radiative forcing is stabilized at 4.5 or 6.0 W m^{-2}, respectively, shortly after 2100. Under the highest pathway (RCP8.5), radiative forcing exceeds 8.5 W m^{-2} by 2100, and then continues to climb until 2250 (IPCC 2014). The reduced emission pathway (RCP2.6) provides an opportunity for avoiding the most severe impacts of climate change.

Chapter 2. Climate Change

2.1 Description and Relevance

Temperature and precipitation are fundamental drivers of ecological and agricultural processes. Changes in temperature and precipitation patterns caused by human emissions of greenhouse gases have caused impacts to natural and human systems across the globe (IPCC 2014). The humid continental climate of NYS has become both warmer and wetter over the last century, and year-to-year variation in precipitation has increased (Horton et al. 2014). The amount of precipitation occurring in extreme events has increased by more than a third across the northeast US over the last century (Hayhoe et al. 2018). These changes are bringing milder winters, earlier spring thaw, hotter summers, and more frequent extreme precipitation events (Rosenzweig et al. 2011). Temperatures across the state are projected to continue increasing throughout the 21st century, and days of extreme heat are expected to become more frequent (Horton et al. 2014). These changes are causing a cascade of impacts to natural and human systems.

2.2 Data and Methods

Gonzalez et al. (2018) used the Parameter-elevation Relationships on Independent Slopes Model (PRISM) time series (1895–2017) to assess trend in temperature and precipitation at national parks across the continental US, including MAVA. They calculated historical trends using linear regression, corrected for temporal autocorrelation. They projected future change using bias-corrected statistical downscaling of output from 33 General Circulation Models (GCMs) for four scenarios representing reduced (RCP2.6), low (RCP4.5), high (RCP6.0) and highest (RCP8.5) emission pathways.

Monahan and Fisichelli (2014) used gridded climate data from the Climatic Research Unit's high-resolution time series to examine 25 climate-related variables over 112 years (1901–2012) at national parks across the nation, including two nearby parks (Roosevelt-Vanderbilt National Historic Sites [ROVA] and Saratoga National Historical Park [SARA]) but not MAVA. They used a moving window analysis at three scales (10-, 20-, and 30-year windows) to characterize each park's historical range of variability (HRV), and to compare recent averages to historical conditions, noting extreme current condition (i.e., $<5\%$ or $>95\%$ percentile compared to HRV).

The Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State (ClimAID) assessed and reported information on climate change trends, projections and impacts for the state, including vulnerabilities and potential benefits of climate change (Rosenzweig et al. 2011). Trends in temperature, precipitation and extreme weather events were assessed from a network of weather stations across the state, and reported for each of seven regions, including the East Hudson and Mohawk River Valley Region, in which MAVA lies. An updated report refined the assessment and projected future climate change using output from 35 climate models under two scenarios representing low (RCP4.5) and highest (RCP8.5) emission pathways (Horton et al. 2014).

Cornell University's Climate Smart Farming (CSF) Program provides tools to help farmers prepare for climate change, including county-level data on current trends and future projections in average and extreme temperature and precipitation (CSF 2020). This tool interpolates county-level data from a national dataset of weather observations (1950–2013; Livneh et al. 2015) and calculates trends using simple linear regression. In order to assess current status, a gridded dataset (1950–2020) was obtained from the Northeast Regional Climate Center (NRCC; ACIS 2021) and trend was calculated using linear regression. CSF also projects change over the 21st century from 32 climate models under low (RCP4.5) and highest (RCP8.5) emission pathways.

2.3 Reference Condition/Values

Reference values for determining condition of climate at MAVA are shown in Table 2. Good condition is defined relative to historical (20th century) baseline conditions. For average annual temperature, significant concern is defined as an increase of more than 1.5 °C (Hoegh-Guldberg et al. 2018). For total annual precipitation and extreme temperature and precipitation days, significant concern represents a 30% change over the historical baseline. For all four metrics, caution is defined as the interval between historical baseline conditions and significant concern. Current condition was determined on the basis of a statistically significant ($p < 0.10$) trend, while potential end-of-century condition was estimated based on model projections.

Table 2. Reference values for determining climate condition. See text for details.

Metric	Good	Caution	Significant Concern
Temperature, average annual	Historical baseline	<= 1.5 °C (2.7 °F) increase	>1.5 °C (2.7 °F) increase
Extreme temperature days (> 32 °C; 90 °F)	Historical baseline (average of 6 days per year)	<= 30% increase	>30% increase
Precipitation, total annual	Historical baseline	<= 30% change	>30% change
Extreme precipitation days (> 2.5 cm; 1 in)	Historical baseline (average of 6 days per year)	<= 30% increase	>30% increase

2.4 Condition and Trend

Current condition of temperature and precipitation variables at MAVA and across the region show extreme warm and wet conditions compared to the historical record (Monahan and Fisichelli 2014). Analysis of gridded PRISM data showed that increases in mean annual temperature of 0.4 ± 0.2 °C (0.7 ± 0.4 °F) and in total annual precipitation of 13 ± 4% have occurred at MAVA over the last century (Figure 2 and 3); continued increases in mean annual temperature of 1.9–5.4 °C (3.4–9.7 °F) and in total annual precipitation of 7–15 % are projected at the park by 2100 (Figure 4; Gonzalez et al. 2018). Current condition of mean annual temperature and total annual precipitation warrant caution, while projected continued increases in temperature warrant significant concern (Table 3). The greatest changes in both temperature and precipitation are predicted for the winter months (Figure 5 and Appendix A; Gonzalez et al. 2018).

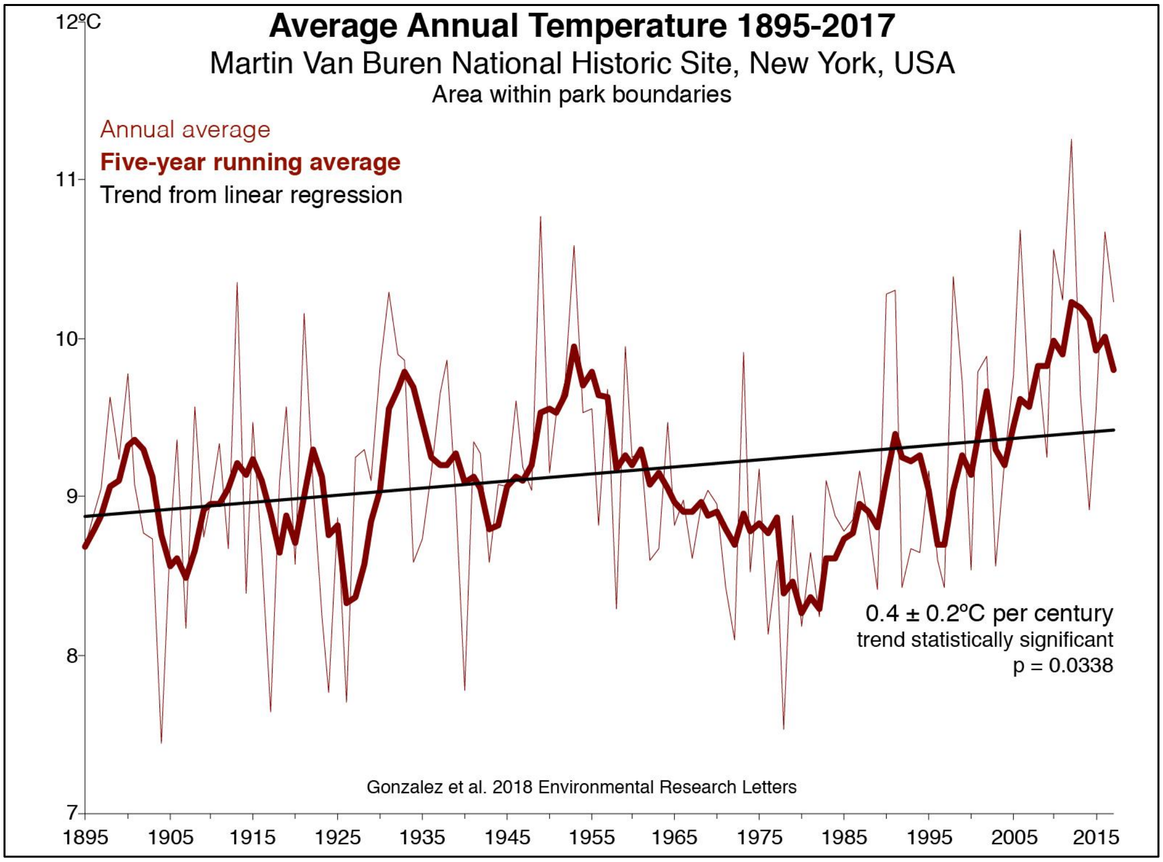

Figure 2. Average annual temperature, 1895–2017, for the area within Martin Van Buren National Historic Site boundaries, with the trend calculated by linear regression, corrected for temporal autocorrelation (Gonzalez et al. 2018).

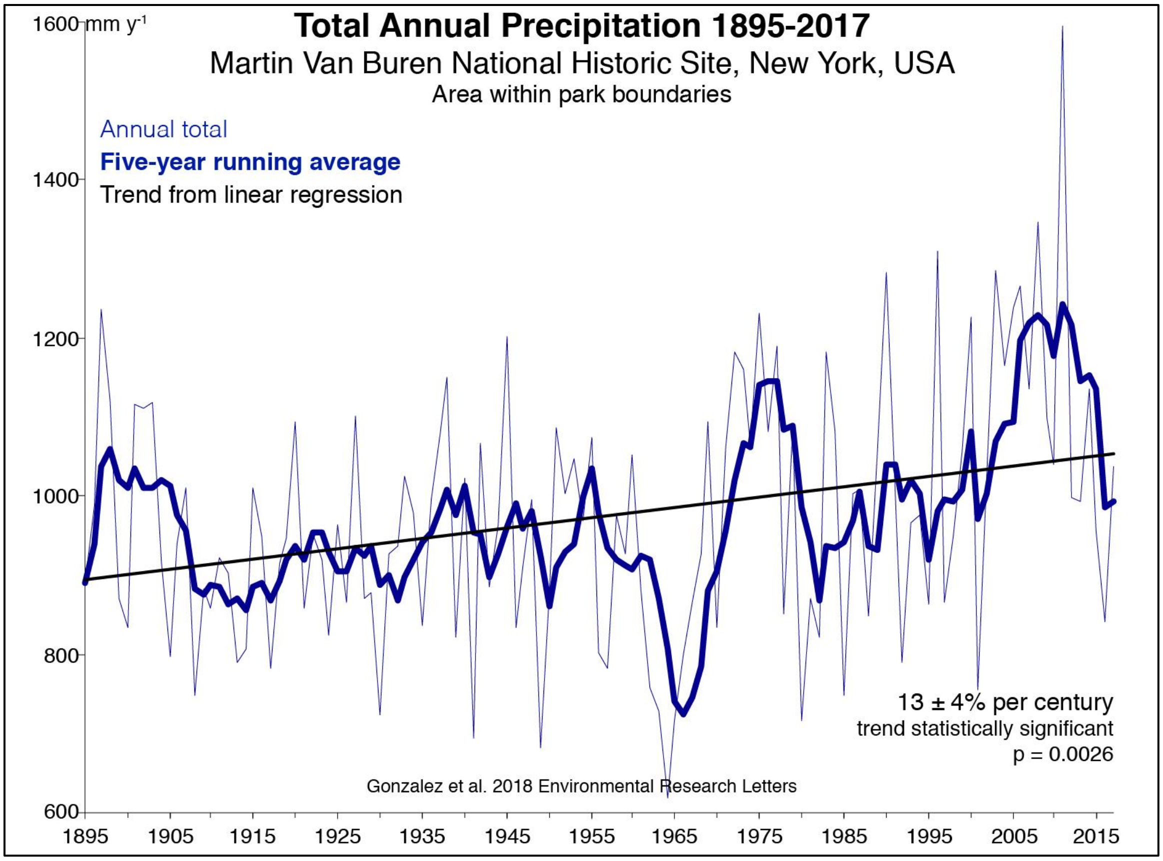

Figure 3. Total annual precipitation, 1895–2017, for the area within Martin Van Buren National Historic Site boundaries (Gonzalez et al. 2018).

Table 3. Current and projected end-of-century condition for climate at MAVA. See text for details.

Metric	Current Status	Current Condition	Projected End-of-century Status	Projected End-of-century Condition
Temperature, average annual	0.4 ± 0.2 °C increase over past century	Caution	Additional 1.9–5.4 °C increase	Significant concern
Extreme temperature days (> 32 °C; 90 °F)	No change detected	Good	>30% increase	Significant concern
Precipitation, total annual	13 ± 4% increase over past century	Caution	Additional 7–15 % increase	Caution
Extreme precipitation days (> 2.5 cm; 1 in)	100% increase since 1950	Significant concern	Additional 0–40% increase	Significant concern

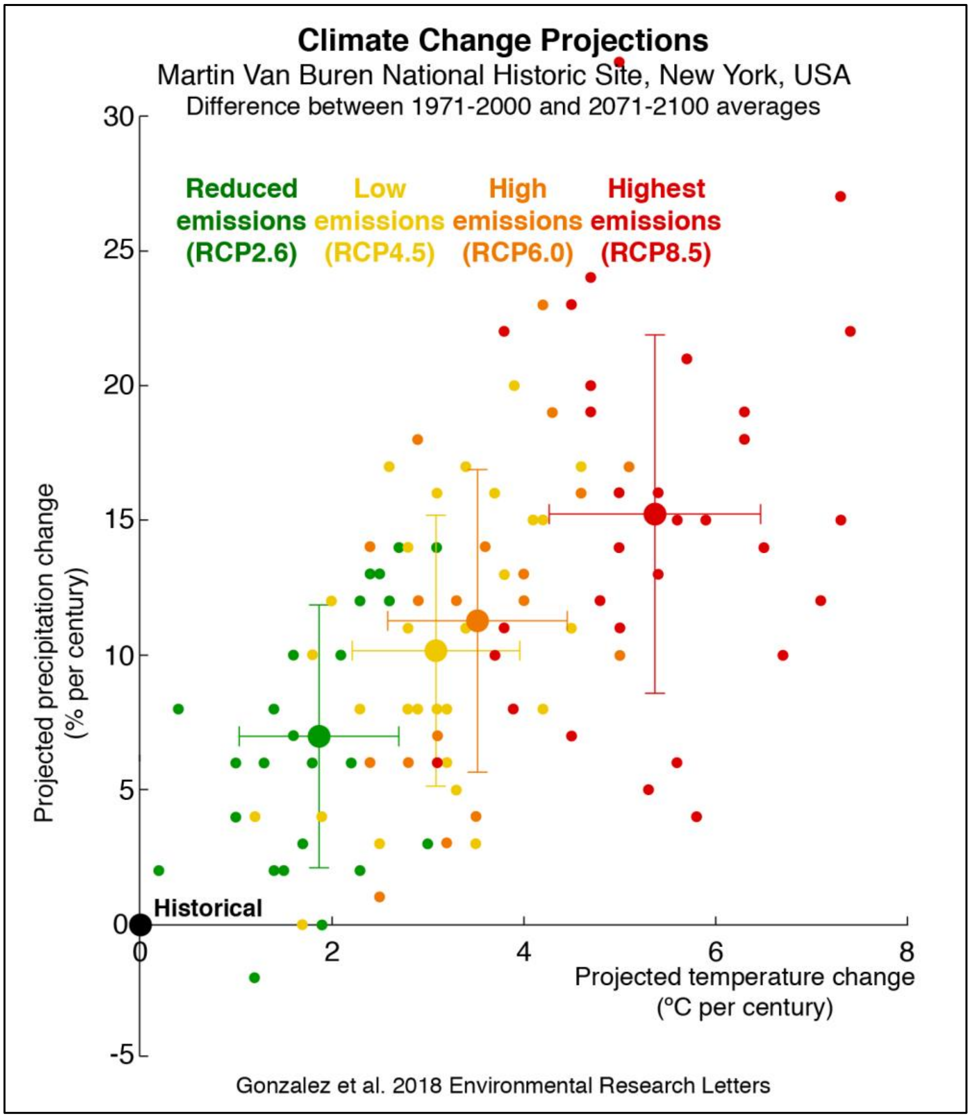

Figure 4. Projections of future climate for Martin Van Buren NHS relative to 1971–2000 average values under four potential emission scenarios (Gonzalez et al. 2018). Each small dot is the output of one of 33 general circulation models, the large color dots are average values for each IPCC emissions scenario, and the crosses are the standard deviations of the average values.

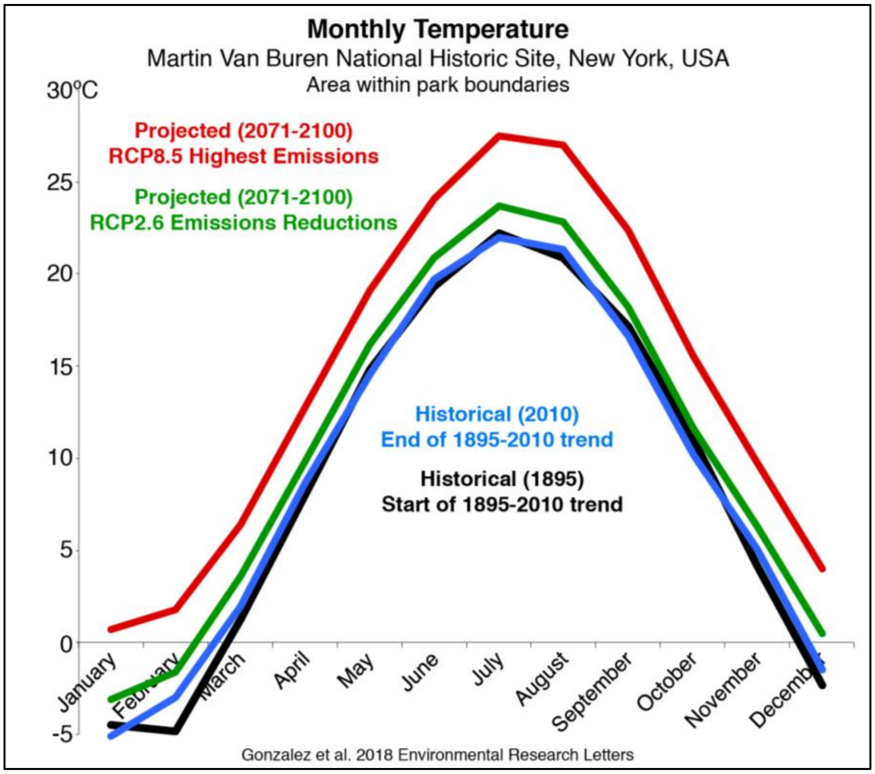

Figure 5. Monthly average temperature at Martin Van Buren NHS for the period 1895–2010 with future projections under two emission scenarios (Gonzalez et al. 2018).

As temperature has increased, the growing season has lengthened, with spring thaw occurring earlier in the year. In Columbia County, the average length of the growing season (above freezing) increased from about 140 days in 1950 to about 160 days in 2010. Projections for low (RCP4.5) and highest (RCP8.5) emission pathways show further increases resulting in growing season length up to 170 to 200 days in Columbia County by 2100 (CSF 2020).

The number of extreme temperature or precipitation days varies highly from year to year. Analysis of the number of extreme temperature days (>32 °C [90 °F]) in Columbia County showed no change during the period 1950–2020. However, projections for low (RCP4.5) and highest (RCP8.5) emission pathways for extreme heat in Columbia County show very large (six to twelve-fold) increases in expected hot days by 2100, which could cause more frequent periods of short-term drought and which would warrant significant concern (CSF 2020, Horton et al. 2014).

At the same time, precipitation events have become more variable and intense in the northeast US in recent decades (Hayhoe et al. 2018). In Columbia County, the average number of days of extreme precipitation (>2.5 cm [1 in]) increased by almost 1 day per decade from 1950 to 2020 (CSF 2020), warranting significant concern. Projections for low (RCP4.5) and highest (RCP8.5) emission pathways show continued increases in extreme rain events in the region from 0–40% over baseline conditions by 2100 (CSF 2020, Horton et al. 2014). Changes in the intensity or frequency of extreme precipitation events can increase flooding and soil erosion, impacting agriculture, and management of both natural and cultural resources.

2.5 Level of Confidence and Data Gaps

Confidence in current condition for climate is high. Confidence in projections of future conditions at local to regional scales is low, due to uncertainty in downscaling climate projections, as well as to uncertainty in future emissions of greenhouse gases.

2.6 Sources of Expertise

- Patrick Gonzalez, NPS Climate Change Response Program
- NYS ClimAID
- Cornell University CSF

Chapter 3. Impacts and Recommendations

Climate change will cause major impacts to natural and cultural resources and to agriculture in the park. Projections for continued change over the 21st century contain considerable uncertainty. By considering the range of projections f+ or future change, park managers can use the best available science as they plan for managing and adapting to the unprecedented challenges posed by climate change.

3.1 Water Quantity

Climate is a primary driver of hydrology, and variation in the timing and magnitude of precipitation and snowmelt are important drivers of water quantity. Regionally, streamflow in the northeast US has increased over recent decades and peak flow, linked to snowmelt, is occurring earlier in the season (Tamuddun et al. 2016, Dudley et al. 2017). At the same time, flooding events along rivers and streams across the northeastern and midwestern US have increased (Slater and Villarini 2016). At MAVA, recent (2013–2017) high-flow discharge in Kinderhook Creek did not depart significantly from the long-term record, though mid-flow and low-flow discharge, regulated by upstream power plants, were significantly higher than the historical record (Tierney and Gibbs 2019).

The park is affected by occasional flooding from Kinderhook Creek on the lower terrace, and across the park road from the spring-fed Upper Pond on the upper terrace (Figure 6). The latter flooding may have been improved by a new culvert installed under the park road in 2019 (Steve Hanaburgh, personal communication, 11/19/20). Kinderhook Creek is used by Roxbury Farm for irrigation; park ponds are not currently used for irrigation but are considered a potential future resource (Megan O'Malley, personal communication, 12/1/2017). Increases in both precipitation and extreme precipitation events could impact flood regimes at MAVA, while increased temperatures during the growing season could increase incidence of short-term drought.

Battaglin et al. (2020) considered a range of future climate scenarios to project surface water runoff for 2030 in national parks across the nation, including MAVA. They used a monthly water balance model with downscaled data from more than 200 future climate simulations representing low (RCP4.5) to highest (RCP8.5) emission pathways to project a range of outcomes. For MAVA, they project that increased temperatures and precipitation by 2030 will drive moderate increases in runoff from January to March, decreased runoff from April to June, and possibly small decreases in runoff the rest of the year, including late summer when runoff is lowest for the year (Figure 7).

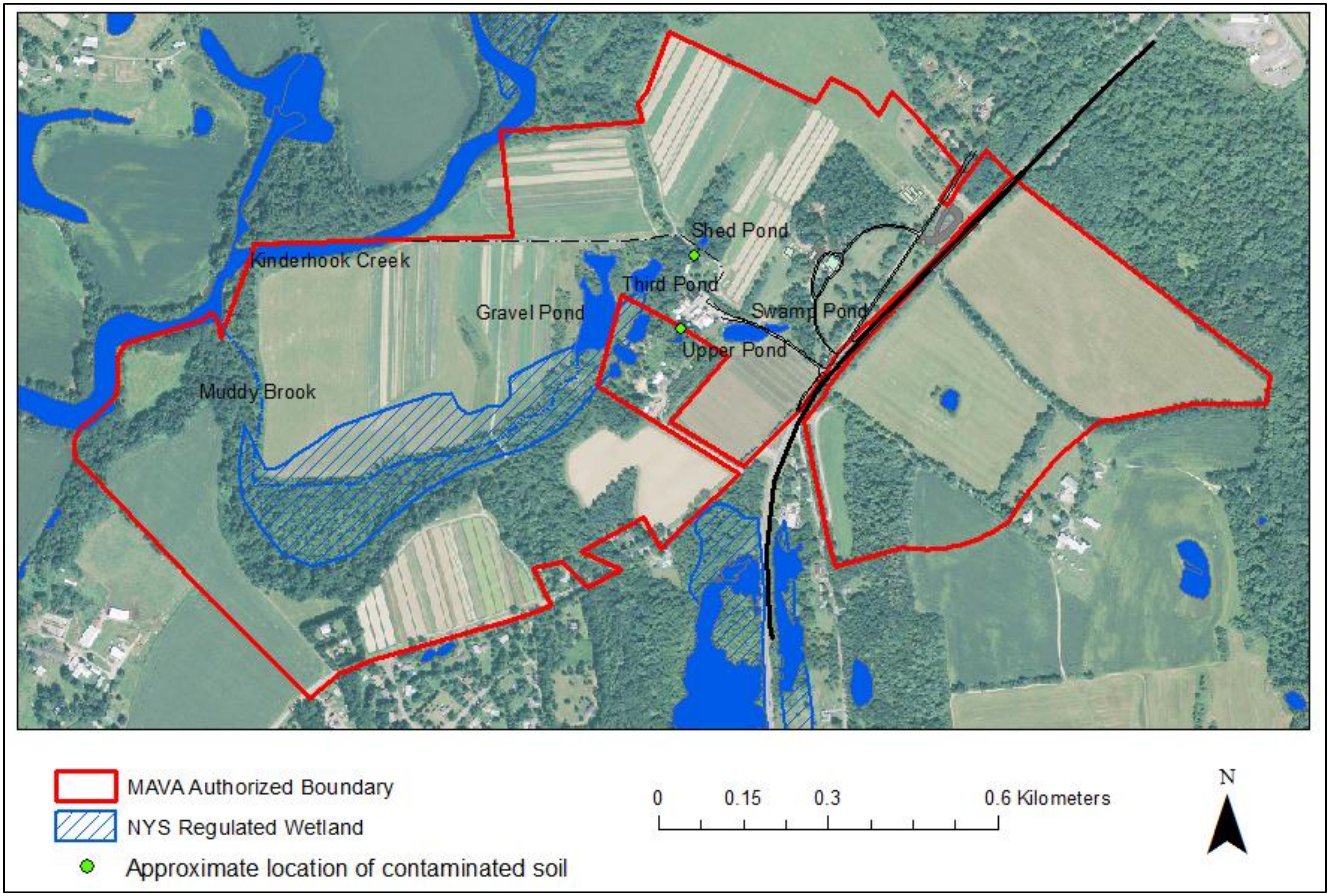

Figure 6. Location of water resources at Martin Van Buren National Historic Site.

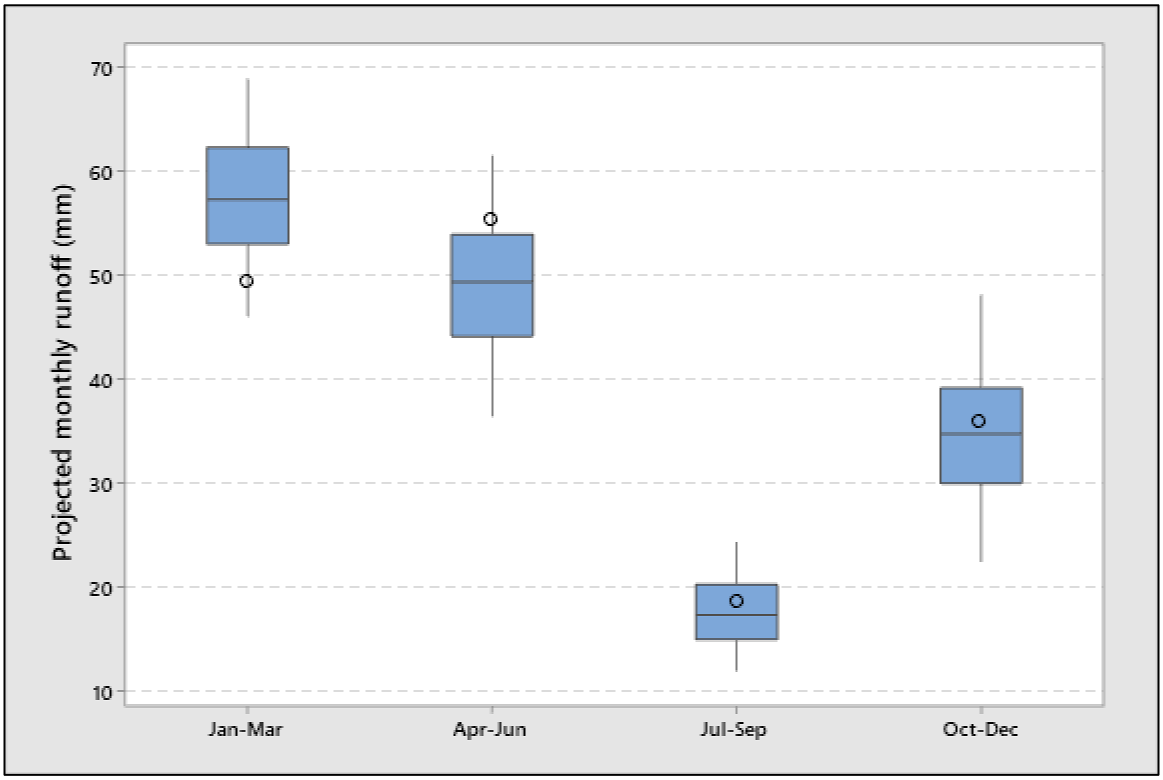

Figure 7. Boxplots of projected average monthly runoff at MAVA under a range of low to high emission pathways for 2030 (adapted from Battaglin et al. 2020). ○ represents baseline (1981–1999) average monthly runoff for each seasonal category.

To better understand how future flood risk may impact the park, this analysis considered future flooding using the First Street Foundation Flood Factor Model. This nationwide probabilistic model seeks to estimate fluvial (riverine), pluvial (rainfall), and coastal flood risk at the individual property level (3-m resolution) for projected future (2035 and 2050) climate conditions using 21 climate models under a low (RPC4.5) emission pathway (First Street Foundation 2020b). The model calculates fluvial flood risk using flood frequency analysis based on river gauge records from monitored catchments, which are extrapolated to ungauged catchments using land cover, topography and other factors. Pluvial flooding is incorporated by applying National Oceanic and Atmospheric Administration (NOAA) rainfall data onto the modeled surface incorporating land cover and impervious surface area. The model accounts for uncertainty by generating three hazard scenarios, low (25%), median and high (75% percentile). However, the model does not account for all factors contributing to flood risk (First Street Foundation 2020b).

This model predicted a 40% increased risk of flood damage at the park for 2035–2050 due to climate change (First Street Foundation 2020a). Model visualizations show the projected 5-year flood encroaching on the edges of fields on the park's lower terrace (Figure 8), while the projected 100-year flood shows substantial encroachment into fields on the lower terrace as well as flooding in the park's Southern Swamp and the ravine connecting Upper Pond to other park ponds and the lower terrace (Figure 9).

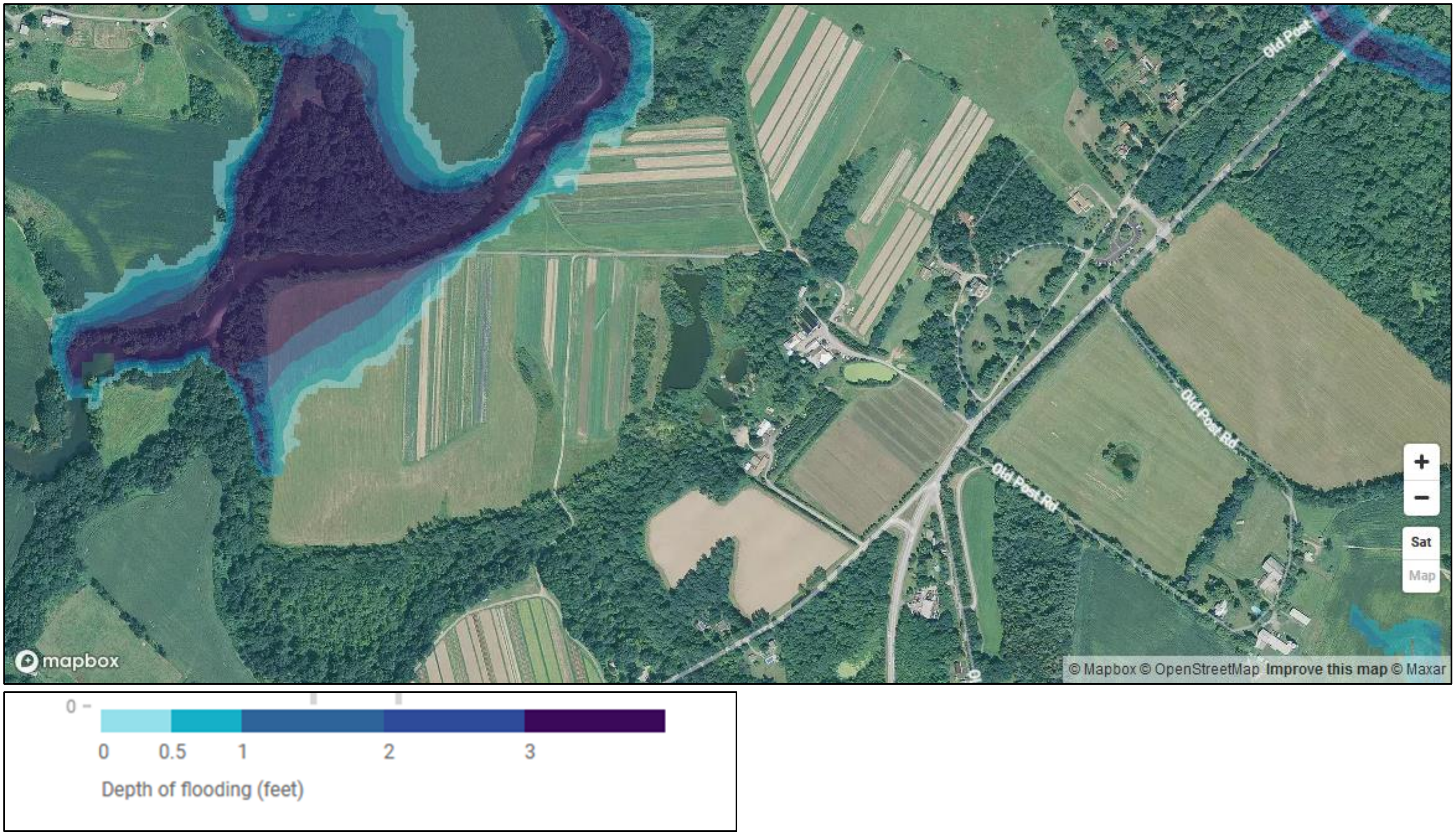

Figure 8. Projected 5-year (20%) flood risk scenario at MAVA for 2035–2050, under a low (RCP4.5) emission pathway (First Street Foundation 2020a).

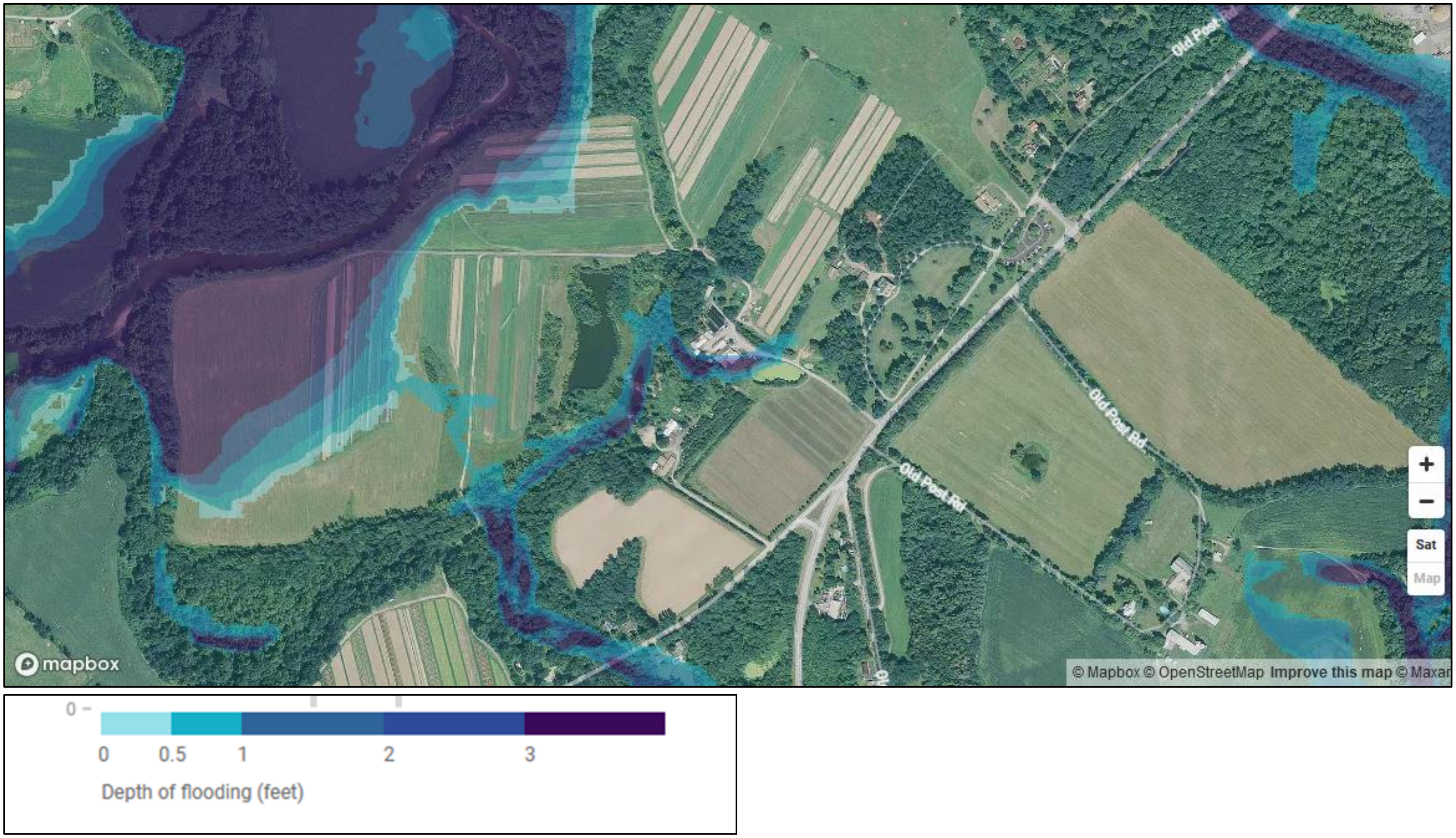

Figure 9. Projected 100-year (1%) flood risk scenario at MAVA for 2035–2050, under a low (RCP4.5) emission pathway (First Street Foundation 2020a).

3.2 Phenology

Climate is a primary driver of recurrent natural (phenological) events which are tied to seasonal cycles. such as flower blooming and insect emergence. Climatic change is altering the timing of these events, which are fundamental to both natural and agricultural systems (IPCC 2014). In temperate fruit trees, bud break and bloom dates are dependent upon overwinter temperatures to meet chilling requirements, and are driven by spring temperatures, with some influence from solar radiation, moisture availability and other factors. This is relevant at MAVA, where NPS plans to restore a historic orchard 2-ha (5-ac) orchard (von Bieberstein and Coffin Brown 2016).

A record of McIntosh apple blooming phenology has been collected for 40 years (1980–2019) at the Cornell University Hudson Valley Laboratory farm in Ulster County, NY (Jentsch Lab 2021). Although the three earliest recorded apple blooming times occur in the latter half of the dataset, linear regression of the 40-year record (1980–2019) of apple bloom phenology did not show a significant temporal trend (Figure 10). Wolfe et al. (2018) modeled end-of-century apple blooming dates and frost risk using a phenology model (including both chill unit and growing degree day accumulation) together with downscaled climate projections from 10 climate models under two scenarios representing low (RCP4.5) and highest (RCP8.5) emission pathways. That effort projected apple bloom dates in central NYS to shift 15 days earlier by 2100, though the response was complicated.

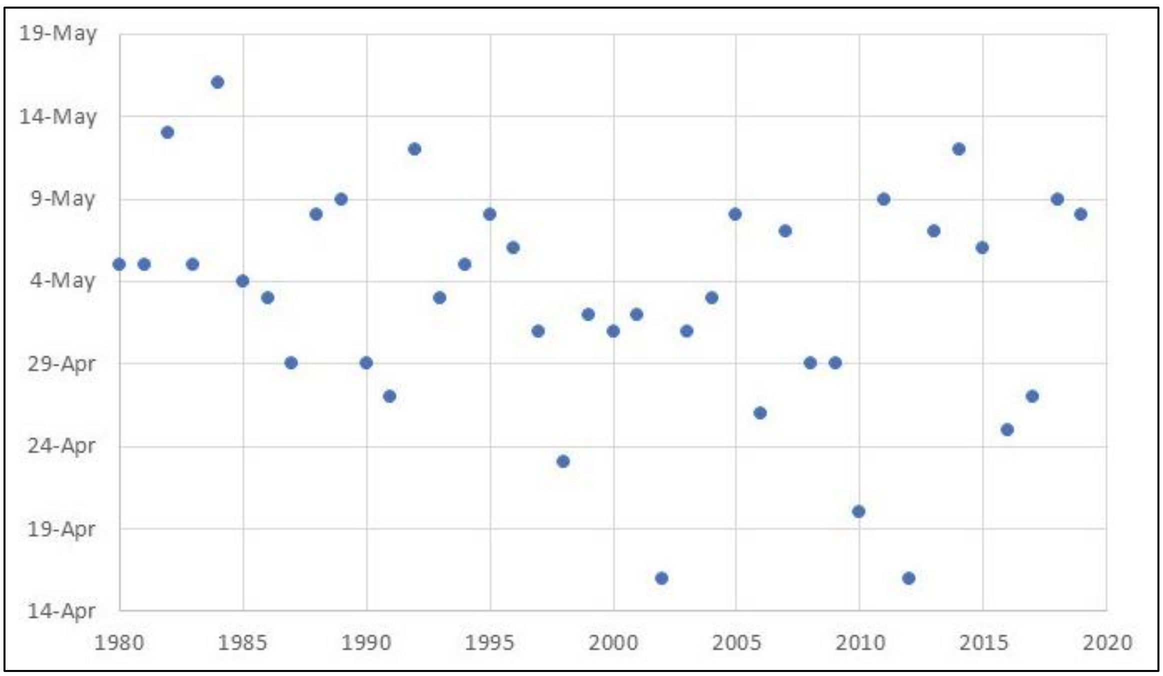

Figure 10. Forty-year record of full bloom dates for McIntosh apples at the Cornell University Hudson Valley Farm in Ulster County, NY (adapted from Jentsch Lab 2021).

The projected shift could leave trees more susceptible to damage from early spring cold temperature events, and to potential mismatch between emergence times of flowers and key pollinators (Degaetano 2018, Gerard et al. 2020). In Columbia County, damage to apple crops accounted for the large majority (95%) of crop insurance payments since 2001 (Reyes and Elias 2019). Apple damage in Columbia County overwhelmingly occurred early in the growing season (April–June), and was caused primarily by hail (54%) and freezing conditions (37%).

3.3 Agriculture

Climate change is causing many direct and indirect impacts to agriculture, creating both unprecedented challenges and new opportunities in New York State (Wolfe et al. 2018). Increases in heavy precipitation events can delay planting, cause physical and flood-related damage to crops, and increase soil erosion. Hotter summers increase summer heat stress, and warmer night-time temperatures can increase carbon loss from respiration, both of which can limit crop growth and decrease yields. Increased temperature and moisture create conditions for increased agricultural pathogen and fungal infection of leaves and root systems. Warmer winters can complicate chill-requirements for fruit tree growers, and increase overwinter survival of plant pests and pathogens. Earlier spring thaw may increase frost damage, and disrupt interactions between plants and pollinators. Climate change is also altering ranges and intensities of agricultural pest and weed species, which will affect agricultural practices and production in ways that are difficult to predict.

However, a longer growing season may offer opportunities to increase yields if other factors are not limiting (Rosenzweig et al. 2011). European wine grape production in the northeast US has benefited from less severe winters over the past several decades (Wolfe et al. 2011). Other crops that could benefit from continued warming in this region include Prunus species (peaches, plums and cherries), watermelon and tomato (Wolfe et al. 2018). Many strategies already in use at Roxbury Farm, including planting a diversity of crop species, improvement of soil health, and managing water availability, will benefit agricultural production at the farm as the climate continues to change.

To better understand climate change impacts to agriculture at the park, impacts on insect pest species, pollinators and invasive weed plants were considered.

3.3.1 Insect pest species

Climate change will increase some pest populations while decreasing others, in ways that are hard to predict due to complex interactions between insects, hosts and predators. These changes will be complicated further by the simultaneous effects of other stressors, including changes in land use and agricultural practices. As climate change progresses, migratory insects are likely to arrive earlier in the season and may expand their ranges northwards, and many insect species may increase the number of generations per year (Skendzic et al. 2021).

The Sweet Corn Pheromone Trap Network (SCPTN) has monitored key insect pests of sweet corn across New York State for more than 20 years, including one site in Kinderhook NY that has been monitored since 2016 (SCPTN 2020). Monitored species include the European corn borer (ECB, *Ostrinia nubilalis*), the migratory corn earworm (CEW; *Helicoverpa zea*) and the fall armyworm (FAW; *Spodoptera frugiperda*), three species that could produce more generations per year in the state under climate change scenarios (Gagnon et al. 2019, Ramirez-Cabral et al. 2017). CEW could also extend its over-wintering range further north (Olmsted et al. 2016). Linear regression of the long-term (1994–2020) dataset of moth captures showed no trend in annual average catch per site across the state for CEW and FAW, while catch of ECB has declined since the 1990s and early 2000s (Figure 11). This decrease in ECB prevalence may be related to land use change, such as the adoption of Bt field corn (Walter et al. 2018). Examining long-term datasets of insect pests in agricultural and forest systems in the US, Walter et al. (2018) found that agricultural insect pests were more likely to be declining in abundance (likely due to changes in land use practices), while forest insect pests were more likely to be increasing.

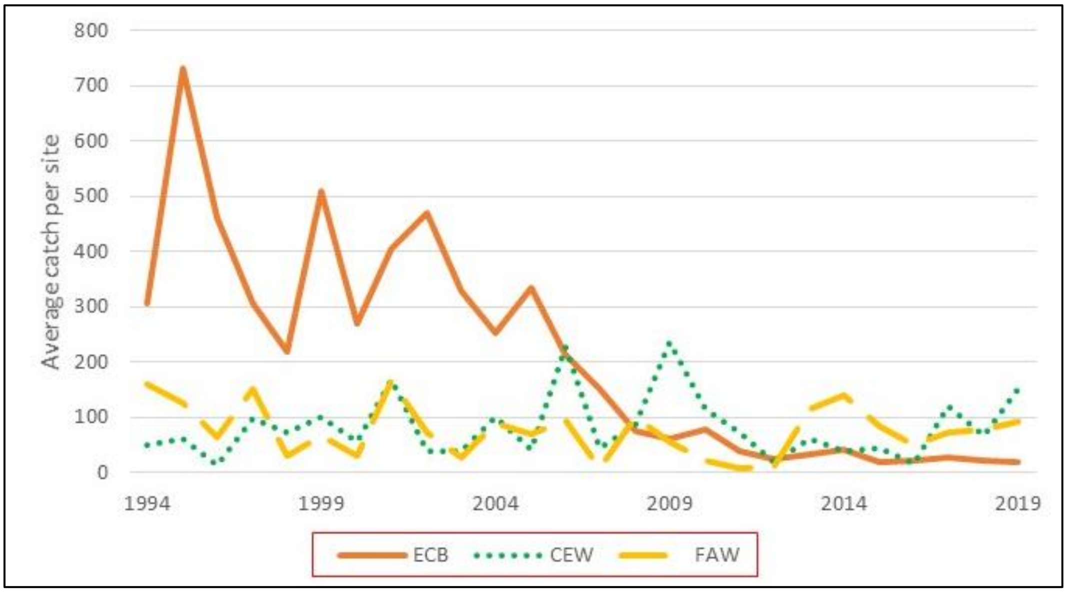

Figure 11. Average annual catch of key corn insect pests at sites across New York State (SCPTN 2020).

3.3.2 Pollinators

Bees and other insect pollinators are vital to the reproduction of wild plants and to the production of a wide range of agricultural crops. Climate change is currently affecting the distribution and abundance of insect species (Kerr et al. 2015). Future climate change is expected to seriously impact plant-insect interactions in agricultural systems (Gerard et al. 2020). A growing body of research investigates the impacts of climate change on managed honey bees and native wild bees, both of which are important to agriculture. Climate impacts can arise from geographical mismatches and/or phenological mismatches between bees and crops which rely on bee pollinators. Climate-related impacts are occurring in concert with impacts from other stressors, such as land use change and invasive species, and affect different species in different and complex ways (Mathiassan and Rehan 2020).

An assessment of long-term observations of bumble bees in North America and Europe found that ranges of many species have contracted at their southern range but failed to expand northwards in response to climate change (Kerr et al. 2015). Looking at a fourteen-year dataset of wild bee populations in the mid-Atlantic states, Kammerer et al. (2021) found climate factors to be the main driver of wild bee abundance and species richness. They found climate changes predicted for the northeastern US (warmer winters, more intense precipitation in winter and spring, and longer growing seasons with higher temperatures) to be associated with lower wild bee abundance.

Carrasco et al. (2020) assessed 15 species of native, sonicating (i.e., buzz-pollinating) bees associated with tomato crop production in North America. Buzz-pollinating bees are wild bees, such as bumble bees and sweat bees, that use vibration to release pollen. This process improves fruit production and quality. That study modeled changes in species ranges across North America for mid-century (2041–2070) and late century (2071–2100) associated with future climate projections from four climate models under both low (RCP4.5) and highest (RCP8.5) emission pathways. Their results suggested an overall loss of species richness of sonicating bees associated with climate change in North America over the coming century, with potential gains in new habitat in northern latitudes and mountainous regions. For Columbia County, NY, their results suggested a small decrease in species richness (1.5 species) averaged across all scenarios assessed.

3.3.3 Invasive weed plants

Changes in climate and CO_2 concentration are expected to increase the competitiveness of some invasive agricultural weed species, particularly in comparison to C3 field crops such as corn (Porter et al. 2014). NYS has been identified as a potential hotspot for invasive species under climate change scenarios (Bellard et al. 2013, Allen and Bradley 2016).

In order to aid early detection and rapid response programs for invasive weeds in the coming decades, Rockwell-Postel et al. (2020) evaluated and prioritized 100 invasive exotic plants already known to be present in the US and projected to invade NYS or southern New England by mid-century under a low (RCP4.5) emission pathway. They prioritized species according to known ecological impacts (high, medium, or low) and identified species known to invade agricultural systems.

Using that list as a starting point, a watch list of potential invasive weed species for agricultural and natural areas in Columbia County was created (Appendix B). Of the 100 species identified by Rockwell-Postel et al. (2020), only those species with medium or high ecological impacts or those known to invade agricultural areas were included. Next, the Bugwood Center for Invasive Species and Ecosystem Health's Invasive Range Expanders Listing Tool Explorer was consulted to determine which species were projected to invade Columbia County by mid-century. This tool projects future range of invasive species predicted by 13 climate models under a low (RCP4.5) emission pathway (Allen and Bradley 2016). Species which were not projected to colonize Columbia County by mid-century were eliminated, and the resulting list of 60 species is included in Appendix B.

Three of the five highest-impact invasive species prioritized by Rockwell-Postel et al. (2020) are projected to find suitable habitat in Columbia County by mid-century: Bur chervil (*Anthriscus caucalis*), large-flower primrose-willow (*Ludwigia grandiflora*), and elmleaf blackberry (*Rubus ulmifolius*). Similar in appearance to the related poison hemlock (*Conium maculatum)*, bur chervil invades moist and disturbed ditches, meadows, open forests and pastures. Currently present in the western US, and detected in South Carolina, it has likely spread as a crop contaminant. Large-flower primrose-willow is an emergent, aquatic perennial, already detected in NYS, that is able to quickly colonize large areas in aquatic and riparian areas and form dense mats, creating anoxic conditions.

Elmleaf blackberry is a brambly shrub, present in several western states, that forms dense thickets in pasture.

3.4 Trees

Trees are important natural and cultural resources at MAVA, providing habitat for a myriad of species, performing vital ecosystem services, and comprising a key part of the cultural landscape. Climate change is projected to alter the suitable geographic range of tree species, as well as the ranges of key forest pests and pathogens. The USFS Climate Change Atlas has modeled suitable habitat for tree species in the eastern US under climate projections representing low (RCP4.5) and highest (RCP8.5) emission pathways for the coming century (Peters et al. 2020). This effort included a migration component of species colonization potential, as well as additional disturbance and biological factors to help project tree responses to climate change scenarios. The model predicts a species ability to cope with projected change based on estimated change in habitat suitability in a region, combined with the species adaptability and abundance in that region. Of 63 tree species that have been documented to occur at MAVA, 40 species were included in this model.

Of these 40 species, 12 (30%) are projected to decrease in habitat suitability in the park region by 2100 under both low and high climate change scenarios, while 9 species (23%) are projected to have increased habitat suitability, and 19 species (48%) showed either no change or mixed results (USFS 2021). After including measures of species abundance and adaptability, model results predict that roughly 1/3 of tree species currently occurring in MAVA are capable of adapting to projected climate change in the region by 2100, while another 1/3 of park tree species are less capable of adapting. These species are listed below. The model also predicted tree species which do not currently occur at MAVA but are likely expand their range into the park region by 2100. Two species of importance to cultural landscape features at the park (American sycamore and black locust) are predicted to have capability to adapt to changing climate at the park, while another important species (Eastern white pine) is predicted to have poor capability. Likewise, one dominant species in the park's southern swamp (red maple) is predicted to have capability to adapt, while two other dominant species in that habitat (slippery elm and green ash) are predicted to have poor capability.

MAVA Tree Species with Capability to Adapt to Changing Climatic Conditions (USFS 2021)

- Boxelder (*Acer negundo*)
- Red maple (*A. rubrum*)
- Silver maple (*A. saccharinum*)
- Sugar maple (*A. saccharum*)
- Bitternut hickory (*Carya cordiformis*)
- Pignut hickory (*C. glabra*)
- Shagbark hickory (*C. ovata*)
- American beech (*Fagus grandifolia*)
- White Ash (*Fraxinus americana*)

- Eastern red-cedar (*Juniperus virginiana*)
- Hophornbeam (*Ostrya virginiana*)
- American sycamore (*Platanus occidentalis*)
- Eastern cottonwood (*Populus deltoides*)
- Black cherry (*Prunus serotina*)
- White oak (*Quercus alba*)
- Scarlet oak (*Q. coccinea*)
- Northern red oak (*Q. rubra*)
- Black oak (*Q. velutina*)
- Black locust (*Robinia pseudoacacia*)
- American basswood (*Tilia americana*)
- American elm (*Ulmus americana*)

MAVA Tree Species with Poor Capability to Adapt to Changing Climatic Conditions (USFS 2021)

- Balsam fir (*Abies balsamea*)
- Serviceberry (*Amelanchier spp.)*
- Yellow birch (*Betula alleghaniensis*)
- Sweet birch (*B. lenta*)
- Paper birch (*B. papyrifera*)
- Gray birch (*B. populifolia*)
- American hornbeam (*Carpinus caroliniana*)
- Flowering dogwood (*Cornus florida*)
- Green ash (*Fraxinus pennsylvanica*)
- Eastern larch (*Larix laricina*)
- Red pine (*Pinus resinosa*)
- Eastern white pine (*P. strobus*)
- Quaking aspen (*Populus tremuloides*)
- Pin cherry (*Prunus pensylvanica*)
- Swamp white oak (*Quercus bicolor*)
- Pin oak (*Q. palustris*)
- Black willow (*Salix nigra*)
- Eastern hemlock (*Tsuga canadensis*)

- Slippery elm (*Ulmus rubra*)

New Tree Species Projected to Migrate into Columbia County, NY by 2100 (USFS 2021)

- Pawpaw (*Asimina triloba*)
- Mockernut hickory (*Carya alba*)
- Hackberry (*Celtis occidentalis*)
- Eastern redbud (*Cercis canadensis*)
- Common persimmon (*Diospyros virginiana*)
- Sweetgum (*Liquidambar styraciflua*)
- Tulip poplar (*Liriodendron tulipifera*)
- Blackgum (*Nyssa sylvatica*)
- Shortleaf pine (*Pinus echinate*)
- Table Mountain pine (*P. pungens*)
- Loblolly pine (*P. taeda*)
- Virginia pine (*P. virginiana*)
- Southern red oak (*Quercus falcata*)
- Blackjack oak (*Q. marilandica*)
- Willow oak (*Q. phellos*)
- Post oak (*Q. stellate*)

3.5 Cultural Resources

The park contains many important cultural resources potentially impacted by climate change. These include:

- three historic structures (the Lindenwald Mansion, the South Gatehouse, the 1843 Farm Cottage);
- four archeological sites (the Lindenwald South Native American Site, the North Field Native American Site, the Lindenwald Estate Site, and the North Gatehouse and Dump site) and five potential archeological sites (the red hillside barn site, the black hay barn site, the Van Alstyne/Van Ness stone house site, the John Utley Native American Site, and the Ancient campsite);[1]

[1] The Stockbridge-Munsee Mohican Tribe considers the entire park site to be a Native American archeological site (N. Allison, personal communication 10/21/20).

- six vegetation features (the wooded escarpment, a historic sycamore tree, the front lawn, the front circular garden area, the locust allee, and the historic pine row and grove);
- two agricultural features (the north orchard woodlot—currently pending restoration—and the agricultural fields);
- two historic views (the View of the Catskill Mountains from the Mansion, and the View of the Mansion from the Old Post Road);
- four constructed circulation features (the Entry Drive, the Old Post Road trace, the circular pedestrian path, and the historic lower farm road);
- two constructed water features (Upper Pond and historic ditch traces);
- and two additional constructed features (the Van Ness monument and the historic well cap).

An understanding of the nature and extent of expected impacts on cultural resources at MAVA will help park managers incorporate these impacts into management planning. Expected impacts will occur due to rising temperatures, increased rainfall and extreme weather events, higher relative humidity, and altered seasonality and phenology, in addition to increased freeze/thaw cycles and increased seasonal drought and flooding. These climatic changes will drive shifts in species occurrence, and also patterns of pollution and development, which will cause further impacts to park resources. A detailed table of climate change related impacts to cultural resources can be found in the NPS Cultural Resources Climate Change Strategy (Rockman et al. 2016). Key climate-related impacts from that strategy are summarized below.

3.5.1 Key climate-related impacts to archeological resources include:

Physical damage, disruption of archeological deposits and soil structure, loss of artifacts in flooding, changes to site soil chemistry, accelerated deterioration of artifacts, more rapid decay of organic materials, increased mold, and increased corrosion of metals.

3.5.2 Key climate-related impacts to buildings and constructed landscape features include:

Direct wind or water damage, increased cracking and deterioration, increased damage to foundations, erosion of soil supporting or surrounding foundation, increased moisture absorption by wood, brick and porous materials, more rapid decay of wood and organic materials, increased activity of termites and other insect pests of wood structures, increased demand for air conditioning[2] and modern drainage systems, and damage to pipes from temperature swings.

3.5.3 Key climate-related impacts to vegetation features include:

Changes in vegetation patterns and species including decline or disappearance of culturally significant species, heat or water stress on significant vegetation, damage to or loss of significant plants particularly trees, loss of synchronicity between species, loss of pollinators and reduced plant

[2] Adequate air conditioning is of particular concern for the protection of historic building fabric (Margaret Breuker, personal communication, 10/08/21).

fertility in historic agricultural landscapes, altered agricultural and maintenance practices due to changes in water supply, increased soil erosion, and decreased soil fertility.

3.5.4 Key climate-related impacts to views include:

Changes in vegetation patterns and species including decline or disappearance of common canopy tree species, increases in invasive species including pest species, changes in agricultural practices and cultivated species, altered landscape due to changes in phenology, damage to or loss of landscape features from wind/storm/flooding/drought damage, and increased development in viewshed.

3.6 Recommendations

Understanding climate change and incorporating future climate scenarios into park planning and management will be essential for preserving the natural and cultural resources at MAVA in the 21st century. The following recommendations for monitoring, planning and management are included to help the park face this challenge.

3.6.1 Outreach

Tell the story of climate change at the park. Using information from this report and on-site monitoring, the park can help the public understand the impacts of climate change on park natural and cultural resources.

3.6.2 Climate monitoring and forecasting

An on-site **weather station** would provide site-specific data to inform management of natural and cultural resources and agricultural operations. Weather data useful for management of the historic mansion include rainfall, barometric pressure, differential pressures (basement, first and second floor) referencing exterior, wind speed and direction, and possibly solar radiation (Margaret Breuker, personal communication, 7/23/21). The Network for Environment and Weather Applications 3.0 (see Appendix D) provides tailored output for agricultural support for farms using on-site weather stations from supported vendors.

Climate **forecasting** tools (such as the NWS Climate Prediction Center; see Appendix D) provide long-range forecasting to help land managers and farmers manage climate risk, including frost, flooding and drought.

3.6.3 Monitoring key species

An annual detection survey for key **invasive exotic species** in all habitats, including agricultural systems, provides essential information to enable rapid response before new species become established. Regional monitoring networks can provide information on new species moving into the area (see Appendix D).

Periodic monitoring of **tree health** in cultural landscape areas, the restored orchard, and the Southern Swamp would detect emerging tree health issues from climate and other stressors. The NPS Northeast Temperate Network (https://www.nps.gov/im/netn/index.htm) is a useful resource for tree health monitoring.

Monitoring **phenology** of key park species would provide a concrete record of change at the park to engage visitors and volunteers. The USA National Phenology Network (https://www.usanpn.org/) provides information and support for phenology monitoring.

Monitoring **bee abundance** in farm fields using bee bowls or direct observation could provide useful information on the status of these key pollinators. The US National Native Bee Monitoring Research Coordinating Network (https://www.usnativebees.com/) provides information and support for bee monitoring.

3.6.4 Agriculture

Maintaining use of best management practices to increase **soil organic matter** will maintain or improve soil infiltration and water holding capacity.

Maintaining or enhancing use of best management practices that minimize the use of fertilizer and pesticides will protect **water quality** in Kinderhook Creek.

Maintaining or enhancing a **diversified production system**, with diversity and integration of crops, livestock and wildlife, will increase adaptive capacity.

Maintaining or enhancing farm **irrigation** system will assist with summer drought conditions. Existing farm ponds should be assessed for contaminants to determine suitability for water storage and irrigation.

Selection of **crop and livestock species, cultivars and breeds** that can tolerate increased summer heat, or that can benefit from a longer growing season, will increase adaptive capacity. A longer season may also allow greater opportunity for enhancing soil with winter cover crops.

Maintaining or enhancing livestock opportunities for **shade and shelter**, will increase adaptive capacity.

Crop **insurance** policies may help buffer risk from changing climate.

3.6.5 Orchard

Careful consideration of **placement** of new plantings for frost protection, and **selection of cultivars** with frost and drought resistance can enhance adaptive capacity. **Coverings or windbreaks** may protect fruit trees from spring frost, and **mulch** can insulate root systems.

3.6.6 Planning and Management

Incorporating **future climate scenarios** into mid- and long-term park planning and management documents, including maintenance of interior micro-climate in historic buildings and land management for areas at-risk for flooding, will help the park adapt to the unprecedented challenge of climate change.

Maintaining or enhancing **shade trees** in key locations can provide shaded areas to enhance the comfort of park visitors.

For new plantings, choosing tree species that have **capacity to adapt** to changing climate at the park (see Section 3.4), while also maintaining cultural and historical aesthetics, can enhance the cultural landscape.

Development of a **Rapid Response Plan** to promptly eradicate newly detected infestations of priority invasive species will improve the park's ability to respond quickly. Regional monitoring networks such as the Capital Region PRISM can provide information on new species moving into the area (see Appendix D).

Maintaining and enhancing **habitat connectivity** across park boundaries provides opportunities for species migration.

Evaluation and maintenance of park **drainage** systems, particularly those on the lower terrace and near the ponds, should consider future climate scenarios.

Maintaining and enhancing **streamside buffers** along Kinderhook Creek will aid erosion control and protection of water quality in the creek.

3.6.7 Archeology

Areas at-risk for flooding (see Figure 9) should be prioritized for **regular archeological monitoring**.

3.6.8 Views

Photo-monitoring of key views provides a visual record and baseline to document change within the park viewshed. This visual record of change at the park could be used to engage visitors and volunteers.

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Appendix A. Climate Averages, Trends and Projections for Martin Van Buren NHS

Table A-1. Historical average temperatures and trends for Martin Van Buren NHS (Gonzalez et al. 2018).

Time period	1971–2000 Mean (ºC) ± SD	1895–2010 Trend (ºC/century) ± SE	1950–2010 Trend (ºC/century) ± SE
Annual	8.9 ± 0.7	0.3 ± 0.2	0.5 ± 0.6
December–February	−3.6 ± 1.6	0.7 ± 0.5	0.7 ± 1.5
March–May	8.2 ± 1.1	0.3 ± 0.3	1.1 ± 0.7
June–August	20.7 ± 0.7	0.2 ± 0.2	0.6 ± 0.4
September–November	10.2 ± 0.9	−0.1 ± 0.3	−0.1 ± 0.7
January	−5.3 ± 2.8	−0.5 ± 0.8	0.1 ± 2.3
February	−3.7 ± 2.6	1.6 ± 0.8 *	0.5 ± 2.5
March	1.8 ± 1.9	0.6 ± 0.6	1.7 ± 1
April	8.1 ± 1.5	0.6 ± 0.4	0.8 ± 1.1
May	14.6 ± 1.4	−0.2 ± 0.4	0.7 ± 0.9
June	19.3 ± 1.1	0.3 ± 0.3	0.5 ± 0.7
July	21.9 ± 0.9	−0.2 ± 0.2	0.1 ± 0.6
August	20.9 ± 0.9	0.4 ± 0.3	1.1 ± 0.7
September	16.3 ± 1	−0.4 ± 0.4	1 ± 1
October	9.8 ± 1.5	−0.7 ± 0.5	−1.8 ± 1.1
November	4.4 ± 1.5	0.8 ± 0.4 *	0.4 ± 0.9
December	−1.7 ± 2.6	0.7 ± 0.6	1.5 ± 1.4

SD = standard deviation.

SE = standard error.

* denotes statistical significance at $p \leq 0.05$.

Table A-2. Projected temperature increases (mean ºC ± SD) for 2000 to 2100 under four emission scenarios at Martin Van Buren NHS, from the average of all available general circulation model projections used for IPCC (2013; Gonzalez et al. 2018).

Time Period	Reduced – RCP2.6	Low – RCP4.5	High – RCP6.0	Highest – RCP8.5
Annual	1.9 ± 0.8	3.1 ± 0.9	3.5 ± 0.9	5.4 ± 1.1
December–February	2.2 ± 1	3.5 ± 1.2	3.9 ± 1.1	5.7 ± 1.4
March–May	1.7 ± 0.8	2.6 ± 1.4	3.2 ± 1	4.6 ± 1.6
June–August	1.8 ± 0.9	2.9 ± 1	3.6 ± 1	5.5 ± 1.3
September–November	1.9 ± 0.8	3.3 ± 1.7	3.5 ± 1	5.7 ± 2.1
January	2.2 ± 1.3	3.7 ± 1.6	3.9 ± 1.1	6 ± 1.7
February	2.1 ± 1.3	3.2 ± 1.3	3.8 ± 1.4	5.5 ± 1.3
March	1.8 ± 1.1	2.6 ± 1.7	3.2 ± 1.4	4.6 ± 1.8
April	1.7 ± 1	2.7 ± 1.5	3.3 ± 1.1	4.6 ± 1.6
May	1.6 ± 0.8	2.5 ± 1.3	3.1 ± 0.8	4.5 ± 1.5
June	1.6 ± 0.8	2.6 ± 1.2	3.2 ± 0.9	4.8 ± 1.3
July	1.8 ± 0.9	3 ± 1.1	3.7 ± 1.1	5.6 ± 1.4
August	1.9 ± 1	3.3 ± 1.2	3.8 ± 1.2	6.1 ± 1.6
September	1.9 ± 1	3.4 ± 1.6	3.8 ± 1.2	6.1 ± 2.1
October	1.8 ± 0.9	3.2 ± 1.9	3.4 ± 1.1	5.7 ± 2.3
November	1.9 ± 0.9	3.2 ± 1.8	3.4 ± 0.9	5.3 ± 2.2
December	2.2 ± 1.1	3.6 ± 2	3.8 ± 1.2	5.7 ± 2.1

RCP = representative concentration pathway.

SD = standard deviation.

Table A-3. Historical average precipitation totals and trends for Martin Van Buren NHS (Gonzalez et al. 2018).

Time period	1971–2000 Mean (mm) ± SD	1895–2010 Trend (%/century) ± SE	1950–2010 Trend (%/century) ± SE
Annual	1028 ± 154	13 ± 5 *	37 ± 16 *
December–February	191 ± 56	9 ± 6	5 ± 17
March–May	271 ± 75	15 ± 8	25 ± 26
June–August	308 ± 71	6 ± 8	54 ± 20 **
September–November	258 ± 72	24 ± 8 **	53 ± 22 *
January	68 ± 40	11 ± 14	20 ± 44
February	55 ± 27	−15 ± 11	−16 ± 27
March	72 ± 29	8 ± 12	43 ± 27
April	88 ± 37	16 ± 11	12 ± 31
May	111 ± 50	20 ± 14	23 ± 41
June	104 ± 53	13 ± 12	70 ± 31 *
July	96 ± 40	4 ± 13	60 ± 34
August	108 ± 43	1 ± 13	33 ± 35
September	89 ± 47	12 ± 12	46 ± 28
October	88 ± 41	35 ± 16 *	93 ± 43 *
November	81 ± 34	26 ± 11 *	15 ± 24
December	69 ± 38	22 ± 13	3 ± 37

SD = standard deviation.

SE = standard error.

* denotes statistical significance at $p \leq 0.05$.

** denotes statistical significance at $p \leq 0.01$.

Table A-4. Projected precipitation changes (mean % ± SD) for 2000 to 2100 under four emission scenarios at Martin Van Buren NHS, from the average of all available general circulation model projections used for IPCC (2013; Gonzalez et al. 2018).

Time Period	Reduced – RCP2.6	Low – RCP4.5	High – RCP6.0	Highest – RCP8.5
Annual	7 ± 5	10 ± 5	11 ± 6	15 ± 7
December–February	9 ± 9	16 ± 9	20 ± 9	27 ± 13
March–May	8 ± 7	11 ± 7	13 ± 7	19 ± 7
June–August	7 ± 8	10 ± 9	6 ± 9	10 ± 12
September–November	4 ± 7	5 ± 8	7 ± 6	7 ± 10
January	12 ± 19	20 ± 17	22 ± 15	34 ± 22
February	8 ± 12	16 ± 15	18 ± 12	26 ± 14
March	7 ± 12	13 ± 9	14 ± 11	20 ± 12
April	9 ± 10	12 ± 14	14 ± 11	20 ± 15
May	9 ± 15	9 ± 12	12 ± 14	16 ± 11
June	8 ± 12	10 ± 13	10 ± 15	11 ± 15
July	7 ± 13	7 ± 12	3 ± 14	6 ± 15
August	7 ± 13	13 ± 17	7 ± 12	13 ± 25
September	4 ± 10	6 ± 14	7 ± 12	4 ± 15
October	2 ± 16	1 ± 16	0 ± 13	6 ± 20
November	5 ± 8	7 ± 10	15 ± 12	12 ± 13
December	9 ± 12	14 ± 10	21 ± 16	25 ± 17

RCP = representative concentration pathway.

SD = standard deviation.

Appendix B. Watch List of Invasive Species for Columbia County, NY

Table B-1. Watch list of invasive exotic plants potentially capable of expanding range into Columbia County, NY by mid-century (Allen and Bradley 2019, Rockwell-Postel et al. 2020). See text for details. Information describing many of these species can be found at the website of the Invasive Plant Atlas of the US (https://www.invasiveplantatlas.org/).

Latin name	Common name	Lifeform	Ecological Impact	Agricultural Systems
Ludwigia grandiflora	large-flower primrose-willow	Aquatic, subshrub	High	Present
Aegilops (ovata) geniculata	ovate goatgrass	Graminoid	Low	Present
Avena sterilis	animated oat	Graminoid	Low	Present
Ehrharta erecta	panic veldtgrass	Graminoid	High	Not present
Festuca (Schedonorus) pratensis	meadow fescue	Graminoid	High	Present
Festuca brevipila	hard fescue	Graminoid	Medium	Not present
Gastridium phleoides	nit grass	Graminoid	Unknown	Not present
Hemarthria altissima	limpograss	Graminoid	High	Present
Oplismenus hirtellus	basketgrass	Graminoid	Medium	Not present
Phyllostachys aurea	golden bamboo	Graminoid, Shrub	Low	Present
Urochloa distachya	tropical signalgrass	Graminoid	Unknown	Not present
Ventenata dubia	North Africa grass	Graminoid	High	Not present
Achyranthes japonica	Japanese chaff flower	Forb/Herb	Medium	Present
Alyssum murale	yellowtuft	Forb/Herb	Medium	Not present
Anthriscus caucalis	bur chervil	Forb/Herb	High	Not present
Asclepias curassavica	bloodflower milkweed	Forb/Herb, Subshrub	Medium	Present
Bellardia trixago	Mediterranean linseed	Forb/Herb	Medium	Not present
Canna indica	indian shot	Forb/Herb	Unknown	Not present
Cardaria pubescens	hairy whitetop	Forb/Herb	Medium	Present
Centaurea iberica	Iberian knapweed	Forb/Herb	Low	Present
Centaurea macrocephala	bighead knapweed	Forb/Herb	Unknown	Not present

Table B-1 (continued). Watch list of invasive exotic plants potentially capable of expanding range into Columbia County, NY by mid-century (Allen and Bradley 2019, Rockwell-Postel et al. 2020). See text for details. Information describing many of these species can be found at the website of the Invasive Plant Atlas of the US (https://www.invasiveplantatlas.org/).

Latin name	**Common name**	**Lifeform**	**Ecological Impact**	**Agricultural Systems**
Euphorbia esula	leafy spurge	Forb/Herb	High	Present
Euphorbia oblongata	eggleaf spurge	Forb/Herb	Unknown	Not present
Kniphofia uvaria	redhot poker	Forb/Herb	Unknown	Not present
Leontodon taraxacoides	lesser hawkbit	Forb/Herb	Low	Present
Liriope spicata	creeping liriope	Forb/Herb	Unknown	Not present
Lotus pedunculatus	big trefoil	Forb/Herb	Medium	Present
Mosla dianthera	miniature beefsteakplant	Forb/Herb	Unknown	Not present
Murdannia keisak	wartremoving herb	Forb/Herb	Unknown	Not present
Peganum harmala	harmal peganum	Forb/Herb	Medium	Present
Sinapis arvensis	charlock mustard	Forb/Herb	Medium	Present
Thymelaea passerina	mezereon	Forb/Herb	Unknown	Not present
Trifolium hirtum	rose clover	Forb/Herb	High	Present
Tripleurospermum (perforatum) inodorum	scentless false mayweed	Forb/Herb	Low	Present
Youngia japonica	Oriental false hawksbeard	Forb/Herb	Low	Present
Alhagi maurorum	camelthorn	Shrub	Low	Present
Ardisia elliptica	shoebutton	Shrub, Tree	High	Not present
Cardaria chalepensis	lenspod whitetop	Shrub	High	Present
Centranthus ruber	red valerian	Subshrub	Medium	Present
Cestrum diurnum	day jessamine	Shrub, Tree	Medium	Present
Cunninghamia lanceolate	Chinese fir	Tree	High	Not present
Cytisus striatus	striated broom	Shrub	Medium	Not present
Dalbergia sissoo	Indian rosewood	Tree	Medium	Present
Daphne laureola	spurgelaurel	Shrub, Tree	Medium	Not present

Table B-1 (continued). Watch list of invasive exotic plants potentially capable of expanding range into Columbia County, NY by mid-century (Allen and Bradley 2019, Rockwell-Postel et al. 2020). See text for details. Information describing many of these species can be found at the website of the Invasive Plant Atlas of the US (https://www.invasiveplantatlas.org/).

Latin name	Common name	Lifeform	Ecological Impact	Agricultural Systems
Hibiscus tiliaceus	sea hibiscus	Shrub, Tree	Low	Present
Mahonia bealei	Beale's barberry	Shrub	Medium	Not present
Nandina domestica	sacred bamboo	Shrub	Medium	Not present
Pinus pinaster	maritime pine	Tree	High	Not present
Poncirus (Citrus) trifoliata	hardy orange	Shrub, Tree	Low	Present
Prunus laurocerasus	cherry laurel	Shrub, Tree	Medium	Present
Quercus acutissima	sawtooth oak	Tree	Medium	Not present
Rubus ulmifolius	elmleaf blackberry	Subshrub, Vine	High	Present
Sesbania punicea	rattlebox	Shrub, subshrub	Medium	Present
Tamarix africana	African tamarisk	Shrub, Tree	Medium	Not present
Tamarix aphylla	Athel tamarisk	Shrub, Tree	High	Not present
Tamarix chinensis	five-stamen tamarisk	Shrub, Tree	High	Not present
Vitex agnus-castus	lilac chastetree	Shrub, Tree	Low	Present
Araujia sericifera	white bladderflower; moth plant	Vine	Medium	Present
Hedera helix ssp. canariensis	Algerian ivy	Vine	Medium	Present
Hedera hibernica	Atlantic Ivy	Vine	Medium	Not present

Appendix C. Lindenwald Environmental Analysis by Margaret Breuker and David Bittermann, HACE, December 2018

Historical Background

On November 14th, 2018, Margaret Breuker, Senior Conservator and David Bittermann, Chief of Design and Preservation Planning for the Historic Architecture, Conservation and Engineering Center (HACE), visited the Lindenwald located in Kinderhook, New York. The purpose of the site visit was to address environmental concerns at the Main house in regard to the overall appearance and preservation of both the building and the collection.

In preparation for the site visit, an analysis of the actual interior microclimate (AIM) of the building was performed using data that has been meticulously collected by the Park for the year June 2017–May 2018 (Figure C-1). In order to determine possible causes for observed conditions of the building and collection, it is useful to understand not only the AIM, but the overall historic interior microclimate (HIM)—how the building was originally conceived and designed to function environmentally, subsequent changes, and how the collections placed in the home have withstood their environment overtime.

The original indoor microclimate of the building, was governed by two flanking chimneys that serviced interior rooms as designed from the two and a half story brick Georgian house built by Peter Van Ness in 1797.[i] The north addition, including the tower, was erected in 1849–1850 by Martin Van Buren's son, Smith Thompson Van Buren.[ii]

Historically, the home used a series of 16 fireplaces that serviced almost every room in the house (rooms 005, 006, 007, 011, 101, 104,106, 109, 111, 112, 114, 118, 201, 205, 209, and 210) for seasonal heating.[iii] In the summer, the house used natural ventilation from large windows on either side of the house, the large doors at the front and back of the house, and subsequently the tower allowed heat to rise up and out of the house.

An alteration to fireplaces in rooms 106 and 109 attributed to Van Buren ca. 1840 was similar to one described by A.J. Downing in The Architecture of Country Houses (Downing 1850, P. 470). This alteration brought fresh air into the room and then heated it. It consisted of creating a 4" opening in the exterior brick wall directly behind the fireplace. The 1985 Historic Structures Report goes on to describe it this way; "This opening allowed fresh air to pass into the base of the recessed area at the back of the firebox. This recessed area was covered with a metal plate, creating a chamber in which the fresh air was heated. The chamber was connected to a horizontal pipe 4" in diameter, which carried the heated air into the room through vents located on either side of the fireplace." [iv]

The fireplace flues in the north addition apparently never performed very well, most likely due to a rather convoluted path, as evidenced from Smith van Buren on November 22, 1849, "The flues from the wash-room, bed-room and bathroom have smoked so badly that the walls are entirely black, and the ceiling also of the bed-room destroyed." (Upton Papers, NYPL) [v]

A hot-air furnace was installed at some point during the 1850's and remained the main source of heat for the house until 1937 when the DeProsse family installed hot water heat.[vi]

Goal

This Environmental Assessment is part of the effort to evaluate and replace the failed HVAC system at Lindenwald, as part of PMIS# 211125. The goal of this assessment is to develop a clear understanding of the building's behavior relative to current climate conditions for guidance in formulating appropriate display environmental parameters. These parameters are determined using the ASHRAE Standards for Climate Control Potential in Buildings.[vii] The building's classification is determined by the construction material, physical envelope, geographic location, sea level elevation, and use.[viii]

Environmental data is collected by the Park using HOBO monitors and analyzed using Excel data sheets.

Psychometric Charts

This graphic visualization shows the relationship between various thermodynamic properties of water and air. Specific for a given elevation (or barometric pressure), the horizontal axis shows the dry-bulb temperature, and the right vertical axis is the humidity ratio, or moisture content of the air. The relative humidity is shown as lines curving upward from left to right, with the leftmost curve representing the saturation line (100% RH).

A psychometric chart can show data points with each depicting a parcel of air at a specific time; data points can also be colored to visualize differences from seasonal effects or before and after implementation of an environmental control strategy. The shaded yellow box is the Long-Term Range which is based upon recommendations from ASHRAE *Chapter 23 Museums, Galleries, Archives and Libraries, 2019.* The dotted red line depicts the short-term limits that would increase the risk of chemical decay; a rise in temperature, and mold germination; a rise in RH to 60%.

A building such as the home at Lindenwald can be classified as a Class III Building (uninsulated masonry, framed and sided walls, single glazed windows), with a Class C environmental control (prevent all high-risk extremes).[ix] A building with this classification in this location can be expected to uphold a target range within 25–65% RH year-round, with a temperature usually below 77°F, but not usually above 86°F.

The Main Hall, whose data is illustrated in the psychometric chart (Figure C-1), contains the critically important historic wallpaper in the home. The white and red dots represent single points of winter and summer data points. While the data for the room is largely in the Long Term Limit range, the summer data is at the upper end of the range, with little room for an increase in temperature or humidity that would result in an increased risk of both chemical decay and mold germination.

Endnotes

[i] William W. Howell. *Historic Structure Report, Architectural Data Section, Lindenwald,* Martin Van Buren National Historical Site. Kinderhook, New York, NPS, Vol. 1 June 1985. p.7.

[ii] Ibid.

[iii] Ibid. p.204.

[iv] Ibid. p.205.

[v] Ibid. p.207.

[vi] Ibid. p.210.

[vii] ASHRAE American Society of Heating, Refrigerating and Air Conditioning Engineers. 2019. Museums, galleries archives, and libraries. In ASHRAE Handbook: Heating, Ventilating, and Air-Conditioning Applications, Inch-pound ed., 23–24. 1–46. Atlanta, GA: ASHRAE. Issued also in a SI edition.

[viii] ASHRAE. Table 3 *Temperature and Relative Humidity Specifications for Collections*. 23.14 Atlanta, GA: ASHRAE. Issued also in a SI edition. 2019.

[ix] ASHRAE. Table 4 Classification of Climate Control in Buildings and Table 3 Temperature and Relative Humidity Specifications for Collections. 2019.

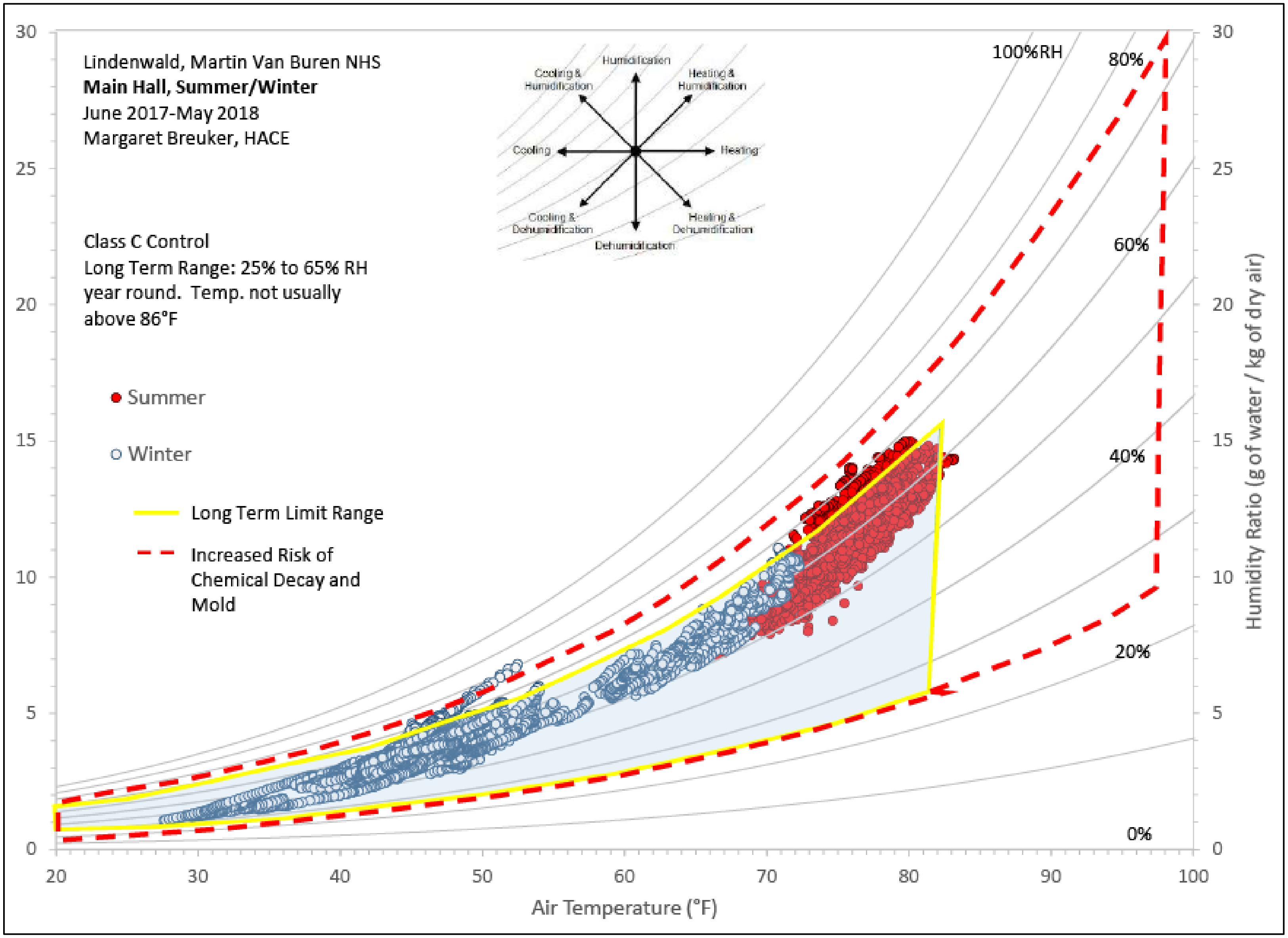

Figure C-1. Actual interior microclimate (AIM) within the Main Hall of the Lindenwald Mansion at Martin Van Buren NHS, June 2017–May 2018.

Appendix D. Resources for Climate Monitoring and Adaptation

Climate

The National Weather Service Climate Prediction Center (https:/www.cpc.ncep.noaa.gov/) provides long-range forecasts, drought monitoring and drought prediction maps, and climate hazard (temperature, precipitation, snow and wind) maps.

The Network for Environment and Weather Applications 3.0 (NEWA; https:/dev.newa.cornell.edu/). Revamped in 2021, this program provides localized weather summaries, soil temperature estimates (http://newa.cornell.edu/index.php?page=soil-temperature-map), degree day calculators (including calculators tracking the development of key pests and disease organisms), and support for apple, berry, grape and vegetable production. Farms which choose to purchase on-farm weather station from Rainwise Inc. or Onset can upload farm data for more tailored output, while data from other farms (including farms near MAVA) is also available for viewing.

The Northeast Regional Climate Center (NRCC; http://www.nrcc.cornell.edu/) provides climate data for the northeast states, including NY, as well as data for agriculture including maps of apple frost risk and grape bud hardiness.

The NYS Mesonet (http://www.nysmesonet.org/) provides maps and data of climate conditions, including solar radiation and soil temperature, from a network of 126 sensors across NY state.

The USDA Northeast Climate Hub (https://www.climatehubs.usda.gov/hubs/northeast) provides climate expertise, tools and opportunities for collaboration for land managers and forestry and agricultural operations in the northeast US.

Water Quantity

The First Street Foundation Flood Factor Model (https://firststreet.org/flood-factor/) provides an online mapping and visualization tool of flood probabilities for individual properties. This nationwide probabilistic model seeks to estimate fluvial (riverine), pluvial (rainfall), and coastal flood risk at the individual property level (3 m resolution) for baseline (1980–2010) climate conditions as well as for estimated future (2035 and 2050) climate conditions using 21 climate models associated with a low (RCP4.5) emission pathway.

The US Drought Monitor (https://droughtmonitor.unl.edu/) maps current, past and future projections of drought conditions across the US.

Phenology

The USA National Phenology Network (NPN; http://usanpn.org/) provides coordination, support and data visualization tools for monitoring and understanding phenological change.

Agriculture

Cornell University's Climate Smart Farming (CSF) Program (http://climatesmartfarming.org/) provides tools to help farmers adapt to climate change. Online tools include county-level data on current trends and future projections in temperature, precipitation and growing degree days, a cover crop planting scheduler tool, and a water deficit calculator.

See also the online resources listed previously under climate; several provide climate change tools specifically for agriculture.

Native species

Nature's Network (http://www.naturesnetwork.org/) is a collaborative project that seeks to "to identify the best opportunities for conserving and connecting intact habitats and ecosystems and supporting imperiled species to help ensure the future of fish and wildlife across the Northeast region."

The USFS Northern Research Station Climate Change Atlas (https://www.fs.fed.us/nrs/atlas/) provides maps and data showing potential changes in suitable habitat for eastern tree species, and potential change in abundance and range for eastern bird species.

The US National Native Bee Monitoring Research Coordinating Network (https://www.usnativebees.com/) is an effort to coordinate and support the monitoring of native bee populations in the US in support of native bee conservation.

Invasive species

Two regional Partnership for Regional Invasive Species Management (Prism) networks operate in the area. The Capital Region PRISM (https://www.capitalregionprism.org/) coordinates invasive species management in Columbia County, while the Lower Hudson PRISM (https://www.lhprism.org/) coordinates invasive management just south of the park, and provides useful information on emerging threats for detection monitoring.

The iMapInvasives portal (https://www.imapinvasives.org/), developed and hosted by NatureServe, is a tracking and visualization tool for invasive species in several regions including NY state.

The Invasive Plant Atlas of the US (https://www.invasiveplantatlas.org/) provides information, photos and distribution maps of invasive species of concern in the US.

The Northeast Regional Invasive Species and Climate Change (RISCC) Management Network (https://www.risccnetwork.org/) aims to improve understanding and share information on the compounding effects of invasive species and climate change in the northeast region.

The University of Georgia's Bugwood Center for Invasive Species and Ecosystem Health has created an Invasive Range Expander Listing Tool (https://www.eddmaps.org/rangeshiftlisting/). This tool projects the mid-century (2040–2060) range of known terrestrial invasive plant species in the US based on 13 climate models (Allen and Bradley 2016).

Adaptation

NPS has published Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service (https://irma.nps.gov/DataStore/Reference/Profile/2279647) to help park planners and managers incorporate adaptation into all facets of park planning and management.

The Northeast Climate Adaptation Science Center (CACS; https://necsc.umass.edu/) seeks to help natural and cultural resource managers apply future climate scenarios to decision-making.

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