Appendix I – Main Report References

Additional Climate References and Data Sources

National Oceanographic and Atmospheric Administration (NOAA) NWS data on historic temperature and precipitation for weather stations in and near Monroe County, NOAA Advanced Hydrologic Prediction Service quantitative precipitation estimates from radar data for historic storms, NOAA Atlas 14 point precipitation frequency estimates, and others.

Wisconsin and Minnesota state climatology office.

Wright, Daniel, Zhe Li and Eric Booth (2020) Using stochastic storm transposition to update rainfall intensity-duration-frequency (IDF) curves for the Coon Creek and West Fork Kickapoo watersheds. Report to NRCS- Wisconsin from University of Wisconsin- Madison.

Updated rainfall frequency analysis for current and future conditions in Wisconsin , developed by Daniel Wright at UW - Madison and available at the Wisconsin rainfall project web portal: https://her.cee.wisc.edu/the-wisconsin-rainfall-project/ .

University of Maryland Center for Environmental Science Analogous Climate tool: https://fitzlab.shinyapps.io/cityapp/ .

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Other helpful resources

A Look Back at Driftless Area Science to Plan for Resiliency in an Uncertain Future: Special Publication of the 11th Annual Driftless Area Symposium. Online at: https://www.tu.org/wp-content/uploads/2019/02/Driftless_Area_Science.pdf

Fourth National Climate Change Assessment, Midwest Chapter: https://nca2018.globalchange.gov/chapter/21/

Millenium Ecosystem Assessment on Environmental Services and Human Health: https://www.millenniumassessment.org/documents/document.357.aspx.pdf

Appendix II – Technical Teams

Technical/Expert Sub-Teams

Climate and Hydrological Modeling Sub-team

Team Lead: Robert Montgomery, PE, Consulting Engineer
Team Members: Joanne Kline, Conservation Strategies Group, LLC; Nick Miller, Director of Conservation Science, The Nature Conservancy; Prof. Daniel Wright, Dept. of Civil and Env. Engineering, UW-Madison
Team Advisor: Dr. Steve Vavrus, Nelson Institute for Env. Studies, UW-Madison

Flood Resilience and Infrastructure Sub-team

Team Lead: Joann Kline, Conservation Strategies Group, LLC
Team Members: Rob Montgomery, PE, Consulting Engineer; Nick Miller, Science Director, The Nature Conservancy; Danielle Shannon, Northern Institute of Applied Climate Science; Megan Duffy, Wisconsin DNR

Agricultural Sub-team

Team Lead: Christina Anderson, Climate Specialist, Wisconsin Land and Water
Team Members: Danielle Shannon, Northern Institute of Applied Climate Science; Pam Porter, WDNR; Emily Bruner, American Farmland Trust
Local Team Members: Jack Herricks, Monroe County Supervisor and farmer; Bill Halfman, UWEX

Forest Sub-team

Team Lead: Fred Clark, Executive Director, Wisconsin's Green Fire
Team Members: Stephen Handler, Northern Institute of Applied Climate Science; Todd Ontl, Northern Institute of Applied Climate Science; Brian Anderson, Wisconsin DNR, Division of Forestry Team Member; Greg Edge, Wisconsin DNR, Division of Forestry; Ann Calhoun, The Nature Conservancy, Wisconsin
Local Team Members / Advisors: Clint Gilman, WDNR Monroe County; Chad Ziegler, Monroe County Forestry and Parks Director; Charles Mentzel, Forester, U.S. DOD Fort McCoy; Brandon Bleuer, Forestry Division Manager, Ho-Chunk Nation Department of Natural Resources.

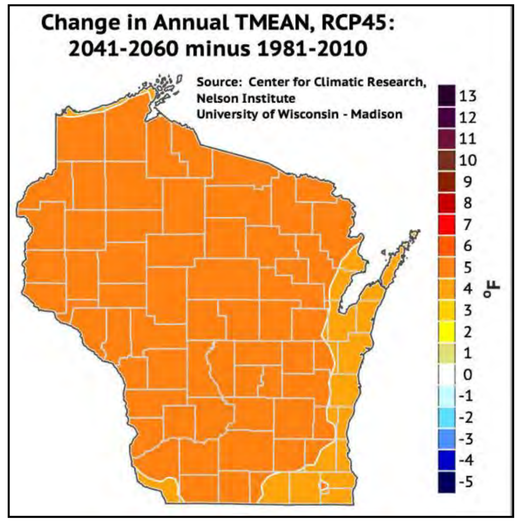
Appendix III – Climate Data

Organization of this appendix

This appendix provides background information and data analysis collected from sources that were used to develop the summary of climatic conditions relevant to the Monroe County project. It is arranged on a topic-by-topic basis with attachments containing additional information.

Climate Data prepared by the UW-Madison

The University of Wisconsin- Madison Nelson Institute Center for Climatic Research (CCR) has been conducting historic and future climate research and analysis for decades. The CCR is one of the lead participants in the **Wisconsin Initiative on Climate Change Impacts** (https://wicci.wisc.edu/). They have created an extensive series of statewide maps describing the historic changes in climate and rezoning rejections of climate future climate change, focusing on temperature and precipitation changes. These graphics and other information are available at: https://wicci.wisc.edu/wisconsin-climate-trends-and-projections/ . An example of one of the maps describing the increase expected in average annual temperature is shown here, and a complete set of the maps provided by CCR for the WICCI update project is included in **Attachment A** to this Appendix.

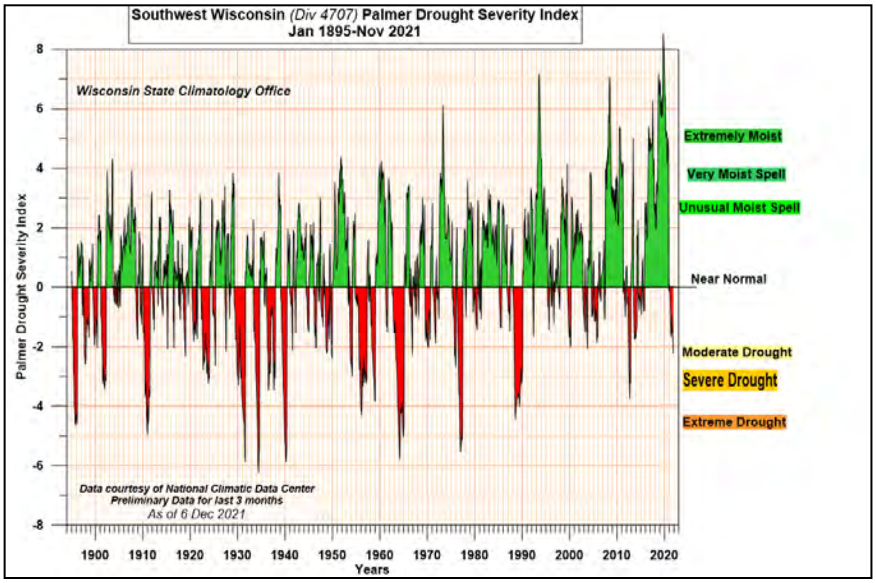


The **WICCI Climate Working Group** has issued the following conclusions from their updated research that will be presented in the WICCI assessment report update to be issued in 2022:

- The past two decades have been Wisconsin's warmest since accurate statewide records began in the 1890s
- Winters are warming more rapidly than any other season, and nighttime temperatures are rising more than daytime temperatures.
- By mid-century, the number of extremely hot days (90°F or higher) in Wisconsin is likely to triple, and the frequency of extremely warm nights (low temperature of 70°F or above) is projected to quadruple.
- The 2010s were Wisconsin's wettest decade on record by far, and 2019 was our state's wettest year.
- During the past decade, there were more than 20 daily rainfalls extreme enough to be considered "100-year events", meaning that, according to statistics based on historic climate data, they are expected to occur only once per century.
- Wisconsin will become wetter in the future, particularly during winter and spring, although we have less confidence in how rainfall amounts will change during summer.
- Extreme precipitation will probably continue to increase in the future, with very extreme rainfalls increasing the most.

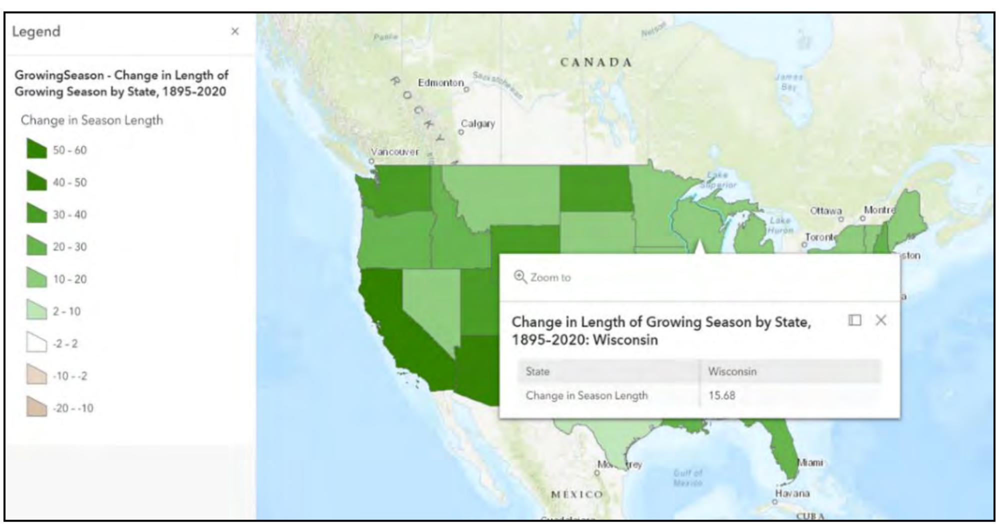
Moisture and drought, 1895 - 2021

Monroe County temperatures and precipitation have been increasing for decades. However, year to year conditions vary considerably. An illustration of this variability is the Palmer Drought Severity index, which is calculated using precipitation, temperature, and vegetative moisture model data. The figure below shows the Palmer drought severity index calculated from 1995 through 2021 by the NOAA national climatic data center. The index shows that recent years, particularly since 1990, have calculated soil moisture content significantly higher than in previous decades.



Changes in Growing Season

ESRI has developed several web-based mapping tools for evaluating climate and environmental issues. One of these is a viewer that lists changes in growing season on a statewide average basis. See: https://www.arcgis.com/apps/mapviewer/index.html?webmap=a35c325d7bf946b1bf038cea9ebbfeeb . this analysis indicates that from 1895 to 2020 the average growing season duration in Wisconsin has become 16 days longer. Monroe County growing season duration can be analyzed separately.

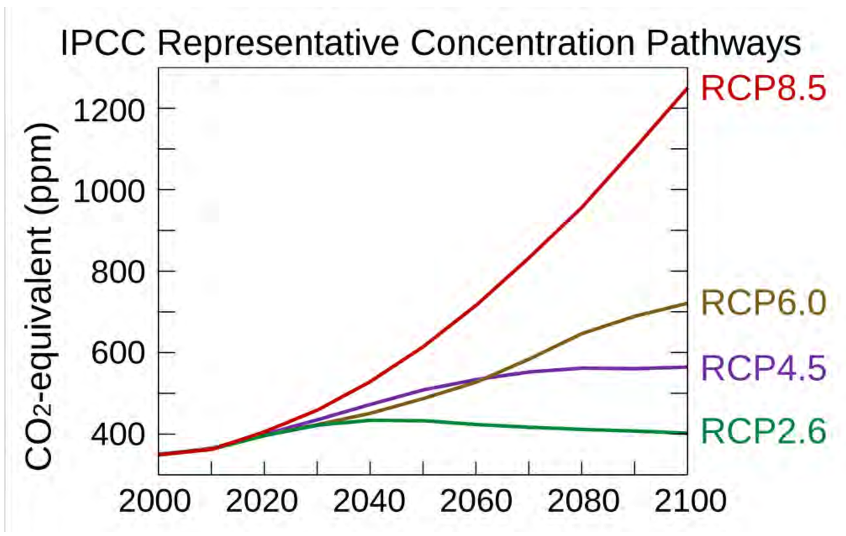


Emission Scenarios and Representative Concentration Pathways

Representative Concentration Pathways (RCPs) are part of the future conditions definitions that are used in climate model predictions. The Intergovernmental Panel on Climate Change has defined several RPCs that are used in many climate models. RPCs define the changes in the emission rate of greenhouse gases in the future. Climate models use these emissions in combination with sequestering by vegetation, solution in ocean water, energy balances, and many other complex factors to make projections of future climate conditions. Two of the RCP scenarios used in climate modeling are:

- RCP 4.5 is an "intermediate emissions scenario" that projects that carbon dioxide (CO2) emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100.
- RCP 8.5 is a "high emissions scenario" that projects little reduction in future greenhouse gas emissions.

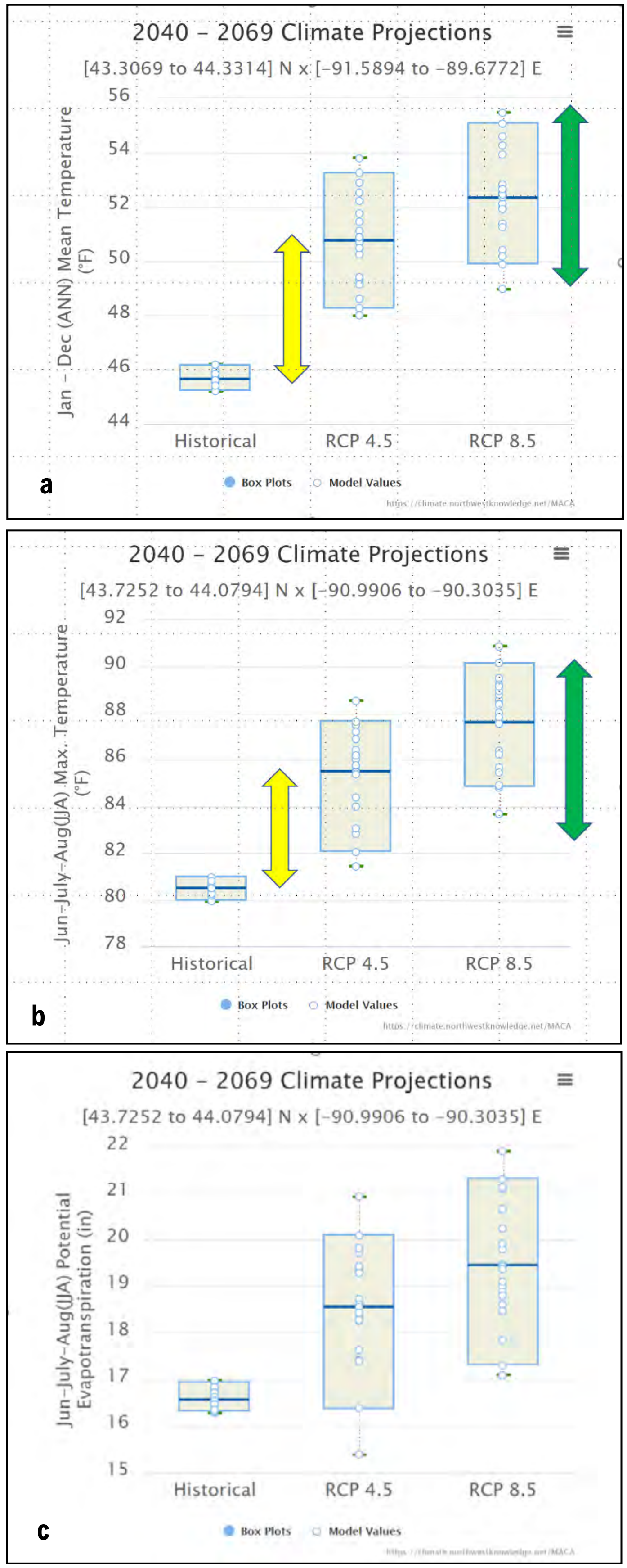
The figure below illustrates the CO2 equivalent atmospheric concentration changes from 2000 to 2100, for several RPCs.



Evaluating the significance and confidence of climate model predictions

Climate model predictions are based on multiple runs of multiple climate models, with the results often transformed to a finer spatial resolution using the techniques of physical and statistical downscaling. Conclusions on changes in climate are based on the compilation of these multiple model results. Useful insight on interpreting climate model predictions is provided by a web-based analysis package prepared by the University of California – Merced. This website allows comparison of individual model downscaling results for Specific locations. Background information and visualization tools are available at: https://climate.northwestknowledge.net/MACA/ . The analysis uses results from 20 global climate models using the coupled model intercomparison project 5 (CIMP5) data set for historical conditions, for RCP 4.5 and 8.5 GHG emission scenarios.

This visualization package was used to evaluate climate model predictions for Monroe County, summarize for several climate variables, below:



Annual mean temperature

The figure to the right (a) below shows results from 20 downscaled global model results for years 2040 – 2069 (open circles labelled model values), for two emission scenarios- RCP 4.5 and 8.5. This allows one to evaluate the significance of the magnitude of projected change by comparing the difference in the average (horizontal line) (yellow arrow) of the model results. The confidence of the projection can be evaluated by looking at the spread of individual model results (green arrow) in comparison with the magnitude of the average projected change (yellow arrow). In the case of annual average temperature projections, the projected change is significant (5 ° F on average), and confidence in the projection is high - model results are clustered around values much different than historical results.

June-July-August Maximum Temperature

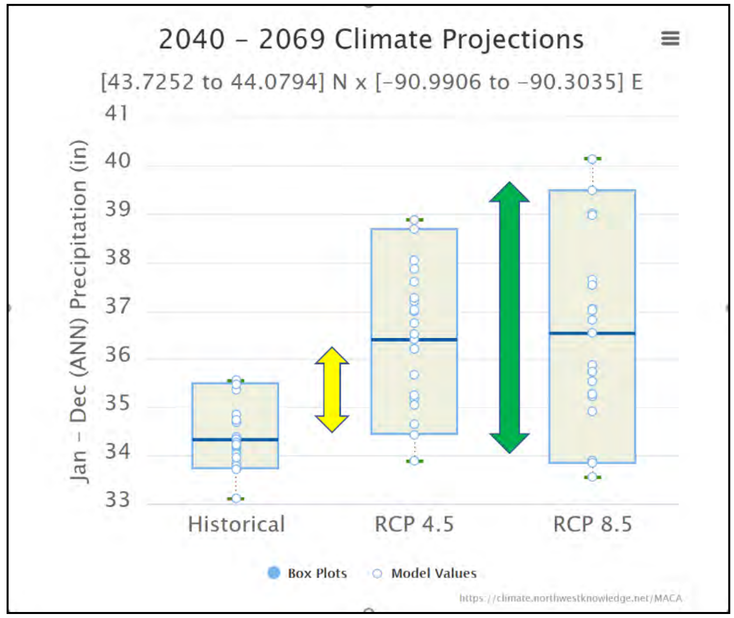
Figure (b) shows that the prediction of increases in maximum temperatures is one of the strongest and most consistent prediction of most climate models. In the case of June July August maximum temperatures in Monroe County, a significant increase (~4 °F) projected with high confidence.

June-July-August Potential Evapotranspiration

Predicted climate variables such as evapotranspiration, which are based on additional analyses using climate model predictions of temperature and precipitation as input, are less certain than the more basic climate variables. Summer potential evapotranspiration (c) in Monroe County is predicted to have a significant increase, projected with moderate confidence. This increase in evapotranspiration could result in decreases in soil moisture and higher incidence of drought conditions in the future.

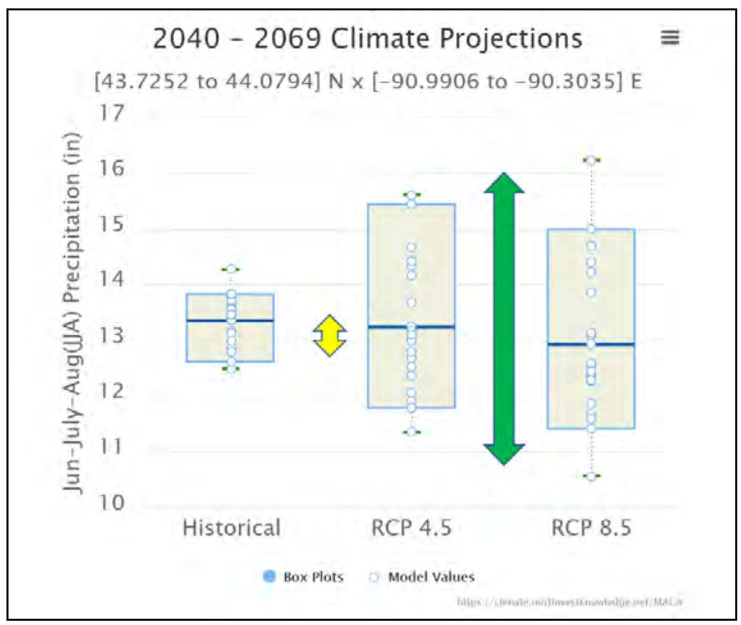
Annual Average Precipitation for Monroe County

In general, precipitation changes are less confidently predicted than temperature by climate models. In the case of Monroe County, annual average precipitation has a projected moderately significant increase (~2 in./yr.), with moderate confidence due to spread of individual model results.



June-July-August average precipitation

We have less confidence in predictions of how Monroe County average summer precipitation will change: The combination of model results together indicates slight change in future summer temperature, meaning low significance. Since individual model results variability is higher than the predicted change in the average prediction, we have low confidence in the predicted change. There is a large difference in model results both above and below the average modeled conditions, suggesting that significant changes are possible.



Location and tracks of extreme storms

Several storms have produced extraordinarily high rainfall in Wisconsin over the past several decades. Two of these storms affected Monroe County: the storm of August 28th, 2018, and the storm of August 19th, 2007. The 2018 storm tracked approximately east-west and had its highest intensity in the southern portion of Monroe County. The 2007 storm also tracked approximately east-west add had its highest intensity in Vernon County, along the Vernon County - Monroe County boundary.

The locations of these extreme storms could suggest that they are in some way related to topographic or other conditions in southernmost Monroe County. A recent analysis of the August 2018 storm led by Daniel Wright at the University of Wisconsin- Madison for the NRCS (https://crawford.extension.wisc.edu/files/2020/10/Rainfall-Analysis_UW-Madison-1.pdf) provides useful information relevant to this question. Part of this project included review of the most extreme precipitation events that have occurred in the past several decades in and near Wisconsin. The extreme storms were seen to occur throughout the state with no identifiable location concentration. Additional review with University of Wisconsin researchers indicates that any portion of Monroe County could be struck by an extremely large storm at some time in the future.

The tracks of the 10 largest storms and the UW-Madison report are included in **Attachment B** to this Appendix

Present and future storm rainfall data

Rainfall Depth and Duration

The “standard” reference for rainfall intensity-duration-frequency data is National Oceanographic and Atmospheric Administration (NOAA) Atlas 14. It is based on statistical analysis of weather observation station data through approximately 2011. The Atlas 14 rainfall data is used to design a wide variety of hydraulic structures, including storm sewers, bridge openings and culverts, as well as to analyze the frequency of other types of hydrologic events that cause environmental consequences such as soil erosion. The observation station records used in developing Atlas 14 often have more than 50 years of data. Because rainfall has become more extreme in recent years, the Atlas 14 predictions could underpredict rainfall depths for a particular return period.

To address this issue, Daniel Wright at the University of Wisconsin- Madison used more recently available NWS radar rainfall data and stochastic storm transposition in the RainyDay analysis package to create the most current extreme rainfall statistics Available for Wisconsin. This work was combined with future climate model data to estimate rainfall statistics for future conditions. Brief descriptions with further reference links for both analysis approaches are contained in **Attachment C** to this Appendix.

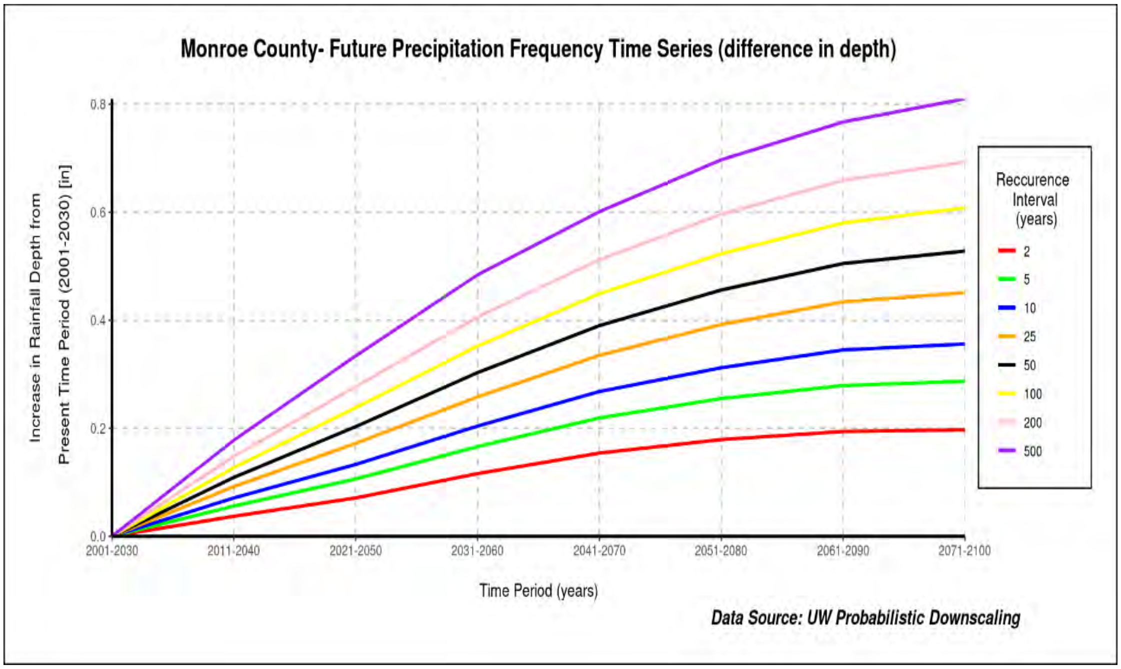
A summary of the results of this analysis for Monroe County is provided below.

Current conditions rainfall statistics for Monroe County based on the Rainy Day software analysis by Daniel Wright, available at https://her.cee.wisc.edu/the-wisconsin-rainfall-project/ . The average 24-hour duration rainfall depths, which are often used in hydraulic design calculations, are highlighted in blue.

Rainfall Depth, Duration and Frequency for Current (2021) Conditions in Monroe County, Wisconsin

Storm Duration, showing average, upper and lower bound	Rainfall depth (in inches) at return periods 2-year through 1000-year								
	2 years	5 years	10 years	25 years	50 years	100 years	200 years	500 years	1000 years
3-hr upper bound	1.99	2.6	3.11	3.9	4.56	5.37	5.96	8.06	11.96
3-hr average	1.94	2.51	2.99	3.66	4.21	4.81	5.43	6.49	7.57
3-hr lower bound	1.9	2.45	2.87	3.43	3.91	4.36	4.88	5.36	5.67
6-hr upper bound	2.46	3.24	3.91	4.96	5.69	6.78	8.36	10.79	13.38
6-hr average	2.41	3.12	3.74	4.63	5.35	6.12	7.11	8.74	9.85
6-hr lower bound	2.35	3.01	3.58	4.37	5.03	5.57	6.13	6.69	7.62
12-hr upper bound	2.6	3.42	4.14	5.17	6.16	7.25	8.68	11.17	13.18
12-hr average	2.55	3.3	3.94	4.88	5.67	6.58	7.54	8.96	10.11
12-hr lower bound	2.5	3.2	3.74	4.54	5.27	5.85	6.62	7.43	7.7
24-hr upper bound	2.89	3.81	4.56	5.74	6.76	7.93	9.21	11.56	13.32
24-hr average	2.83	3.69	4.39	5.39	6.25	7.15	8.07	9.55	10.73
24-hr lower bound	2.77	3.57	4.24	5.09	5.8	6.59	7.25	7.97	8.34
48-hr upper bound	3.31	4.32	5.18	6.51	7.51	8.98	9.95	12.47	14.06
48-hr average	3.24	4.19	4.97	6.14	7.06	8.06	8.97	10.51	11.74
48-hr lower bound	3.17	4.04	4.78	5.78	6.62	7.38	7.98	8.81	10.08
4-day upper bound	3.85	5.07	5.93	7.35	8.51	9.56	10.67	12.89	14.22
4-day average	3.75	4.89	5.74	6.97	7.93	8.86	9.78	11.18	12.18
4-day lower bound	3.68	4.74	5.52	6.63	7.46	8.24	9.06	9.81	10.36
10-day upper bound	4.45	5.75	6.72	8.17	9.5	10.66	12.06	15.62	18.29
10-day average	4.36	5.6	6.54	7.85	8.89	9.91	10.98	12.69	14.48
10-day lower bound	4.27	5.44	6.32	7.5	8.37	9.12	10	11	11.53

Increases and rainfall depth are projected into the future, using techniques discussed in the reference in Attachment C. A plot of these results for the low emissions RCP 4.5 scenario for Monroe County is shown below:



For interim planning purposes until more detailed analysis are conducted, suggested increases in 24-hour precipitation depth in year 2050 for use in the Monroe County project are listed below. The precipitation depth increases are approximate averages of results for the RCP 4.5 and 8.5 emission scenarios.

Interim Estimates of year 2050 24-hour rainfall depths for Monroe County

24-hour duration rainfall	**Return Period**		
	2-year	***10-year***	***100-year***
Current rain depth from Rainy Day, inches	2.8	4.4	7.2
Increase for 2050 conditions, inches	0.2	0.3	0.6
Interim 2050 precipitation depth, inches	3.0	4.7	7.8

<u>Rainfall Intensity</u>

Predictions of future rainfall intensity would be useful to evaluate the potential for increased soil erosion and other Land Management issues. Direct future climate model results do not provide detailed information on increased storm intensities but do indicate that extreme rainfall depths will increase, such as indicated in the future conditions rainfall data described above.

The updated Rainy Day current conditions intensity duration frequency data listed above provides guidance on current intensities. An evaluation of the rainfall intensity distribution of extreme storms was conducted by Daniel Wright and described in the UW Madison report to NRCS included in Appendix C. Figure 3 from that report, shown below, shows the rainfall accumulation rate for the ten largest storms in the rainfall database. Higher rainfall intensities are indicated by steeper data plots in the graphs for various storms. In addition to the record storms, design storm rainfall distributions are also shown. Two commonly used design storm distributions are also shown: the MSE4 distribution and the older SCS Type II distribution. Analysis described in the report indicates that the NRCS/SCS Type-II distribution yields a more intense peak hourly rainfall rate than all but one of the largest ten storms from the SST analysis, while the MSE4 storm is comparable to the "average" behavior of the ten storms.

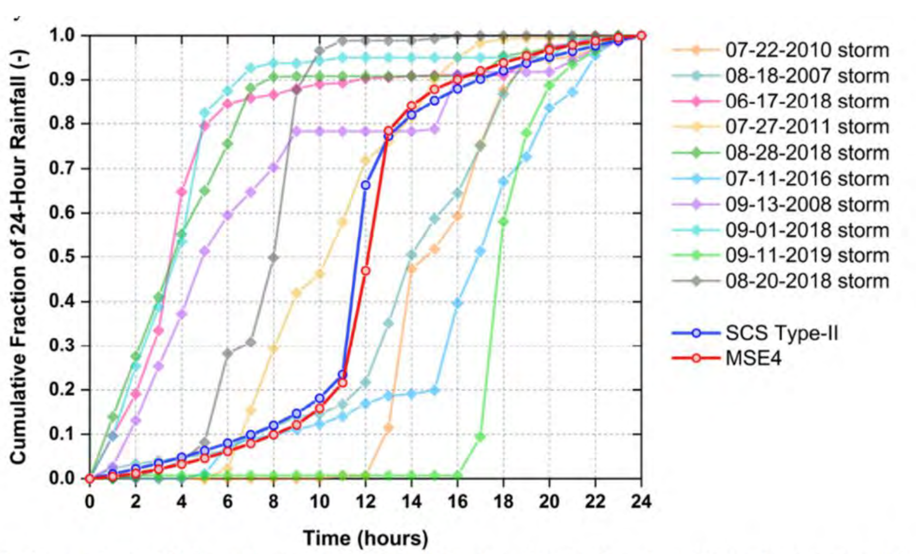


Fig. 3: Comparison of 24-hour dimensionless cumulative time distributions from the ten largest storms from the storm catalog used for the SST analysis. The NRCS/SCS Type-II and MSE4 distributions are also shown.

For interim purposes in analyzing extreme storm intensity, we suggest that the MSE4 distribution is an appropriate choice until additional analysis, particularly for more frequent and shorter duration storms, is available.

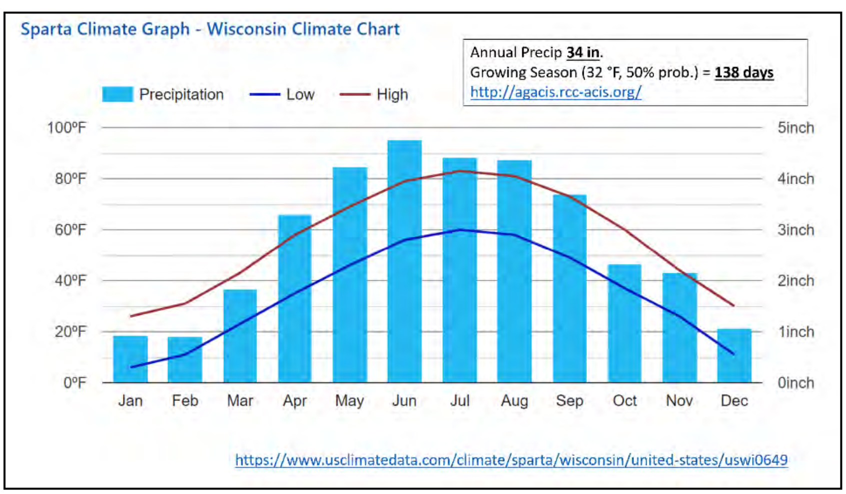
Climate analogue areas

Several areas in the United States currently have climate conditions similar to those projected for Monroe County under future conditions. Identification of these areas can be useful because they can illustrate agriculture forestry and land management practices that could be applicable to Monroe County in the future. A way to identify these climate analogue areas is included in a University of Maryland web -based analysis tool https://fitzlab.shinyapps.io/cityapp/ . This tool uses 12 different criteria to describe climate at various locations, including minimum and maximum temperature and total precipitation for winter, spring, summer, and fall. This information is combined with results from 27 different climate models to project analogous climate areas for two GHG emissions scenarios, for a target year of 2080. One scenario (RPC 8.5) assumes high current emissions to continue, and the other (RCP 4.5) assumes emissions peak mid-century and then decline. The low emissions scenario analysis indicates that the climate in Monroe County in 2080 will be similar to that which currently exists in Ottumwa, Iowa, located 220 miles southwest of Sparta. For the high emissions scenario, the current climate in Lansing, Kansas, 390 miles southwest of Sparta. These projections are certainly subject to some variance and potential error, but do give useful insight:

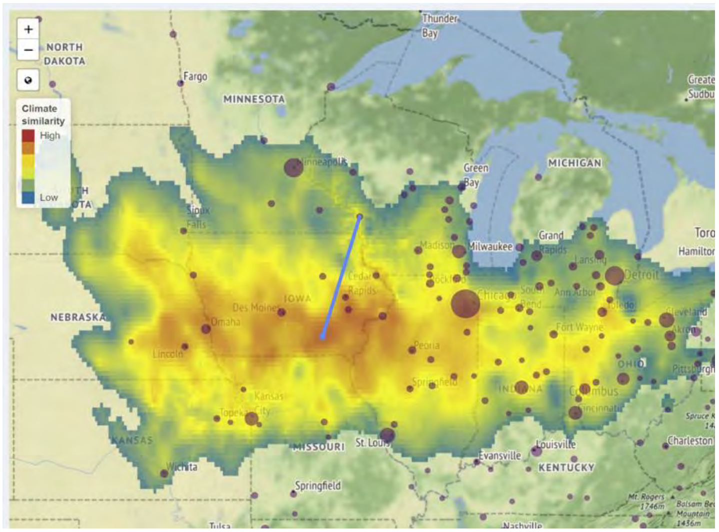
- Temperatures are higher in the identified analogous locations, and precipitation is similar but may have less rainfall in summer
- Agriculturally significant climate data is available for these locations, for example, the growing season at Ottumwa is more than a month longer than it is in Monroe County

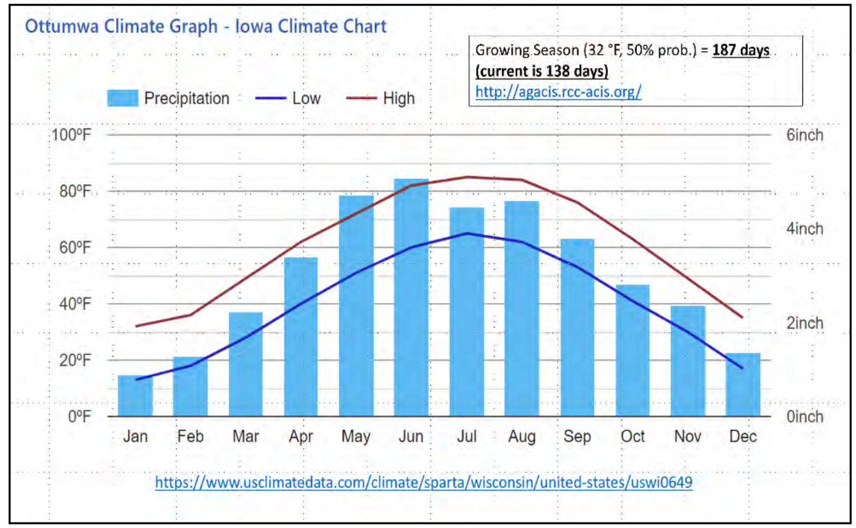
Note that the climate characteristics of these locations need to be carefully evaluated to understand potential agricultural and forestry implications.

The figures below illustrate the web tool results for future conditions in La Crosse WI, the closest available location to Monroe County. The figures include the analogous climate area locations and graphics illustrating current climate conditions at Sparta, Ottumwa, Iowa, and Kansas City. Web links to data sources are included in the figures.

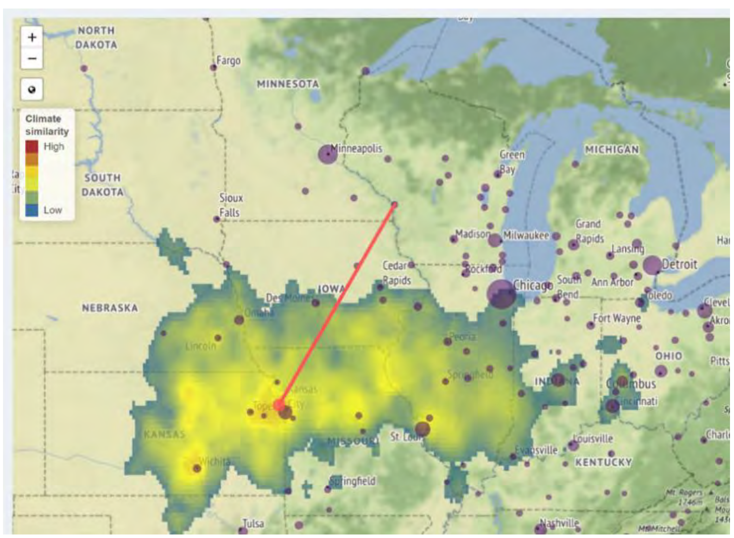


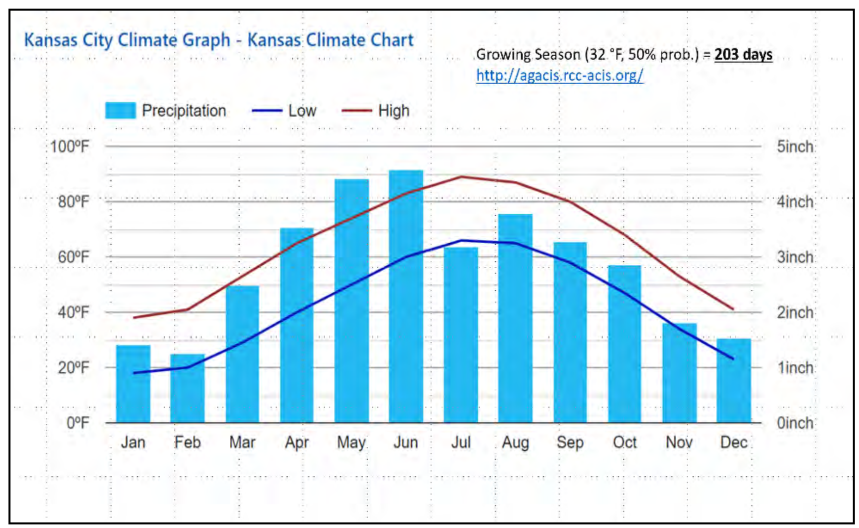
University of Maryland analysis results for emission scenario 4.5 at year 2080





University of Maryland analysis for emission scenario 8.5 at year 2080

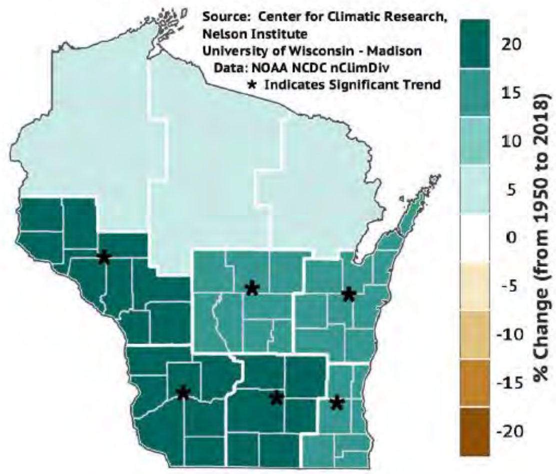




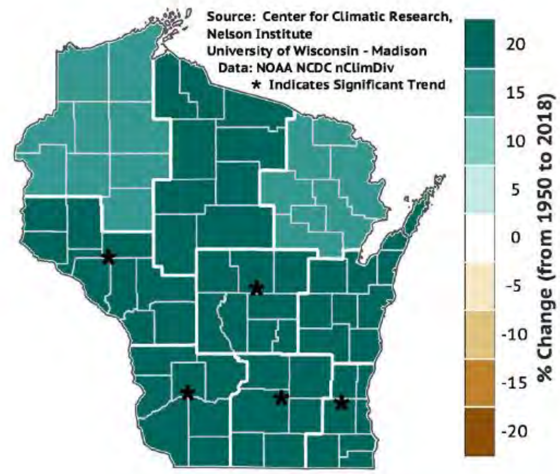
Attachment A

Climate Maps prepared by the University of Wisconsin - Madison

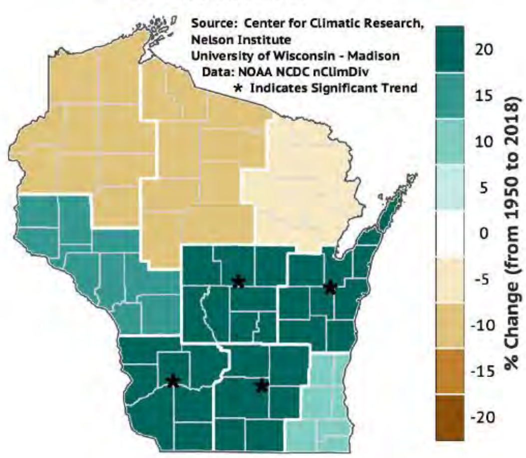
Historical Change in Annual PRECIP (%) from 1950 to 2018



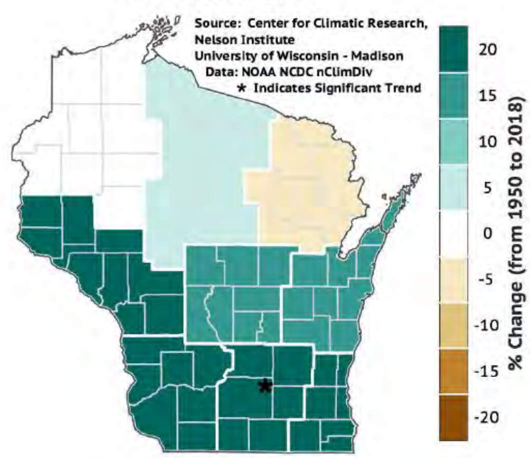
Historical Change in DJF PRECIP (%) from 1950 to 2018



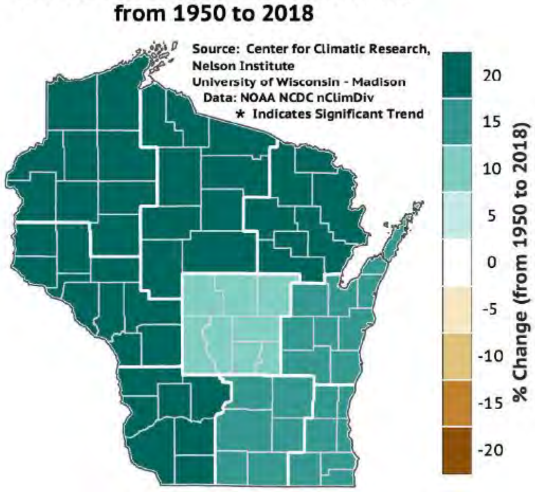
Historical Change in JJA PRECIP (%) from 1950 to 2018



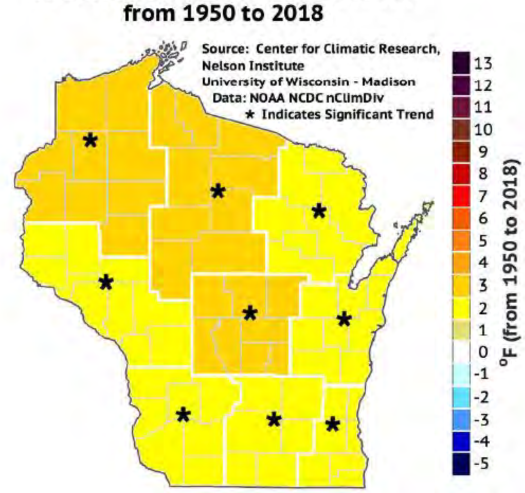
Historical Change in MAM PRECIP (%) from 1950 to 2018

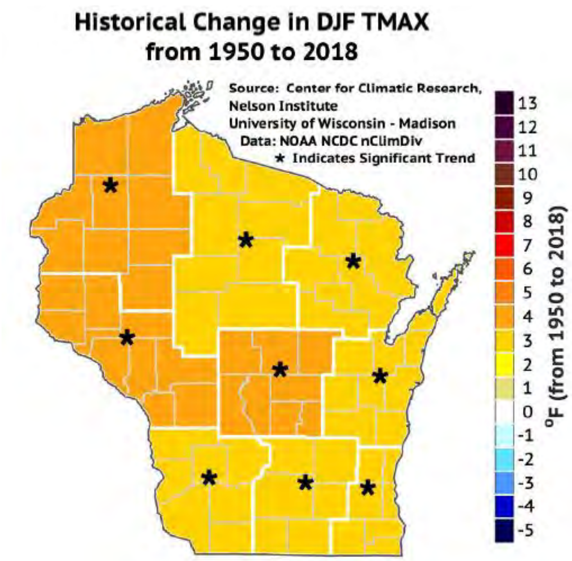


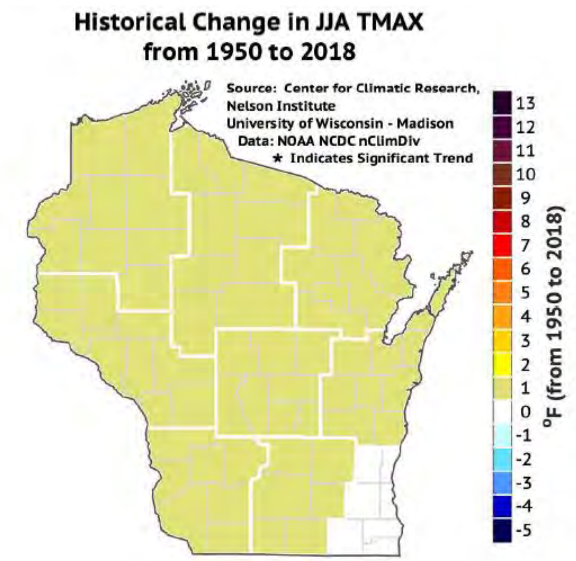
Historical Change in SON PRECIP (%) from 1950 to 2018



Historical Change in Annual TMAX from 1950 to 2018




Historical Change in DJF TMAX
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
°F (from 1950 to 2018)


Historical Change in JJA TMAX
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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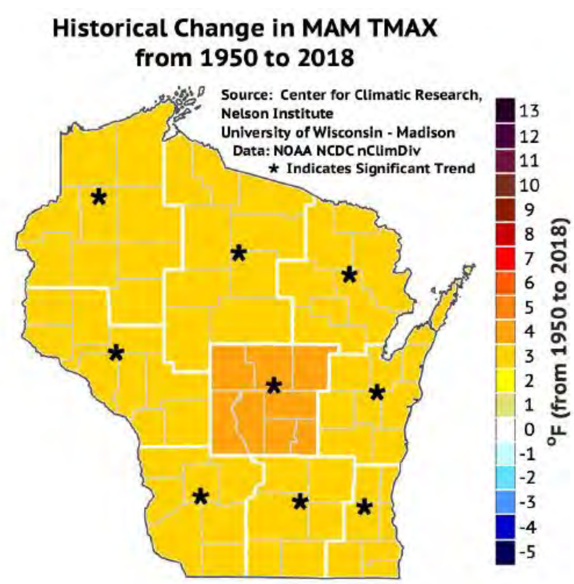
°F (from 1950 to 2018)


Historical Change in MAM TMAX
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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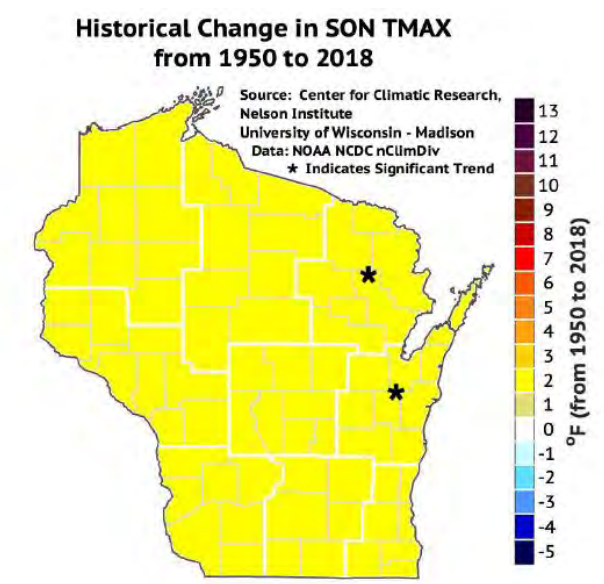
°F (from 1950 to 2018)


Historical Change in SON TMAX
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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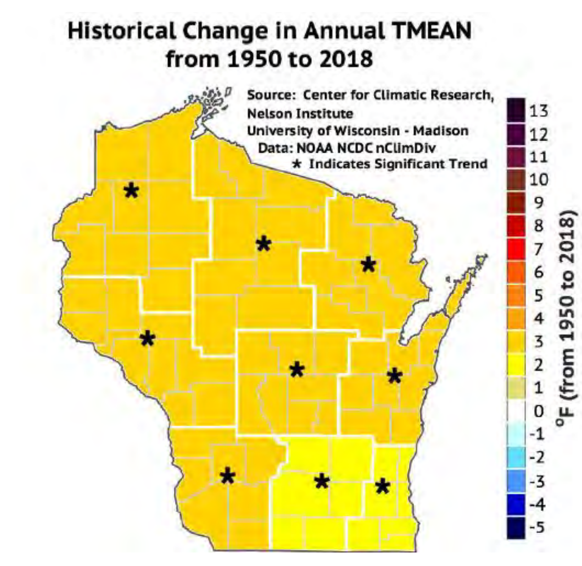
°F (from 1950 to 2018)


Historical Change in Annual TMEAN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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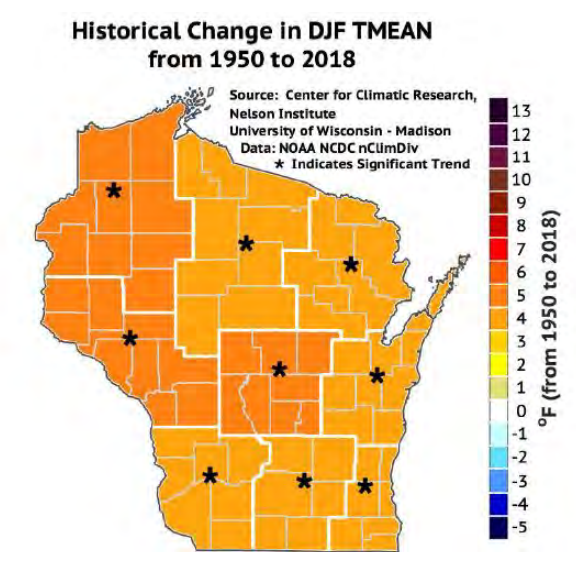
°F (from 1950 to 2018)


Historical Change in DJF TMEAN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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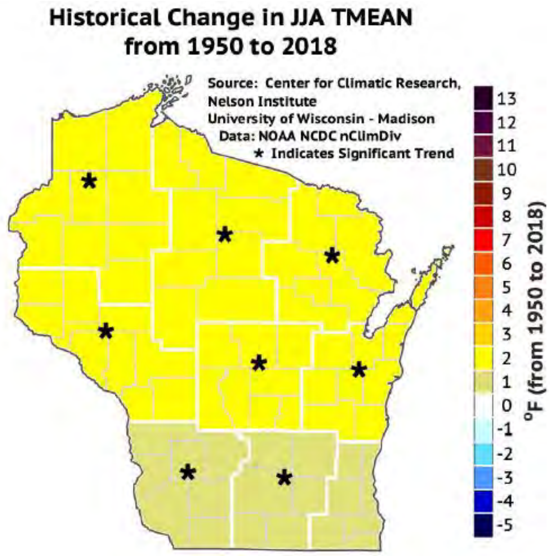
°F (from 1950 to 2018)


Historical Change in JJA TMEAN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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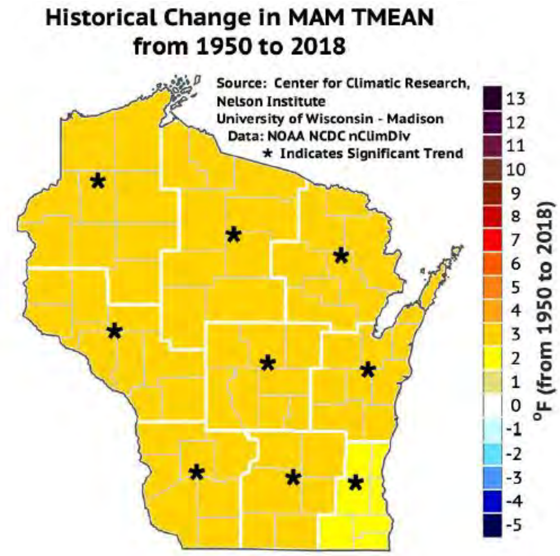
°F (from 1950 to 2018)


Historical Change in MAM TMEAN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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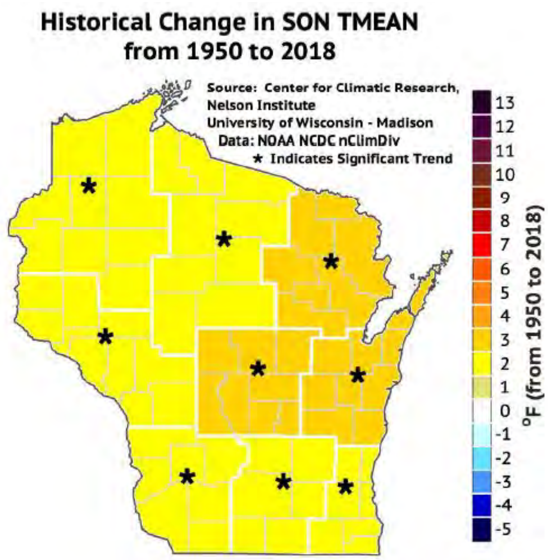
°F (from 1950 to 2018)


Historical Change in SON TMEAN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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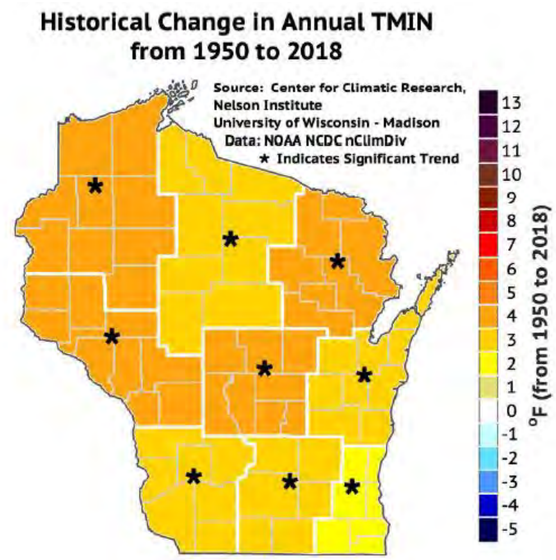
°F (from 1950 to 2018)


Historical Change in Annual TMIN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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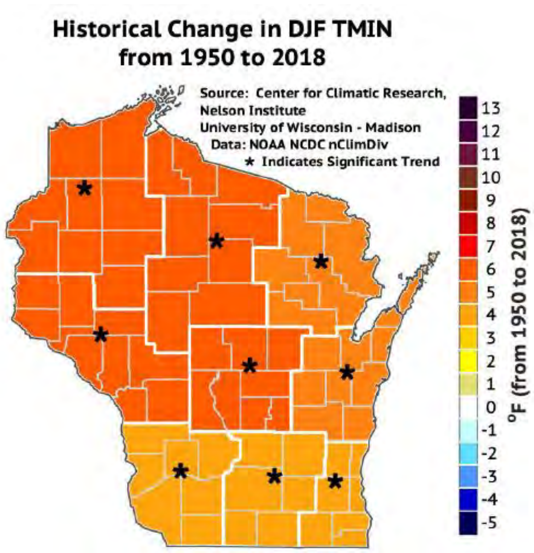
°F (from 1950 to 2018)


Historical Change in DJF TMIN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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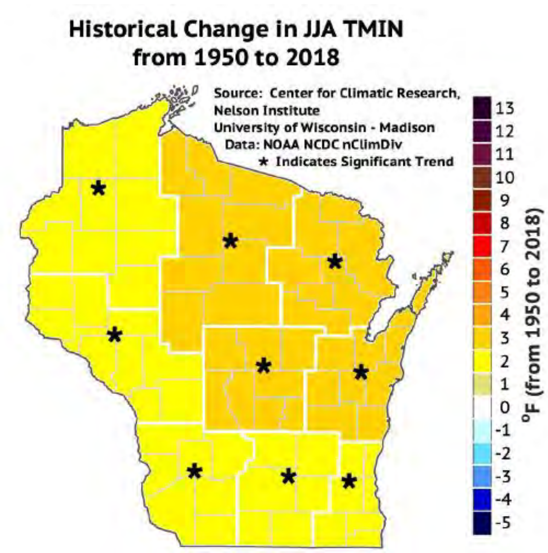
°F (from 1950 to 2018)


Historical Change in JJA TMIN
from 1950 to 2018
Source: Center for Climatic Research,
Nelson Institute
University of Wisconsin - Madison
Data: NOAA NCDC nClimDiv
★ Indicates Significant Trend
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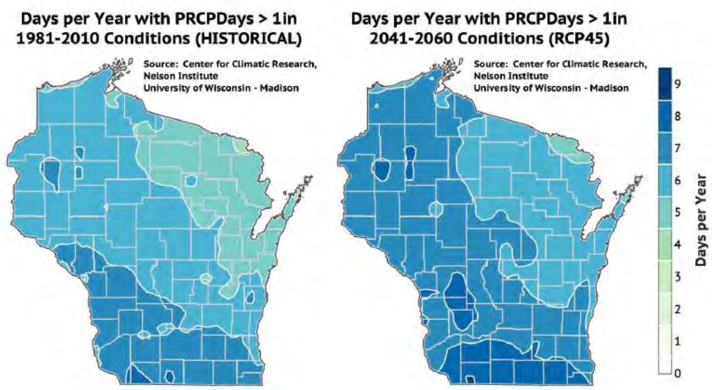
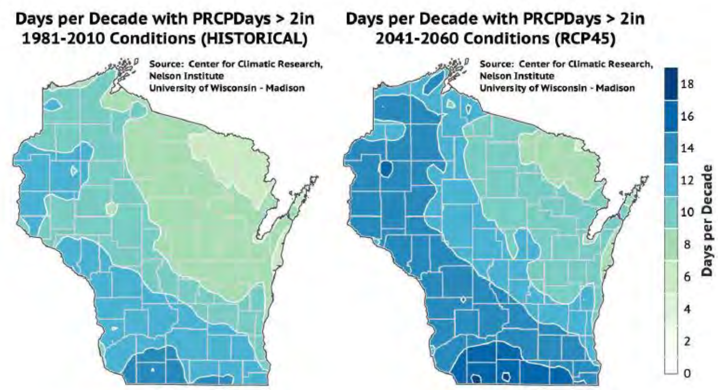
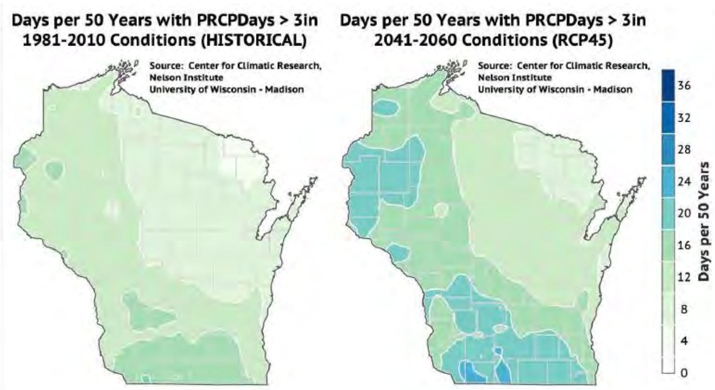
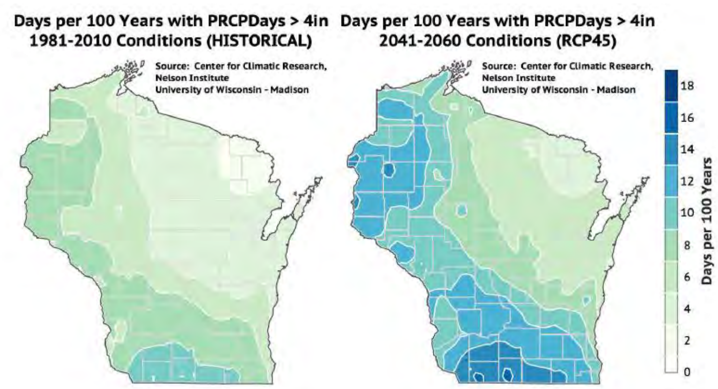
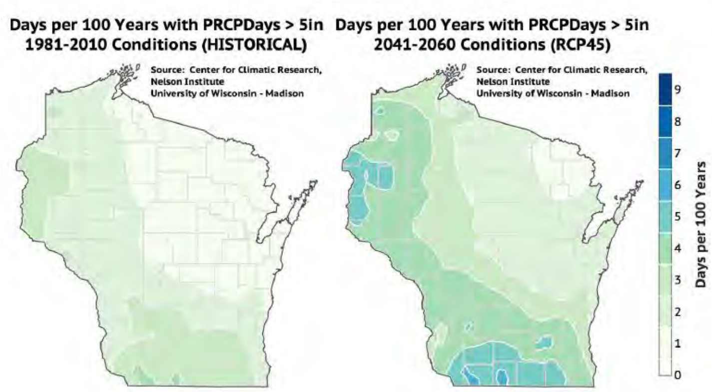
°F (from 1950 to 2018)

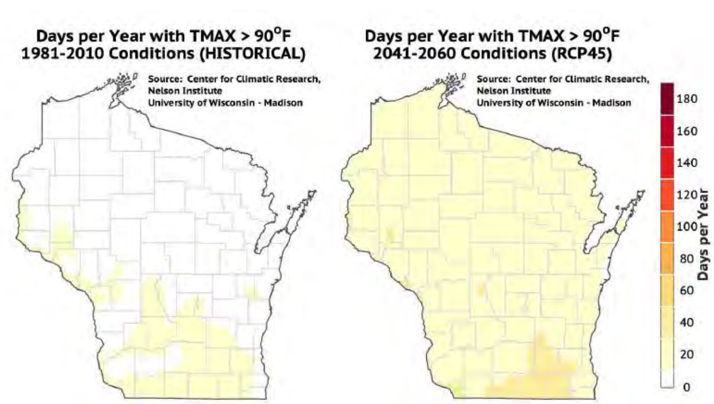

Days per Year with PRCPDays > 1in
1981-2010 Conditions (HISTORICAL)
Days per Year with PRCPDays > 1in
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per Year

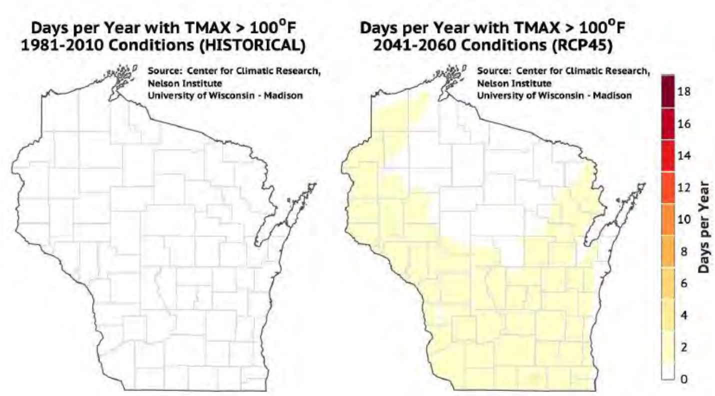

Days per Decade with PRCPDays > 2in
1981-2010 Conditions (HISTORICAL)
Days per Decade with PRCPDays > 2in
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per Decade

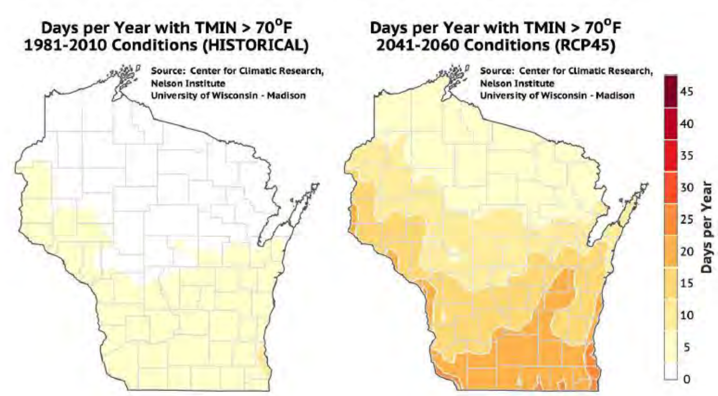

Days per 50 Years with PRCPDays > 3in
1981-2010 Conditions (HISTORICAL)
Days per 50 Years with PRCPDays > 3in
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per 50 Years

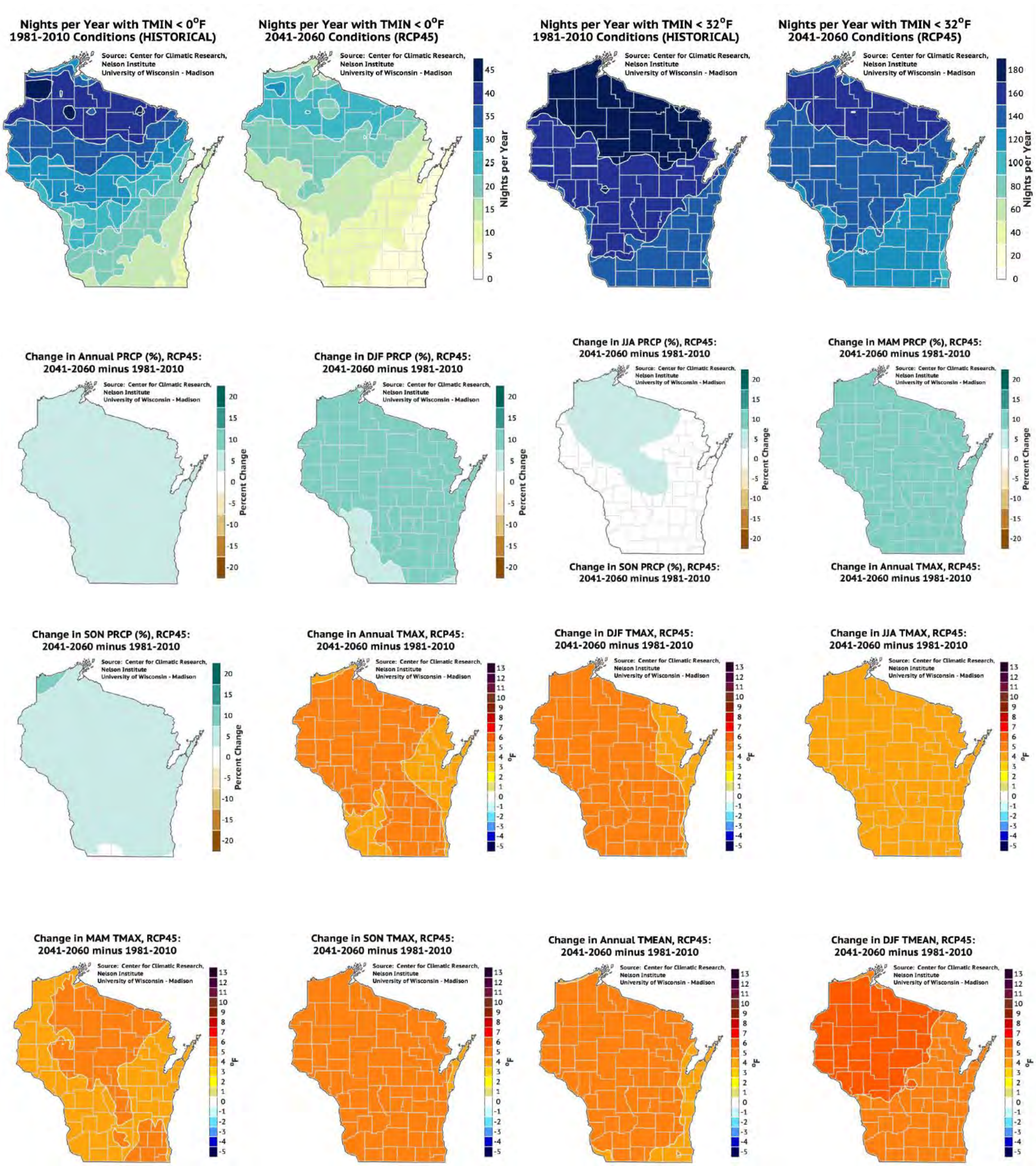

Days per 100 Years with PRCPDays > 4in
1981-2010 Conditions (HISTORICAL)
Days per 100 Years with PRCPDays > 4in
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per 100 Years

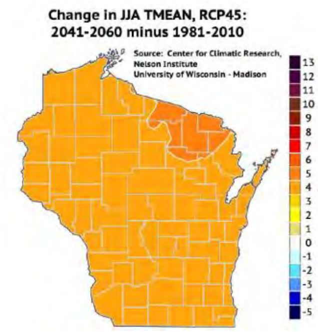

Days per 100 Years with PRCPDays > 5in
1981-2010 Conditions (HISTORICAL)
Days per 100 Years with PRCPDays > 5in
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per 100 Years

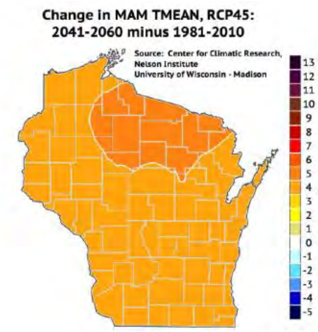

Days per Year with TMAX > 90°F
1981-2010 Conditions (HISTORICAL)
Days per Year with TMAX > 90°F
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per Year

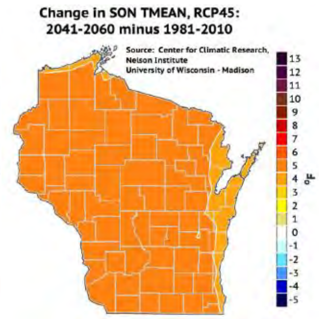

Days per Year with TMAX > 100°F
1981-2010 Conditions (HISTORICAL)
Days per Year with TMAX > 100°F
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per Year

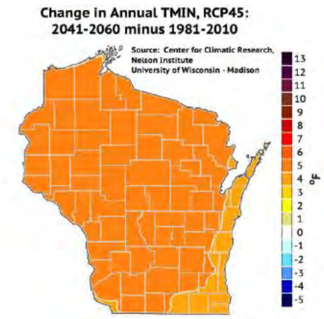

Days per Year with TMIN > 70°F
1981-2010 Conditions (HISTORICAL)
Days per Year with TMIN > 70°F
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Days per Year

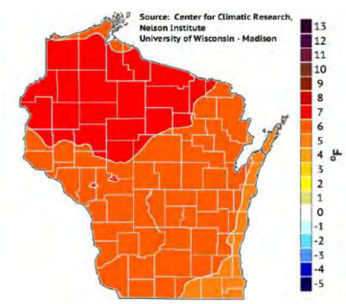

Nights per Year with TMIN < 0°F
1981-2010 Conditions (HISTORICAL)
Nights per Year with TMIN < 0°F
2041-2060 Conditions (RCP45)
Nights per Year with TMIN < 32°F
1981-2010 Conditions (HISTORICAL)
Nights per Year with TMIN < 32°F
2041-2060 Conditions (RCP45)
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison
Nights per Year
Change in Annual PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in DJF PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in JJA PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in MAM PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in SON PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in Annual TMAX, RCP45: 2041-2060 minus 1981-2010
Percent Change
Change in SON PRCP (%), RCP45: 2041-2060 minus 1981-2010
Change in Annual TMAX, RCP45: 2041-2060 minus 1981-2010
Change in DJF TMAX, RCP45: 2041-2060 minus 1981-2010
Change in JJA TMAX, RCP45: 2041-2060 minus 1981-2010
Change in MAM TMAX, RCP45: 2041-2060 minus 1981-2010
Change in SON TMAX, RCP45: 2041-2060 minus 1981-2010
Change in Annual TMEAN, RCP45: 2041-2060 minus 1981-2010
Change in DJF TMEAN, RCP45: 2041-2060 minus 1981-2010
°F

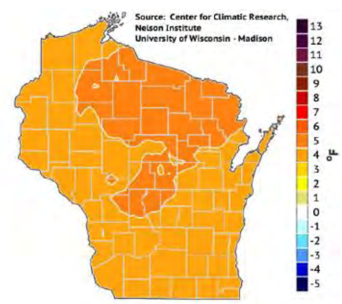

Change in JJA TMEAN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison

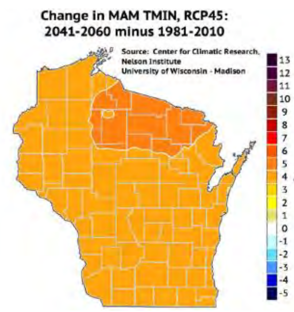

Change in MAM TMEAN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison

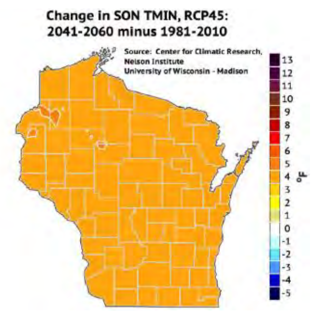

Change in SON TMEAN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison


Change in Annual TMIN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison

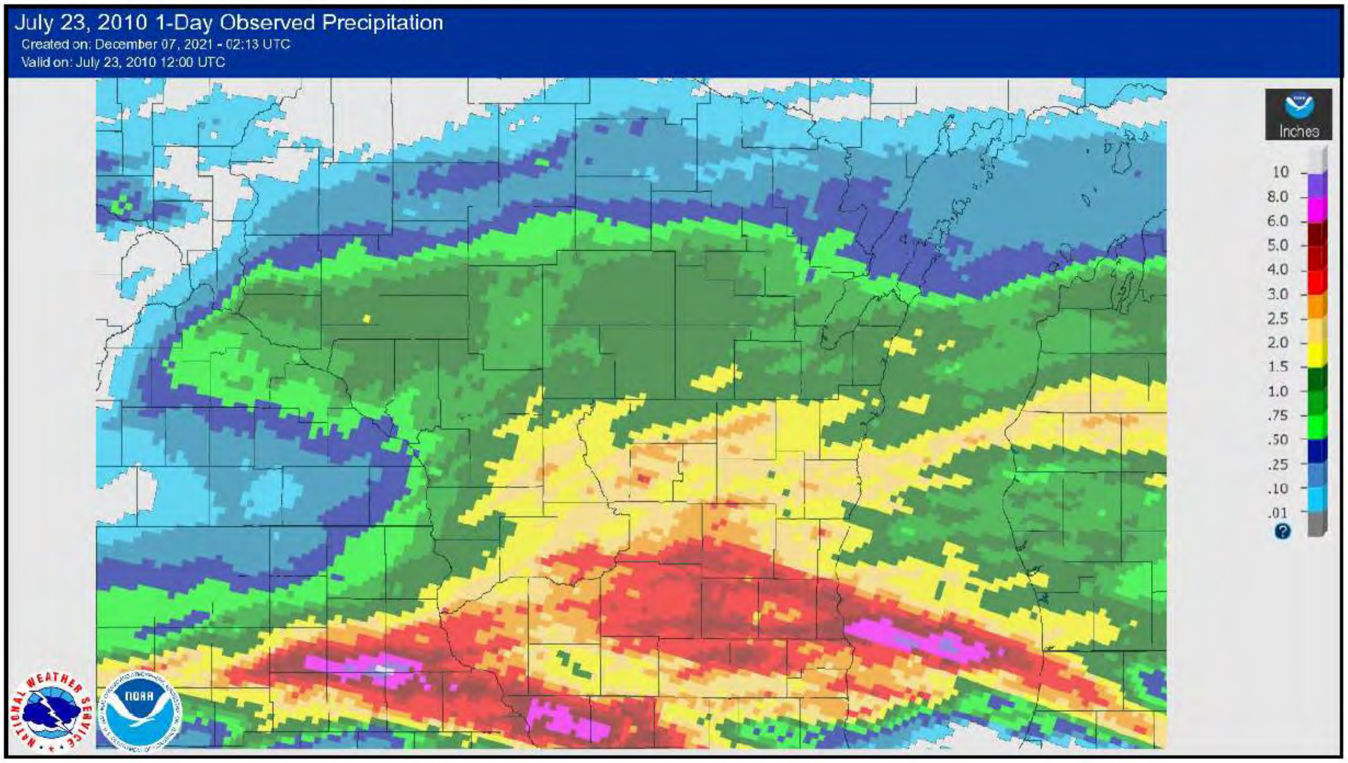

Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison

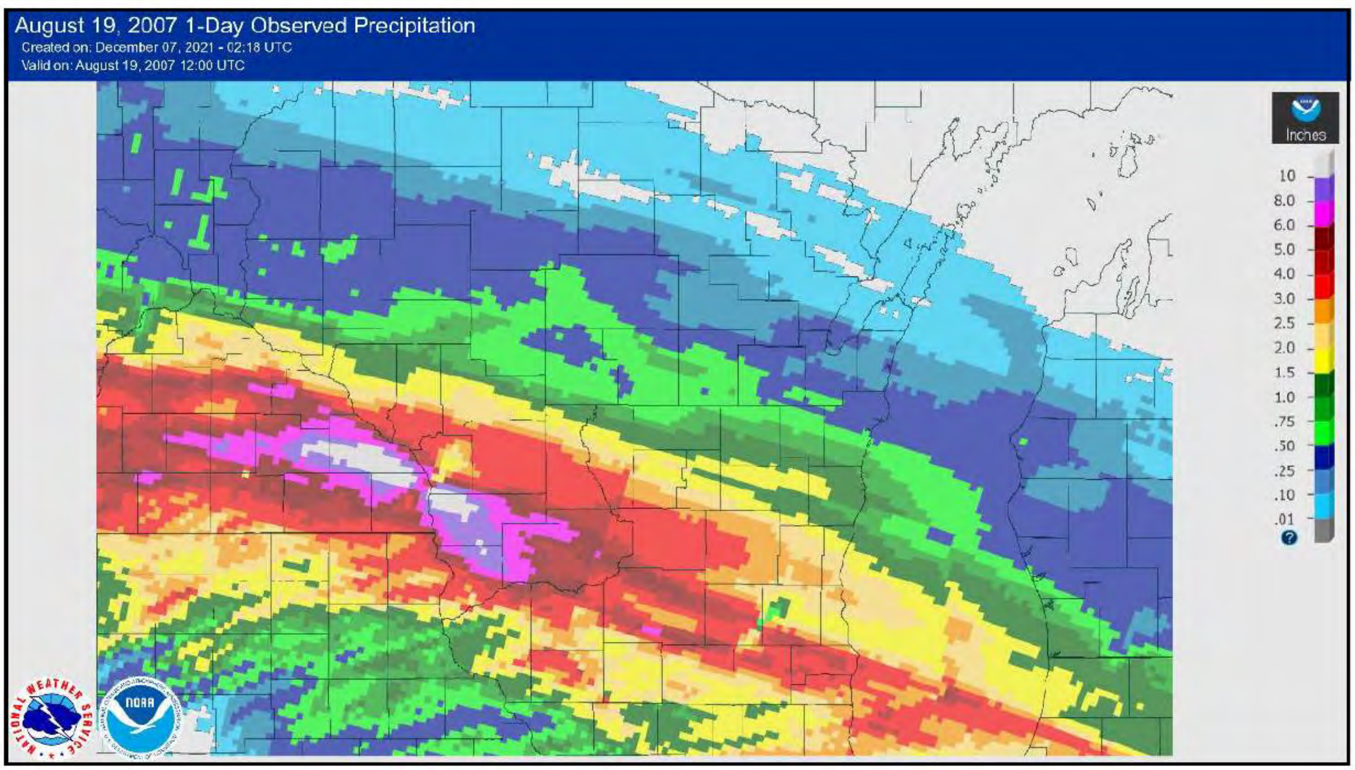

Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison


Change in MAM TMIN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison


Change in SON TMIN, RCP45:
2041-2060 minus 1981-2010
Source: Center for Climatic Research, Nelson Institute University of Wisconsin - Madison

Attachment B
Track and location of 10 largest storms in the Wisconsin extreme storm dataset





Attachment C
Additional information on updated present and future rainfall data

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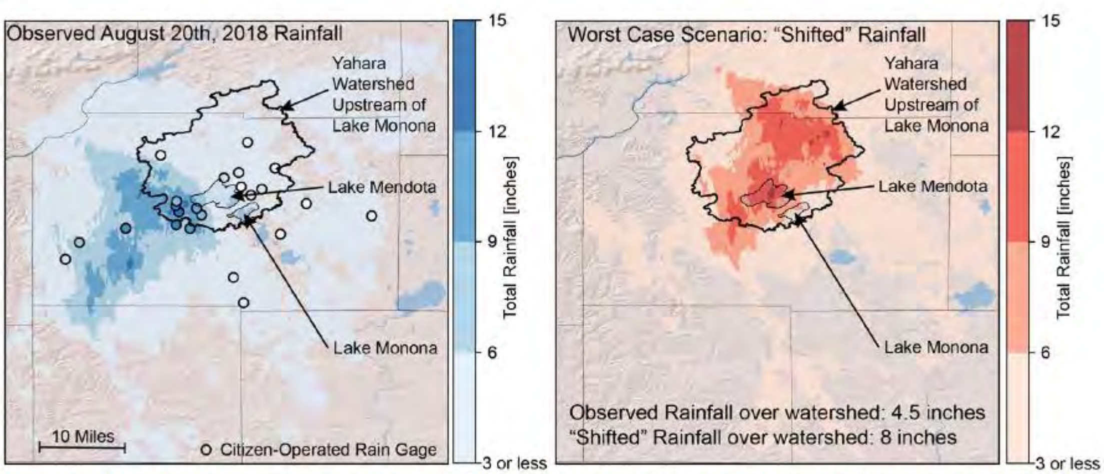
WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

FACT SHEET—Creating Updated Extreme Rainfall Information using RainyDay

Rainfall values such as the 100-year 24-hour storm published by the National Weather Service are used as inputs to infrastructure design and planning. In Wisconsin, these values are calculated from rainfall records that typically span multiple decades but *do not include data more recent than 2012*. There are growing concerns about those values' neglect of recent storms and a warming climate that is resulting in more heavy rainstorms. As part of the Wisconsin Rainfall Project, the UW-Madison/WICCI research team has created rainfall statistics for present-day conditions using the RainyDay software developed at UW-Madison.

RainyDay uses a technique known as stochastic storm transposition combined with recent weather radar data and rain gage measurements to generate rainfall statistics intended to better reflect recent and current rainfall likelihood and severity. Weather radar provides detailed spatial pictures of extreme storms that were previously unavailable using only sporadic rain gages. Meanwhile, the basic premise of stochastic storm transposition is that a storm that occurred in one location in real life could have hit somewhere else with equal or different probability. Therefore, that storm can be transposed (that is, moved) to help understand how often and how severe storms can be—thus providing estimates of values such as the 100-year storm.



Left—National Weather Service radar and citizen rain gage observations for the August 20, 2018 storm in Dane County and surrounding areas. Right—Transposition of the same storm 15 miles to the northeast, directly over the upper Yahara watershed (upstream of Lake Monona), which is outlined in black. Stochastic storm transposition of hundreds of recent storms is repeated thousands of times by the RainyDay software to evaluate many possible "alternative realities" of extreme rainfall and its likelihood.

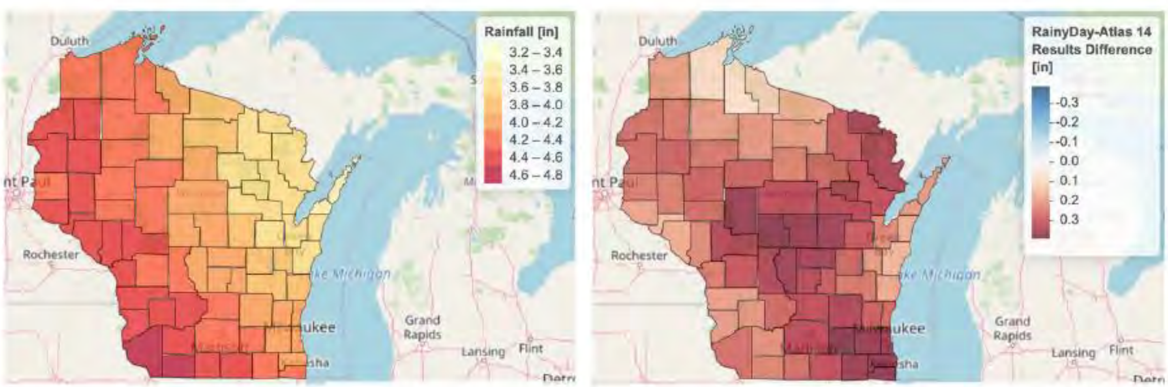
The RainyDay approach has undergone significant scientific peer review. It has also been previously used in work funded by the federal Natural Resources Conservation Service to create updated extreme rainfall statistics for dam safety analyses in Vernon County, Wisconsin, and has been used to study rainfall and flooding throughout the midwestern US and elsewhere.

Summary of Data

- County-level rainfall Intensity–Duration–Frequency (IDF) statistics and uncertainties for 3, 6, 12, 24, and 48-hour as well as 4-day and 10-day durations based on gage-corrected National Weather Service radar rainfall observations from 2002-2019 (19 years)
- Recurrence Intervals: 2, 5, 10, 25, 50, 100, 200 500, and 1,000 years
- Direct comparisons with NOAA Atlas 14 results (available here)
- Uncertainty estimates—in the form of 90% confidence intervals—for all estimates

Example Results and Key Findings

Below Left: 10-year 24-hour rainfall from the UW-Madison RainyDay-based analysis. Below Right: Difference between the 10-year 24-hour rainfall from RainyDay and the National Weather Service Atlas 14 Volume 8. These maps show more heavier rainfalls from the RainyDay approach than from Atlas 14, though this result varies with location, rainfall duration and return period.



Further Information

- Daniel Wright, David Lorenz, and Zhe Li, *Final Project Report—The Wisconsin Rainfall Project: Current and Future Rainfall Information for Infrastructure and Planning*, technical report to Wisconsin Dept. of Natural Resources, March 31, 2021 (download here)
- Daniel Wright, Ricardo Mantilla, and Christa D. Peters-Lidard. *A Remote Sensing-Based Tool for Assessing Rainfall-Driven Hazards*. Peer-reviewed scientific paper published in the journal Environmental Modeling and Software in 2017 (download here)
- Web-based data visualization and download portal (access here)
- **Contact:** Daniel Wright (danielb.wright@wisc.edu)

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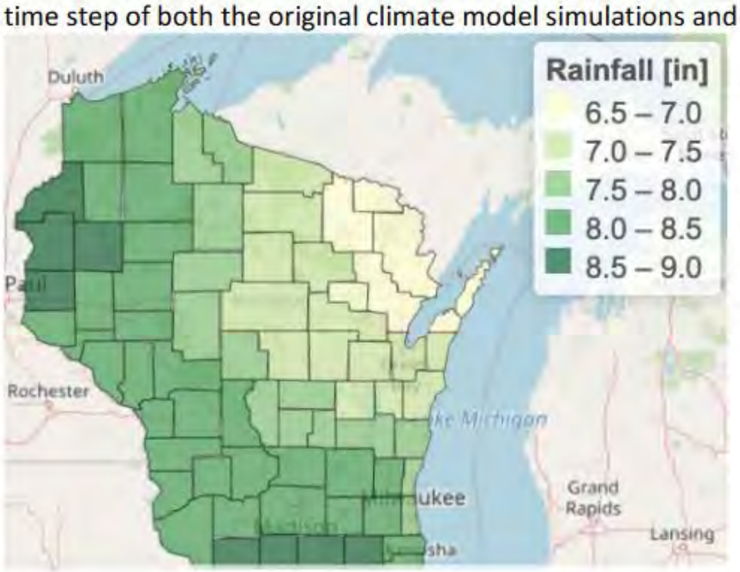
UNIVERSITY OF WISCONSIN-MADISON

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

FACT SHEET—Past and Future Extreme Rainfall Information using Downscaling

While useful, global climate models lack the local detail needed for infrastructure design, planning, and related applications. Downscaling is a term that describes methods to convert these coarse resolution climate model output to finer scales. As part of the Wisconsin Rainfall Project, the UW-Madison/WICCI research team has created local-scale rainfall statistics for past, present, and future conditions using a method known as University of Wisconsin Probabilistic Downscaling (UWPD). In a recent project funded by the National Weather Service and carried out by researchers at UW-Madison and the University of Illinois, UWPD was shown to have advantages over other downscaling methods in its ability to predict extreme rainfall conditions.

To capture local-scale rainfall patterns in UWPD, coarse resolution climate model simulations are merged with historical local and regional rain gauge measurements to create statistical equations of the likelihood and amount of precipitation each and every day for both past and future climate conditions. This expression varies in time and by location as the atmosphere changes. For example, when a climate model predicts a warm, humid day with high atmospheric instability, UWPD would predict not only a high probability of rain but also a possibility of very heavy rain. This prediction is based on prior comparison of model-simulated atmospheric conditions to historical rainfall observations. From this set of day-to-day predictions, it is possible to predict the largest rainfall value at all locations for each year. From the largest values from each year, one can calculate statistics such as 10-year and 100-year storms across a region. Unlike some rainfall statistics, however, UWPD results are limited to the 24-hour duration, since that is the time step of both the original climate model simulations and rain gauge measurements.



Left: 100-year 24-hour rainfall map for the end of the 21st century, based on the average downscaled projections from 22 global climate models. This map shows the results for the RCP8.5 "business as usual" high emissions scenario (for more explanation of this and other emissions scenarios, see here).

Appendix IV - Hydrological Modeling

Objective

The objective of the hydrologic analysis conducted for the Monroe County project was to identify runoff generation areas across several watersheds within the county, and then to evaluate the sensitivity of runoff generation to future rainfall conditions and to potential future changes in land use. The analysis results provide observations for consideration in the vulnerability analysis portion of the project.

The analysis was conducted on several subwatersheds selected to be representative of the range of land use conditions in the county. The analysis was limited to evaluating runoff generation areas only and did not include detailed hydrologic modeling for predicting flood flows in streams or detailed hydraulic modeling to identify floodplain extent or a stream crossing performance.

Methods

The analysis approach drew on ideas from a University of Wisconsin-Madison Water Resource Management practicum workshop project conducted on the Rullands Coulee watershed, in southwestern Monroe County. The analysis for this project was conducted within QGIS, an open-source geographic information system analysis package (https://www.qgis.org/en/site/). A QGIS plugin was used to calculate runoff curve numbers for parcels within the watershed using soil characteristics and land cover data. Input data included GIS-based hydrologic soil group delineations and land cover from the National Land Cover Dataset updated in 2019. Runoff curve numbers were calculated using standard NRCS / SCS hydrologic analysis methods as described in the NRCS National Engineering Handbook (https://directives.sc.egov.usda.gov/viewerFS.aspx?id=2572). Runoff depths across each analysis parcel were calculated using the calculated curve numbers and input storm rainfall depth.

5 HUC12 watersheds within Monroe County were selected for evaluating runoff response. The watersheds were selected to be in different drainage basins exiting Monroe County and have a range of land covers representative of conditions within the county. Four of the watersheds selected were in the driftless area, and one with its upstream portion in the driftless area but draining eastward into the Wisconsin sand plain areas in the eastern portion of the county. The watersheds are listed in Table 1 below and shown on Figure 1. The percent of woodland cover is listed for each watershed as it is one of the watershed land use characteristics most related to runoff generation. Watersheds with higher woodland cover are anticipated to produce less runoff from storm events. Maps 1 through 5, below, show the land use distribution in the five analyzed watersheds. For the five watersheds located in the driftless area (maps 1 through 4) agricultural lands are concentrated in the relatively flat upland areas and relatively flat lowland areas adjacent to streams and rivers. The wooded areas are primarily located in the steeper Valley slopes. The Bear Creek watershed is shown on Map 5 and has a substantially different land cover because of the flatter terrain. Woodland and wetland areas dominate the eastern downstream portion of the watershed.

Table 1
Characteristics of 5 watersheds selected for GIS-based runoff analysis

HUC 12 Watershed Name	Downstream River	Percent Woodland
Timber Coulee	Coon Creek	36.9
Headwaters Little La Crosse	La Crosse River	48.5
Moore Creek	Kickapoo River	37.3
Rathbone Creek	Black River	69.5
Bear Creek	Lemonweir River	43.4

Existing conditions runoff modeling results

Runoff analyses were conducted through QGIS for the five analysis watersheds for the approximate 2- year, 10-year and 200- year, 24-hour rainfall depths. The storms were selected to provide an evaluation of runoff generation from smaller storms that occur relatively frequently (the 2-year storm) to an extremely large storm (the 200-year storm) that would occur only very rarely. The storm rainfall depths (listed below in Table 2) were selected based on preliminary evaluation of Wisconsin Rainfall Project projections. Note that these rainfall depths are similar to but slightly different than the rainfall depths proposed for using Monroe County based on final output of the Wisconsin Rainfall Project data portal, listed in the climate sections of the report and appendices. Results are presented in Table 2, below. The runoff depths listed are watershed- wide averages.

Table 2 Modeled runoff from 5 watersheds for 3 storm events

Return Period	2-yr	10-yr	200-yr
Rainfall	2.89	4.56	7.93
Watershed Runoff (inches)			
Timber Coulee	0.52	1.14	2.68
HW Little La Crosse	0.54	1.11	2.55
Moore Creek	0.64	1.36	3.04
Rathbone Creek	0.32	0.61	1.60
Bear Creek	0.90	1.80	3.73

The results listed in Table 2 illustrate the progressive increase in runoff depths as storm rainfall depth increases and show a general correlation with percent woodland cover listed in Table 1.

Maps 6 through 10, attached below, show the distribution of runoff depth generation for each of the land use parcel across the watersheds for the approximate 200-year event. The important observation from these figures is that runoff generation is derived mainly from the non-woodland areas.

Analysis of runoff impacts of potential future conditions scenarios

Analyses of the impact of several potential future conditions scenarios were conducted using the QGIS analysis procedure for the Timber Coulee watershed. one scenario investigated the response of the watershed to the anticipated 2020 storm rainfall under the current land use conditions. three other scenarios were developed to evaluate sensitivity of runoff response to several altered potential future land use conditions. These conditions were not specifically anticipated to occur throughout Monroe County, they were developed to test the runoff sensitivity of potential extreme changes in land use. the potential future land use scenarios were evaluated using the currently defined rainfall (not future rainfall), to enable a clearer comparison of the land use change effects alone. The scenarios evaluated were:

- Conversion of all of the agricultural land two permanent pasture cover;
- Conversion of all of the agricultural land to row crop production; and
- An increase of 20% in the area of forested land.

Results of this sensitivity analysis are shown in Table 3.

Table 3: Results of Preliminary Runoff Modeling for Timber Coulee Watershed				
Return Period, years		2-yr	10-yr	200-yr
Annual Exceedance Frequency		0.5	0.1	0.01
Rainfall Depth, inches		2.89	4.56	7.93
Runoff, inches				
Existing Conditions		0.52	1.14	2.68
Current rainfall, ag land converted to meadow		0.40	0.95	2.39
All Ag Land converted to Row-Crop		0.66	1.37	3.02
Forest Area expanded by 20%		0.45	1.01	2.45
Future rainfall on existing land use		0.56	1.22	2.88
Percent Change in Runoff Depth				
Existing Ag to All Meadow		-23%	-17%	-11%
Existing/All-Row		27%	20%	13%
Existing/20% forest		-14%	-12%	-9%
Existing to future rainfall		7%	7%	8%

The results of this analysis indicate that the variation of potential future conditions could be more important than anticipated changes in storm rainfall in changing watershed runoff. This sensitivity to land use change is particularly apparent for the frequent storms such as the 2-year storm. These smaller storms our most frequent and produce the bulk of watershed runoff response and water quality impacts. This sensitivity is further illustrated in Figure 2, below.

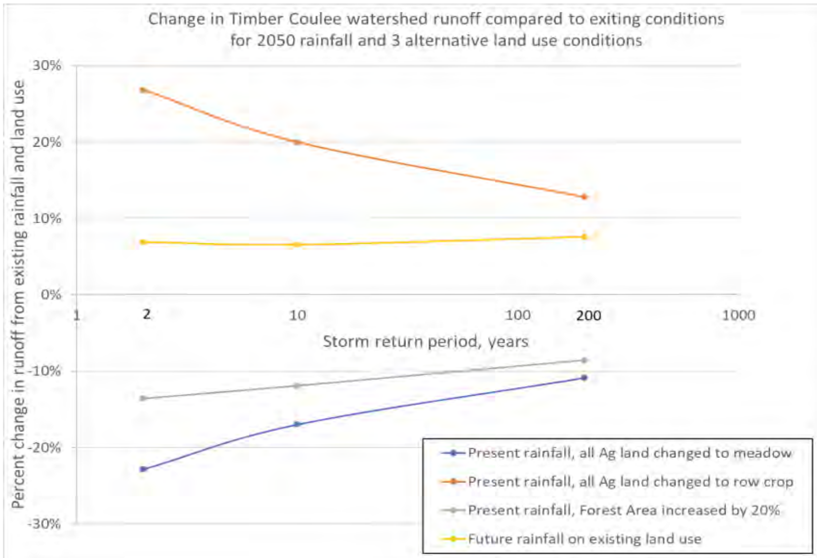


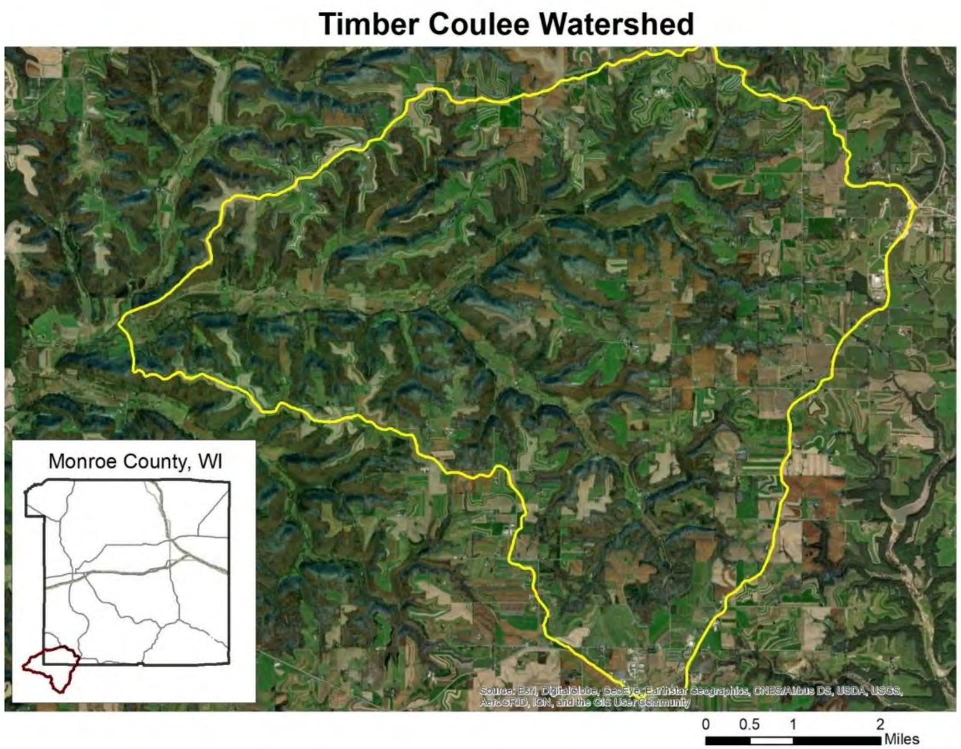
Figure 2: Sensitivity of Timber Coulee runoff response to Future Condition Scenarios

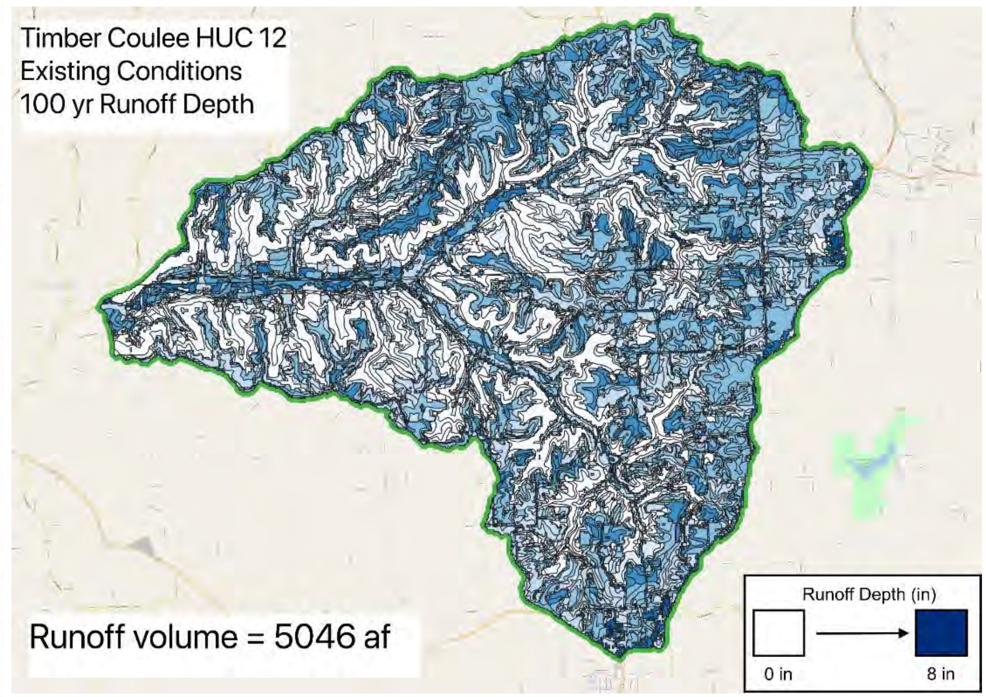
Observations

The most significant results of this analysis include:

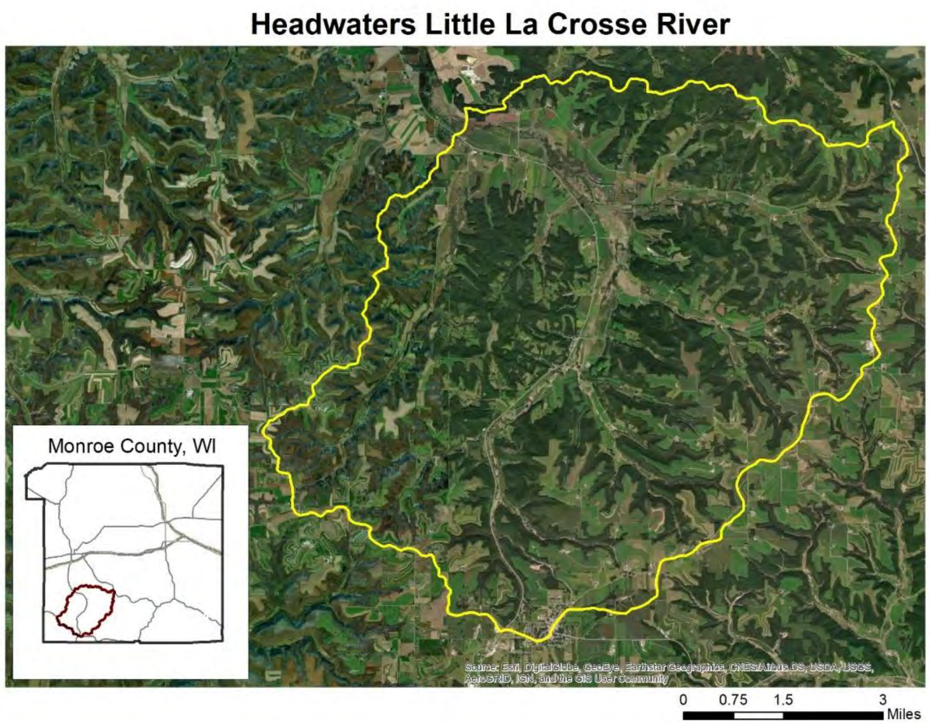
- Most of the runoff for both current and future conditions is generated from agricultural lands. Wooded areas produced much less runoff, indicating the importance of woodland areas in promoting interception and infiltration while reducing runoff.
- The runoff effects of potential future land use change were greater than those of increased future rainfall, especially for storms that occur relatively frequently such as the 2-year storm. Changing all agricultural land use to row crop increased runoff volume from existing conditions approximately 25%, whereas changing existing land cover to all pasture cover reduced runoff by more than 20%. These results indicate that that adopting agricultural practices that maximize perennial cover such as pasture or include seasonal cover crops will have beneficial effects in reducing small storm runoff, which has soil conservation and stream water quality benefits.
- Increasing the woodland area by approximately 20% reduced runoff volume by approximately 13% for the 2-year storm and less than 10% for the 200-year storm. These substantial reductions indicate that restoring woodlands in select areas would also reduce runoff depth.
- Changes in land use that may occur by year 2050 could have more impact on watershed hydrologic response than changes in storm rainfall.

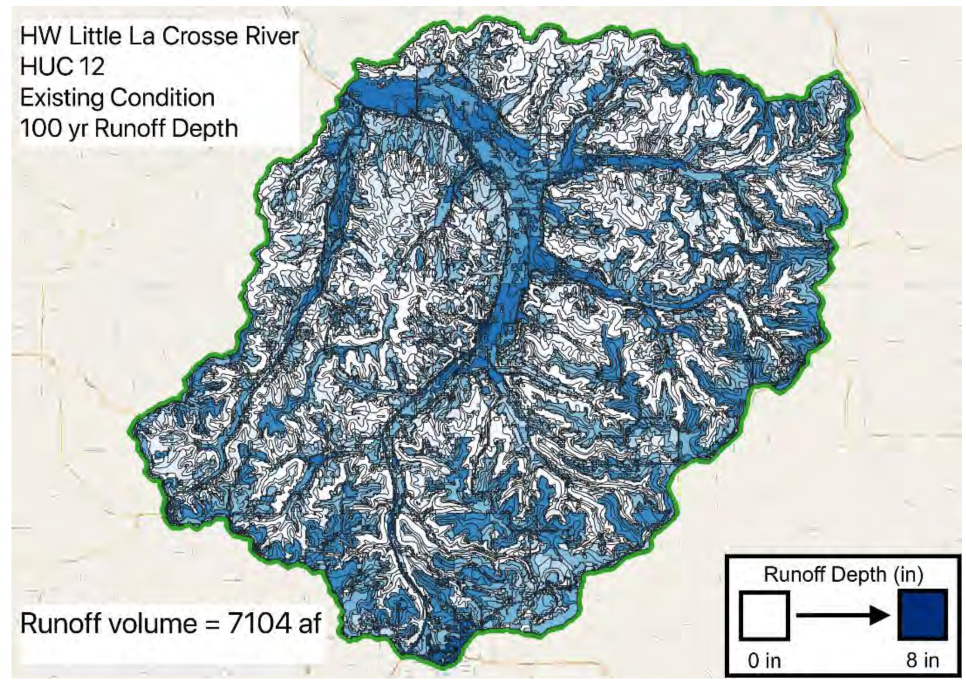
Maps



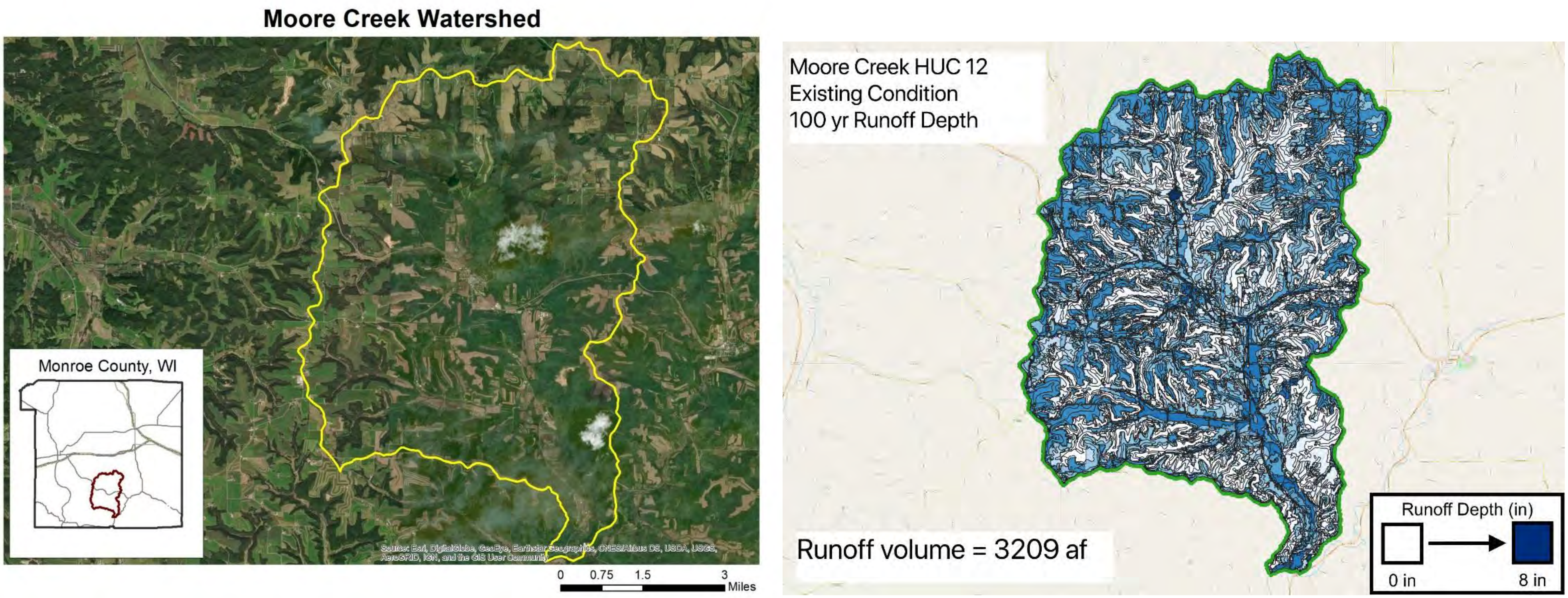


Map Set 1 Land use in the Timber Coulee watershed (left) and areas of runoff generation in the Timber Coulee watershed (right).

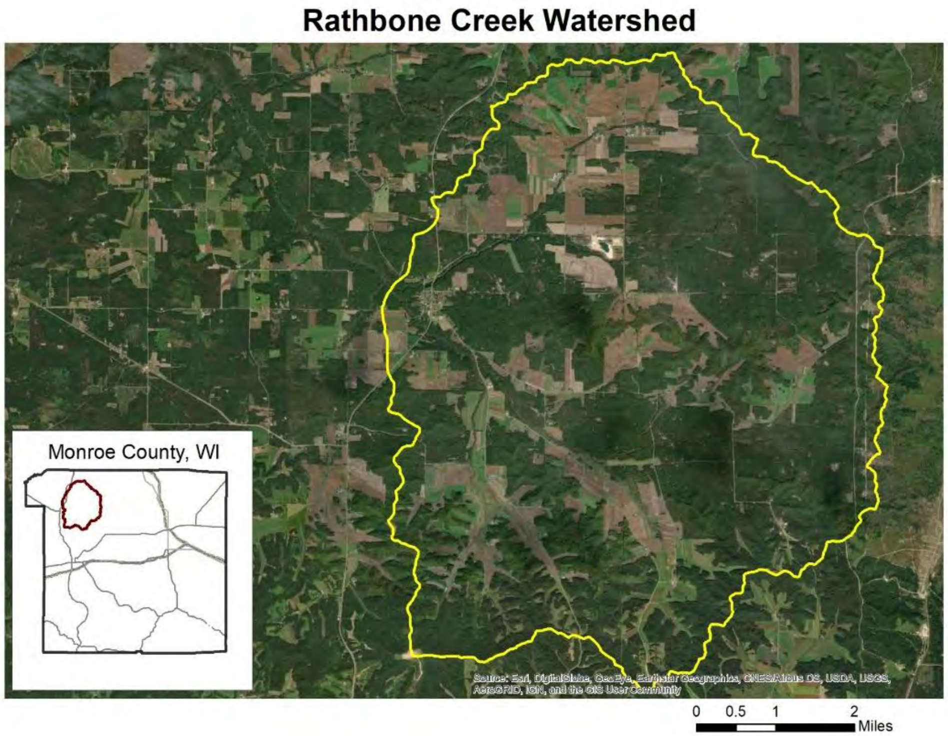


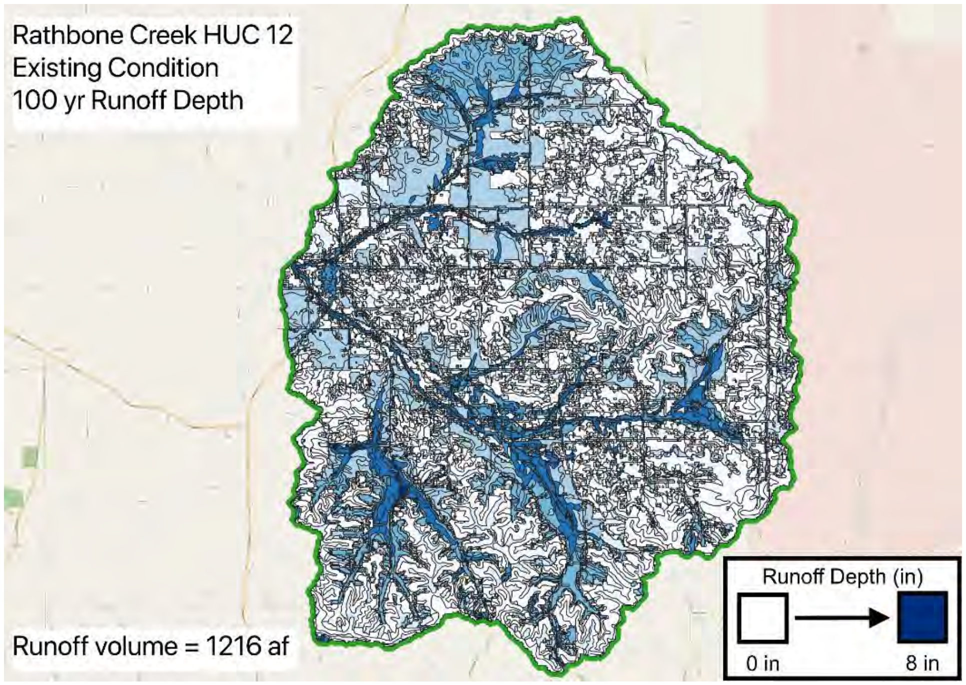


Map Set 2 Land use and areas of runoff generation in the Headwaters Little La Crosse River watershed

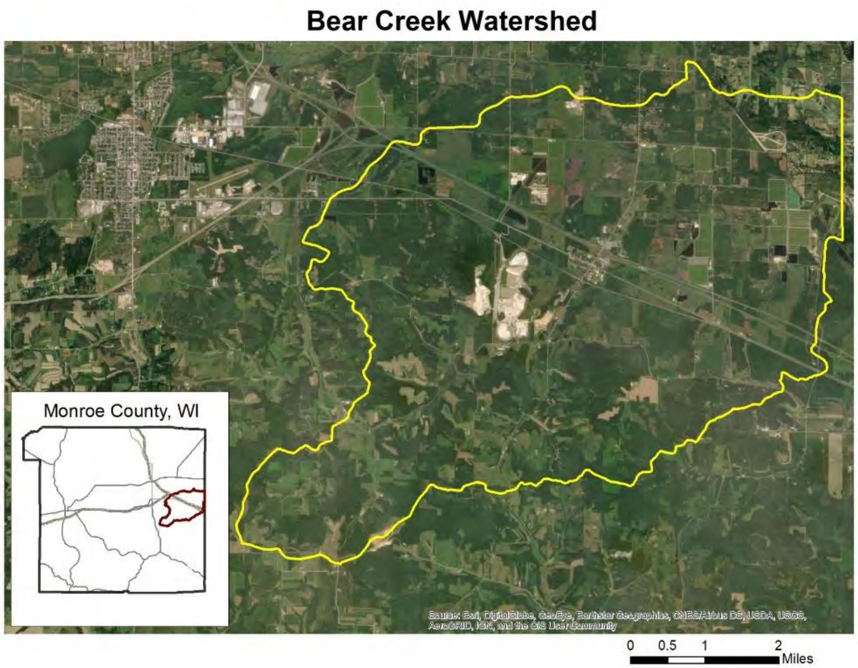


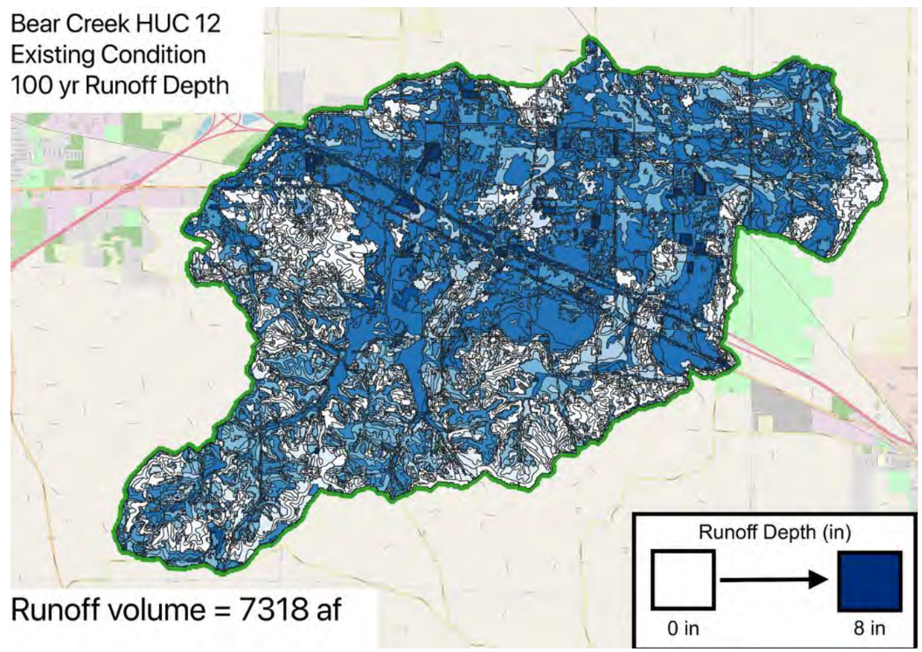
Map Set 3 Land use and areas of runoff generation in the Moore Creek watershed



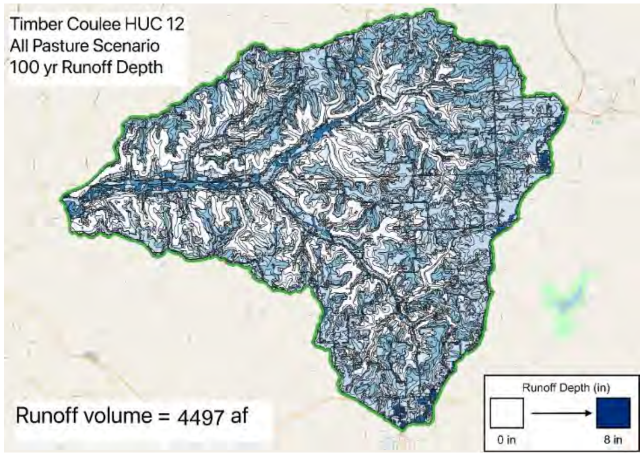


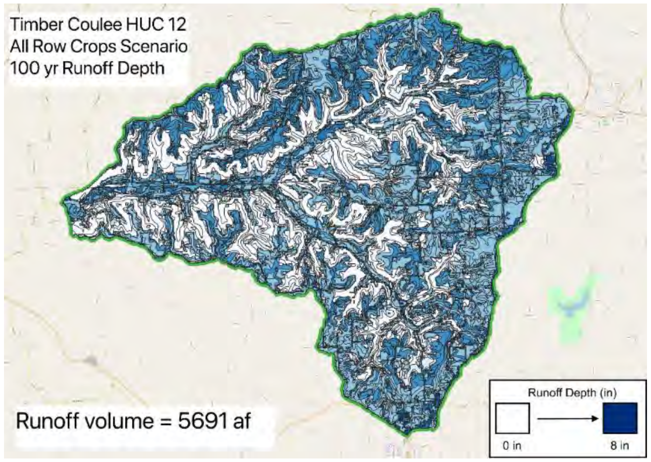
Map Set 4 Land use and areas of runoff generation in the Rathbone Creek watershed

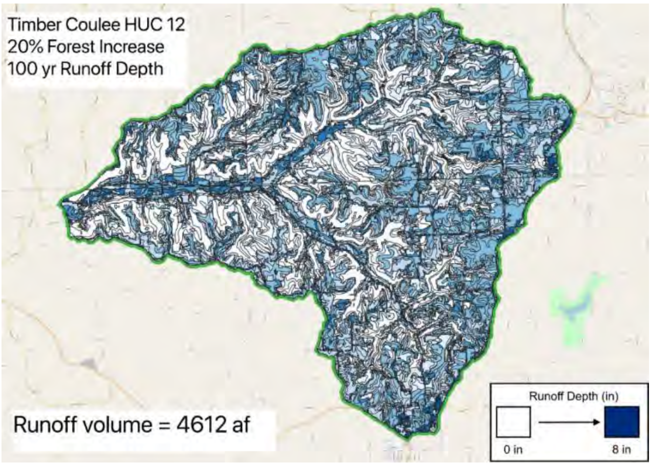




Map Set 5 Land use and areas of runoff generation in the Bear Creek watershed







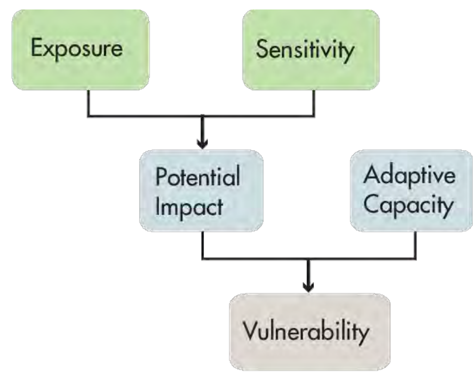
a b c

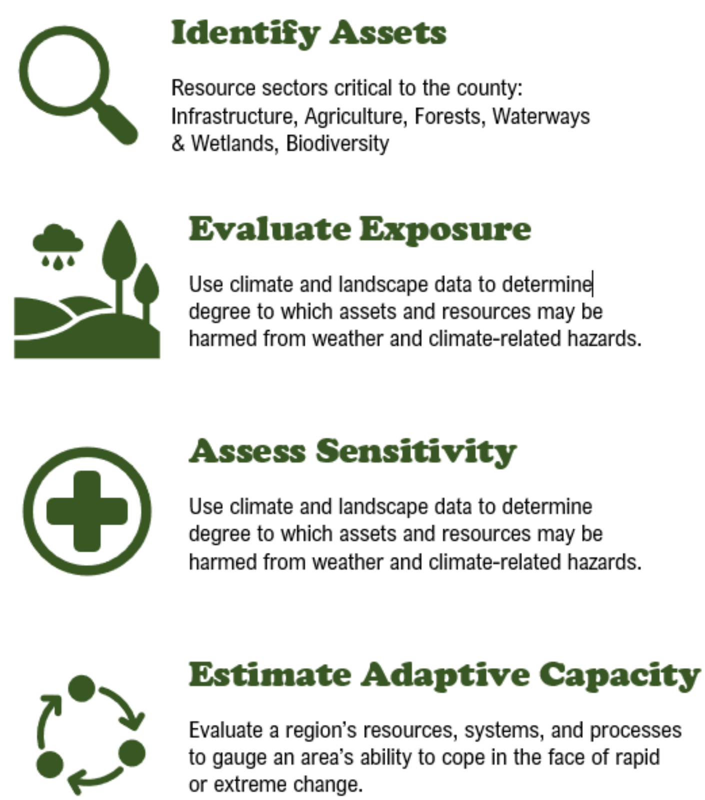
Map Set 6 Areas of runoff generation if all agricultural land is converted to pasture (a) or to row crop (b) or a 20% forest increase (c)

Appendix V – Watershed Vulnerability Assessments Methods

A Rapid Vulnerability Assessment is a short-term version of the vulnerability assessment process that is focused on local interests, primarily uses data and resources that are already available, together with metrics to rank or quantify vulnerability. A given area's vulnerability to changes in climate is typically measured by 3 elements: **exposure, sensitivity**, and **adaptive capacity** (See Section 2 and the US Climate Resilience Toolkit for more detail). Collectively, these elements can measure vulnerability, and therefore guide steps to resilience.

We used a rapid vulnerability assessment approach to address vulnerability and risks to the five asset categories (infrastructure, agriculture, forests, waterways and wetlands, and biodiversity) to determine the relative risk of each watershed in the county. Watersheds are important because the streamflow and the water quality of a river are affected by the things happening in the land area "above" the river-outflow point. Therefore, a watershed is an interconnected landscape, in which ecological processes are driven by interacting land and water features. Watersheds are useful for assessing and managing ecological systems, land use practices, and weather driven events such as floods.





Watersheds in the county vary in their resilience to climate change, based on both current ecological conditions and anticipated future conditions. Watersheds that are more ecologically intact and have fewer stressors are more resilient under extreme conditions. For example, in many cases, conditions in intact watersheds will enable plants and animals to recover or move in response to climate impacts. Watersheds that have more stressors will be more vulnerable and less resilient.

To conduct this watershed-level analysis, we developed a method for converting both expert knowledge and on-the-ground watershed-level data into a metric of overall vulnerability. This Watershed Vulnerability Assessment (WVA) tool was adapted from an existing IUCN tool, while also being informed and modified by the WDNR Integrated Watershed Health study and The Resource Innovation Group's *Toward a Resilient Watershed* approach. This approach combines baseline non-climate stressors (current ecological conditions) data, projected climate data, and the expert knowledge of climate specialists, ecologists, agricultural specialists, and more.

This analysis had two main goals: 1) provide a spatial (geographic) component to identify the most vulnerable watersheds in Monroe County; and 2) identify the most critical areas of concern specific to each locale (watershed) contributing to ecological and climate stress. Using this analysis allowed us to identify the areas of the county most at-risk, and also identify the particular stressor(s) within watersheds that are most in need of attention.

A critical component of assessing current (non-climate) ecological conditions and baseline stressors was the use of Watershed Health Indices from the US EPA (found here). The EPA data uses a compilation of ecological information that is measurable, comparable and consistent across the area of the assessment, and relevant to assessing a watershed's condition. Data within the ecological index include percent forest in the watershed, percent wetlands, mean aquatic condition score, habitat condition index and more. Categories of data within the EPA's stressor index include measures of soil erosion, percent cultivated crop in the riparian zone, stream-road crossing density, percent ag on slopes, percent non-buffered agriculture, percent imperviousness (impervious surfaces), and more.

Data inputs used in the climate change vulnerability component of the analysis included forest diversity, existing forest species adaptability to climate change (based on Northern Institute of Applied Climate Science Climate Change Field Guide), presence of invasive species (plants only), number of toxic sites in the watershed (e.g. Brownfield sites), and more. These components were chosen as they tend to increase the sensitivity of a watershed to extreme weather events. For example, a toxic site could become especially problematic during a large-scale flood even that could carry harmful chemicals downstream. Measures of adaptive capacity included percentage of the landscape in natural vegetation (which tends to be more resilient to extreme events), measures of resiliency from The Nature Conservancy's Resilient and Connected Landscapes, and the ability for an area to tolerate (or even benefit from) flood, fire, drought, and other extreme conditions.

Scores for each index in the WVA tool were ranked 1-3, categorized by minimum, mean, and maximum values throughout the county. The results of the WVA tool, therefore, should be used in a comparative or relative sense: a watershed's rank indicates how it scored when compared to all other watersheds in the county. The results can be used as a broad-level evaluation and planning tool to compare watersheds to one another and begin guiding appropriate monitoring and management actions for specific watersheds and locations.

Appendix VI – Climate Resilient Conservation and Restoration

Creating landscapes that can withstand extreme weather will take a multilayered approach to ensure increased infiltration, controlled runoff, and restored hydrology throughout all landscapes and new development. Research worldwide has observed that highly altered and degraded lands are more susceptible to climate change impacts[1]. This is particularly true in areas with steep ravines and valleys, where intense rainfall events create extensive opportunity for flood, soil erosion, and more[2]. Protecting existing natural systems and restoring degraded lands is important to create resilient and sustainable landscapes, increase greenhouse gas (GHG) absorption, mitigate climate change, improve socio-economic conditions and to ensure food security[3,4].

Forests

Forests cover approximately 50% of Monroe County's landscape, contributing to regional air quality, erosion control, forest products economy, and wildlife habitat. Forest conservation, restoration, and management offer the most effective, low-cost, nature-based solutions for mitigating climate change[5]. While offering potential contributions to climate change mitigation, forests are also at risk from the impacts of climate change. As such, while part of forest conservation lies in preventing the conversion of forests to other uses, assisting local forests in adapting to climate change is also highly important. This will include measures such as invasive pest management, fire management (including controlled burns), and restocking degraded forests with more native, climate-adapted species (see the Climate Change Field Guide for Southern Wisconsin Forests). To achieve this, landowners would benefit from incentives that "keep forests as forests", such as property tax incentives, investing in carbon markets, and partnerships with resource managers (e.g. US Forest Service, NIACS, NRCS) to implement climate-resilient practices within the forests on their land. Forests also often harbor unique and sensitive habitats such as ephemeral ponds, rookeries, springs and seeps. Protection of these habitats, both within and outside of forests, is crucial for maintaining hydrologic integrity, ecosystem services, biodiversity, and carbon sequestration functions.

Reforestation efforts can aim to restore natural "wild" habitats or be integrated into urban areas and working lands. By using the watershed vulnerability assessments in this report, new and restored forests can be strategically sited on marginal, highly erodible, and high-risk lands in highly vulnerable watersheds. Trees can be integrated into working lands through agro-forestry efforts (see below), and greenspaces in urban and other built areas can provide shade, flood control, and other benefits.

Prairies and Grasslands

Native grasslands of the Midwest region also hold great potential for carbon sequestration, with added benefits for biodiversity, wildlife habitat, and more. As part of photosynthesis, prairie plants pull carbon dioxide from the atmosphere and store it in their stems, leaves and roots. Unlike trees, however, grasslands store most of their carbon underground, in their roots and deep into the soil. Deep root systems deposit carbon into deep soil layers, which is important because the rate of carbon sequestration increases with soil depth (see Minnesota Board of

Water and Soil Resources). This deep root system is what can, in a future climate scenario, potentially make them more reliable "carbon sinks" than forests; because carbon is stored in the soil, it is not released back into the atmosphere when grasslands burn, as it is when trees burn in forest fires[6]. This suggests that **a landscape consisting of forests as well as grasslands will contribute to a diverse "portfolio" of land uses and habitat types that will contribute to a more resilient, adaptable landscape.**

Similarly to forests, the restoration of prairies can also be conducted on a gradient of natural wildlands to integrated working lands and even urban backyards. Large-scale prairie restoration, while potentially costly and effort-intensive, can mitigate carbon, provide wildlife habitat, recreation opportunities, and benefits to pollinators. Alternatively, however, native prairie can be integrated into working lands as prairie (filter) strips and potentially even as income sources in the form of biofuel feedstocks from harvestable buffers (see **Appendix VII**). Native wet prairie plantings can also be used in bioswales, detention basins, and rain gardens in urban and suburban areas.

Waterways and wetlands

Lakes, streams, and wetlands offer many ecosystem services to people, including water quality improvement, flood mitigation, and wildlife protection. Freshwater is essential for all living organisms on Earth, and provides indirect benefits for humans for agriculture, transportation, wildlife and fish habitat, energy production, and more. Protection of freshwater, both in quality and quantity, is essential for human life now and in the future. Monroe County has some of the best conditions in southern Wisconsin to become a trout fishing destination, even as the climate warms. Spring-fed streams help keep water temperatures cool despite rising ambient temperatures, and topographic features help to provide natural shade. Despite this, without purposeful stewardship, many of these cold-water fisheries could be at risk. Because rivers and streams continuously funnel precipitation from the surrounding landscape through the interconnected lakes, rivers, and wetlands, they are sensitive even to distant land-use activities. Non-climate stressors on freshwater systems include activities that change system hydrology (such as dams and diversions), water extraction, pollution and excessive nutrients, and sediment loading. These stressors, coupled with climate change impacts – such as increased flooding leading to increased sedimentation, warming waters precipitating algal blooms, and periodic droughts – can have devastating impacts on local freshwater rivers, streams, and lakes. Protection of rivers and streams will require the reduction of non-climate stressors to improve the natural capacity for these systems to withstand a changing climate.

Wetlands (also known as marshes, swamps, fens, bogs) are also a critical component of freshwater ecosystems. Wetlands often act as "sponges", absorbing water during times of excess (i.e. flooding) and serving as critical storage of water during drier times. Because of their anoxic wet conditions, wetlands are optimal natural environments for sequestering and storing carbon from the atmosphere[7]. Wetlands furthermore provide critical habitat for many amphibians, birds, and plants. As with forests, avoiding the loss of wetlands (conserving them) tends to be less expensive than wetland restoration[5] and therefore improving surveys, mapping, and conservation of wetlands is a priority for improving landscape resilience.

Restored wetlands, however, are an extremely useful nature-based action for increasing resilience to climate change. Restoration of riverine wetlands (those adjacent to rivers and streams) is especially useful for storing and holding flows, including peak flows, which tend to produce flood damage. Wetland restoration in areas that reconnect streams to their floodplains, restore ditches to natural channels, and help divert and disperse surface flows to reduce flood severity and associated impacts will provide the greatest function and co-benefit opportunity. Coincidentally, marginal agricultural lands (define here) frequently occur in saturated and periodically flooded areas near rivers and streams, therefore presenting an opportunity to restore ecological function while minimally competing with land use for food production (see **Appendix VII**).

Conservation and Restoration on Agricultural Lands

Agriculture is the only major emissions contributing sector that has the ability to shift from a net carbon source to a net carbon sink. Better understanding carbon and greenhouse gas emissions on agricultural lands will help Monroe County contribute to state, federal, and global carbon off-set goals. A strategic approach will help to maintain a strong agricultural economy, with the potential to supplement farmer incomes by generating carbon credits that can be sold in carbon offset markets. The conservation toolbox is full of practices designed to limit soil erosion, reduce and redirect runoff, improve nutrient efficiency, and support more sustainable farming systems. While many practices and conservation programs were intended to meet soil and water quality goals, they are also robust and effective in mitigating and adapting to a changing climate. Re-thinking the landscape through a carbon lens can help reduce the effects of climate change, create resilient landscapes, and meet water quality goals. As such, recommendations are focused on building resilient soils while supporting land use practices that keep water on the land, slow the flow of runoff to streams, and buffer waterways from excess nutrient runoff.

Carbon is also an important element in soil health. Increasing soil organic carbon improves water holding capacity, infiltration rates, soil density, and nutrient availability, better protecting landscapes from rain events, drought, pests and invasive species. Practices that store carbon also have many co-benefits that improve water quality by limiting erosion and filtering nutrients.

Many strategies exist for reaching both soil health and climate change goals on the agricultural landscape. Cover crop techniques are one such example, frequently used in soil health, but with added co-benefits for climate resilience. Cover crops help prevent soil erosion, limit nutrient runoff, reduce soil compaction, increase soil organic matter which raises soil moisture holding capacity, and can even help suppress some pests. Cover crops provide economic benefits by increasing crop yields, out-competing weeds, break disease and insect cycles, host beneficial organisms, attract pollinators, and supply forage. Furthermore, cover crops can help producers cope with excess spring waters through cover crops, which can help dry out wet fields before planting[8]. Increased continuous living cover on agricultural land also helps to reduce the need for fertilizer applications and associated N2O emissions (a greenhouse gas) and increase soil carbon storage. Strategies that reduce disturbance of soil will also contribute to soil health, stability, and carbon storage. Disturbance can be minimized by avoiding or reducing tillage for planting, weed control, or other purposes, and increasing soil cover with mulch and compost can help to conserve soil moisture and reduce soil temperatures[9,10].

Agroforestry and silvopasture techniques also have the potential for enhancing ecosystem resilience to extreme climatic conditions[11], as well as creating economic opportunities on farms. Agroforestry - a system in which trees or shrubs are grown around or among crops or pastureland - produces a wide range of useful and marketable products while contributing to reforestation, soil stabilization, and more. Silvopasture techniques integrate trees into livestock grazing land, in which animal manure all help improve the soil and tree nutrition. Grazing by livestock, meanwhile, controls competing brush species and reduces fire hazard and can result in greater timber yield[12]. Trees in turn create a sheltered microclimate to protect animals from heat – a protection that may become a greater need as the day and nighttime highs increase. By diversifying and expanding farm production to include a wider array of annual crops, perennial fruits or nuts, forage, timber or other forest products, agricultural producers also help ensure their own economic stability by reducing risks of climate change impacts to staple crops and risks related to market fluctuations[9,13](and see USDA Climate Hub Adaptation Resources for Agriculture).

Prairie strips are a conservation practice that integrates "strips" of warm season and cool season grasses as well as native wildflowers into row crop fields. Prairies strips have been observed to deliver enormous soil, water and nutrient benefits while increasing wildlife habitat. Studies from Iowa State University have documented through rigorous research that converting just 10% of a crop field to prairie strips could result in reduction of 95% of the sediment, 90% of the phosphorus and 84% of the nitrogen from overland flow of surface water[14].

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Appendix VII – Integrated Approaches to "Slow the Flow" While Promoting Economic Opportunity

"Slowing the flow" is an intuitive approach to reducing flood risk (as well as droughts) by utilizing the natural water storage capacity of watersheds and ecosystems[1]. It means slowing the rate that water (precipitation) runs across the landscape and to larger order streams by increasing upstream water storage in soil, vegetation, and groundwater. Approaches to slow the flow of water on the landscape can occur in upland areas in the form of permanent/year-round vegetation, on hillsides where reforestation activities are highly effective, and in valleys and floodplains which often serve as water catchment areas for the landscape.

Conserving or restoring floodplain ecosystems through reforestation, riparian buffers and wetlands/forested wetlands is a common example of a nature-based approach to slowing the flow that can be integrated into working landscapes. Vegetated buffers along streams and rivers (i.e. riparian areas) are excellent examples of nature-based actions that can greatly increase the resilience of a system. Riparian buffers can provide a number of ecosystem services, including water quality protection, erosion and flood control, carbon sequestration, and wildlife habitat[2,3,4].

Riparian buffers can be designed in a number of ways, depending on the function they are intended to provide. The width of the buffer (distance from the stream edge) varies, depending on which of these services a land manager or landowner desires to achieve. For example, streambank stability can generally be achieved with a 30-foot buffer, however near-total nutrient removal cannot be achieved until buffer widths are greater than 120 feet. Corridors for wildlife travel and habitat can generally be achieved in a 150-300 foot buffer, however riparian buffers aimed at providing habitat for threatened, endangered, and sensitive species is generally not achieved in under 600 feet (Figure 1).

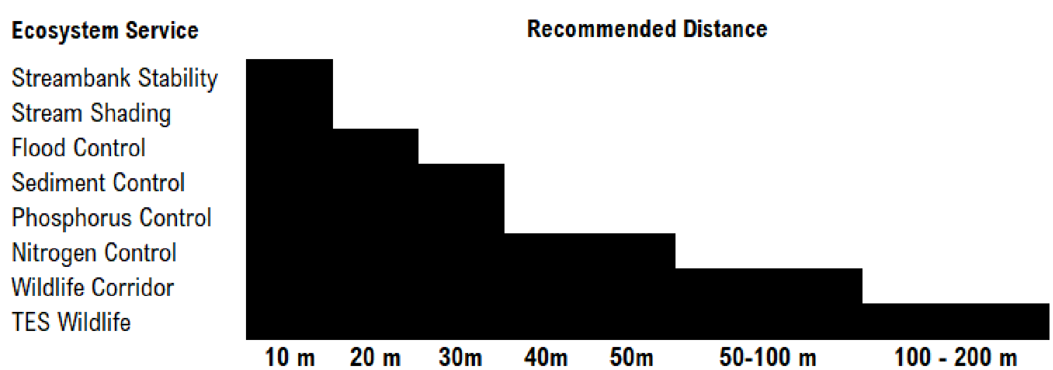

Figure 1. Recommended riparian buffer widths (distance from stream) from research literature for various ecosystem service goals (references listed below).

It is important to note that while these are generalized recommendations, various circumstances can change effective distances. For example, the Southeastern Wisconsin Regional Planning Commission recommends a 50-foot buffer to achieve 75% sediment removal during small, low intensity storms, but found that buffers more than

150 feet wide are necessary to achieve the same sediment reduction during more severe storms. Nearby slope gradients will also have an impact on the effectiveness of buffers of varying widths. It will be important for landowners to work with local land and water conservationists (for example, from Monroe County Land Conservation Dept or local NRCS conservationists) to determine the most effective buffer distance for their goals on their land.

Because there is great flexibility in the way that streamside buffers can be designed and still accomplish intended ecological function, this flexibility can also be used to generate innovated agricultural products and diversify income on farmland. Riparian buffers can be thought of as having 3 distinct zones with distinct functions as well as a potential for diversifying income on farmlands[5]. Zone 1 is the narrow area closest to the stream bank and can include a mixture of native trees, shrubs, and/or forbs that are adapted to wet conditions. The principal goal of this zone is to stabilize the bank and provide shade for aquatic habitat. Zone 2 is a much wider area, consisting of fast-growing trees and shrubs that can tolerate periodic flooding. The primary function of this zone is nutrient uptake and storage and slowing floodwater. This zone can be managed or additional income from nuts or wood products. Lastly, Zone 3 is the area adjacent to crop fields or grazing lands that provides high infiltration, sediment filtering, nutrient uptake and can help disperse concentrated runoff. Native grasses and wildflowers are often preferred for providing wildlife and pollinator habitat, but dense, stiff-stemmed grasses can also be established and occasionally harvested for biofuels as an additional source of income.

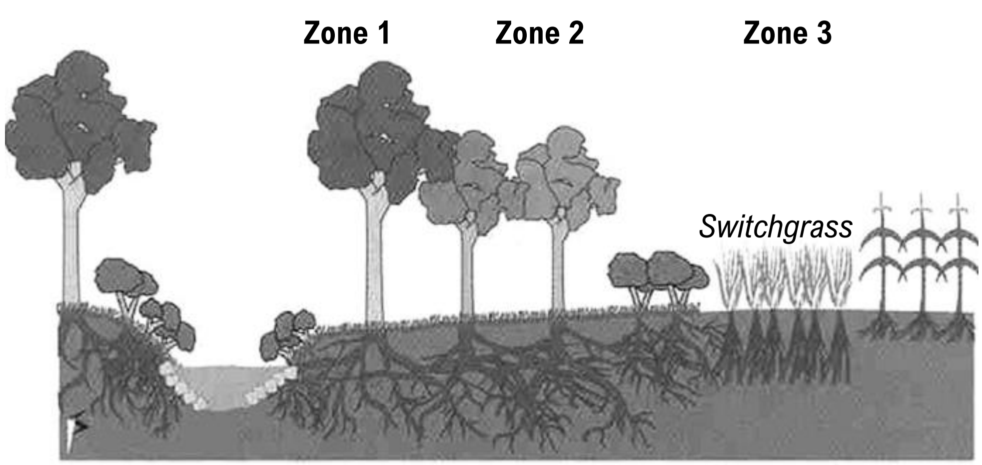

Figure 2. Conceptual design of a 3-zone riparian (streamside) buffer in which Zones 2 and 3 can be managed for harvestable crops such as wood products and switchgrass for biofuels.

Biofuels as a Conservation Practice

Increasing landscape resilience in the face of climate change is an important goal for many land managers and landowners, however, such actions can, at times, be in competition with other land uses such as food and fuel production. Use of native perennials is a potential solution to this tension, with native grasses such as switchgrass (*Panicum virgatum*) showing high potential for biofuel production. Switchgrass is a warm-season, native perennial grass adapted to Wisconsin's climate, and can be used for livestock grazing, riparian herbaceous buffer, wildlife cover, and as a biofuel crop. Furthermore, harvests occur once a year; if harvesting occurs 2-3 weeks after the first frost, the plant will recycle nutrients and likely reduce future fertilization as well as drying costs[6].

The benefits of switchgrass can be especially prominent on “marginal lands”, which are often defined as lands that have are frequently flooded, shaded, or otherwise characterized by low productivity and reduced economic return for agricultural use. Oftentimes in Wisconsin, marginal lands occur on hydric soils – defined by USDA NRCS as those soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Other marginal lands can include lands on steep slopes, those that are subject to high levels or erosion, or other attributes (such as shade) that causes low rates of returns on annual crop production. The establishment of native perennial biofuel plantations on marginal soils has been frequently promoted as having the ability to restore degraded soils, sequester SOC, improve soil quality, and benefit the environment[7,8].

Biofuels have been promoted for their many benefits; for growers, some biofuels can be planted in marginal lands and as an extra source of income; for wildlife, biofuels make a better habitat alternative to annual crops; and for ecosystem services, biofuels sustain soils and reduce runoff[9]. Following the 3 Zone model above, riparian buffers could provide numerous ecosystem services while also providing additional income in the form of woody biomass fuel stocks (Zone 2) and herbaceous biomass fuel stocks (Zone 3). Within Zone 2, fast-growing woody species such as willow and poplar, which are also adapted to hydric conditions, can be grown as a source of woody biofuel stock. Within Zone 3, native perennial grasses can be established as a “transition zone” between the woody riparian buffer and traditional row crops. Switchgrass crops need little to no maintenance or input once established; nutrients trapped in riparian buffers can largely meet the needs of switchgrass.

Economically, the establishment of switchgrass plantings and riparian buffers can come at a cost to landowners, both in the form of the initial establishment as well as lost income during subsequent years that the land is taken out of production. Despite this, the establishment of native, perennial biofuel stock can not only offset the costs of establishing a buffer, but also provide positive net income for landowners in subsequent years. Native perennials may cost less in the long term to maintain than annual crops, as they only need to be planted once, can be grown on marginal land, and annual inputs such as pesticides will be minimal[9]. Xu et al. (2019) found that harvesting switchgrass as a biomass feedstock can offset the costs of riparian buffer installation, at a biomass price >$20 per dry ton. Once the biomass market matures and prices reach $40 per d/t, switchgrass harvesting would not only offset the cost of riparian buffer implementation but also generate significant positive revenues for farmers and landowners[10].

Other biofuels, such as roundwood, logging residues, and other cellulosic feedstocks may become a viable income source on agricultural lands, providing an opportunity to integrate conservation and restoration into working lands. Demand for biofuels already outpaces supply[9] and the Energy Information Administration anticipates that production of biofuels within the US will increase substantially through 2050. Political/economic incentives seem to be on the rise: In the US, 36 billion gallons of renewable fuels will be required with the Energy Independence and Security Act by 2022[11]. The US Department of Energy has developed iterative versions of The Billion Ton Report (BTR) which aims to assess the US ability to develop a billion tons of renewable energy annually. BTR data estimated in 2016 that Monroe County could be producing as much as 16,000 dry tons of whole-tree biomass from approximately 1,465 acres by the year 2030. They also report the potential for up to 28,000 annual dry tons being produced in the county from farmed willow and poplar feedstocks (Medium housing, medium energy demand, $60 d/t market; see the BTR interactive data download site here). Ultimately, the use of marginal lands for bioenergy production, combined with comprehensive management practices, could potentially increase soil carbon sequestration, enhance soil and water quality and support ecosystem services[11], while providing an economically feasible income source for landowners.

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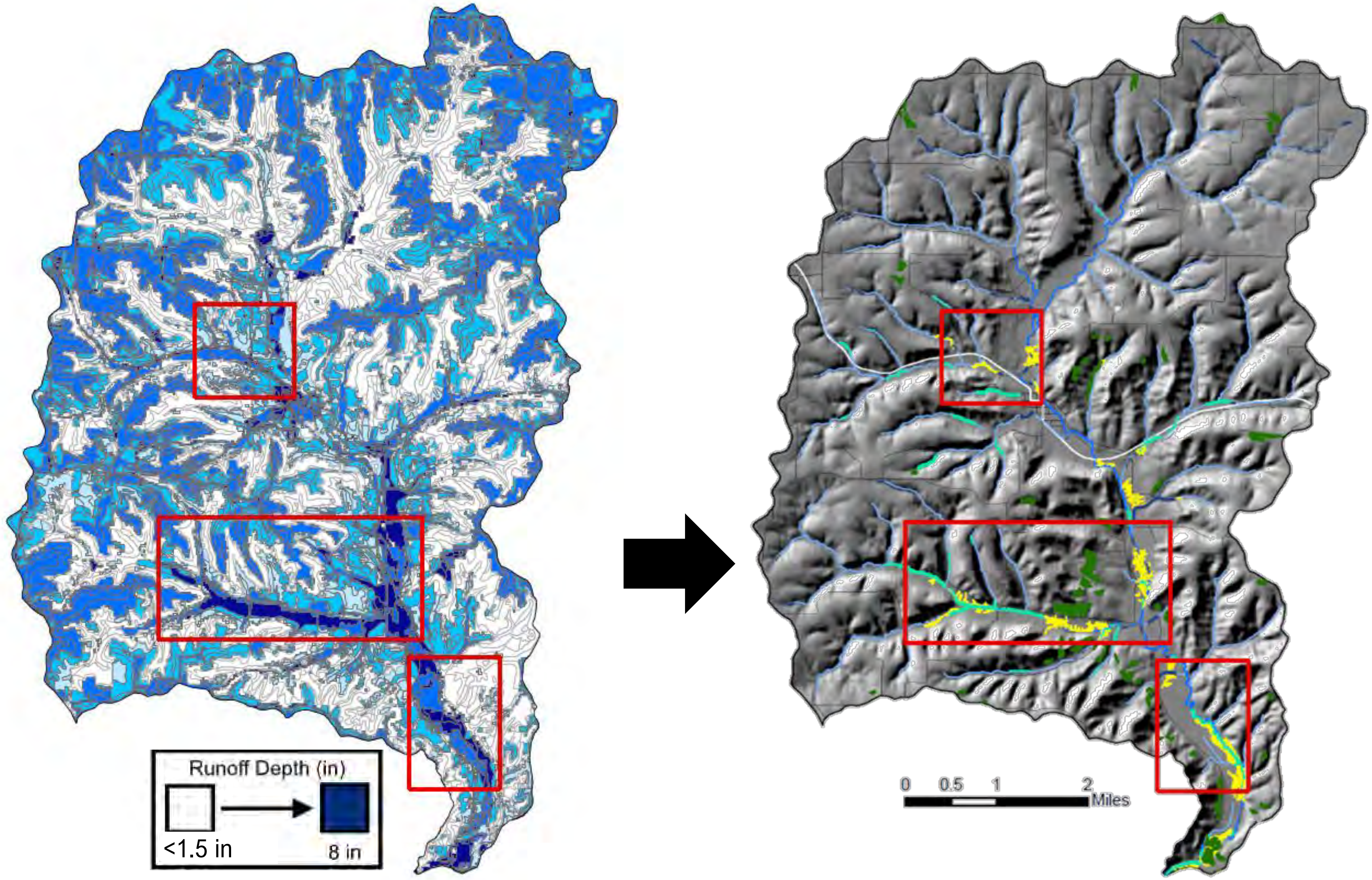
Appendix VIII - Opportunity Assessments Methods and Maps

This analysis focused on 3 primary areas of potential ecological restoration: reforestation, potentially restorable wetlands (PRWs), and riparian buffer restoration. Reforestation opportunities were identified using The Nature Conservancy's Reforestation Hub spatial data, modified and refined to reflect accuracy issues. Areas amenable to the restoration of riparian buffers were identified in ArcGIS as current row crop/dairy rotation areas within 100 feet of a stream. This 100-foot "general" buffer distance has been demonstrated in the research to provide streambank stability, stream shading (where applicable), some level of floodwater control, and sediment control, under "typical" storm events. Riparian restoration areas were further prioritized as buffer areas (as described above) within 100m of a high slope area (>30%). Ideally, buffers would be 150 feet or wider to more completely filter nitrogen and phosphorus, however, buffers of this size will likely be case-specific and dependent on nearby geomorphological characteristics. Furthermore, some of these areas could be significantly expanded on when combined with marginal soils/high-priority potentially restorable wetland (PRW) areas.

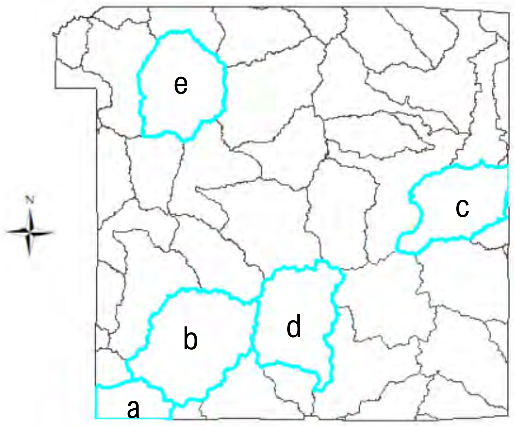
Potentially restorable wetlands are areas identified as likely being historic wetland (open marsh, emergent wetland, forested wetland etc.), with hydric soil, not currently mapped as a wetland, and have a land use compatible with restoration techniques. A total of 78,652 acres of PRWs have been identified by the WDNR in Monroe Co. Because restoration is often expensive, complex, and time-consuming, prioritization of PRWs is important for multiple benefits, particularly flood control, erosion control and nutrient runoff, is therefore important. High-priority PRWs were identified as those hydric soils within 450 feet of a steep slope (>30%), within 600 feet of a stream, and within 1 mile of a recent (2017-2021) recorded flood damage site.

This analysis identified over 470 miles of unbuffered stream in the County, accounting for more than 7,000 acres of streamside restoration opportunity (using a 100-foot buffer distance). Prioritizing only those areas within 100m of a high slope area (>30%), 2,569 acres of "high priority" riparian buffer conservation opportunity exists in the county. Prioritization of PRWs in the county resulted in the identification of 2,405 acres of high-priority areas; of these, 1100 acres intersect, overlap, or are partially within already identified high-priority riparian buffer areas, and many (1350 acres) of these locations fall within FEMA floodplains. The Nature Conservancy's Reforestation Hub, with necessary additional processing, resulted in a total of 20,991 acres of reforestation opportunity in the county. See Table 1 below for watershed-level results.

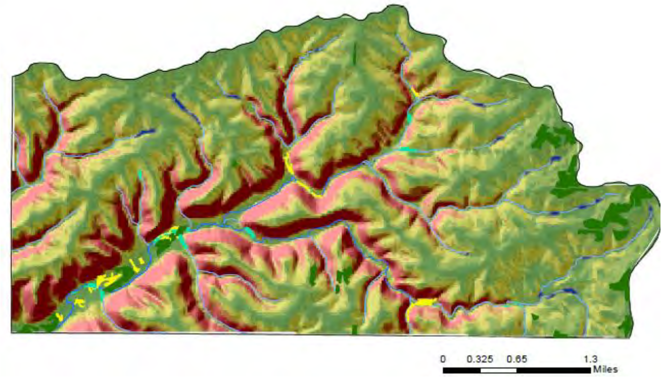
While this analysis was conducted for the entire county, detailed maps are provided below for the watersheds studied and reported on in the hydrological runoff model, for comparison purposes.



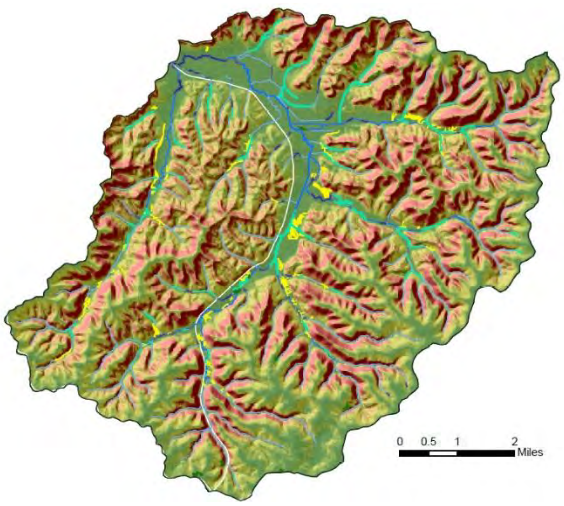
Depiction of modeled runoff depth (left) and modeled high-priority conservation/restoration opportunity areas (right). Conservation and restoration sites in the floodplain and along rivers and streams prioritizes "slowing the flow", but also provides nutrient filtration, wildlife habitat, and carbon sequestration.



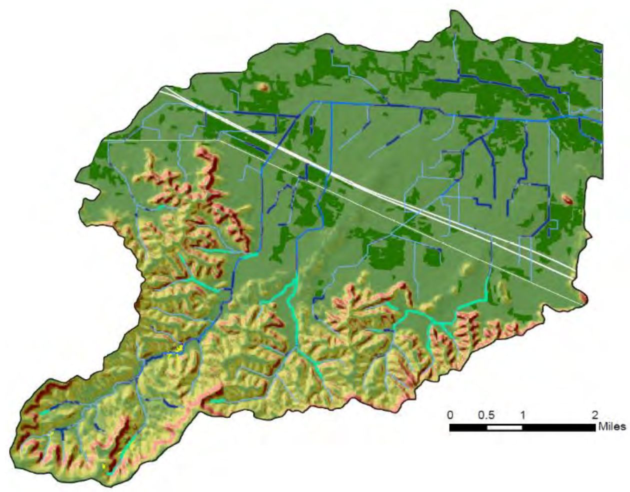
Timber Coulee Creek (a)



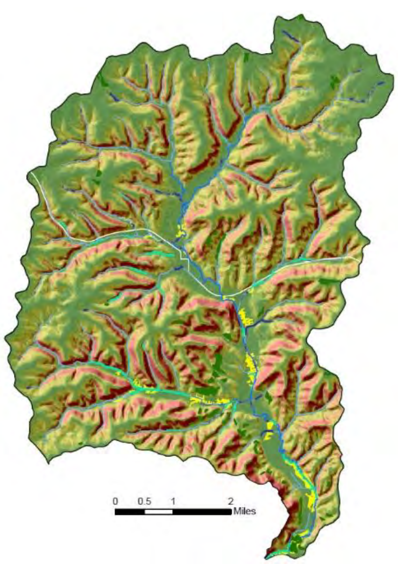
Headwaters of the Little La Crosse River



Bear Creek (c)



Moore Creek (d)



Rathbone Creek – Soper Creek

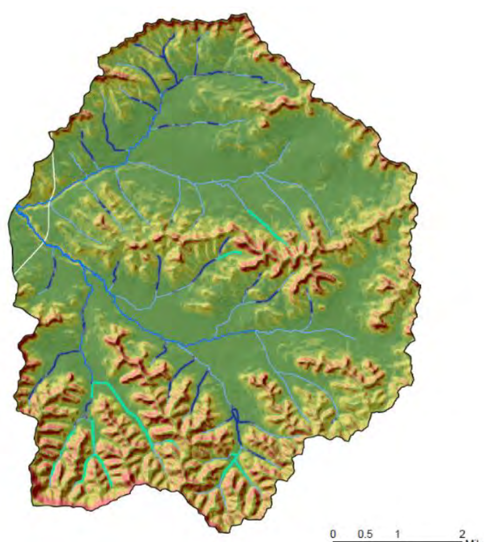


Table 1. Watershed-level results of restoration opportunity assessment.

HUC-12 Watershed Name (HUC-12 Code)	HUC12 Total Acres±	Miles Unbuffered Stream	General Stream Buff (acres)	High Priority Stream Buff (acres)	High Priority PRWs (acres)	Reforestation Opportunity (acres)	Eco Index	Stress Index
Bailey Creek-La Crosse River (70400060204)	17363	13	160	79	0	9	42.99	32.21
Bear Creek (70700031601)	21558	37	423	156	22	2927	15.22	59.43
Beaver Creek (70400060302)	11294	16	130	130	0	0	17.99	46.35
Big Creek (70400060305)	9220	14	158	61	0	3	17.79	48.3
Billings Creek (70700060302)	7737	6	27	53	44	1317	26.45	41.54
Brandy Creek-Lemonweir River (70700031507)	21578	5	84	0	0	1552	51.65	12.92
Brush Creek (70700060301)	13431	10	58	65	118	382	20.92	45.3
Clear Creek (70400071005)	13994	0	0	0	0	253	62.36	9.08
Cleaver Creek (70700040101)	2029	1	4	0	4	7	10.02	58.87
Cook Creek (70700060103)	5771	5	23	44	85	543	22.73	44.12
Cutler Ditch-Lemonweir River (70700031602)	3270	5	69	22	0	311	43.57	28.82
Dandy Creek-Lemonweir River (70700031508)	11835	10	154	0	0	1708	49.01	27.27
Dutch Creek (70400060308)	911	1	8	0	0	0	23.32	46.97
Eagle Nest Flowage-Beaver Creek (70700031402)	6153	2	39	0	0	721	60.52	6.67
Farmer's Valley Creek (70400060301)	14920	12	90	91	7	23	29.69	36.7
Fish Creek (70400060307)	5241	7	5	104	0	0	23.45	48.32
Fountain Creek-Little Lemonweir Riv (70700031604)	261	1	5	0	0	0	14.25	50.34
Glenn Creek-Robinson Creek (70400071006)	4715	1	0	10	0	92	66.36	5.98
Headwaters La Crosse River (70400060202)	24900	2	21	9	0	270	59.58	10.82
Headwaters Little La Crosse River (70400060303)	33350	38	155	445	395	35	20.15	47.62

HUC-12 Watershed Name (HUC-12 Code)	HUC12 Total Acres±	Miles Unbuffered Stream	General Stream Buff (acres)	High Priority Stream Buff (acres)	High Priority PRWs (acres)	Reforestation Opportunity (acres)	Eco Index	Stress Index
Headwaters of the Baraboo River (70700040102)	19045	12	158	4	62	961	11.59	52.8
Indian Creek-Little Lemonweir Riv (70700031603)	20660	17	145	99	86	12	17.75	47.13
Jay Creek-East Fork of Lemonweir Riv (70700031506)	7950	0	0	0	0	409	53.05	10.95
Knapp Creek-West Fork Kickapoo Riv (70700060202)	1784	3	47	0	0	76	18.24	46.32
Kreyer Creek-South Fork Lemonweir Riv (70700031504)	23772	23	269	33	121	2133	14.6	51.68
Lake Tomah-South Fork Lemonweir Riv (70700031501)	19393	23	255	89	0	39	5.69	55.74
Little La Crosse River (70400060304)	19656	24	343	56	328	23	17.56	45.44
Moore Creek (70700060102)	25988	21	119	173	434	251	18.02	47.88
Mud Creek (70700031502)	11075	7	115	0	0	638	16.6	39.13
Poe Creek-Kickapoo River (70700060104)	20676	19	126	119	408	1398	22.11	45.73
Rathbone Creek-Soper Creek (70400071201)	24064	26	324	129	0	48	39.45	29.15
Roaring Creek-Black River (70400071205)	7400	2	26	8	0	132	34.55	39.38
Sand Creek (70700031505)	12273	3	52	0	0	1605	53.77	15.63
Seymour Creek (70700040103)	7840	5	54	3	6	1802	8.56	62.54
Silver Creek (70400060203)	24641	13	87	93	0	21	44.46	25.44
Sleighton Creek-Kickapoo River (70700060101)	22450	22	160	134	264	843	18.28	49.33
Spencer Creek-Big Creek (70400071202)	18199	16	101	186	0	84	39.62	27.49

HUC-12 Watershed Name (HUC-12 Code)	HUC12 Total Acres±	Miles Unbuffered Stream	General Stream Buff (acres)	High Priority Stream Buff (acres)	High Priority PRWs (acres)	Reforestation Opportunity (acres)	Eco Index	Stress Index
Stony Creek-Robinson Creek (70400071007)	7651	9	119	49	0	124	58.21	20.29
Tarr Creek (70400060201)	13717	8	33	96	0	167	49.75	19.57
Timber Coulee Creek (70600010101)	8559	5	31	21	77	176	20.4	47.66
Town of Sparta-La Crosse River (70400060306)	9633	3	52	0	0	20	17.48	33.79
Upper Coon Creek (70600010102)	3743	4	32	10	9	25	24.29	47.53
Water Mill Pond-Lemonweir River (70700031503)	16121	22	324	17	0	1628	20.52	46.6
Totals		470	4586	2588	2470	22764		

± For watersheds that fall partially outside of Monroe Co, only the acres within Monroe County are reported.

Appendix IX – Understanding Urban Climate Vulnerability

Cities and other urban areas are major contributors to climate change (producing more than 60% of GHG emissions worldwide[1]) but simultaneously among the most susceptible landscapes to the impacts of climate change[2]. Cities concentrate both people and infrastructure, contributing to the development of "heat islands", and are often situated along rivers and other waterways, making homes, industry, and transportation highly vulnerable to floods and flood damage. Extreme weather in urban areas causes disruptions to critical infrastructure like water systems, sewer systems, roads, and power plants, particularly those already aging and in need of repair[3].

Furthermore, human vulnerability in urban areas is often unevenly distributed; that is, lower-income and underserved communities are often at higher risk to climate change impacts, due both to the geographic location of many of these communities (often near to polluting industrial and flood-prone areas) and the lack of available resources to escape or cope with disasters. Here we discuss elements of urban contributions to climate change and the vulnerabilities unique to these areas. While an in-depth assessment (for example, neighborhood-level) of all urban areas in Monroe County is outside the scope of this phase of the project, vulnerability of urban areas can be derived from our watershed analysis and some specific situations are highlighted below.

Floods in Urban Areas

Cities are tightly concentrated areas of "gray infrastructure" – roads, dams, canals, and more – built of concrete and other impervious, hard-surface materials that seal the soil and warm the environment[4]. Such "sealed soil" leads to increased storm water run-off, often artificially diverted to larger streams via canals and straightened drainage ditches, increasing the speed and volume of water reaching rivers during a storm event. Floodwaters may reach industrial sites, construction areas, and other areas of loosened soil substrates, carrying excess siltation, debris, and other hazards to downstream locations.

Critical infrastructure located in cities, such as hospitals and public safety sites, can be damaged, destroyed, or inaccessible due to flood waters and people may become stranded in their homes when roads are overcome. Flooding also brings risks of contamination and disease to residents. Floodwaters can carry raw sewage, leaked toxic chemicals from industrial areas, and runoff from hazardous sites. The impacts of flooding can be ubiquitous across a city, however due to the propensity for lower-income and underserved communities to be located near industry, toxic sites, landfills, and flood-prone areas[5], the risk of being impacted by floodwaters and the contaminants they can carry increases for these communities greatly.

Based on Flood Factor data, both Tomah and Sparta are likely to experience flooding in coming decades. Tomah is situated alongside the South Fork of the Lemonweir River and Council Creek, while Sparta is intersected by the La Crosse River. Flood Factor® data indicates that Tomah will generally have a moderate risk of flooding in coming decades, while Sparta's risk is much greater (major to severe risk; Figure 1).

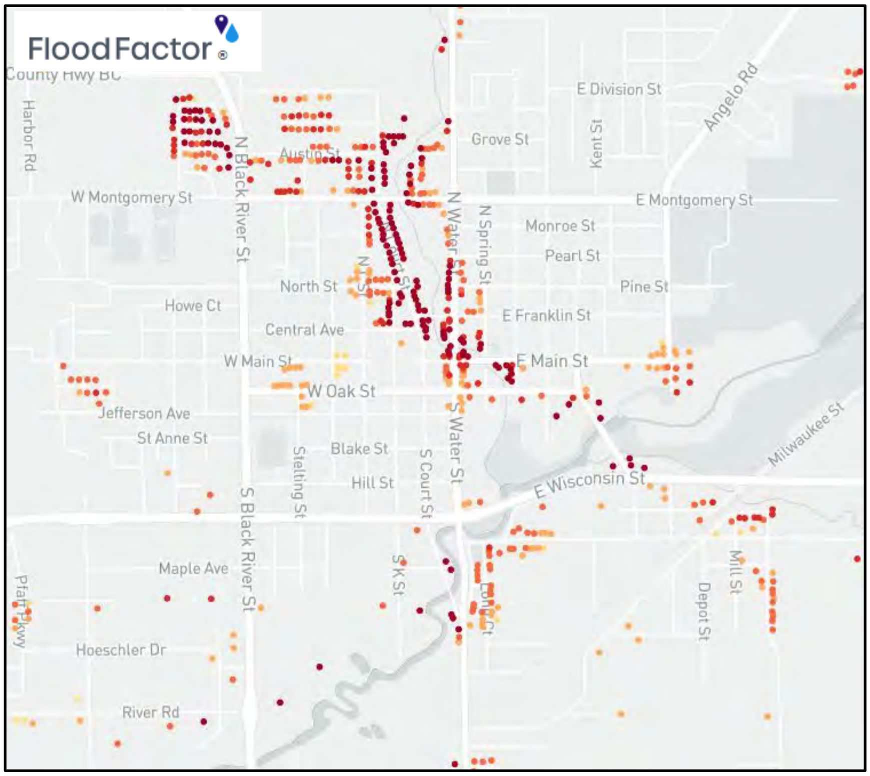


Figure 1. Flood Factor risk assessment for a portion of Sparta. Points represent overall risk (residential, industry, infrastructure, etc), with the darkest red dots considered to be in "extreme risk" of flooding by 2050 and those in orange considered "moderate".

Toxic Sites – Brownfields and Superfunds

Because toxic sites (often called Superfunds and Brownfields) are typically the result of manufacturing practices, improperly disposed industrial waste, and landfills, a vast majority of them are located within cities. **Superfund sites** are a formal Federal designation (CERCLA) through the US EPA and are considered severely polluted toxic locations requiring a long-term response to clean up hazardous material contaminations. Because of the severity of the contamination, Superfund EPA National Priorities List (NPL) designation allocates Federal dollars and resources to the clean-up of the site and authorizes Federal bodies to investigate responsible parties. The principal goal of Superfund remediation is to reduce the risks to human health through cleanup and controls. A secondary goal is to return the site to productive use as a business, recreation or as a natural ecosystem. A **Brownfield** is also contaminated but differs from a Superfund in that it is less severely contaminated, and thus less likely to be cleaned up with federal funds. Oftentimes Brownfield sites are former Superfunds that have received some level of cleanup and remediation, lowering the level of contaminants, but still requiring additional action to reduce or eliminate toxicity.

Data obtained from the Wisconsin DNR indicates that there are 4 Superfund sites and 26 Brownfield sites in Monroe County. Of these, 1 Superfund site and 4 Brownfields are in or within 100 feet of the floodplain, presenting risks of downstream hazardous waste contamination during a flood. One Superfund site and 8 Brownfields are located within Sparta, and 3 Superfunds and 7 Brownfields are located within Tomah.

Heat Islands

Engineered materials such as roads, parking lots and buildings alter the reflectivity of the land surface; rather than reflecting incoming solar radiation, cities absorb 80–85% of it, making them hotter than non-urban locations[6]. In addition, industrial and transportation activities produce waste heat emissions. Urban areas therefore become "islands" of higher temperatures, referred to as "heat islands." Heat islands can form day or night, in small or large cities, in northern or southern climates, and in any season. Daytime temperatures in urban areas can be up to 7°F higher than temperatures in outlying areas[7].

Heat islands in turn exacerbate climate change due to an increased demand for air conditioning to cool buildings. This increases overall electricity demand, peak energy demand, and air pollutants (due to increased power demand from fossil fuel power plants). During extreme heat events, which are exacerbated by heat islands, the increased demand for air conditioning can overload systems and cause blackouts or "brown-outs", causing the loss of critical cooling for many homes and businesses.

These factors in turn, contribute to heat-related deaths and illnesses ranging from respiratory difficulties to heat exhaustion and heat stroke. Sensitive populations are particularly at risk during these events. Older adults are among the most vulnerable to extreme heat events, however young children may also be at increased susceptibility. Populations with low-income are at greater risk of heat-related illnesses due to poor housing conditions, including lack of air conditioning and small living spaces, and inadequate resources to find alternative shelter during a heat wave. Disadvantaged communities, who have statistically higher rates of health conditions such as heart disease, diabetes, and asthma, are also at higher risk, as heat stress can exacerbate heart disease and diabetes, and warming temperatures result in more pollen and smog, which can worsen asthma and COPD[8].

Recommendations

Flood risk in urban areas should be evaluated more thoroughly using Flood Factor, FEMA, and other resources to evaluate risk and plan for adaptation. Areas near industrial sites, contamination sites, housing (esp. low-income and underserved areas) should receive special attention to ensure evacuation routes, resource availability (including access to emergency services), and contamination control. Efforts should be made to evaluate the extent of cleanup and remaining toxicity of Superfunds and Brownfields sites in Sparta, Tomah, and other areas throughout the county.

Mobile home parks, which are often placed in or near floodplains and industrial sites, are particularly at risk. The structural integrity of mobile homes likely would not be able to withstand damage from flood waters, and escaping residents may be exposed to floodwaters inundated with sewage and toxic wastes. Indeed, previous studies have investigated the flood exposure of mobile home residents and found them to be vulnerable due to widespread siting of mobile home parks in floodplains, structural fragility, and poverty[9]. This case example represents the interacting elements of climate factors interacting with non-climate stressors and hazards, in an area with socially vulnerable people and critical infrastructure. **Environmental justice issues, especially in urban areas, should be more thoroughly assessed in the County.**

Appendix IX References

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Flood Factor data for Monroe County can be found at: https://floodfactor.com/county/monroe-county-wisconsin/55081_fsid