Climate Modeling and Stormwater Capture/Infiltration Goals: Choosing the Best Mitigation Strategy

Introduction

In order to inform the goal of our research and calculate the quantity of stormwater handled by green infrastructure on our study site, we must explore which climate modeling method or alternative mitigation strategy would be most beneficial in preparing for future impacts in Wisconsin. Potential methods include offsetting future annual precipitation increases, extreme precipitation events, recent extreme rainfall years and events, and average rainfall levels by season or non-climate model based strategies, such as capturing the first ½-inch of rainfall, decreasing the amount of impervious surfaces and preparing for a range of conditions. All of these methods accomplish different goals in relation to stormwater management.

Mitigation Strategies Informed by Future Climate Projections

Offset Future Annual Precipitation Increases

This method focuses on capturing the excess rainfall produced annually, as outlined by the WICCI climate projections, along with other climate modeling. Planning for this mitigation strategy means that we have the choice of how far in future we would like to plan, such as 20-30 years or 50-70 years. The time period will affect the predicted percent increase in annual precipitation [1]. This method assumes that we will be prepared for the total amount of water produced annually. However, it does not take into account the expected increase in severe precipitation events, and as UW-Madison professor emeritus of civil and environmental engineering Ken Potter mentioned, annual rainfall alone is not a good measure of flood risk. Furthermore, climate scientists predict an increase in both severe precipitation events and droughts. The models which predict an annual precipitation percentage are also calculating dry periods and therefore increases in severe precipitation events may be concealed by the annual averages. Additionally, as Michael Notaro from the WICCI Climate Working Group suggested, these annual predictions for precipitation are less reliable than other models because summer precipitation projections are still uncertain.

Prepare for Increases in Extreme Precipitation Events

This method aims to prepare for the expected increase in severe precipitation events in Wisconsin. These severe rainfall events, often ranging from 1 to 5 inches, contribute to flooding, erosion, and other impacts associated with stormwater management [2]. Planning with this mitigation strategy means that we also have the choice of how far in future we would like to plan and for which sized rain event. Creating green infrastructure plans which could handle the rainfall from severe precipitation events would be a successful strategy to mitigate the adverse impacts of climate change. However, the majority of rain events are smaller than ½-inch and this stormwater plan would be designed to handle much larger quantities, such as 1 or 2 inches during a single period. While severe rain storms are predicted to increase with climate change, they do not occur as frequently as smaller rainfall events and therefore preparing green infrastructure plans for the large precipitation events may not be the most cost-effective method of handling stormwater.

Offset Annual Precipitation Increases by Season

as recommended by Michael Notaro from WICCI Climate Working Group

As Michael Notaro suggested, summer precipitation projections are much more uncertain than cold-season projections because “the global models struggle with representing convection.” In contrast, climate projections widely agree that cold-season precipitation will continue to increase in Wisconsin. Another mitigation strategy could plan for increases in precipitation by individual season and focus on the seasons where precipitation increases are more certain, such as in fall, winter, and spring [7]. This method may be a better option than using the annual precipitation projections, which take summer precipitation into account, and therefore may be less reliable. Planning with this mitigation strategy means that we also have the choice of how far in future we would like to plan. However, something to consider would be how well the green infrastructure practices perform in the cold seasons and whether it is feasible to plan green infrastructure scenarios for the winter months in cold climates.

Mitigation Strategies Not Informed by Future Climate Projections

Offset Recent Extreme Rainfall Years and an Additional 5-10%

as recommended by Chris Kucharik from WICCI Agriculture Working Group

In the last ten years Wisconsin has experienced unprecedented levels of annual rainfall, from 34.5 inches in 2010 to over 46 inches in 2019 for Madison, WI [3]. This extreme increase in annual precipitation has resulted in flooding, erosion, and other large stresses on our stormwater management infrastructure. This method accounts for the extreme years of rainfall that are not illustrated in many of the annual climate projections. Furthermore, it seeks to use the impacts that we have already experienced in Wisconsin as a guide for our stormwater planning, while assuming that these recent trends will continue to increase. However, it does not take into account the possibility of drought in future years, when plans that offset large amounts of rainfall will not be necessary. Additionally, as Michael Notaro from the WICCI Climate Working Group mentioned, these recent extreme precipitation years may be due not only to climate change, but also “natural variability from stochastic rain episodes.” Therefore, these recent events may not represent a trend which is expected to continue.

Prepare for the Extreme Precipitation Events that We Have Experienced

as recommended by Ken Potter, UW-Madison professor emeritus of civil and environmental engineering

Ken Potter suggested that Wisconsin ordinances do not often take into account the recent increases in extreme precipitation events in current planning practices. He states that "the extreme rainfall statistics we use for the design of facilities do not account for recent increases in the magnitude and frequency of extreme rainfall." Therefore, another potential mitigation strategy would be to plan for the extreme precipitation events that we have experienced in Wisconsin in recent years. In August, 2018, for example, the UW-Madison campus received almost 4 inches of rain during one storm while other areas of the county received over 10 inches [8]. By offsetting the rain from large magnitude events like those we have already experienced, we would be preparing for their increased frequency of occurrence. However, while this method would take into account the increase in severe precipitation events, planning for these large-scale rainstorms may not be the most cost-effective method, as most rain events in Wisconsin are smaller than ½-inch.

Capturing the First ½-inch of Rainfall

as recommended by MMSD in the Regional Green Infrastructure Plan (2013)

In their Green Infrastructure Plan, MMSD claims that capturing the first ½ inch of rainfall is the most cost-effective way to manage stormwater. They explain that "designing for smaller storms is more efficient because the storage volume is full for many storms, while big storms don't happen that often so designing for these larger storms all the time is not as cost-effective." According to their analysis, more than 70% of average annual rainfall capture results from storms of less than ½-inch [4]. Capturing the first ½-inch of rain that falls on a site will therefore take into account the increase in rain events, but does not plan for the increase in severity of those events.

Decreasing the Amount of Impervious Surface

This method of stormwater management also does not focus on climate modeling, but rather aims to decrease the amount of impervious surfaces within a site. The Philadelphia Stormwater Management Guidance Manual uses this method as a guide for managing stormwater and states that, "Every acre of impervious cover in Philadelphia produces about 1 million gallons of polluted runoff per year, causing sewer overflows, degraded stream habitat, and water quality problems" [5]. Furthermore, according to a 1996 study by Arnold and Gibbons, a stream is greatly impacted by the amount of impervious surface and is protected only when that amount is less than 10% [6]. Decreasing impervious cover will simultaneously decrease polluted runoff, improve the health of water bodies, and handle increases in rainwater by allowing more water to infiltrate into the ground. However, while this method may inadvertently mitigate the issue of severe precipitation events, it does not plan for this goal. Therefore, the amount of surface turned pervious may not be enough to handle the water from the increasingly severe precipitation events or extreme annual rainfall levels.

Alternative Mitigation Strategies

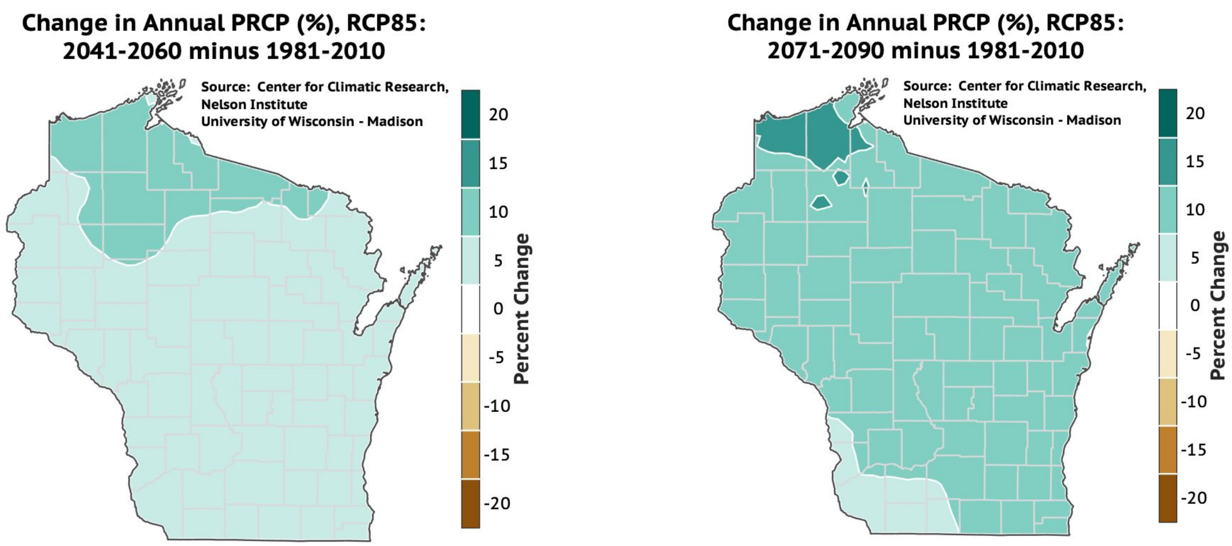
Preparing for a Range of Conditions

as recommended by Dan Wright from WICCI Infrastructure Working Group

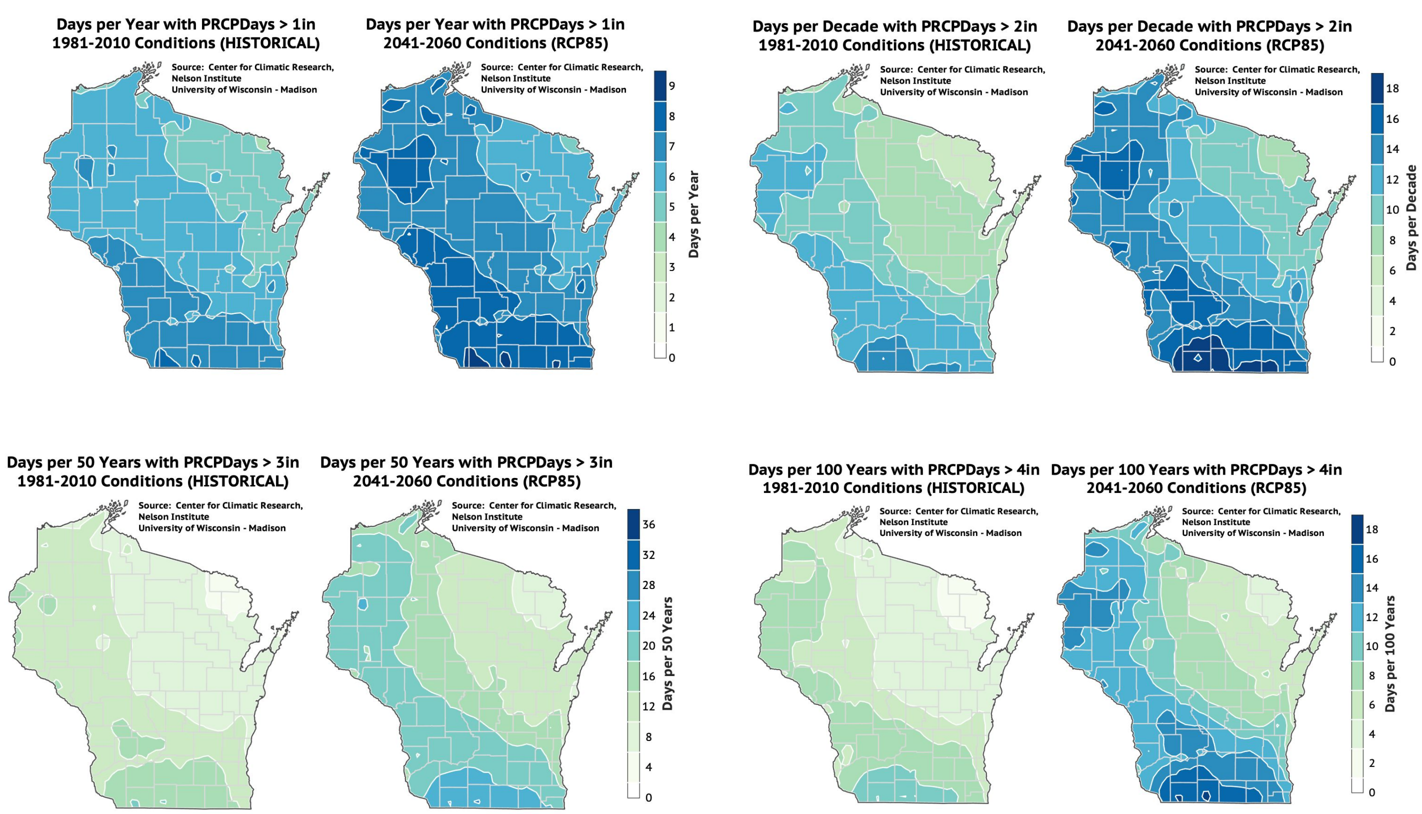
This alternative method focuses on using all the above strategies to inform a stormwater management plan. Rather than choosing a single method, this idea suggests that many possible conditions should be considered in order to plan for future impacts. These include the increase in annual precipitation and average precipitation by season, severe weather events, both storms and droughts, and the recent extreme levels of storms and annual precipitation. By considering all these variables, we may prepare green infrastructure plans which can handle severe storms, decrease the levels of impervious surfaces, and consider the recent extreme years and events. A way that this may be put into practice is choosing one mitigation strategy to create a green infrastructure scenario, but then using the same scenario to calculate if it can handle the stormwater from other modeling or mitigation strategies, therefore choosing the strategy that can handle multiple stormwater goals. For example, a green infrastructure plan which can handle the first ½-inch of rain or which captures severe rainfall events of 1 or 2 inches will also likely be able to handle a 5 or 10% increase in annual precipitation, as suggested by the annual climate projections.

<u>Sources and Figures</u>

[1] WICCI Climate Projections for an Annual Increase in Precipitation

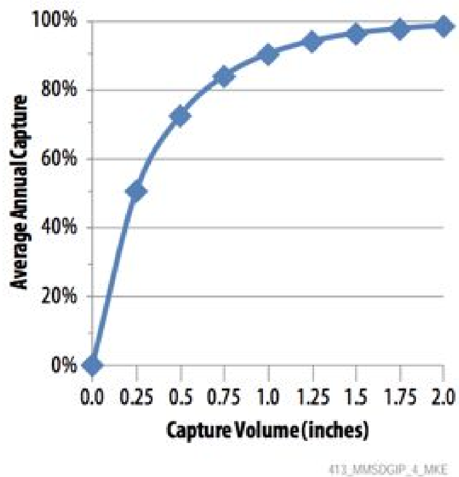


[2] WICCI Climate Projections for the Increase in Severe Precipitation Events



[3] nbc15.com: 2019 was the 5th wettest year on record for Madison
[4] MMSD Regional Green Infrastructure Plan (p.31)

FIGURE 12
Rainfall Capture Analysis Based on Daily Rainfall Data at Milwaukee's General Mitchell International Airport (1940-2011)



[5] Philadelphia Water Department: The Philadelphia Stormwater Management Guidance Manual
[6] Impervious Surface Coverage: The Emergence of a Key Environmental Indicator

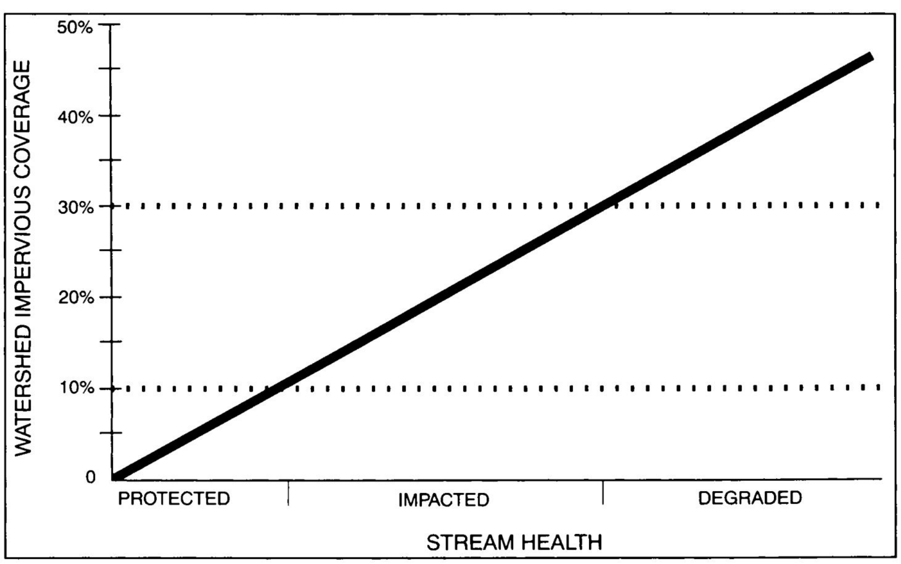
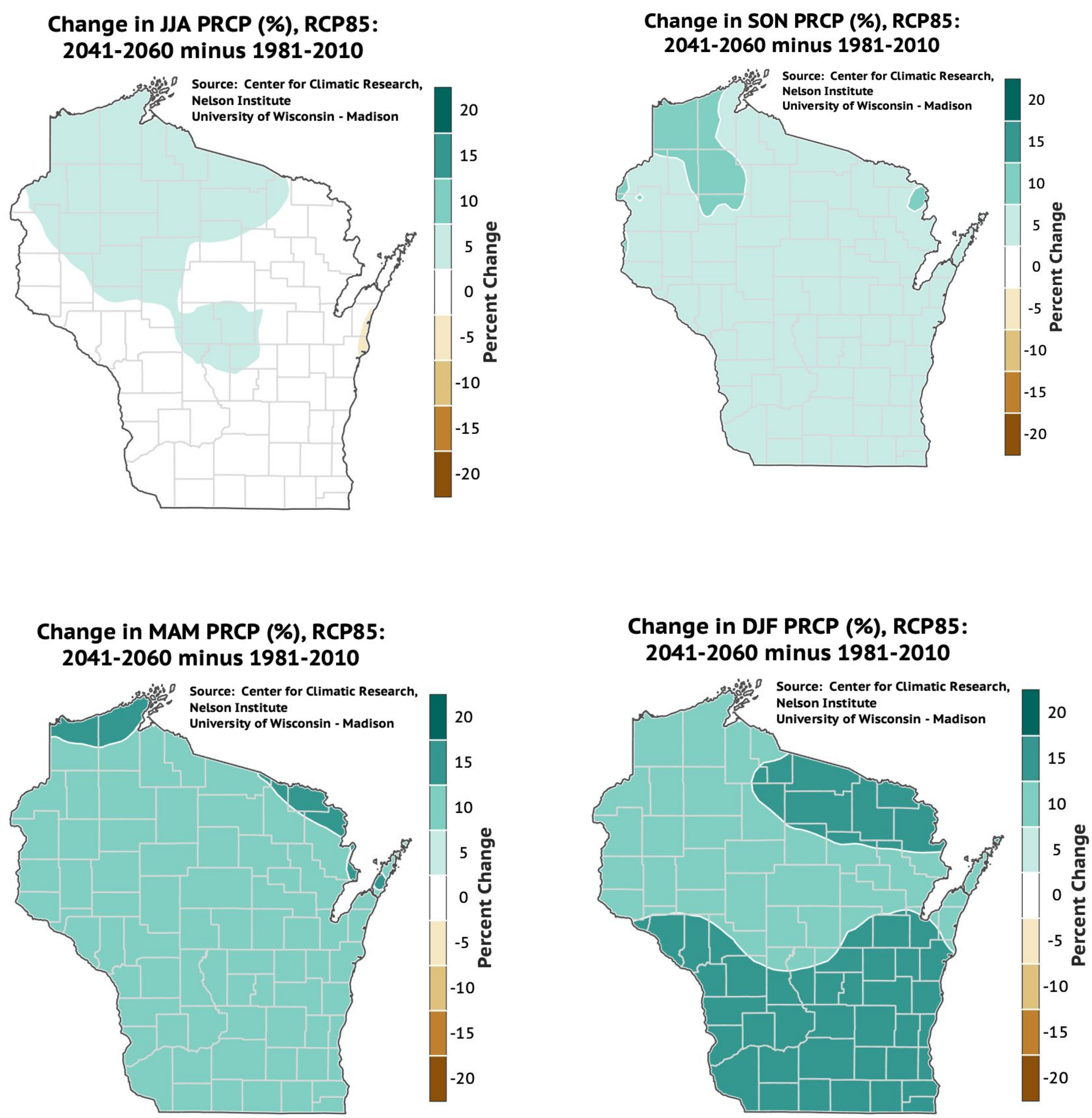


FIGURE 2. Stylized relationship of imperviousness to stream health
Modified from Schueler 1992

[7] WICCI Climate Projections for an Annual Increase in Precipitation by Season



[8] [Wisconsin State Journal: “2018 ends as second-wettest year recorded in Madison”]