Climate Risks and Resilience at Dickinson College: Ecosystem Services, Green Infrastructure, and Stormwater Management

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Introduction

Climate change in the 21st century is changing the ways humans interact with their environments, putting populations at risk. Within higher education, climate change has begun to pose certain risks to the students, faculty, and staff that these institutions are designed to protect. In order adapt and mitigate to the many challenges that climate change brings, it is critical that humans view this time in history as an opportunity to make spaces safer, more inclusive, and healthier considering the future of our planet. University and college campuses are landscapes that are typically in urban settings, built environments, that present key opportunities for setting the standard for climate resilience and exemplary planning on climate change related issues. Through the inherent value put on education, teaching, and discovery within higher education and its institutions, we must look towards capitalizing upon the benefits that a sustainable, climate safe, and resilient campus can bring to its stakeholders.

To begin this work towards improving the resilience of college campuses, it is critical to analyze the current values, strengths, assets, as well as vulnerabilities, that exist at the college. From an environmental perspective, understanding the college's willingness to implement more climate resilient measures on campus is critical if the college is to commit to long term change. Climate risks, such as frequency of intense weather, drought, extreme heat events, flooding, and biodiversity threats are stressors that college campuses, and their populations, are now facing. To accelerate climate action, it has become critically important to look inward at these stressors, research them, present the risks they bring, and propose solutions to improve resilience through higher education.

This report is one of a series of reports being prepared for *Building Climate Resilience at Dickinson and in Central Pennsylvania*, a joint initiative of Dickinson College, the Borough of Carlisle, and Cumberland County that is part of the Resilience Commitment of Second Nature (Center for Sustainability Education, 2024). It focuses on climate-related risks and resilience of ecosystem services, stormwater management, and green infrastructure at Dickinson College. Other reports produced for the initiative address other categories of climate risks and resilience for the college as well as for Carlisle and Cumberland County. The intention of the reports and initiative is to provide information to support planning and action to increase climate resilience at Dickinson College and in the wider region.

Information for the report was gathered through interviews with knowledgeable stakeholders and published reports and articles on climate change risks and resilience. Interview participants include community planners, Dickinson staff members, professors, and professionals in the field. Additionally, college land uses were mapped using GIS to characterize locations and extent of green areas, tree canopy, and impervious surfaces. Information from these different sources is presented in the report to provide an assessment of the current state of resilience ecosystem services, green infrastructure, and stormwater management at Dickinson.

Second Nature

Leadership and Committing to Resilience

Second Nature is committed to accelerating climate action in and through higher education. Acting through bold commitments to sustainability, the goal is to scale up resilience efforts with the intention of generating community-based research as well as innovative climate solutions. Through the utilization of higher education institutions, Second Nature encourages campus communities to take leadership in climate change and resilience solutions. As climate change risks are continuing to be felt within campus and surrounding communities, it is critical to understand that these risks are projected to become more severe over time. Through this leadership, resilience reports will be created by a variety of campuses with varying land use types, stakeholders, and climate risks.

Strengths/Assets and Vulnerabilities

The assessment of resilience is intended to provide a baseline of the current state of resilience activities on the campus and to identify the current vulnerabilities that are likely to impact the community. In addition to identifying vulnerabilities, it is important that the report emphasizes the strengths and assets that can be used to build climate resilience. Building upon the strengths of the community is key to the strategy of Second Nature, especially when working within institutions with limited budgeting and a wide spectrum of climate knowledge. It is critical to note the relevance of these issues as the metrics designed to analyze them cover a wide range of stakeholders. This research is designed to provide the college with the necessary information regarding its current and future resilience strategies with an integral focus on climate change and the wellbeing of campus community life.

Ecosystem Services and Green Infrastructure

As noted by Second Nature's guidelines on assessing campus resilience, "ecosystem services include the environmental systems and services preset in the campus community, including assessment of stormwater management, biodiversity, and landcover assessment" (Second Nature, 2021). Ecosystem services are multidimensional in their benefit on university and college campuses, advancing the hydrology of the campus, cooling, reductions in energy use, aesthetic value, and high potential for educational opportunities. Second Nature identifies quantitative and qualitative indicators to assess the ecosystem services within a campus community including urban green space coverage, tree canopy, rainwater management strategies, climate suited vegetation, and access to outdoor recreation. Ecosystem services can also be accelerated with the implementation of green infrastructure. Utilizing management practices such as rain gardens, bioretention facilities, and tree canopy, campuses can accelerate their resilience to flooding, heat stresses. Lastly, through these measures, institutions intend to enhance community education on climate change and its associated risks.

Climate Stressors and Risks

Heat Stress

Rising Temperatures

The climate is warming and changing in other ways that is exposing people, economies, and natural systems to greater climate hazards throughout the world and in Pennsylvania. Looking to the future, the climate will continue to warm and change in response to growing atmospheric concentrations of greenhouse gas pollutants, as indicated by a range of emissions scenarios analyzed by the Intergovernmental Panel on Climate Change (IPCC). Depending on how much greenhouse gas pollutants are emitted, and how strongly the climate responds to the gases, global average temperatures are projected to increase 1.2 to 3.0° C (or 2.2 to 5.4° F) by mid-century compared to temperatures in the period 1850 - 1900. By the end of the century, unless deep reductions are made in emissions of greenhouse gas pollutants, temperatures will continue to rise to even higher levels. (IPCC, 2021).

Consistent with global and North American trends, Cumberland County experienced temperature increases at the rate of 0.2°F per decade over the time period 1895 – 2018. A review of future climate projections for the County reveals that our region, like the rest of the world, is expected to grow hotter. For a scenario of high emissions of greenhouse gases, average temperatures in the County are projected to increase 2.0 to 3.8° F by 2035 relative to the baseline period 1971 – 2000. By mid-century, 2046 – 2065, temperatures are projected to increase 4.3 to 7.2° F relative to the baseline and by late-century, 2076 – 2095, the projected increase is 6.5 to 11.4° F. (Leary, 2023).

As average temperatures rise, the frequency and severity of extreme heat events will very likely increase throughout the world, including in Cumberland County. In the near-term, through 2035, the average number of days that exceed 90° F per year is projected to increase from 7 days per year in the baseline period to 15 to 33 days per year in a future with high emissions of greenhouse gases. By mid-century, the average number of days hotter than 90°F is projected to increase to 30 to 60 days per year, and by late-century 48 to 96 days per year are projected to exceed 90°F. (Leary, 2023).

Increases in the frequency and severity of extreme heat events can severely impact human health, particularly in developed areas that experience Urban Heat Island (UHI) effects, as documented in a companion report on human health and wellbeing (see Semma, 2024). Rising temperatures and extreme heat can also negatively impact vegetation, wildlife, ecosystems, and biodiversity. Tree growing patterns within natural and urban spaces

(Stevens, 2024). Stevens notes, “as greenhouse gas emissions nudge temperatures higher, trees’ growing ranges are moving northward… ‘plant hardiness zones’ will be left behind and northern latitudes will welcome new species from the south” (2024). Climate change is expected to present numerous species with novel circumstances which may increase the uncertainty of how species react to heat or disperse differently as heatwaves increase (McElwee et al. 2023).

Urban Heat Island

The development of urban areas with increased amounts of impervious surface and heat absorbing materials has posed risks to increased exposure to extreme heat for urban dwellers. Buildings and infrastructure replace vegetation and “often create microclimates in changes in energy balance associated with the built environment” (Doyle and Hawkins, 2008). Referred to as the urban heat island effect (UHI), it is critical to analyze the potential risks associated with certain urban areas as it has the potential to increase the risks to populations vulnerable to extreme heat. Residents exposed to UHIs cause detrimental effects to those with pre-existing conditions, putting them at increased risk of heat exhaustion and heat stroke.

In a study conducted by Doyle and Hawkins at the Shippensburg University in Shippensburg, Pennsylvania, temperature data was collected from several urban and rural areas over the summer months to note temperature differences across the two spaces. The researchers concluded that the UHI present within the small urban area was smaller and less significant than UHIs in larger cities (Doyle, 2008). While periods of extreme heat may exacerbate the conclusions of the study, the maximum difference of 0.8°C UHI occurred during nighttime hours (between 19:00 and 06:00), suggesting minimal effects of urban heat island in a moderately urbanized setting. College campus green space, however, were found to provide an *urban oasis* effect during peak day time hours, especially in the summer months (May through September) (Doyle and Hawkins, 2008). Urban oases develop in shaded areas within urban spaces, enhancing cooling by nearly 1°C. Typically, campuses with higher metrics of tree canopy and green ground cover mitigate the effects of UHI effects.

Strengths and Vulnerabilities

Regarding the potential risks that extreme heat may pose to the populations at Dickinson College, there are multiple strengths that the campus benefits from in terms of providing shade and heat mitigation. There is moderately strong tree canopy on campus providing significant cooling and shade to students and faculty. Moreover, with strong environmental values, Dickinson has also invested in improving emphasis on biodiversity and pollinator habitat, which limits implementation of more impervious surface in place of green space.

In an interview with Allyssa Decker, Professor of Environmental Science and Urban Sustainability at Dickinson College, she noted, “I think one of the issues that needs to be prioritized is around the issue of heat… mostly because we have had some infrastructure changes happen on campus," referring to the recent loss of trees on Dickinson's Rush Campus. She adds, "there were some trees that had died and had been removed from parking lots that have the ability to increase the heat signature of campus by limiting shade and evaporation potential." Tree canopy on Dickinson's campus is a legitimate concern as, within recent years, the campus has lost a significant percentage of its trees in frequently trafficked areas. A campus with minimal shade may pose risks to vulnerable populations on the campus grounds by removing the ability to shelter in shaded areas. Student athletes with increased risk of heat stress during outdoor practices may also benefit from increased tree coverage as it provides areas for recovery when buildings are not immediately accessible.

Shifting Weather Patterns

Rain Events, Flooding Risks, and Drought

Rising temperatures lead to greater evaporation and drying of land surfaces but also increases in the water holding capacity of the air and the amount of water vapor in the atmosphere. The expected result is for globally averaged precipitation to increase, though some regions will experience increases while other regions experience decreases with a general pattern of dry regions becoming drier and wet regions becoming wetter. These changes amplify the water cycle, causing thunderstorms, extratropical rainstorms, snowstorms, and tropical cyclones to produce more intense precipitation events and greater flood risks. Greater land surface drying can increase drought risks despite increases in precipitation. Access to available water resources also becomes a challenge as these changes in extremes, drought one month and floods the next, may change the functionality of water management. (Trenberth, 2011).

In Cumberland County, annual average precipitation increased 4.6 inches over the period 1971 – 2000, nearly a 10% increase. Heavy rain events also increased during this period in the County. The average number of days with over 1 inch of rainfall increased 2.8 days from 1971 – 2013, or 60%. The number of days in Cumberland County with very heavy rain, 0.8 inches or more, is projected to increase another 14% to 38% by mid-century and 18% to 52% by late century. The number of days with extremely heavy rain, 1.4 inches or more, is projected to increase 18% to 65% by mid-century and 31% to 96% by late century. The volume of rain that falls in very heavy and extremely heavy rain events is also expected to increase. Despite projected increases in average annual rainfall and in numbers of heavy rain days, climate models indicated the potential for more frequent and severe droughts due to higher evaporation in the warmer climate. (Leary, 2023).

The hotter and wetter climate that we are likely to experience in Cumberland County, coupled with the possibility of greater drought risks, pose risks to Dickinson's students and employees, it's built infrastructure, landscaping, trees, other vegetation, and biodiversity.

Strengths and Vulnerabilities

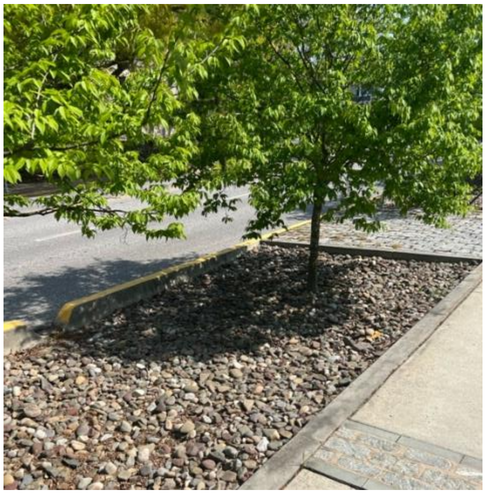
Dickinson College Campus has effectively addressed issues of excess stormwater and flooding in certain areas on the campus. The introduction of bioretention and improved below ground stormwater diversion along W. Louther Street have significantly reduced the potential for flooding on streets and in depressed areas in the lower residential quadrants, such as Davidson Wilson Hall (see below).

Effective use of green infrastructure, such as the bioretention along W. Louther St. allow for the mitigation of stormwater buildup and runoff. Using curb cuts and elevation to direct flow and vegetation to promote infiltration, these sustainable solutions have been increasingly effective at managing stormwater and excess rain. There are also basins for bioretention along Cherry Street. continuing to benefit the hydrology of the area outside of the Kline Athletic Center. These areas around Dickinson's campus also have signage which help to educate the community about the benefits of stormwater resilience techniques. Bob MacGregor, certified Master Gardener at Dickinson argues "it [climate change] effects my work, case and point, right here on Louther Street and on Cherry [street]... they put two rain gardens in and before that the lower quads would flood." Such management practices are effective, especially for a campus with its values rooted in sustainability education and for spaces that could benefit from decreased risk of flooding.

2'' Snow Melt on Sidewalk, W. Louther, 2024

Bioretention Basin, W. Louther, 2024

Outlined below are various best management practices (BMPs) for stormwater management infrastructure from the USEPA Green Infrastructure Design Toolkit. Including these management solutions in this report is intended to provide starting points for identifying, discussing, and evaluating common approaches that campuses may use to mitigate unsuitable conditions (US EPA Campus RainWorks, 2023). Green infrastructure has proven to be an effective technique for managing stormwater on Dickinson's campus, with some solutions being low-cost and require lower levels of maintenance. Lee Skabelund, professor of landscape architecture at Kansas State University notes "green roofs, while sometimes difficult to implement on a campus, provide a wide range of benefits... stormwater, pollinators, some biodiversity."



Pollinators, Natives, and Maintenance

Dickinson Pollinator Garden

Various initiatives for including pollinator friendly gardens have been implemented on Dickinson's campus. 'Pollinators have the innate ability to increase the biodiversity of certain landscapes while simultaneously increasing the resilience of the gardens themselves," notes Lee Skabelund of Kansas State University. Dickinson's pollinator garden also supports the Hive Cooperative on Dickinson's campus, providing both ecological and educational benefits to the community. Skabelund, professor of landscape architecture, added "you have to emphasize the importance of native plants and systems that infiltrate and provide diversity for pollinators." Pollinator gardens, then, serve a dual purpose for they can both increase the resilience of the garden itself while also improving the hydrology of a given area; infiltrating stormwater runoff and improving biodiversity (Lepczyk, 2017).

Maintenance of bioretention basins, pollinator gardens, and sustainable stormwater techniques poses potential challenges, such as maintaining general aesthetic value and increased labor costs. As urban spaces conduct the flow of stormwater at a much faster rate it causes stormwater to flow over a shorter period and at a higher magnitude during heavy rain events which may provide challenges to the few stormwater solutions Dickinson has in its current state (Subramaniam, 2024). Maintenance of various green infrastructure solutions is a significant variable in maintaining the ecological benefits and function of these management practices. Especially with the risk of extreme rain and drought, the cost of maintenance must be considered as gardens of this size require frequent upkeep. “The bioretention basins on Cherry St. that were previously filled with native grasses have recently been covered with rocks to reduce the need for maintenance in these areas, whether it has to do with monetary or labor costs I’m unsure,” notes Decker. While green infrastructure can be more cost effective than implementing traditional management infrastructure, the costs of maintenance remain unclear (Subramaniam, 2024). Without proper maintenance, hydrologic function of green infrastructure solutions is lost, such as infiltration potential.

To curtail maintenance costs, the use of native plant species is critical. Native species, if researched and chosen carefully, can be significantly more resilient to extreme weather events and drought, especially native grasses. “We want to look at how they [green infrastructure] change over time, how much maintenance we can provide, and which species are working well without irrigation or constant upkeep,” says Skabelund. For bioretention and rain gardens, Penn State University outlines three zones for which plants are selected: the wet zone, the mesic zone, and the transition zone (2014). Each zone, depending on its levels of inundation and exposure to water, supports different varieties of grasses, shrubs, and trees.

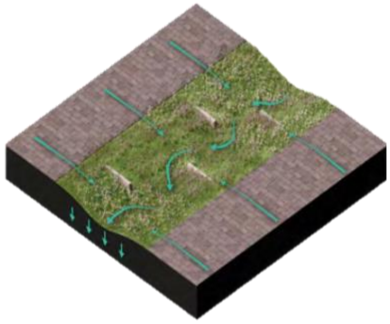
For example, the rain garden swale at the entrance of Kaufman Hall effectively supports these various plants and zones of inundation which has proved efficient for lower maintenance over time, as noted by Bob MacGregor. In recent years, however, the adjacent parking lot, formerly paved with permeable asphalt with a flow drain leading to the rain garden swale, was sprayed over with an impermeable substitute. In conversation with Allyssa Decker, she argues that “without the original drainage plan in place, the species intended for the rain garden will have a more difficult time thriving in adverse conditions, leading to maintenance issues over time.” Such changes to infrastructure are critical for the resilience of Dickinson’s stormwater management systems and must be noted as climate risks continue to develop. With maintenance costs rising and greater emphasis on gardeners maintaining these systems, climate risks may pose too high a demand for maintenance than what the campus infrastructure is currently able to uphold.

Green Infrastructure Best Management Practices (BMPs): USEPA Design Toolkit (2023)

Dry Bioswale

Bioswales are designed to capture, treat, and direct stormwater without an underdrain to promote infiltration and lessen flood risk. Small trees, native grasses, and water tolerant shrubs are common for this method.

Bioswale, Kaufman Hall



Bioretention

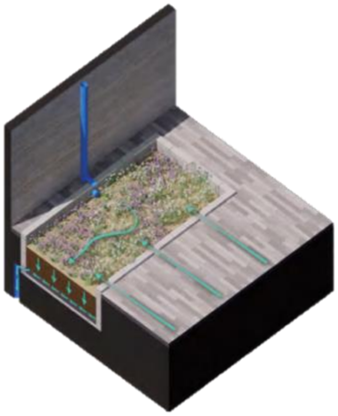
Bioretention areas are normally shallow basins designed to capture and treat stormwater runoff. Normally, bioretention basins are constructed with an underdrain or overflow drain to prevent excess flooding back onto roadways or near buildings.

Bioretention, West Louther St.

Flow-Through Planter

Flow-Through Planters are above-ground structures with permeable bottoms with various plantings and soil types. Designed for higher influxes of stormwater, moisture tolerant plants and small trees are commonly utilized. Water is allowed to infiltrate before it is discharged or relocated.

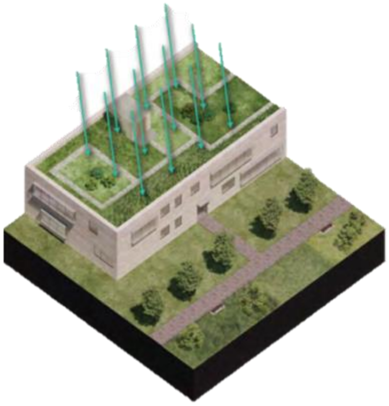
Flow-Through Planter, Cherry St.



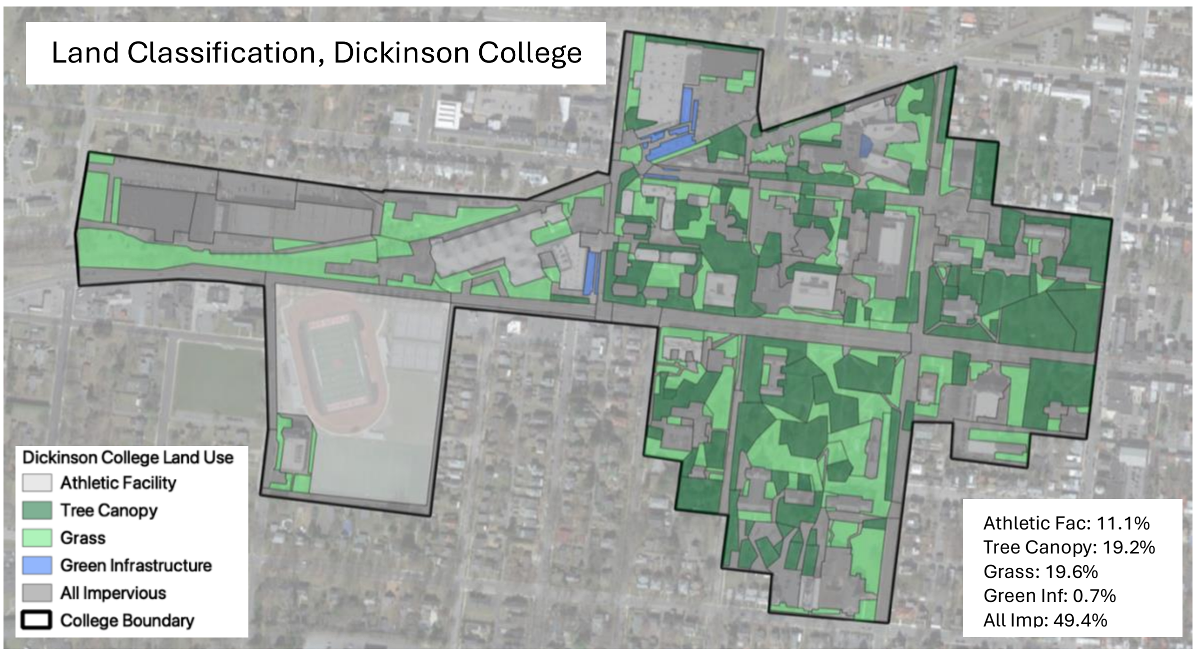
Green Roof

Green Roofs are alternatives to traditional roof surfaces using lightweight soil media. Stormwater runoff is captured and delayed in its release, infiltrating into the soil. Depending on the roof, green roofs may be intensive (thicker soil layer), or extensive (light weight, thin layer of soil media).

Experimental Green Roof, Tome Hall



Second Nature recommends that colleges committed to climate resilience should be aware of the various land uses of campus grounds. Using GIS software, Dickinson's 144 acre campus was mapped. Using satellite imagery, estimates of various land use at the college were manually outlined. In the map below, important metrics such as impervious surface, tree canopy, and amount of green infrastructure on the campus were considered for assessing resilience. Calculating the combined areas of the metrics below, 19% of the campus is covered by tree canopy, 11% by athletic fields, 19% by lawn or grass without trees, 0.7% by various forms of green infrastructure, and nearly 50% by impervious surface. This map is a start to a possible larger project that could study land use more in depth to differentiate impervious surfaces for buildings, parking lots, patio areas, sidewalks, walking paths, and other types of infrastructure.



In comparison to other higher education institutions committed to resilience through Second Nature, levels of impervious surface and tree canopy are comparable. According to Ohio State's report on ecosystem services and resilience, the campus holds values of 45% impervious and 15% tree canopy to Dickinson's 50% impervious and 19% canopy (2018). While Ohio State University operates on a larger scale both economically and spatially, Dickinson's baseline metrics show strength in its tree canopy numbers. With a smaller campus, there is ample opportunity for improving the campus' tree canopy by replacing areas previously planted with trees with additional canopy. According to Yale University's Central Campus Ecosystem Services plan, "Grey infrastructure disconnects significant portions of the campus allowing water to quickly drain from streets and roofs with no endpoint" (Bouffard et al. 2011). Increasing the connectivity of a campus through green space and canopy can be a critical strategy for improving overall resilience to stormwater and heat stressors. "Shade trees and ground vegetation reduce incidence of direct solar radiation while also absorbing radiation and promoting evapotranspiration effects" (Alexsandrowicz et al. 2017). Green infrastructure methods and practices can significantly improve campus connectivity, while increasing biodiversity and resilience to UHI and stormwater management (Bouffard et al. 2011).

Carlisle Connections, Community Engagement, and Education

Proximity and access to Dickinson's campus by residents also benefits the surrounding Carlisle Borough, especially for low-income areas located near campus. The 144 acre campus incorporates significant green space and tree canopy and has a lower density of buildings and other types of built infrastructure than surrounding neighborhoods, which likely helps to mitigate urban heat island effects for neighborhoods close to campus. The open campus can also serve as a place to escape the heat.

In conversation with Allyssa Decker, she added "There are some interesting breakdowns in terms of the way that the demographics of Carlisle are spread out... there are some neighborhoods with excellent tree cover, they have bigger lot sizes with more infiltration potential, you can really see this gradient between low-income areas and poor street tree cover and richer parts with higher cover." As a large central point of the Carlisle community, Dickinson's campus can provide space for residents who may be experiencing climate change stressors such as urban heat. Implementing climate resilience measures also provides opportunity for community engagement, education, and research. Yale University denotes community engagement as one of the main targets in their resilience plan while ensuring "connectivity with New Haven and the outside community, adding to stakeholder investment stewardship and education" (Bouffard et al. 2011).

Urbanization is a critical factor in the ways in which communities experience climate change and its stressors. The greater Carlisle area with Dickinson a major factor in resilience planning presents an opportunity to further educate students and Carlisle residents on the ways in which climate change affects them. Moreover, understanding how urban spaces function and the practices to best mitigate climate change effects is critical when designing safe, accessible, and resilient communities. At the Ohio State University, the implementation of ecosystem service-supporting infrastructure has been identified as "critical benefit for the university that provides opportunity for learning, teaching, and discovery" (Ohio State, 2018). Using a 'living lab' strategy, Ohio State has been enabled its students and faculty to focus on campus ecosystems and utilize them as "test beds for solving real world problems" (Ohio State, 2018). Also employing a 'living lab' strategy, Penn State University specifically utilizes its green infrastructure to produce research publications and enable these spaces to maintain a high priority for continued maintenance (Penn State Sustainability, 2024). Increased emphasis on living labs at Dickinson may provide dual benefits, as they provide both educational opportunities and increased rationale for maintaining these spaces.

On Cherry Street (top) and West Louther (bottom) Dickinson has implemented signage describing the various green infrastructure management practices the campus has used. Bob MacGregor, Dickinson master gardener, adds “our mission as master gardeners is to educate, we get to educate a segment of the Carlisle population - students, and community members – which would give them opportunities to conduct research or be active in the maintenance, it’s a win-win.”

Throughout the academic year, Dickinson also holds “lunch and learns,” according to MacGregor, “we’ve done a butterfly workshop, one on pollinators, garden workdays… we usually have around 30 students and faculty attend which is also a win.” While efforts to increase awareness regarding sustainable management has continued to grow, Dickinson may benefit from a more concrete ‘living lab’ program.

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