2022
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M | SEAS

Cities + Mobility + Built Environment

Characterizing the Urban Tree Canopy to Elevate its Role in Mitigating Climate Change and Creating a Healthy and Vibrant Community in Ann Arbor, MI

Presenters: Thomas Estabrook, MS (GDS); Alyssa Sklar, MS (GDS); Christian Schluter, MS (GDS); Lyndsay Zemanek, MS (GDS)

Advisor: Shannon Brines

Location: Ann Arbor, Michigan, USA

Client: Ann Arbor Office of Sustainability and Innovations

The City of Ann Arbor is home to a rich canopy of nearly 1.5 million trees that provide an estimated $4.6 million in annual benefits. Identifying, describing, and quantifying the urban tree canopy and associated benefits needs to be carried out for the City of Ann Arbor. Of particular interest are many fragments of old-growth forest on private land where it is difficult for conservation planners to identify and document.

Our team sought to develop three data layers to support decision-makers in Ann Arbor's Environmental Commission and Office of Sustainability and Innovations. First, we created a map of native forest fragment locations. Second, we developed a map of turf grass to aid in identifying tree planting sites and focus areas for incentivizing sustainable lawns. Third, we developed a map of Ann Arbor's urban canopy classified by tree genus.

To create the native forest fragment map, we used aerial imagery, a canopy height model, and input from experienced locals to manually delineate native forest fragments. We created the turf grass map by using an unsupervised clustering algorithm in combination with LiDAR. For the genus classification, we compiled 65,000 labeled tree stems to use as training and testing data and fed these, along with LiDAR and aerial imagery, into a variety of machine learning classifiers. After testing 33 approaches to genus classification, we achieved a maximum of 54% accuracy.

As final deliverables, we created quality-tested data layers from the native forest fragment and turf grass analyses along with a detailed writeup of the genus classification process for future researchers to build on. We also assembled an ArcGIS StoryMap to convey our findings to stakeholders.

EcoWorks Resilience Hub

Presenters: Meghan Oesterle, MS (SusSys); Maegan Muir, MS (EPP); Jamie Pew, MS (EPP); Amber George, MS (EJ)

Advisor: Justin Schott

Location: Detroit, Michigan, USA

Client: EcoWorks

Climate change poses an immense threat to plants, animals, and human life. As the ever-increasing effects are felt across the globe, communities face increasing stressors such as hotter summers, colder winters, severe flooding, energy blackouts, and decreased food and water supplies. To overcome these challenges, communities will need to become more resilient.

What makes communities resilient, and how do they become more resilient? A relatively new concept, Resilience Hubs have quickly become a mechanism of choice as they leverage existing community resources and bring them together into one centralized network. Resilience Hubs provide accessibility to residents and facilitate more effective responses in times of crisis, in addition to reducing cost burdens to nonprofits and mutual aid groups.

Through a literature review and interviews with existing Resilience Hubs across the United States, we assembled a set of best practices. These findings form the foundation of a successful Resilience Hub, though each community can tailor their approach to address their unique mix of challenges, needs, and assets. We have worked alongside our nonprofit client EcoWorks as they work to establish a Southwest Detroit Resilience Hub, conducting focus groups and interviews within the proposed community.

Our approach allowed us to tailor a Resilience Hub framework report specifically to EcoWorks' needs. From these two different sets of interviews, we created a tool kit for EcoWorks to utilize as they connect with the community and build awareness, engagement, and excitement for the possibility of a more resilient future.

Consumer Adoption of Electric Vehicles: An Evaluation of Local Programs in the United States

Presenters: Matilda Kreider, MS (BEC, EJ); Tressa Greschak, MS (BEC); Nathan Legault, MS (SusSys)

Advisor: Dr. Michael Moore

Location: Ann Arbor, Michigan, USA

Client: Dana Jackman, U.S. Environmental Protection Agency Office of Transportation and Air Quality

While transportation electrification is imperative for reducing greenhouse gas emissions, light duty electric vehicle (EV) adoption by individuals is still very low in the United States. The Biden administration has begun taking major actions to support the EV transition, particularly through the Infrastructure Investment and Jobs Act, and many state governments also have taken action to support EVs. Less is known about actions being taken to advance EV adoption on the local level, as municipal government EV programs historically have been a patchwork of uncoordinated efforts. This project is aimed at understanding local EV adoption programs, including the types of actions that they use and the socio-geographical characteristics of municipalities with EV programs. The project involved examining a random sample of more than 2,000 municipalities of all sizes from all 50 states and documenting any EV-related programs; these programs were then analyzed qualitatively using a codebook of EV adoption actions in the categories of infrastructure, policy, financial incentives, equity, and education/awareness. Additionally, a sample of 60 investor-owned utilities was analyzed to understand how utilities support EV adoption. The results of this research process include a report, an interactive map of local-level EV programs, and a searchable database containing the codebook, the sampled municipalities and utilities, and descriptions of all of the EV actions identified. The goals of this research are to create a better understanding of the measures taken to support EV adoption at the local level and to ultimately accelerate the nationwide transition to EVs.

Detroit Home Repair Landscape

Presenter: Jessica Yan, MS (EJ)

Advisor: Dr. Rebecca Hardin

Location: Detroit, Michigan, USA

One of the plagues upon Detroit is tax foreclosure. Thanks to years of illegally inflated property assessments, homeowners in Detroit have had to pay increased property taxes or face foreclosure. As a result, many homes in Detroit need major repair assistance—which then increases in need over time—due to the mass foreclosures and relocation of household income. There are few home repair loans available for Detroit homeowners who can afford a loan, but there are even fewer grants for those who can't qualify for a loan or afford to pay off a loan. Working with U-M Poverty Solutions and community organizations, I helped to update the 2019 Detroit Home Repair Resource Guide, an online, public guide available for residents and homeowners to find resources and repair grants and loans to fund their homes. This guide has led to an analysis of the overall Detroit repair landscape and the relationship between the homeowner community and institutions such as the University of Michigan and the City of Detroit. Using my experience of working at a community organization and for U-M Poverty Solutions, I hope to illuminate the nuances and complexities of homeownership in Detroit and highlight the extreme need for funding to make these homes not just habitable but sustainable and comfortable for the household.

Detroit 2030 District:
Transportation Greenhouse Gas Emissions

Presenters: Robert Killeen, MS (EPP); Katherine McMahon, MS (EPP, EJ); Zhiang Zhang, MS (EI), MSI; Haodong Jiang, MS (SusSys, EPP); Bita Davoodi, MS (BEC), MBA

Advisor: Dr. Geoffrey Lewis

Location: Detroit, Michigan, USA

Client: Detroit 2030 District

Working with the Detroit 2030 District and its members, the goal of the project is to present analyzed per-building emissions data, gathered through survey collection, and make recommendations for the use by our client. An analysis of aggregated greenhouse gas emissions data will be presented, both in pre-COVID-19 pandemic as well as post-COVID-19 pandemic scenarios. These results will show the mode of transportation used by Detroit commuters, as well as the differences in commuting emissions from before and after the pandemic.

Greenprint Detroit

Presenters: Sharni Smith, MLA; Jingzhi Fan, MLA; Yiyuan Wang, MLA; Yizhu Lu, MS (GDS), MLA

Advisor: Lisa DuRussel

Location: Detroit, Michigan, USA

Client: OSD

Detroit is among the most vibrant, densely populated areas of Michigan, but it is faced with disproportionate environmental and health burdens in addition to aging stormwater infrastructure. These challenges are expected to become more pressing in the future with an expected climate migration to the Great Lakes and increased precipitation, putting further demands on infrastructure and services. Meanwhile, urban agriculture, sustainability, and green design opportunities are expanding in the City of Detroit due to an excess of vacant land. For Detroit communities looking to make an impact, the first step is often gaining ownership of this land.

Navigating the various government programs for vacant land purchase in Detroit can be overwhelming, often resulting in confusion and frustration. Within this context, Greenprint Detroit aims to provide a toolkit for residents on how to attain and transform vacant land through processes already in place by the Detroit Land Bank Authority. Grounded in community engagement and climate adaptation, the project hopes to begin the process of developing a citywide Greenprint; one that represents a vision for a creative, holistic, systemwide network of reclaiming vacant, interstitial open space.

Climate + Energy

Quantifying the Impact of Override Behavior on a Summer Direct Load Control Program

Presenter: Pamela Wildstein, MS (SusSys)

Advisors: Dr. Michael Craig; Dr. Parth Vaishnav

Location: California, USA

Demand response (DR) programs represent an important tool for mitigating electric grid reliability risks posed by extreme weather, heat events, and increased electrification. Residential direct load control (DLC) programs with behavioral elements, such as an override option, are often used during the summer to reduce load from air conditioners (AC). Although override options make DLC more attractive to consumers, the high likelihood of an imperfect response can significantly reduce the effectiveness of the program overall. Thus, utilities must understand the impact of these behavioral elements on load-shaving capabilities. To fill this gap, we design a regression-based, deterministic model to predict the behavior of thermostats participating in ecobee's Donate Your Data initiative under various temperature conditions. The model is then used to quantify the impact of the override option on the performance of 414 ecobee thermostats participating in Southern California Edison's 2019 Summer Smart Energy Program. Our analysis estimates that although the group's participation in the DLC program led to a 42% reduction in AC demand, 32% of potential load reduction was lost to exercise of the override option. Similarly, most of the so-called DR events followed a pattern of near-perfect participation for a short duration of time preceded by a steady increase of overrides as the event progressed. DLC programs with an override option are effective at reducing demand in the aggregate, but designers must consider the savings lost to behavior.

A Techno-economic Analysis of Distributed Energy Resources versus Wholesale Electricity Purchases for Fueling Decarbonized Heavy Duty Vehicles

Presenter: Larson Lovdal, MS (SusSys), MSE

Advisor: Dr. Michael Craig

Location: Ann Arbor, Michigan, USA

Electric and hydrogen vehicles can help decarbonize heavy duty vehicles (HDV). Few studies examine how to meet energy requirements of decarbonized HDVs, and all assume electricity will come from centralized systems. However, decarbonized HDVs could significantly increase energy demands in areas with limited transmission access, potentially favoring deployment of distributed energy resources (DERs). We develop an optimization-based techno-economic model that minimizes costs of meeting HDV energy demands by optimizing investments in and operations of DERs, investments in transmission interconnections, and wholesale electricity purchases. We apply it to a modeled U.S. dataset of electric HDV charging demands to quantify the deployment and value potential of three DERs: solar, batteries, and nuclear small modular reactors (SMRs) in the year 2040. For fleets of 100% electric HDVs to 60% electric and 40% hydrogen HDVs, DERs are deployed at 78% to 95% of all charging stations and meet between 24% to 30% of total HDV energy demand. Investments in DERs reduce annual costs by $647 million to $1.9 billion across all stations, while individual stations can save between $20 million and over $100 million annually. SMRs make up over 99% of total deployed DER capacity, indicating significant potential for SMR deployment in this emerging market. Widespread DER deployment is robust to capital cost uncertainty in SMRs and transmission lines, wholesale electricity prices, and other factors.

Lessons Learned From EJSCREEN: Incorporating Tribal Environmental Justice into the Climate and Economic Justice Screening Tool

Presenter: Haley Mullen, MS (EJ, GDS)

Advisors: Dr. Kyle Whyte; Dr. Andrew Gronewold

Location: Ann Arbor, Michigan, USA

The Biden-Harris administration has invested considerable policy focus on environmental justice, including the Justice40 Initiative and relationship-building with tribal communities. This work has included financial investments in tribal economies, prioritizing tribal healthcare, and major tribal infrastructure investments as part of the proposed Build Back Better Plan. Further, the Justice40 Initiative, which aims to deliver at least 40% of federal investments in climate and energy to disadvantaged communities, demonstrates significant potential for tribes to receive major federal benefits related to environmental justice. However, the recent White House Tribal Nations Summit Progress Report, which discusses Justice40 and its potential benefits related to climate, energy, transportation, housing, pollution, and infrastructure, fails to articulate how such benefits will be specifically delivered to tribes. Importantly, Justice40 investments also include a new Climate and Economic Justice Screening Tool that seeks to identify communities that should be targeted by such investments. Executive Order 14008 references how this new screening tool should be built off of lessons learned from EJSCREEN. For tribes, however, EJSCREEN does not adequately represent infrastructure and other environmental justice needs relevant to the goals outlined in Justice40. In this thesis, I discuss issues with EJSCREEN and other tools that must be addressed in the Climate and Economic Justice Screening Tool in order for tribes to receive meaningful benefits toward the pursuit of environmental justice.

Assessing a Post-COVID World: Impacts of Travel Demand and Remote Work on Sustainability

Presenters: Jinhu Li, MS (GDS); Xiao Guo, MS (GDS); Mingyu Wang, MS (GDS); Yixuan Feng, MS (SusSys)

Advisor: Dr. Greg Keoleian

Location: Ann Arbor, Michigan, USA

Client: Chul Kim & Robb De Kleine, Ford Motor Company

Lockdown and social-distancing policies drove U.S. workers to switch to teleworking during the COVID-19 pandemic in 2020. Teleworking has been widely perceived as a sustainable way of working in terms of less energy consumption and less greenhouse gas (GHG) emissions. However, the situation is more complex than most people thought. Existing studies have contradictory results and few of them have quantitative estimation of individual teleworking-related activities including transportation, commercial building, residential building, and information communication technology (ICT). In our project, we adopt a quantitative bottom-up accounting framework to model the energy consumption as well as the GHG emissions of teleworking. The results show that teleworking does have a net positive environmental impact, by roughly 5%–14% net energy savings and roughly 6%–15% net GHG emission savings, depending on different teleworking scenarios.

Impact of Changes in the Bioenergy-Biochar Mix and Plant Size on the Economics and Environmental Performance of Distributed Biomass Gasification Systems

Presenter: Sofia Camarero, MS (SusSys), MSE

Advisors: Dr. Jose Alfaro; Dr. Parth Vaishnav

Location: Ann Arbor, Michigan, USA

Agriculture and forestry residues are potential sources of sustainable energy that do not compete with food or demand land use changes. Small-scale biomass gasification could be used to generate decentralized renewable electricity where these biomass stocks are locally available, while co-producing biochar to sequester carbon. This study evaluated how the scale and the bioenergy-biochar trade-offs impact the economics and decarbonization potential of a gasification system. A small-scale downdraft gasifier fed with logging residues in Michigan was used as a case study. A life cycle assessment (LCA) approach was used to formulate economic benefit (EB) and carbon abatement (CA) objective functions that formed a multi-criteria decision analysis (MCDA) optimization problem. Feasible product mix and scale configurations were mapped, and a pareto frontier was identified. EB is maximized when the electricity generation and the scale are maximized, at the expense of -4.721 kg CO2eq/kWh of CA. Conversely, CA is maximized to 0.348 kg CO2eq/kWh for the highest biochar and the smallest scale. Results were found to be sensitive to external factors: EB optimum shifted to maximize biochar when the carbon price was increased to match 2030 projections, CA increased 112.0% when higher grid electricity emissions were assumed, and EB reached 0.166 $/kWh depending on electricity prices. For different stakeholders and contexts, the maximization of positive impacts can require different technology configurations. The developed LCA-MCDA combined methodology provides an example of a framework that could inform decision-making in the deployment of biomass gasification to reconcile economic and climate change mitigation objectives, for instance.

Advancing a 'Climate Plan for Public Lands' through Collaborative Advocacy

Presenter: Amanda Wheelock, MS (EPP)

Advisor: Dr. Steven Yaffee

Location: USA

Client: People, Public Lands, and Climate Collaborative

Public land management is an oft-overlooked but vital part of efforts to solve the climate crisis. Changes in public land management policy could dramatically shift incentives for production of both fossil fuels and renewable energy, increase carbon sequestration and ecosystem resilience, and support or hinder a just transition for communities with local economies historically dependent on nonrenewable resource extraction. The People, Public Lands, and Climate Collaborative (PPLCC) is an informal network of nonprofit organizations that was formed in 2020 to ensure that public lands are part of a just and equitable climate solution. This practicum was undertaken to provide capacity to further PPLCC goals via advocating for congressional action. Through an iterative process of partnership, several tools were developed to identify, analyze, and compare the relative merits of federal legislative proposals that would help achieve PPLCC priorities if passed. These tools included a legislative tracker, a rubric for analyzing and comparing legislation, and a scorecard to visually demonstrate these comparisons. This report details the development of these tools and their implementation by the PPLCC. It also contains a case study to be used by future SEAS students studying environmental policy and politics to better understand the benefits, challenges, and relevant considerations for working in a collaborative with members that represent a variety of organizational missions, strategies, techniques, and structures.

Integrating Renewable Energy Practices into the Kgora Farmer Training Centre

Presenters: Rachel Kaup, MS (SusSys), MSE; Jack Teener, MS (SusSys), MSE;
Vinicius Briganti, MS (SusSys), MBA

Advisors: Dr. Jose Alfaro; Dr. Aline Cotel

Location: Mahikeng, South Africa

Client: Kgora Farmer Training Centre

Farmers in the North West province of South Africa are finding it difficult to earn a decent living, largely due to electricity. They experience load shedding on a regular basis, which causes livestock mortality, leaves them unable to irrigate crops, and forces them to buy costly fuel for generators. Despite the unreliable electricity, they still face astronomical electricity bills that can take up about 90% of their revenue. In response, this project was conducted through a partnership with the Kgora Farmer Training Centre in Mahikeng, South Africa, with the objective of establishing a renewable energy demonstration site at Kgora where farmers can be trained in renewable energy practices they can establish on their own farms. Methods include the implementation of a survey that queries farmers' interest in renewable energy, their biomass availability, and gender roles in the agriculture industry. In addition, a microgrid model was created based on Kgora's energy usage data to determine the optimal mix of renewable energy for the Centre. Survey results found that most farmers are highly interested in renewable energy and would be willing to invest in it if it saved them money in the long run. In addition, the microgrid model found an optimal energy generation mixture consisting of 27.6 kW of solar and 30 kW of gasification. To finish, a 15 kW gasifier will be installed at Kgora in August 2022 to be used as a demonstration site for farmers to learn and train on, and will be the first step in powering Kgora entirely with renewable energy.

Greenhouse Gas Inventory and Corporate Climate Strategy for Ocean Spray Cranberries, Inc.

Presenters: Averi Cumings, MS (EJ, SusDev); Seoyeon Jang, MS (SusSys, ESM), MPH;
Krystal Krygowski, MS (SusSys, ESM); Isabel (Izzy) Nakisher, MS (BEC, EJ);
Melissa Warshauer, MS (SusSys), MSCM

Advisor: Dr. Michael Mazor

Location: Ann Arbor, Michigan, USA; Middleboro, Massachusetts, USA (remote)

Client: Ocean Spray Cranberries, Inc.

According to the Greenhouse Gas Protocol, the Corporate Value Chain (Scope 3) Accounting and Reporting standard, Scope 3 greenhouse gas (GHG) emissions constitute emissions that result from indirect activities or assets not owned by an organization. Of all the GHG emissions generated by the food and beverage industry, as much as 90% are Scope 3, often stemming from complex agricultural, manufacturing, and distribution supply chains out of the direct control of large brands. In an effort to address and mitigate climate change for its farmer-owned cooperative, Ocean Spray Cranberries (OSC) sought help to conduct a GHG inventory of Scope 3 emissions and identify Scope 3 reduction targets.

The University of Michigan master's project team was tasked with conducting a GHG inventory of Scope 3 emissions to assess the baseline of OSC indirect emissions. A value chain map was created in conjunction with OSC's sustainability team. A specialized Scope 3 calculator relevant to OSC'S Scope 3 categories and updated emissions factors also was created to move the goal of this project forward. In addition, the team helped calculate upstream transportation and distribution emissions reductions associated with shifts to regional production in Canada and Australia.

This project provided tools to help inform OSC's corporate climate strategy to mitigate the effects of and adapt to climate change. Students received better insight into the challenges associated with accounting for and reducing indirect Scope 3 emissions.

Feasibility and Potential Benefits of Agrivoltaics on Southeast Michigan Urban Farms

Presenters: Rebecca Turley, MS (EPP); Brian Geiringer, MS (ESM, SusSys); Jessica Tang, MS (EJ); Karlene Robich, MS (SusSys); Julian Tabron, MS (GDS)

Advisor: Joseph Trumpey

Location: Ann Arbor, Michigan, USA; Detroit, Michigan, USA

Client: University of Michigan Campus Farm; D-Town Farm; Michigan State University-Detroit Partnership for Food, Learning, and Innovation; We the People Opportunity Farm; Cadillac Urban Gardens

The practice of placing solar panels above working farmland, also known as agrivoltaics (APV), is relatively new around the world and is still in its earliest stages in the United States. In particular, little work has been done to understand how this technology can support the work of small-scale and urban farms. For this project, we worked with five small and urban farms in southeast Michigan, each with unique site characteristics and organizational purposes. Our research objective was to explore APV as a mechanism for supporting the overarching goals of our partner organizations, and to understand what benefits it might offer to small and urban farms through a feasibility study. The methods used to assess APV feasibility included: a review of APV, food justice, and relevant policy documents and literature; client interviews and site visits; site suitability mapping with arcGIS; estimated energy demand assessments; hand calculations for system sizing; and associated payback period calculations. This information was compiled into design briefs, which included both APV and traditional photovoltaic system options, to adequately respond to our partner sites' stated goals and needs. Of the five farms we partnered with, only the two university farms showed serious interest in installing on-site APV. A combination of factors contributed to this difference, including the university farms having higher funding and more interest in the demonstration of APV technology.

Carbon Storage in Coffee Shade Tree and Gasification Assessment of Coopedota's Cooperative

Presenters: Linnet Leon, MS (SusSys), MBA; Victoria Griffin, MS (ESM); Alyssa Rausch, MS (ESM); Frances Arthur, MS (SusSys)

Advisor: Dr. Jose Alfaro

Location: Ann Arbor, Michigan, USA

Client: Coopedota

The objective of this work is to enhance the net-zero efforts of Coopedota by supplementing previous carbon accounting efforts with an estimate of the carbon stored in shade biomass in their properties and the properties of farmers participating in the Rainforest Alliance Certification, as well as introducing the option of gasification of residues as an energy and carbon storage solution. To achieve the objective, the project carried out a) an evaluation of the farmers participating in the RFA program through surveys and their perspective on the program, b) a carbon inventory of the shade biomass in the program and the private farms at Coopedota, and c) a life cycle assessment of coffee production, including a gasification and biochar as an end-of-life alternative to composting for the treatment of coffee pulp.

Decommissioning Trends, Circular Economy Policy Incentives, and Secondary Markets for Solar Photovoltaics

Presenters: Matthew Boelens, MS (SusSys), MBA; Nolan Woodle, MS (SusSys), MBA; Christian Koch, MS (EPP); Christina Pastoria, MS (SusSys), MAE; Xindi Huang

Advisor: Dr. Michael Craig

Location: Ann Arbor, Michigan, USA

Client: National Renewable Energy Laboratory

As solar photovoltaic (PV) deployment increases in the United States, so will the volume of decommissioned PV panels and balance of system equipment. Large amounts of annual waste are anticipated by the early 2030s. Currently, there are over 65 GW of solar PV installed in the United States, which is the equivalent of over 5 million tons of PV panels. In order to get ahead of this looming and current challenge, our team has worked with the National Renewable Energy Laboratory to conduct an in-depth study of material flow pathways from PV system decommissioning to secondary-use applications and recycling in order to inform an evidence-based assessment of decommissioning trends and regulatory policy in the United States. Our study focused on four main themes: (1) an analysis of U.S. decommissioning policies and regulations, (2) an analysis of U.S. decommissioning costs, plans, and trends, (3) a comparative analysis of international decommissioning policies and regulations, and (4) a market analysis of the potential for a U.S. PV system circular economy. By conducting market and policy research, interviewing industry experts and local political leaders, and analyzing decommissioning plans and market data, we have developed a thorough understanding of this complex problem and the steps being taken to solve it through policy and industry.

GHG Emissions for U-M Purchased Goods and Services

Presenters: Anna Ostrander, MS (SusSys); Jacob Namovich, MS (SusSys)

Advisors: Dr. Greg Keoleian; Dr. Geoffrey Lewis

Location: Ann Arbor, Michigan, USA

This project was conducted to support the University of Michigan's (U-M) President's Commission on Carbon Neutrality in footprinting the institution's Scope 3 purchased goods and services emissions. The research goals were to 1) develop a method for estimating Scope 3 purchased goods and services (PGS) emissions; 2) disaggregate spending to identify key drivers of emissions; and 3) identify and recommend U-M system modifications to reduce Scope 3 PGS emissions and streamline progress tracking. The project used an Environmentally-Extended Input-Output method to evaluate greenhouse gas emissions from purchased goods and services. U-M spending data were disaggregated and assigned emissions factors according to spending account description and corresponding Supply-Chain Emission Factor industry activity. Results yielded a Scope 3 PGS emissions footprint range between 356 and 1250 kT CO_2e, with an average emissions estimate of 673 kT CO_2e. Recommendations to U-M fall into two categories: strategies for reducing emissions and strategies for improved emissions tracking. Ultimately, the project found that more consistent, higher-quality purchasing data is needed to make confident emissions estimates, and emissions reductions could be more easily achieved in the presence of process-level environmental data from suppliers.

Conservation + Restoration

Landscape Predictors of Mule Deer Road Crossing Behavior in the American Southwest

Presenter: Kaitlyn Frank, MS (GDS)

Advisor: Dr. Neil Carter

Location: Salt Lake City, Utah, USA

For large, wide-ranging mammals like mule deer (Odocoileus hemionus), home range requirements and seasonal migrations often necessitate road crossings, posing threats to human safety, property, and deer survival. Although general relationships between road crossings, collisions, and landscape features have been described, there is variation across locations and species in predictors of crossing frequency and collision risk. We aim to evaluate the extent to which various landscape, environmental, and human factors influence the location of mule deer road crossings near Salt Lake City, Utah. Specifically, we are interested in how elevated artificial nightlight influences deer road crossing locations. By integrating NASA nightlight products with GPS collar data from 82 mule deer over a seven-year period, we used a resource-selection framework to assess factors influencing seasonal crossing intensities at a fine spatial scale (based on mean daily movement distances) and within seasonal home ranges. Findings indicate both anthropogenic and environmental factors influence mule deer road crossings. Artificial nightlight was very influential, with deer avoiding crossing available roads in their home ranges with elevated light in both seasons and at multiple scales in the models. Most models implicated lower light as a driver of crossings, which could improve targeting of collision intervention locations and methods. Furthering our understanding of influential landscape factors in crossing point selection, especially how artificial nightlight may attract or repel human-tolerant wildlife species from roadways, presents an opportunity to mitigate collision risk while improving population management strategies for an economically and ecologically important species in an expanding metropolitan area.

Evaluation of Competitive Moose-Beaver Herbivory on Isle Royale National Park

Presenters: Austin Crane, MS (ESM); Krysta December, MS (EJ, ESM); Theresa Dowker, MS (ESM); Luke Skowronek, MS (GDS, ESM)

Advisor: Dr. Inés Ibáñez

Location: Isle Royale National Park, Michigan, USA

Client: Isle Royale National Park (National Park Service)

Beavers (Castor canadensis) play a key role in creating aquatic habitat and sustaining aquatic biodiversity in freshwater ecosystems across North America, including in Isle Royale National Park (ISRO). The National Park Service (NPS) hypothesizes that competitive pressure from moose (Alces alces) in ISRO will drive beavers to forage at greater distances from their lodges, which may place them at greater risk for predation and ultimately have negative implications for the park's aquatic ecosystems. Determining whether this occurs in ISRO, and if so, the degree to which it occurs, is an important research goal for NPS. The objective of this study is to identify common foraging preferences for beavers and moose and to investigate whether competition from moose leads to changes in beaver foraging behavior. Using forest structure, beaver herbivory, and moose herbivory survey data provided by NPS, we developed a predictive model forecasting beaver foraging behavior in response to moose herbivory pressure. While the literature to date supports that distance and vegetation type influence beavers' foraging preferences, our model results only found the effect of distance to water, but were inconclusive with respect to vegetation preferences and the impact of moose on beaver foraging. Output from our analysis was limited by the amount of available data, and the disjoint protocols, i.e., beaver and vegetation-moose data were collected at different locations. To better identify beaver preferences and any potential competition, we recommend that future data collection include vegetation transects that record both beaver and moose browse data and vegetation structure.

Long-Term Habitat Restoration and Community Engagement for Michigan Audubon's Bernard W. Baker Sanctuary

Presenters: Catherine Watts, MS (ESM); James Johnson, MS (ESM); Jenna Happach, MLA, MS (ESM); Nick Tsichlis, MS (ESM); Megan Livingston, MS (ESM)

Advisor: Dr. Brian Weeks

Location: Bellevue, Michigan, USA

Client: Michigan Audubon

Michigan Audubon needed an updated long-term habitat and restoration plan for its Bernard W. Baker Sanctuary focusing on key indicator bird species. Specifically, existing tallgrass prairie, oak savanna, and wetland habitats were areas of restoration concern, with invasive plants encroaching native habitat. Further, Michigan Audubon wanted qualitative research on community engagement strategies to broaden its reach to underserved audiences.

The goal of Michigan Audubon is to restore and maintain ecological function and species diversity as well as increase community engagement through outreach and education. To address the habitat and restoration plans, we conducted biological surveys of birds and plants. The bird surveys gave information about the current state of bird species in terms of richness and abundance at the sanctuary. The plant surveys gave information about what and where plant species were present and what that meant in terms of habitat restoration. To address the community engagement aspect of this project, we created a GIS story map, as well as planted a native educational garden. Further, we have provided Michigan Audubon with several suggestions to increase their community engagement, such as updating their on-site kiosks, trail signage, and marketing strategies to increase their presence.

From the bird surveys, as well as eBird data, we can see which bird species are reliant on the sanctuary and at what times of the year. From the plant surveys, we can give specific recommendations to increase native species and biodiversity that will, in turn, promote the bird populations. The community engagement strategies and recommendations will increase public awareness of Baker Sanctuary, which will lead to more educational opportunities and increased volunteer involvement.

Interdisciplinary Ecological Baseline Assessment Contributing to the Understanding of the Health and Value of Watersheds Protected by the Center for Alaskan Coastal Studies

Presenters: Kristin Armstrong, MS (ESM, GDS); Ashley Machus, MS (ESM, EJ); Nicholas Hansen, MS (ESM, GDS); Kyle Barnes, MS (ESM, GDS)

Advisor: Dr. Allen Burton

Location: Homer, Alaska, USA

Client: Center for Alaskan Coastal Studies

Not only do watersheds act as critical habitat for various species of flora and fauna, they provide numerous important ecosystem services to humans, including water and air filtration, carbon storage, and nutrient cycling. Monitoring and managing watersheds appropriately is important in order to maintain healthy and intact ecosystems that may continue to provide for plants, animals, and humans. Due to this, the Center for Alaskan Coastal Studies (CACS) in Homer, Alaska, recruited our master's project team to aid in conducting an interdisciplinary analysis of watershed properties. This involved conducting ecological baseline data collection on CACS' Wynn Nature Center, Inspiration Ridge Preserve, and Peterson Bay Field Station properties. Ecological data collection involved fish trapping, macroinvertebrate sampling, breeding bird surveying, peat depth probing, and vegetation assessments. Through our sampling we found a diversity of flora and fauna present on CACS properties and pristine stream ecosystems. In addition to sampling, our project aims include creating protocols that CACS may use for future monitoring efforts, and producing outreach materials for the public and policymakers to share about the importance of conserving and protecting watershed ecosystems.

An Active Warming Method for Open-Cup Nests Reveals Contrasting Effects of Temperature on Size in Wild Songbirds

Presenter: Madeleine Klemz, MS (ESM)

Advisor: Dr. Brian Weeks

Location: Ann Arbor, Michigan, USA

Temperatures during development can affect bird physiology and morphology. As the climate changes, understanding these impacts across diverse sets of species in natural systems is increasingly important. Previous studies of the relationship between ambient temperature and bird development have largely relied on field experiments using nest boxes, or have removed eggs from the wild to warm them in an incubator. Fewer studies have tried to manipulate the temperature of open-cup nests, largely limiting experiments to cavity-nesting species that are willing to nest in nest boxes. Warming open-cup nests is challenging, as they are more variable in their construction and accessibility and are exposed to disturbances in the environment. We developed an active warming device that consistently and accurately warms nests to a specified set level above the ambient temperature and maintains this elevated temperature throughout the incubation period. In this study, we warmed the nests of three North American passerines, gray catbirds (Dumetella carolinensis), American robins (Turdus migratorius), and northern cardinals (Cardinalis cardinalis) 2 degrees Celsius above ambient temperature throughout the incubation and nestling period. We found contrasting effects of the experimental warming across species, with warming resulting in a smaller size in catbirds and a larger size in robins. We suggest that these differential responses may be explained by differences in the relationships between the ambient temperature at the study site and the optimum breeding temperature for each species. Our method allows the study of warming-mediated developmental plasticity in wild birds that can facilitate comparative analyses to better understand general impacts of warming on birds.

Developing a Methodological Framework for Linking Climate Change to Biodiversity and Ecosystem Services in the Hindu Kush Himalayas

Presenters: Emily Johnson, MS (EPP); Kasey McDonald, MS (GDS); Lindsey Spero, MS (GDS)

Advisor: Dr. Avik Basu

Location: Kathmandu, Nepal (remote)

Client: International Centre for Integrated Mountain Development; United Nations Framework Convention on Climate Change

Climate change is warming the Hindu Kush Himalayas (HKH) at a higher rate than the global average, causing a cascade of bioclimatic effects and threatening both ecosystems and livelihoods of people in the region. Protected areas represent an important tool for preserving ecosystems in the HKH, but due to their static physical boundaries in the midst of shifting climatic and ecological conditions, they may be insufficient to protect both biodiversity and ecosystem services. Recently, greater emphasis has been placed on adaptive management, an iterative process that utilizes stakeholder collaboration and social and ecological monitoring to inform subsequent management plans. Here, we present a geospatial methodology to assess how possible ecoregion shifts due to climate change may affect the utility of protected areas within the Kangchenjunga Landscape, a transboundary landscape in the HKH. We used an environmental stratification model to predict ecoregion shifts under multiple climate change scenarios and qualitatively assessed how these shifts may impact the preservation of biodiversity and provisioning ecosystem services within protected area boundaries. Our results suggest that ecoregion shifts will likely decrease overlap between wildlife habitat and protected area boundaries, therefore decreasing the efficacy of protected areas to preserve existing biodiversity. Such shifts will likely also impact community accessibility to fuel wood and non-timber forest products, which could pose difficulties for both the agricultural sector and the well-being of individuals reliant on subsistence farming and foraging.

Does Mineralization and pH Control the Distribution of Ammonia-Oxidizing Archaea in Temperate Forest Soils?

Presenter: Jennifer Wen, MS (ESM)

Advisor: Dr. Donald Zak

Location: Ann Arbor, Michigan, USA; Manistee National Forest, Michigan, USA

Nitrification is a key process in nutrient cycling that is controlled by ammonia (NH3)-oxidizing microorganisms. As such, nutrient availability in forest ecosystems can be highly influenced by the soil microbial communities that are present. The upland forests of Manistee National Forest in Michigan present an interesting case, as some sites vary widely in nitrification rates, despite sharing similar climate, age, soil texture, and plant communities. This prompted an investigation into the soil microorganisms across this natural gradient that could be driving differences in nitrification rates, as well as factors that could be driving differences between soil communities.

We addressed (1) how NH3-oxidizing archaea (AOA) vary in abundance and diversity across Manistee sites, and (2) how environmental factors such as pH and mineralization may be associated with these variations. From soil samples collected in the field, we amplified and sequenced ammonia monooxygenase (amoA)—a functional gene in AOA associated with NH3 oxidation. After classifying amoA sequences for each site, we compared AOA abundance across the Manistee nitrification gradient. Then, we determined correlations between changes in AOA populations, soil pH, and mineralization across sites. Through this study, we addressed a previously unexplored phenomenon in Manistee National Forest, while contributing to an understanding of landscape-level changes in nutrient cycling from a microbial ecology perspective.

On an Island in the Sun: Effects of Malarial Infection and Island Variation on Aegean Wall Lizard Health

Presenter: Christopher Hal Terry, MS (ESM)

Advisor: Dr. Johannes Foufopoulos

Location: Cycladic Islands, Greece

While parasites are often associated with an individual host, they are just as subject to wider ecological conditions, such as habitat fragmentation. Previous studies have found that the malarial parasites Hepatazoon are affected by such dynamics within Aegean islands. To understand the impacts of this parasite in the Aegean wall lizard (Podarcis erhardii), I examined the health and locomotion conditions between infected and uninfected lizards from 17 Cycladic islands. Health was inferred from measures of body mass and length, while locomotion was assessed through lizard running trials. Significant declines in condition were found in infected populations, though only in male lizards, suggesting a sex-specific response to infection. Mixed-model analyses also suggest that island-level characteristics can affect the health and locomotion of lizards. These results indicate variability in the impacts of malarial infection across Aegean wall lizard populations.

Restoring the Shiawassee Flats

Presenters: Josh Fishbein, MS (ESM); Matthew Conrad, MS (ESM); Claire Watts, MS (ESM); Kuiran Zhang, MS (ESM)

Advisor: Dr. Paul Seelbach

Location: Ann Arbor, Michigan, USA

Client: Shiawassee National Wildlife Refuge

The Shiawassee National Wildlife Refuge in Saginaw, Michigan, is undergoing a large-scale restoration of several thousand acres, but large wetland restoration projects have little precedent in the scientific record. Our 2021-2022 team is the third in a long-term restoration monitoring project of the refuge, and we set out to monitor three recently flooded units, a reference unit flooded in 1958, and the nearby Shiawassee River, and provide recommendations for further research to our clients and future monitoring efforts. So that our clients can make the best management decisions, we compared water quality parameters and vegetation, fish, and macroinvertebrate communities between pools and months. We are also in a multiyear development project to use machine learning models to detect fish movements into the refuge using an Adaptive Resolution Imaging Sonar (ARIS) camera. Our efforts and those before us have resulted in a rare multiyear ecological dataset that will inform the future of this unique inland coastal wetland, possibly document heretofore unknown fish migrations from Lake Huron, and provide vital ecosystem services to animal and human communities of central Michigan.

Institutional Ethnography of Rights and Resources Initiative: Coalition-Building, Strategy, and Land Tenure Advocacy

Presenters: Anjali Thakker, MS (EJ, ESM); Victoria Rachmaninoff, MS (EPP); Haley Riley, MS (EPP, EJ); Maxime Groen, MS (EJ)

Advisors: Dr. Arun Agrawal; Dr. Cristy Watkins

Location: Global (Africa, Asia, Latin America)

Client: Rights and Resources Initiative

Established in 2005, the Rights and Resources Initiative (RRI) is a global coalition dedicated to promoting land tenure and policy reform for Indigenous peoples, local communities, Afro-descendants, and women. In order to carry out its mission, good coalition governance is imperative. Furthermore, with diverse partner and collaborator organizations around the world, including rights-holder groups and international NGOs, understanding the strategies that coalition members use to achieve their goals helps to enrich the field of land tenure reform. This project aims to create an institutional ethnography of RRI, analyzing their workings as a coalition, strategies, successes, and challenges. Furthermore, the project investigates the key factors that drive RRI, their strategies, and the institutional landscape RRI navigates within. In order to carry out the research, the team employed a rich ethnographic framework based on semi-structured in-depth interviews and participant observation. Over 30 members of the coalition from around the globe participated in the interviews. As one of the most influential organizations in the field of land tenure, understanding the governance and strategies of the coalition will not only prevent knowledge loss within the organization, but also help to deepen knowledge around key strategies to achieving tenure reform.

Diurnal Time-Activity Budget of the Common Loon (Gavia immer) in Northern Michigan

Presenter: Alia Kirsch, MS (ESM)

Advisor: Dr. Sara Adlerstein-Gonzalez

Location: Ann Arbor, Michigan, USA

Animals must navigate trade-offs in many areas, including how they spend their time. These trade-offs can be measured with time-activity budgets, which can vary between species and within them. In July 2021, I collected observational data on the common loon (Gavia immer) at Douglas Lake in Pellston, Michigan, during morning, afternoon, and evening activity time periods and analyzed differences between these periods, particularly with regards to foraging behaviors. I found that loons were far less likely to forage during the evening (7%) rather than morning (55%), and that the most common activity during the morning period was diving, while the most common activity during the evening period was resting. Knowing the activity patterns and foraging habits of common loons can help researchers protect the common loon, which is a threatened species in Michigan.

Using Fuzzy Cognitive Mapping to Assess the Impacts of Climate Change on Great Lakes Ecosystem Services

Presenters: Lucas VanderBilt, MS (ESM, GDS); Justin Huber, MS (ESM); Pradip Shrestha, MS (GDS); Andrew Nowicki, MS (EPP)

Advisors: Dr. Casey Godwin; Dr. Subba Rao Chaganti; Dr. Michael Fraker; Dr. Ayumi Fujisaki-Manome; Dr. Runzi Wang

Location: Ann Arbor, Michigan, USA

Client: Cooperative Institute for Great Lakes Research, University of Michigan

The ecosystem services the Great Lakes provide are imperative in sustaining human well-being and economic viability. The benefits people receive from the delivery of ecosystem services are beyond the tangible material and production gains. Among other stressors, climate change is likely to alter or eliminate certain ecosystem services in the future. To better understand the consequences of climate change and to develop effective means of adapting to them, it is critical that we improve our understanding of the links between climate change and ecosystem service. This study examines the impact of climate change on the ecosystem distribution and the subsequent production and value of key ecosystem services in the Great Lakes basin. Leveraging cross-discipline research methodology, we examine the climate sensitivity and associated implications to the vulnerability of ecosystem services, at scale. Spatially explicit ecosystem service assessment has an essential role in the strategic planning of restoration efforts and future research by identifying areas with the greatest potential to enhance societal benefits from the efforts.

Food

Response of Crops, Vegetation, and Coquí Populations to Hurricane María in Coffee Farming Agroecosystems

Presenter: Ember Bradbury, MS (ESM, EJ)

Advisor: Dr. Ivette Perfecto

Location: Utuado, Puerto Rico

The response of agricultural systems to natural disasters remains largely unexamined, despite their importance for food production. To address the lack of literature surrounding agricultural ecosystem change after hazard events, this study evaluated the response of vegetative factors and populations of three common vertebrate predators, all coquí frogs (Eleutherodactylus antillensis, Eleutherodactylus brittoni, and Eleutherodactylus coqui), to Hurricane María (September 16, 2017 to October 2, 2017) in Puerto Rican coffee agroecosystems within the Cordillera Central region. We compared vegetative and coquí population data taken in May 2017 before Hurricane María and again afterward in November 2018. This comparison found that vegetative factors were highly negatively impacted by the natural disaster, whereas coquí populations remained stable. Our results suggest that E. antillensis, E. brittoni, and E. coquí may be resilient to hurricanes even while their agroecosystem habitats are dramatically altered.

Agriculture Carbon Market Development

Presenters: Sean Cannady, MS (GDS), MBA; Katharine Chute, MS (ESM), MBA; Wesley Davis, MS (SusSys), MBA; Colleen Sain, MS (BEC), MBA

Advisors: Dr. Jennifer Blesh; Shannon Brines

Location: Midwest, United States

Client: Carbon Yield

Carbon markets are a promising tool to combat climate change but until recently, agricultural soil has been underutilized as a carbon sink. Row crops grown and harvested for food can also sequester carbon into the soil but the quantity depends on the adoption of regenerative farm management practices. Carbon markets financially incentivize growers to adopt practices that sequester more carbon but barriers exist for many growers to fully participate in this nascent marketplace. This study identifies the barriers row crop growers in the Midwest United States face and assesses possible opportunities to enable broader participation. Qualitative interviews were conducted with a cohort of farmers in order to understand their full experience with carbon markets and a survey regarding growers' attitudes toward carbon markets was conducted at the 2022 Great Lakes Crop Summit. We identified technical, psychological, and financial barriers as the most significant obstacles to broader farmer participation in carbon markets.

Investigating Intercropping as an Adaptive Management Strategy for Climate Change

Presenter: Andriana Miljanic, MS (ESM), MBA

Advisor: Dr. Ivette Perfecto

Location: Ann Arbor, Michigan, USA

Climate change has resulted in increasing global temperatures and increasing inter-annual temperature variability. Studies have shown that rising temperatures negatively affect crop yield, however, these studies focused on intensive monoculture systems, and there has been little consideration of diverse farming systems as a way to adapt to climate change. Here, we propose that intercropping can be employed to prevent reductions in crop yields due to temperature increases associated with climate change. Existing theoretical models for calculating yield sets can be modified to consider the variability of temperature as well as the increased facilitative effect of intercropping under high temperature scenarios. To test this hypothesis, corn and soybeans were planted in monocultures and polycultures in a greenhouse at two temperature treatments: a control ambient temperature and approximately +2 degrees C. Plant growth was measured weekly and above- and below-ground biomass was measured once plants had reached maturity. We found that corn yields were significantly greater when planted in polyculture and at lower temperatures. We found that soybean yields were significantly greater when planted in monoculture and no effect of temperature on yield. Corn received facilitative benefits from being planted in polycultures with soybeans, however, our study found stronger competitive effects on soybeans grown in polyculture. Furthermore, our study demonstrated that growing corn and soybeans in polycultures yield more than monocultures when considering the same land area. Future research should continue to explore intercropping as an adaptive management strategy for climate change.

Urban Agriculture Interventions in Refugee and Immigrant Communities: A Scoping Review

Presenter: Sophee Langerman, MS (EJ), MSW

Advisors: Dr. Rebecca Hardin; Dr. Odessa Gonzalez Benson

Location: Ann Arbor, Michigan, USA

Urban agriculture, known as urban farming, urban gardening, or community gardening, has become an important avenue for community development, food security, and economic stability in response to increased urbanization. Researchers recognize the role of urban agriculture and farming as important interventions for populations and tools for building community strength and connectivity, where refugee and immigrant communities are at-risk to feelings of social isolation, experiencing financial insecurity, and barriers to accessing healthy foods. The objective of this scoping review is to synthesize the already existing literature on impacts of urban agriculture in immigrant and refugee communities. A search was conducted using inclusion and exclusion criteria on SCOPUS based on the population, intervention, and scale of intervention. Articles examined had impacts ranked in five domains, three levels of participation, and three scales of intervention. The majority of articles in the study did not include formal discussion of level of participation, which is a relevant theme to incorporate in future research. Recommendations for further advancement in these areas include interdisciplinary research that recognizes impacts on both persons and the environment, and research on food systems centered on marginalized communities, such as immigrants and refugees.

GreenSwapp: Developing a Framework to Assess and Standardize Carbon Footprints to Affect Behavior Change in Consumers

Presenters: Brett Pickett, MS (BEC); Hang Chen, MS (GDS); Valerie Fritts, MS (EPP, EJ); Tianyi Zhang, MS (SusSys), MSE

Advisor: Dr. Martin Heller

Location: Ann Arbor, Michigan, USA

Client: GreenSwapp

Our current diets and the global food system are incompatible with efforts to limit contributions to and effects of climate change. Through this project, we sought to further understand what factors contribute to food products' greenhouse gas emissions (GHGE) to aid our client, GreenSwapp, in improving its LCA estimation model, and provide guidance on GreenSwapp's efforts to get grocery store customers to shop more sustainably.

The overarching goal of this research is to enable our client, GreenSwapp, to provide its users with reliable information on the GHGE metrics associated with food products or product categories and to use that data, along with behavior change techniques, to encourage its users to purchase more sustainable food products.

To achieve this objective, our team compared GreenSwapp's carbon footprint database to Tesco's comprehensive database, to determine if, on average, Tesco's carbon footprint data significantly differs from GreenSwapp's. Our team also tested to see if GreenSwapp's carbon footprint estimation, which applies a single carbon footprint data point, is significantly different from Tesco's more product-specific and varied carbon footprint values. We also completed a literature review on behavior change interventions, specifically nudges, to provide guidance on GreeSwapp's efforts to get consumers to shop more sustainably.

Through testing, we found that GreenSwapp's database did not significantly differ from Tesco's database on average. However, we did find that for some product classifications, GreenSwapp's carbon footprint estimation method shows some difference from Tesco products' distribution. Through literature review, we found several effective behavioral interventions for GreenSwapp, social norm marketing, choice architecture, and feedback. We also used our research to derive new behavior nudge interventions, as well as a before-and-after experimental design for GreenSwapp to test the efficacy of the nudge interventions.

Implementing and Expanding ReFED's Influence to New and Existing Partners

Presenters: Maham Zafar, MS (SusSys, EJ); Sarah Cole, MS (SusSys), MBA; Connor Donnelly, MS (EJ), MBA; Kyle Kasten, MS (SusSys), MBA

Advisor: Joseph Trumpey

Location: New York City, New York, USA

Client: ReFED

Food waste is an issue that has detrimental environmental impacts. To address this issue and the larger climate crisis, ReFED, a national nonprofit, is working to end food loss and waste across the food system through data-driven solutions. The project team was responsible for identifying and working with a variety of initiatives to increase both the number and diversity of stakeholders engaging in food waste reduction strategies. The project was divided into multiple phases. First, we researched high potential opportunities for organizations willing to integrate food waste reduction strategies. Next, we identified key criteria for prioritizing the various opportunities surrounding organizations, memberships, certifications, standards, educational programs, and measurement. Third, we reached out to partnership opportunities that we considered had the greatest potential with ReFED. Seventeen out of the original 100 opportunities were evaluated as worth pursuing by ReFED. Over half of the 17 pursued opportunities received recommendations from ReFED and are still being implemented within their organization. At a high level, we considered a plethora of organizations that could improve their waste reduction strategies. However, most organizations were not willing to collaborate even when our selection process for outreach was deliberate and thorough. Indeed, only nine out of the 100 original opportunities we researched were interested in collaborating with ReFED. ReFED has decided to create resource documents for organizations to learn from and to only pursue partnership collaborations if an organization reaches out to them directly.

Milking Welfare: Agricultural Technology and Subject Formation on the Industrial Dairy Farm

Presenter: Evan Andrés Klasky, MS (EJ)

Advisor: Dr. Bilal Butt

Location: Ann Arbor, Michigan, USA

Agricultural intensification and animal welfare are being pursued simultaneously in the dairy industry through a range of technologies, including sensors, machine learning, robotics, biotechnology, and more. Through this process, the subjective experiences of cows (e.g., pain, pleasure, comfort, fear, stress) become included in the commodification of dairy products in the market. I aim to understand how the use of these technologies is shaping industrial modes of production around these subjective experiences of cows. I examine scholarship, government publications, and journalism regarding welfare and technology in the dairy industry to identify how production is being structured around welfare technology, and how this is impacting relationships of power between cows and humans. I draw a theoretical foundation from Giorgio Agamben's biopolitics to conceptualize cows as political subjects in relation to humans in complex ways that can vary in different moments and spaces. I argue that, rather than limiting or reducing violence on the farm, the operationalization of these technologies changes the experience of industrial modes of production for cows and consumers, and reorients the conditions for the exploitation and disciplining of cows.

Information + Education

Visualizing Climate Technology Needs of Non-Annex I Parties of the Paris Agreement

Presenters: Sarah Collins, MS (BEC, SusDev), MA; Lauren Davis, MS (EPP, EJ); Yeri Kim, MS (EJ, SusDev); Bhavesh Rathod, MS (SusSys)

Advisor: Dr. Jose Alfaro

Location: Ann Arbor, Michigan, USA; Fairfax, Virginia, USA; Copenhagen, Denmark

Client: Climate Technology Centre & Network

The Center for Climate Technology and Network (CTCN) is a global network of technology companies and institutions tasked with providing rapid assistance to countries in need of technical or non-technical assistance in realizing their contributions to the Paris Agreement. CTCN, therefore, not only has to analyze the documents submitted by countries to the United Nations Framework Convention on Climate Change to understand trends in climate technologies being prioritized, but also track all climate technology needs to ensure its network has the technical and non-technical capacity to meet these changing technology needs. To this end, CTCN has to rely on synthesis reports which collect relevant information across documents and countries over years. This study intends to define an alternative interactive visual approach to highlighting trends and showcasing how climate technology prioritizations are connected between various countries. First, climate technology prioritization and needs were analyzed for non-annex I countries. This information was then used to create a web application that parses climate technologies to create an interactive network diagram. Through this study, a tool was developed that allows for quick visualization of climate technologies, prioritizes any subset of countries analyzed, and provides easy access to underlying data. The tool also highlights areas where countries might need assistance and guidance from CTCN in determining their technology needs. Outputs from the tool were then used to analyze how climate technology needs for countries in Western Africa align with expected impacts of climate change to showcase how the tool fits in the wider ecosystem of climate technologies analysis.

Maximizing the Value of Schoolship Data: Recommendations for a Long-Term Citizen Science Monitoring Strategy

Presenters: Connor Roessler, MS (BEC); Brianna Ellis, MS (ESM, GDS); Xiao Qin, MS (ESM, GDS); Cecelia Batterbee, MS (ESM)

Advisor: Dr. Paul Seelbach

Location: Suttons Bay, Michigan, USA

Client: Inland Seas Education Association

The Inland Seas Education Association (ISEA) operates educational programs aboard their schooner with the mission of "inspiring Great Lakes curiosity, stewardship, and passion in people of all ages." For over 30 years, they have consistently utilized students to collect limnological data to build a unique citizen science dataset that supports environmental education. Despite a clear educational strategy, ISEA has lacked defined scientific monitoring goals to guide data collection and management decisions. Consequently, data are stored in unharmonized formats, siloed to internal use, and unable to reach their full potential. To address this, we observed ISEA's education program and data collection; interviewed volunteers, environmental educators, and experts; and surveyed participating teachers. Combining all results, we determined which aspects of the data ISEA's customers and the regional scientific community found valuable and interesting, including benchmarks of ecological change. We developed recommendations to define goals for a monitoring program that complements ISEA's existing data collection, as well as to improve QA/QC and database management to facilitate data sharing. Such improvements will allow ISEA to achieve their educational goals and expand their reach to the broader community and research interests in the Great Lakes region. Our recommendations may help other environmental education and community groups building or evaluating citizen science monitoring efforts.

Climate Change Education and Incorporation Best Practices

Presenters: Andrea Bustamante, MS (SusSys), MBA; Mackenzie Dallas, MS (SusSys), MBA; David Duckett, MS (EPP), JD; Jeremiah Eaton, MS (EPP), MBA; Lenny Su, MS (SusSys), MBA

Advisor: Dr. Andrew Hoffman

Location: Ann Arbor, Michigan, USA

Client: Zurich Insurance

Zurich Insurance does not have industry-specific strategy guidance on how customers should be transitioning towards a 1.5C future, or a product's services that can support customers in their transition. This is largely due to inconsistent levels of underwriters' understanding of how climate change impacts their day-to-day jobs. The goals for this project consisted of two key workstreams. The first of these workstreams included developing easily interpretable overviews of the transition pathways across 10 industries of interest for underwriters to reference. The second workstream involved understanding the current state of climate change and sustainability awareness at Zurich Insurance and researching and benchmarking best education practices for climate change across academia and companies. Methods used involved conducting interviews with individuals both in academia and in sustainability-related roles at companies across different industries.

Taking It Outside: Designing Outdoor Learning Opportunities for Saline High School

Presenters: Yuexin Chang, MS (GDS); Sicheng Cui, MLA; Yingpeng Feng, MLA; Emily Hernandez, MLA, MS (EPP); Bihui Zhuang, MS (GDS), MLA

Advisor: Stan Jones

Location: Saline, Michigan, USA

Client: Drew Denzin, Saline High School

In this project, our team set out to provide ideas for design interventions and for creating educational opportunities for Saline High School's campus. With the construction of a new high school in the early 2000s, the Saline campus incorporated what used to be surrounding wetlands, agricultural, and forested land, and preserved some of the habitat areas while converting the majority of the land into a more "traditional" high school campus landscape. There is ample space and opportunity to provide the school with creative design solutions that would allow the school community to better utilize their campus while also infusing sustainability, environmental awareness, and a culture of stewardship into the curriculum. Teachers at the school remarked on the lack of dedicated space for gathering a whole class for outdoor learning. Outdoor classrooms were included in nearly every one of the eight design areas. Each design area has associated educational opportunities tailored to the area and proposed design. Every effort was made to incorporate educational opportunities for a diverse set of subjects, from science and math to art and language. This project incorporates research-based design practices to develop design recommendations focused on enhancing the local environment and providing educational opportunities to Saline High School students.

Shifting Capital to Climate Change Mitigation and Adaptation Solutions

Presenters: Laura Dyer, MS (BEC), MBA; Nathan Lohrmann, MS (BEC), MBA; Max Berry, MS (SusSys), MBA; Max Odena, MS (ESM), MBA

Advisor: Dr. Andrew Hoffman

Location: Boston, Massachusetts, USA

Client: CapShift

Climate change poses an existential threat to humanity, but funding to mitigate and adapt to our changing climate is not commensurate with the scale of the problem at hand. Meanwhile, high-net-worth individuals (HNWIs), their fiduciaries, and organizations have difficulty investing their philanthropic capital (worth US$140+ billion) into meaningful climate change mitigation and adaptation solutions. The goal of CapShift is to shift the philanthropic capital of their clients (HNWIs, their fiduciaries, and organizations, together "CapShift clients") into socially and environmentally friendly investments; the objective of this project was to facilitate the shift of that capital into climate change mitigation and adaptation investments, specifically. We met this objective by performing research and a landscape overview of existing literature and frameworks, then synthesizing this information into a unique framework. The framework was delivered to investors in the form of a primer. Our project approach and deliverables helped address the problem stated above by providing an actionable lens for current and prospective CapShift clients to make climate investments and drive more investors and investment dollars to climate adaptation and mitigation solutions.

School for Environment and Sustainability (SEAS) Camp and Leadership Program

Presenters: Hannah DeHetre, MS (ESM); Danielle Vermeer, MS (BEC)

Advisor: Shannon Brines

Location: Ann Arbor, Michigan, USA

Client: School for Environment and Sustainability

The goal of this project is to develop a SEAS education camp and leadership program that emulates an interdisciplinary, decolonized curriculum. Diversity, Equity, and Inclusion (DEI) principles are prioritized to provide scholarship opportunities and outreach strategies that make the camp more accessible for historically underrepresented students. The program aims to give all campers an opportunity to learn and become leaders in the environmental and sustainability arena.

Developing an Equity Lens and DEI Plan for Vermont's Natural Resource Conservation Districts

Presenters: Anna Cone, MS (EJ, ESM); Toyosi Dickson, MS (EJ); Miranda Dupre, MS (EJ); Maisy Rohrer, MS (EJ); Allison Williams, MS (EJ, EPP)

Advisor: Dr. Kyle Whyte

Location: Vermont, USA

Client: Vermont Natural Resource Conservation Districts

In February 2021, a productive collaboration was formed between University of Michigan (U-M) graduate students and Vermont Natural Resource Conservation District (NRCD) and Vermont Association of Conservation Districts (VACD) staff. This partnership came to fruition as a team of NRCD and VACD staff, known as the core team, made a commitment to Diversity, Equity, and Inclusion (DEI) work in the NRCDs. The core team sought out U-M master's students studying in the School for Environment and Sustainability to conduct research supporting the wants and needs of Vermont conservation districts as it pertains to DEI.

Both the core team and the U-M team wanted to center the voices of NRCD and VACD staff in this DEI work. To assess the attitudes, beliefs, and vision for the future of DEI in the Vermont NRCDs, the U-M research team, with the guidance and mentorship of U-M Environmental Justice Professor Dr. Kyle Whyte, began their research using the Delphi Survey model, an iterative process in which a small, committed group of interviewees helps to create a well-calibrated survey for their community. After multiple feedback sessions, the U-M team analyzed interviewee input for consensus for the development of a final survey, titled "Vermont Conservation Districts' Survey: Organizational DEI Self-Assessment." The final DEI survey was sent to staff from all 14 conservation districts between December 2021 and January 2022, and had a 77% response rate, with 92 responses. The final DEI Self-Assessment and Growth Guide is informed by the survey responses received in January 2022.

Sustainability + Development

Analysis of CO2 Emissions: Impact of Fully Transitioning to Preferred Fibers

Presenters: Greg Allinson, MS (SusSys), MBA; Jess Halter, MS (BEC), MBA; Amy Schatz, MS (BEC), MBA; Annie Zaro, MS (SusSys), MBA

Advisor: Dr. Ravi Anupindi

Location: Ann Arbor, Michigan, USA

Client: prAna

PrAna is a $150M active lifestyle apparel and accessory brand that has committed to transitioning 100% of their fibers to preferred versions that are more sustainable than fibers currently used in production. Through the analysis completed as part of this project, prAna learned how to transform their product line into being fully preferred fiber-based and understands the environmental impact of making this shift. In order to run this analysis, the research team calculated the environmental impact of a complete assortment conversion to using preferred fibers, mapped how to convert prAna's existing product line to using preferred fibers to maximize sustainability while maintaining key qualities and characteristics, and outlined opportunities for continuous assessment and integration of new preferred fibers into future development cycles. The team compiled data from prAna's complete inventory database of products in production, the associated volumes of each product sold in a given year, and life cycle assessment data in the Higg Index to complete the analysis. The final result is that the full transition to preferred fibers can have a significant impact on the emissions from their products and confirmed that this strategy is a key part of meeting the company's carbon emission reduction goals.

Working at the Nexus of Climate Justice and Nature-Based Solutions

Presenters: Thea Louis, MS (EJ); Jyoti Bodas, MS (EPP, SusSys); Kristen Buchler, MS (BEC); Trevaris Brown, MS (ESM)

Advisors: Dr. Rosina Bierbaum; Kristin Baja

Location: Ann Arbor, Michigan, USA

Client: Urban Sustainability Directors Network

Since 2008, the Urban Sustainability Directors Network (USDN) has worked steadfastly to increase urban sustainability in over 180 different cities, and their Nexus Program focuses on operationalizing racial equity into local governments. The Nexus Program addresses issues surrounding systemic and institutionalized racism and discrimination in government processes and programs in order to move forward so as to best and most holistically serve all peoples and environments. In this project, our goal was to identify deeper opportunities for climate action that benefit and connect racial equity-centered work with biomimicry and nature-respected solutions—particularly with local governments and community partners. Through the use of literature review, stakeholder engagement, and qualitative interviews, we gathered data to analyze what has been done about existing inequities that contribute to environmental and social harms thus far, what is currently being worked on at various stages of government, and what opportunities for growth and improvement exist in these areas. Our findings indicate that concerted and collaborative efforts must be incorporated into existing processes, and ultimately may replace those processes and systems that continue to perpetuate injustices. In doing so, a sustainable and just environmental future can be achieved.

Solar and Biomass Microgrid in Adjuntas, Puerto Rico, 2021-2022

Presenters: Weiqing Yu, MS (GDS), MLA; Jason Crisostomo, MS (EJ)

Advisor: Dr. Jose Alfaro

Location: Adjuntas, Puerto Rico

Client: Casa Pueblo, Parador Villas Sotomayor

This master's project aims to help the hotel Villa Sotomayor establish a microgrid to offset the high energy costs and instability in electricity supply that they currently face. After Hurricane María in 2018, the hotel went without grid electricity for nearly 200 days. We also worked with a nonprofit on the ground, Casa Pueblo, which has an initiative to help the island of Puerto Rico run on more renewable electricity. The primary objectives of the project are: 1) conducting an inventory of biomass available at the Sotomayor farms, including seasonality, amount, and necessary preprocessing (drying, chipping, pelletizing); 2) sustainable development planning around the biomass supply chain (placement of biomass storage, gasifier, and generator) and solar power potential at Villa Sotomayor; and 3) shooting a virtual tour for Parador Villas Sotomayor. We recorded our data and finished our shooting workload on the ground in Puerto Rico last summer, and finished our design part on a computer in Ann Arbor. Our results and purpose include a launchable virtual experience for Villa Sotomayor aimed at attracting more tourists and providing an experience for people who can't travel, and a designed development proposal for Villa Sotomayor containing biomass and solar grid strategies.

National Strategy for Bioeconomy in Costa Rica

Presenters: Annie Linden, MS (EJ, SuSDev), MURP; Chelsea Johnson, MS (EJ, SusDev); Veronica Correa, MS (BEC, SusDev); Siri Kore, MS (SusSys), MBA

Advisor: Dr. Jose Alfaro

Location: Costa Rica

Client: United Nations Development Program's Biodiversity Finance Initiative

The United Nations Development Program (UNDP) is concurrently implementing its Biodiversity Finance Initiative (BIOFIN), a global project that aims to help governments develop a strong case for increased investment in biodiversity. In Costa Rica, BIOFIN works in conjunction with the Ministry of Science and Technology and Telecommunications (MICITT) to support the National Strategy for Bioeconomy (NSB) as part of a prioritized financial solution: the "bio business platform." As a result of this project, Coopetarrazu and Nicoverde will have an independent assessment of the biodiversity and environmental impacts of their production processes and future project plans. The results will be shared with the BIOFIN regional group in Latin America and the Costa Rican ministerial team.

Our primary service was providing an independent sustainability assessment of two companies' biorefinery products; we applied an environmental life cycle assessment (eLCA), social life cycle assessment (SLCA), and a biodiversity assessment to help the companies measure their technological, sustainability, and biodiversity impact. For Nicoverde, we conducted an eLCA, SLCA, and biodiversity assessment of their pineapple production. For Coopetarrazu, we built off of previous work done by the Costa Rican Institute of Technology to conduct an eLCA, SLCA, and biodiversity assessment. Additionally, for Coopetarrazu, we created a green projects portfolio summarizing sustainability projects at the cooperative that can potentially be launched onto the green bond market. For each company, we compiled an external facing case study.

Biodiversity and Social Impact Assessment at Banke-Bardiya Complex Along East-West Electrified Railway Alignment in Nepal

Presenters: Nathaniel Allen Arringdale, MS (GDS); Samuel Dylan Lisak, MS (ESM, EPP); Ryan Maddison Pickerill, MLA; Caitlyn Melanie Renowden, MS, (ESM, SusDev, EJ)

Advisor: Dr. Neil Carter

Location: Banke-Bardiya Complex, Nepal

Client: World Wildlife Fund (WWF) Nepal

An electrified railway is being built east-to-west across Nepal, bisecting key ecological regions and carrying significant potential to disrupt wildlife connectivity and peoples' land relationships. We worked with World Wildlife Fund (WWF) Nepal to analyze where wildlife occupancy is highest in Banke-Bardiya (BB) Complex, where key endangered species moved within the landscape, and how habitat fragmentation and human-wildlife conflict can be mitigated through effective management and railway design. Additional objectives were to analyze village fragmentation and Indigenous rights. Methods involved utilizing Geographic Information Systems, occupancy modeling using camera trap data, remote sensing, habitat selection modeling, and conducting literature reviews. Our results revealed high biodiversity within key wildlife corridors, the active use of these corridors by these species, and the potential for human-wildlife conflict given the proximity of wildlife to developed areas. We found that the modeled movement overlapped highly with actual wildlife movement and identified two potential best crossing locations. We strategically designed crossing structures at these points to facilitate movement of key species. We determined approaches to maintain connectivity and minimize human-wildlife conflict in general, including crossing structure standards, fencing, and habitat management techniques, as well as approaches related specifically to key species. Finally, we proposed a Free, Prior, and Informed Consent (FPIC) protocol to support Indigenous peoples' rights prior to railway construction in BB Complex. This study has the potential to mitigate harm to both humans and wildlife, presenting a good model for future projects in achieving sustainability and development goals.

Nitrogen Management in a Perennial Grain-Legume Intercrop System

Presenter: Erika Dodge, MS (SusDev, ESM)

Advisor: Dr. Jennifer Blesh

Location: Ann Arbor, Michigan, USA

Synthetic nitrogen fertilizer inputs to farms are major drivers of global change, damaging surrounding ecosystems through processes such as nitrate leaching and aquatic eutrophication, and greenhouse gas emissions, particularly for nitrous oxide, a potent greenhouse gas. Ecologically driven approaches to nitrogen management in agricultural systems focus on managing crop diversity and building soil organic matter to increase soil nitrogen cycling capacity, reducing the need for harmful external inputs. The objective of this research builds upon a growing body of literature on the benefits of perennial grain systems in agriculture, with a particular focus on the incorporation of leguminous intercrops to reduce synthetic nitrogen demands. Using the University of Michigan Campus Farm, the experiment was planted in a randomized complete block design. From the site, soil and forage samples were collected for analysis. Ultimately, we found that both the alfalfa and white clover intercrops used in this experiment supply sufficient nitrogen to the field to balance intermediate wheatgrass nitrogen uptake. The alfalfa intercrop plots proved to be more land use efficient, and supplied more nitrogen from fixation.

Analyzing Emission Patterns and Addressing Sustainability Solutions within the Detroit Department of Transportation Using GIS Systems

Presenter: Kamerhon Moses, MS (SusSys), MSE

Advisor: Dr. Jose Alfaro

Location: Detroit, Michigan, USA

Many city, state, federal, and private decision-makers have heeded the climate research demonstrated by adopting policy and regulations that favor the mutual interests between the environment and society. In Detroit, Michigan, this has emerged as a citywide Sustainability Action Agenda that addresses four umbrella goals of a healthy/thriving population, equitable housing, updated neighborhood-built infrastructure, and an overall green city. The Detroit Department of Transportation (DDOT) and the Suburban Mobility Authority for Regional Transportation (SMART), which serve the Southeast Michigan transit system including Detroit, requested federal funding to procure several electric buses and install charging infrastructure. The grants from the Federal Transit Authority (FTA) enabled the purchase of six Proterra electric buses that are to immediately be put into service in the Detroit area, allowing for the retirement of older, diesel-fueled buses in DDOT and SMART's fleets. The purpose of this project is to analyze the routes set by SMART and DDOT to serve the Detroit community and reference them against a GIS tool that identifies areas that suffer from particularly high environmental emissions. By identifying the routes that are primarily in these highly impacted areas, DDOT and SMART can choose to deploy the newly acquired electric buses where they would be most effective in reducing citizen transportation emission exposure. This would align with the city's goals that include improved air quality and reduction to emissions exposure, leading to a healthier populace.

Obtawaing Biosphere Region Expansion

Presenters: Samuel La Russo Frederickson, MS (GDS, ESM);
Daniela Fernandez Mendez Jimenez, MS (BEC, ESM)

Advisors: Jon Allan; Adam Schubel; Dr. Knute Nadelhoffer

Location: Pellston, Michigan, USA

Client: University of Michigan Biological Station

The University of Michigan Biological Station biosphere reserve (BR) is expanding and being redefined as the Obtawaing Biosphere Reserve (OBR) during its current 10-year United Nations Educational, Scientific, and Cultural Organization (UNESCO) review. OBR is part of the Man and the Biosphere (MAB) Programme, which is part of UNESCO, and seeks to establish a scientific basis for enhancing the relationship between people and their environments. It combines the natural and social sciences with a view to improving human livelihoods and safeguarding natural and managed ecosystems, thus promoting innovative approaches to economic development that are socially and culturally appropriate and environmentally sustainable.

This expansion will include land with multiple "core" regions that will involve collaboration with various partners including, but not limited to, local land conservancies, academic institutions, governmental agencies, and tribal communities. Due to this expansion, this research team will help OBR understand the needs of its various partners, research other BR practices, geovisualize the region, and support administrative tasks. Methods that were used to answer these objectives included informal conversations with partners, online research on national and international BRs, and visualizing the environment and its inhabitants through GIS. This helped support OBR and the Rivers, Trails, and Conservation Assistance (RTCA) program during its re-definement and strategic planning process.

Waste + Circular Economy

Assessment of Food Waste Reduction Interventions for MDining

Presenters: Colton Babladelis, MS (SusSys), MBA; Marney Coleman, MS (SusSys), MBA; Celia Bravard, MS (SusSys), MBA; Janet Genser, MS (SusDev), MBA

Advisor: Dr. Andrew Hoffman

Location: Ann Arbor, Michigan, USA

Client: MDining

Food and agricultural wastes are major contributors to greenhouse gas (GHG) emissions. Global food loss and waste equate to approximately 4.4 gigatons of carbon dioxide equivalent (CO2e) per year, meaning if food waste were a country, its carbon footprint would rank as the third top emitter after the United States and China. The University of Michigan Dining Services, MDining, serves approximately 2.5 million meals per academic year to over 10,000 students via nine dining halls. U-M's President's Commission on Carbon Neutrality (PCCN) includes a goal to divert 40% of waste from landfills. The team's objective was to identify and analyze a variety of different food waste interventions and solutions across the value chain within the university context, specifically with MDining, to help reach the university's 40% goal. The interventions were assessed on the following criteria: economic, environmental, financial, and feasibility. Methods include literature review, expert interviews, quantitative analysis, observations, and development of a multi-criteria decision analysis (MCDA) dynamic tool. The final tool allows MDining leadership to adjust intervention criteria to bolster decision-making related to supporting U-M PCCN goals and maintaining fiscal responsibility while considering implementation feasibility.

Urban Ashes: Building a Circular UrbanWood Triconomy™

Presenters: Anna Norman, MS (SusSys), MBA; John Pontillo, MS (SusSys), MBA; Justin Pryor, MS (SusSys), MBA; Diane Simunek, MS (SusSys), MBA; Molly Barstow, MS (SusSys, EPP), MBA

Advisor: Dr. Andrew Hoffman

Location: Ann Arbor, Michigan, USA

Client: Urban Ashes

By and large, within the United States, wood from urban trees and wood products from deconstructed buildings are seen as a burden on municipalities and are largely handled as waste, for simplicity's sake. With an estimated 64% of above-ground tree biomass being merchantable, it is estimated that missed opportunities per year in the state of Michigan equate to the following: 1.26 million board feet of lumber; 1.54 million metric tons of carbon; 27.6 million USD industry. In addition to carbon storage and feedstock for wood products, trees offer incredible value in terms of ecosystem services, such as leaf litter to support vegetation growth, reducing runoff into streams resulting in cleaner water, urban air filtering resulting in healthier urban air, the cooling of urban heat islands resulting in lower energy costs, and improved community mental health and well-being through the benefits of green spaces. Urban Ashes is uniquely positioned to create and scale its Circular UrbanWood Triconomy™ (CUT) consulting business model across Michigan and the United States by diverting urban wood from landfills and creating a market for circular urban wood products in partnership with organizations that operate with a triple bottom line approach. Workstreams for development and realization of the CUT model have been split into the three distinct features of the triple bottom line or Triconomy™: environmental sustainability, social equity, and economic diversity. The U-M SEAS team established a proof of concept for this business model, focused on Ann Arbor, and validated the triple bottom line benefits.

Water

Development of a Reasoned Approach to Chloride Reduction in Michigan

Presenters: Michael Harrington, MS (EPP); Daniela Tapia Pitzzu, MS (SusSys); Meghan Williamsen, MS (EPP)

Advisor: Dr. Sara Hughes

Location: Ann Arbor, Michigan, USA

Client: Michigan Department of Environment, Great Lakes, and Energy

Chloride has become a major pollutant throughout the United States' water system. It is harmful to both aquatic plants and animals, and has been shown to corrode infrastructure. To combat this problem, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) recently developed water quality values (WQVs) in accordance with the Clean Water Act (CWA) to reduce chloride levels to those safe for aquatic life. Our objective was to identify point and nonpoint chloride discharge sources into Michigan's surface waters. Through our partnership with EGLE, we developed a comprehensive statewide chloride budget conveying chloride sources and generated sector-specific options aimed at reducing chloride concentrations in Michigan's surface waters. We emulated the research methods utilized by the University of Minnesota in their efforts to evaluate chloride contributions sources for Minnesota. We determined that the largest contributors of chloride discharge in Michigan were from road salt application and National Pollutant Discharge Elimination System (NPDES) permittees. To assist EGLE in their communication strategy, we developed educational outreach solutions targeted for specific stakeholders to use. They included a best practices checklist for road salt applicators, a pamphlet for water softener and deicer use aimed towards the general public, a concise summary of our project's goals and findings, and alternative strategies for chloride mitigation geared towards food processors and wastewater treatment plants (WWTPs).

Supporting Project Integration and Translation: Smart Urban Stormwater Tools for the Clinton River

Presenters: Megan DiCocco, MS (ESM); Daniel Dominique, MS (GDS); Timothy Marchman, MS (ESM); Analise Sala, MS (ESM); Huayile Zhang, MS (ESM)

Advisors: Dr. Paul Seelbach; Dr. Andrew Gronewold

Location: Ann Arbor, Michigan, USA; Southeast Michigan, USA

Clients: Michigan Department of Environment, Great Lakes, and Energy; Clinton River Watershed Council; University of Michigan Department of Civil and Environmental Engineering; Michigan State University Institute of Water Research

Interdisciplinary investigators from the Michigan Department of Environment, Great Lakes, and Energy; the University of Michigan; and Michigan State University have been collaborating on the Clinton River Smart Stormwater Management Project. The project aims to develop a stormwater decision-making toolkit for the Clinton River in response to challenges from urbanization and climate change. The large project involving multiple institutions has inherent communication challenges between researchers, clients, and stakeholders across institutional and disciplinary boundaries. Therefore, our master's project objectives were to support overall project communication and connectivity between investigators, provide technical assistance, translate knowledge to end users, and evaluate deliverable effectiveness. To accomplish these objectives, we integrated ourselves into the larger project subteams, assisted with project management and evaluation, provided GIS assistance to principal investigators, and sampled river water to gather additional field data. As a result, we successfully improved internal and external project communication and knowledge translation. We delivered technical data in the form of GIS layers and research on E. coli dynamics in the river system. Deliverables of this project will be accessible to and used by water resource managers in Macomb and Oakland counties to assist in stormwater decision-making.

An Assessment of Coastal Resilience in Great Lakes Communities

Presenters: Andrea Paine, MS (EPP); Annika Tomson, MS (EPP); Hannah Paulson, MS (ESM); Kat Cameron, MS (EPP), MURP; Elsa Soderberg, MS (BEC); Anna Kaczmarek, MS (EPP)

Advisor: Dr. Paul Seelbach

Location: Great Lakes Basin Cities, United States and Canada

Client: National Oceanic and Atmospheric Administration Office for Coastal Management, Great Lakes and St. Lawrence Cities Initiative

High water-level events across the Great Lakes Basin in 2017 and 2019 caused widespread flooding and shoreline erosion, damaged property and infrastructure, and resulted in an increased interest among communities to protect their coastlines and implement resiliency measures. In response, the Basin experienced an influx of resources and funding to assist communities in adopting solutions. While some municipalities have begun executing measures such as improving stormwater management and installing shoreline armoring, many communities continue to face barriers in assessing risk, planning projects, accessing funding, implementing plans, and collaborating with other coastal communities. The current state of resources and funding were compiled and evaluated to understand the influx that had occurred following the 2019 flood event. By analyzing interviews with 41 municipalities, 11 resource providers, and two focus groups, this research confirmed existing gaps and identified potential solutions to improve the implementation of coastal resiliency measures at a local scale. Coastal municipalities continue to struggle with protecting their communities from the impacts of climate change due to a lack of staff capacity to determine funding, evaluate resource options, and prepare applications. As a result, decision-makers are faced with the possibility of incurring debt and a short window of opportunity before climate impacts are no longer urgent to community members and the impetus to make change is gone.

Whose Water Crisis? How Government Drought Responses Widen Inequality

Presenter: Olivia David, MS (EPP, EJ)

Advisor: Dr. Sara Hughes

Location: California, USA; Western Cape Province, South Africa

Recent severe droughts in California and the Western Cape Province, South Africa, attracted global attention as water scarcity threatened cities, rural communities, agricultural industries, and ecosystems in varied ways. Government responses to these challenges succeeded in achieving water conservation targets, and scholarship evaluating both droughts from diverse perspectives emerged. This study extends existing scholarship by comparing drought responses in terms of their lasting effects on social inequality as evinced in relationships to water access networks. In so doing, I explain how and why the responses materialized and manifested in widened inequalities. For this study, I collected data from the relevant literature, policy documents, and interviews with key informants in each region about their perspectives on the droughts and the ensuing policy responses. I analyzed these data using mechanism-based process tracing methods. Comparing the ways and mechanisms by which inequalities widened in each case reveals: 1) the resilience of dominant social values and constructions, even during socio-environmental crises; 2) the key role of historical and institutional contexts in shaping the outcomes of events such as droughts, and related responses and impacts; 3) the pertinence of information collection and communication to shaping social impacts of drought responses; and 4) the particular importance of decisions around groundwater resources during drought events. To conclude, I suggest policy implications and recommendations based on these insights, and areas for future research.

The Policy Failures of Rental Housing: Examining Plumbing Poverty Among Renters in Detroit, MI

Presenter: Heather Newberry, MS (EPP, EJ)

Advisor: Dr. Sara Hughes

Location: Detroit, Michigan, USA

"Plumbing poverty," or the lack of access to in-home water for drinking, cooking, and sanitation due to inadequate plumbing infrastructure, is a growing challenge in the United States and affects renters at a higher rate than homeowners. At the nexus of housing and water, plumbing poverty has critical health and equity implications for renters. While most cities have regulatory structures that govern rental housing, plumbing poverty persists. Little research has been done to investigate the social, political, and policy dynamics that perpetuate such rental water insecurity. Understanding these dynamics is essential for creating effective policies that protect renters from plumbing poverty.

This paper investigates why rental housing policies in Detroit, Michigan, have failed to ensure adequate plumbing infrastructure and access to water for renters. To situate the scale of plumbing poverty for Detroit renters, I analyzed descriptive quantitative and spatial data on selected demographic characteristics of Detroit renters. Additionally, I conducted interviews to understand why Detroit renters struggle with plumbing poverty despite regulatory protections, and what barriers exist to addressing rental plumbing poverty in Detroit.

Ultimately, I find that plumbing poverty for Detroit renters is perpetuated by the implementation of city policies and legal tools that is under-informed and misaligned with the socio-economic dynamics of rental housing in Detroit. Central to these dynamics is a cycle of financial instability and reduced capacity in renters, landlords, and the city government. These dynamics of instability leave renters without social power and economic mobility, landlords without capital, and the city without meaningful policy tools.

Social Vulnerability to Flooding in the Contiguous U.S.

Presenter: Wanja Waweru, MS (GDS)

Advisor: Dr. Joshua Newell

Location: United States

Flooding is one of the most expensive and deadly natural disasters in the United States. Currently, FEMA's National Flood Insurance Program (NFIP) is the primary federal mechanism for providing flood insurance to residents and encourages the development and adoption of flood risk mitigation actions in U.S. communities. However, the quality and accuracy of FEMA's flood insurance risk maps are inconsistent across the United States. In response to the limitations of the NFIP and other national-level flood risk maps, a recent flood risk data set created by the nonprofit research and technology group First Street Foundation identified nearly 6 million properties unaccounted for in the 100-year floodplain. Furthermore, sociodemographic factors such as income and race have been found to have a significant relationship with how well an individual can prepare for and recover from a natural hazard event. We used a bivariate Local Indicators of Spatial Association (LISA) model to identify areas where high flood risk and a high proportion of properties unaccounted for by FEMA co-occur. Using multinomial regression modeling, we also investigated if there are socially vulnerable communities in these high-risk regions. We identified four high-risk regions: the Pacific Northwest, Central Appalachia, the Gulf Coast, and the Southeast Atlantic Coast. Despite the variation in sociodemographic factors significantly related to flood risk across the regions, housing type was found to have a significant relationship to flood risk in each of the four regions. These findings can be used to respond to the unique needs and cultures of vulnerable communities. We anticipate that using data at a higher spatial resolution will be more "relevant" to understanding neighborhood-level vulnerability and provide a more nuanced understanding of vulnerability to flooding across the United States.

Gelman Site Groundwater Contamination Plume Spatio-temporal Forecasting

Presenter: Yifan Luo, MS (ESM, GDS)

Advisors: Dr. Andrew Gronewold; Dr. Derek Van Berkel

Location: Ann Arbor, Michigan, USA

Client: Scio Township

Groundwater systems are intrinsically heterogeneous with dynamic temporal-spatial patterns, which cause significant challenges in quantifying and mapping their complex processes. However, accurate forecasting of regional groundwater contamination is commonly needed to better identify the spatial-temporal change of contamination to help the public anticipate the timing and severity of potential groundwater quality issues and possibly serve as an early warning system. This study focuses on modeling a plume of 1,4-dioxane originating from the Gelman site beneath the City of Ann Arbor, Michigan. It proposed a novel methodology to consider the spatially and temporally irregular and uncertain nature of groundwater contamination data to analyze the historical trends of dioxane concentration and predict its transportation: 1) We developed a Random Forest model to fill in or extend fragmented time series data gaps among all the monitoring wells; 2) A Mann Kendall test was applied to evaluate the trend of dioxane concentrations at various wells; 3) We used the automated time series machine learning (AutoTS) package for predicting time series values based on comparing thousands of combinations of data preprocessing steps and algorithms to assess which best forecasts future values; 4) An R-based Shiny web application was designed to allow visualization and quantification of dioxane contamination analytical data; and 5) Residual error analysis and validation of observed and predicted dioxane levels were performed. This research introduced a novel framework for filling temporal and spatial data sampling gaps in groundwater contamination to offer an effective and promising way to predict future plume concentration and its spatial distribution.

Thank You, Clients!

Our sincere thanks to the project client organizations (listed below). You provide SEAS students with key opportunities for research and the development of professional skills. We greatly value your partnership.

Ann Arbor 2030 District

Carbon Yield

CapShift

Casa Pueblo, Parador Villas Sotomayor

Center for Alaskan Coastal Studies

City of Ann Arbor Office of Sustainability and Innovations

Climate Technology Centre & Network

Clinton River Watershed Council

Cooperative Institute for Great Lakes Research (CIGLR), University of Michigan

Detroit 2030 District

EcoWorks

Environmental Protection Agency Office of Transportation and Air Quality (EPA OTAQ)

Ford Motor Company

Great Lakes and St. Lawrence Cities Initiative

GreenSwapp

Inland Seas Education Association

International Centre for Integrated Mountain Development (ICIMOD)

Isle Royale National Park (National Park Service)

Kellogg Company

Kgora Farmer Training Centre

MDining

Michigan Audubon

Michigan Department of Environment, Great Lakes, and Energy (EGLE)

Michigan State University Institute of Water Research

National Oceanic and Atmospheric Administration Office for Coastal Management

National Renewable Energy Laboratory (NREL)

Nature and Nurture Seeds

Ocean Spray

OSD

People, Public Lands, and Climate Collaborative

prAna

ReFED

Rights and Resources Initiative (RRI)

Saline High School

Shiawassee National Wildlife Refuge

Steelcase

University of Michigan Biological Station

University of Michigan Campus Farm at Matthaei Botanical Gardens

University of Michigan Department of Civil and Environmental Engineering

University of Michigan Landscape Informatics Lab

University of Michigan School for Environment and Sustainability

United Nations Development Program's (UNDP) Biodiversity Finance Initiative (BIOFIN)

United Nations Framework Convention on Climate Change (UNFCCC)

Urban Ashes

Urban Sustainability Directors Network (USDN)

Vermont Natural Resources Conservation District

World Wildlife Fund (WWF) Nepal

Wyandot of Anderdon Nation

Zurich Insurance

University of Michigan

One of the nation's top public universities, the University of Michigan has been a leader in research, learning and teaching for more than 200 years. U-M's alumni body is one of the largest in the world and includes a U.S. president, scientists, actors, astronauts and inventors. The university, which also boasts a world-renowned intercollegiate athletics program, has been the site of many important events in U.S. history, including JFK's announcement of the Peace Corps, LBJ's "Great Society" speech, and the clinical trials of the Salk polio vaccine. The main campus in Ann Arbor comprises 19 schools and colleges; there are also regional campuses in Dearborn and Flint, and a nationally ranked health system, Michigan Medicine. In 2017, U-M celebrated its bicentennial, marking 200 years since its founding in the city of Detroit.

School for Environment and Sustainability (SEAS)

The School for Environment and Sustainability's overarching objective is to contribute to the protection of the Earth's resources and the achievement of a sustainable society. Through research, teaching, and outreach, faculty, staff, and students are devoted to generating knowledge and developing policies, techniques, and skills to help practitioners manage and conserve natural and environmental resources to meet the full range of human needs on a sustainable basis.

Land Acknowledgement

The School for Environment and Sustainability acknowledges the university's origins through an 1817 land transfer from the Anishinaabek, the Three Fires People: the Odawa, Ojibwe, and Bodewadami, as well as Meskwahkiasahina (Fox), Peoria, and Wyandot. We further acknowledge that our university stands, like almost all property in the United States, on lands obtained, generally in unconscionable ways, from Indigenous peoples. In addition, our research on environmental science and sustainability has benefited and continues to benefit from access to land originally gained through the exploitation of others. Knowing where we live and work does not change the past, but understanding and acknowledging the history, culture, and impacts of colonial practices is an important step towards the creation of an equitable and sustainable future.

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