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A CELEBRATION OF GRADUATE STUDENT RESEARCH

2021

Cities + Mobility + Built Environment

Financing the transition of the University of Michigan Blue transit buses to an all-electric fleet - A Project Finance Model

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ADVISOR: Dr. Peter Adriaens

LOCATION: Ann Arbor, Michigan, USA

The U-M President's Commission for Carbon Neutrality (PCCN) reports a goal of fully electrifying the transit bus system called Magic Blue Bus by 2035 as part of the wider goal of achieving carbon neutrality from scope 1 and scope 2 emissions by 2025. This will require the purchase of new battery electric buses (BEB) and the expansion of the current transit infrastructure to include charging facilities, all of which provide large upfront costs. The current method of financing the Magic Blue Buses includes grants and awards from Michigan Medicine. However, to attain a successful transition, more sustainable financing models must be set up. A Project Finance Model is proposed in which the university becomes an off-taker of electric bus services through a lease agreement with a Special Purpose Vehicle (SPV) set up by Proterra. In this model, the university refinances the lease through debt from bond issuance in the capital market, and gains revenues from the sale of carbon credits and the resale of excess electricity stored in the electric battery. A financial model is set up to calculate the Cost-Benefit analysis, Net Present Value (NPV), the Payback Period, and the Internal Rate of Return for the Project Finance Model. A sensitivity test is also performed to determine the optimal interest rates that investors can charge on their capital. The work provides an alternative model for various stakeholders involved in assessing the cost feasibility of a transition to a BEB fleet at U-M Ann Arbor campus by 2035.

Stories of a Pandemic: Narratives from Gratiot/7 Mile Residents

STUDENT TEAM: Maite Elizondo Piñeiro, MS (BEC); Madeleine Lane, MS (EPP, BEC)

ADVISOR: Dr. Mark Lindquist

LOCATION: Detroit, Michigan, USA

CLIENT: City of Detroit Planning and Development Department

In 2019, the City of Detroit Planning and Development Department began to formulate the Gratiot/7 Mile Neighborhood Framework Plan, which will be used to guide neighborhood planning and future development in the northeast Detroit neighborhood. At the end of 2019, the world faced an unprecedented health crisis as COVID-19 began to spread across the globe. The pandemic changed people's lives and had major implications for the use of public space. Through this project, we explore the impact of the COVID-19 crisis on Gratiot/7 Mile neighborhood residents by collecting oral histories on their personal experiences of the crisis. These personal narratives allow us to explore how the COVID-19 pandemic affected residents' daily lives, their use of neighborhood space, and their connection to their community. In an interactive ArcGIS Storymap, we document the stories of Gratiot/7 Mile residents and other members of the community as part of their community history. These narratives also prompt future research avenues as social scientists, urban planners, landscape architects, and Gratiot/7 Mile neighborhood residents seek to understand how the COVID-19 pandemic has altered neighborhood planning and development, both in the Gratiot/7 Mile neighborhood and beyond. We found that the pandemic shifted how neighborhood residents used public space and interacted with each other. As the City of Detroit Planning and Development Department continues to develop the Gratiot/7 Mile Neighborhood Framework Plan, we would encourage consideration of how the pandemic has transformed residents' lives to inform the City's planning efforts.

Greening the Common Ground: Mapping Equitable Access to Joe Louis Greenway

STUDENT TEAM: Yanling Mo, MLA, MS (EPP); Meng Jia, MLA, MS (ESM); Yan Li, MLA, MS (EPP); Chuhan Xing, MLA, MS (GDS)

ADVISOR: Dr. Derek Van Berkel

LOCATION: Detroit, Michigan, USA

CLIENT: SmithGroup

Public investment in green space should be nondiscriminatory. Studies have examined that green space is likely to distribute unevenly in American cities. In this project, we collect environmental, demographic, and socioeconomic data in neighborhoods that intersect with and surround Joe Louis Greenway—one of the largest public projects in Detroit, Michigan; use quantitative analysis to find neighborhoods confronting severe environmental injustice issues and are in urgent need of access to green space. On a smaller scale, we develop a landscape plan in Ford Park, Highland Park, as an extension of the proposed greenway to emphasize accessibility for people of all abilities and multifunctionality. Drawing on previous literature, the city's framework plan and feedback from public meetings, we provide measurable metrics to assess and monitor the outcomes of greenway constructions. Finally, we discuss how to achieve equitable development by actively engaging the community in a long-haul process using novel tools such as mobile apps. Achieving a more sustainable city includes distributing opportunities and risks equitably, and our project aims to provide environmental, fiscal and economic, and social benefits to people of all races, economics and social status.

Environmental and Social Impact Assessment of Electric Motorcycles in Kampala, Uganda

STUDENT TEAM: Calzavara, Jacob; Courtright, Thomas; Park, Junghoon

ADVISORS: Dr. Michael Craig; Dr. Pamela Jagger

LOCATION: Kampala, Uganda

CLIENT: Zembo

In Kampala, Uganda, motorcycle taxis - boda bodas - play a critical role in moving people and goods across the city. This informal industry is a significant source of income for an estimated 150,000 people within Kampala and a million across the country. Yet, boda boda is considered a low-profit business, the drivers are marginalized, and they are at risk of extortion, accidents, and hostility. The motorcycles running on internal combustion engines (ICE) also contribute to both local air pollution and global greenhouse gas emissions. Zembo is a Kampala-based company that produces electric motorcycles targeting the boda boda market. While electric vehicles are generally thought to have positive social and environmental impact compared to ICE vehicles, the literature is scarce regarding the impact on electric motorcycles in urban environments with high degrees of poverty and informality such as Kampala City. We engaged in this research to better understand the degree of impact that electric motorcycles have in both social and environmental dimensions. We hypothesized that electric motorcycles would benefit the boda boda drivers by improving their net income and social well-being; and emit significantly less local air pollutants and greenhouse gases compared to the conventional motorcycles currently in use.

Climate + Energy

Beyond the energy bill: integrating climate, health, and resilience into solar plus storage assessments for public buildings

STUDENT: Amanda Farthing MS (SusSys), MSE (Environmental Engineering)

ADVISORS: Dr. Tony Reames; Dr. Michael Craig

LOCATION: Ann Arbor, Michigan, USA

Local governments are increasingly looking to invest in solar and storage to power publicly owned facilities. Typically, investment decisions for these technologies are based on a comparison of lifetime costs to electricity bill savings for each proposed location. However, this approach fails to fully capture the value of these systems to local governments, considering the burden their communities bear from power outages and power plant emissions. In this study, we assess the impact of incorporating climate, health, and resilience impacts into the optimal sizing of behind-the-meter solar plus storage, with a particular focus on public buildings. Our work expands upon the REopt model, which allows for the valuation of resilience, by further incorporating the monetized benefit of avoided climate and health damages from grid electricity, using location-specific marginal emissions rates and costs. To illustrate the use of this new model, we take Ann Arbor, Michigan—a city actively considering investments in solar plus storage—as a case study. We compare the cost-optimal system sizes and net present value of solar plus storage when considering only energy bill savings versus additionally capturing health, climate, and resilience impacts. Our results show that incorporating these value streams results in significantly larger cost-optimal battery systems. When accounting for emissions and resilience co-benefits, the net present value of each investment is also orders of magnitude greater, with benefits being largely dominated by avoided health impacts. These results illustrate how investment decisions would change when the scope of benefits of solar plus storage is expanded beyond bill savings.

Integration of biomass gasification to help increase community resilience—Design and model of a solar+biomass microgrid in Adjuntas, Puerto Rico

STUDENT TEAM: Andrew Richardson, MS (SusSys); Larry Borum III, MS (SusSys);
Stephen McShane, MS (SusSys), MEng (Energy System Engineering)

ADVISOR: Dr. Jose Alfaro

LOCATION: Adjuntas, Puerto Rico

CLIENT: Casa Pueblo and Parador Villas Sotomayor, Puerto Rico

The viability of integrating biomass gasification into microgrids for rural or energy-insecure communities is an area of active investigation. Excess biomass is a carbon-neutral resource readily available to many vulnerable communities that offers the potential to lower the cost to maintain a stable microgrid while also increasing community autonomy and sustainability. This research aimed to model a small-scale grid that integrated solar PV and biomass gasification for a large community inn to better understand the economic and technical effects of using biomass as a fuel source. This research also sought to design a gasifier using CAD to allow for future biomass gasification experimentation. HOMER Pro and Helioscope were used to model the microgrid, while Fusion 360 was used to design the CAD model of the prototype hybrid gasifier. The model demonstrated that biomass gasification would help increase community energy resilience and potentially could lower the cost of energy for the local business. However, future investigation is needed to design a circular supply chain to process and store the excess biomass. The completed design of the new model gasifier will also contribute to future thesis work exploring biomass energy characteristics. This work is part of an ongoing engagement by U-M's Sustainability Without Borders organization, and thus will continue with the next Master's Project team.

Biodiversity does not enhance algal feedstock production when exposed to fungal infection: An experimental test in outdoor ponds using a before-after-control-impact (BACI) design.

STUDENT: Spenser Widin, MS (ESM)

ADVISORS: Dr. Bradley Cardinale; Dr. Meghan Duffy

LOCATION: Arizona Center for Algal Technology and Innovation, Mesa Arizona, USA

For outdoor cultivation of algal feedstocks to become a commercially viable and sustainable option for biofuel production, algal cultivation must maintain high yields and temporal stability in environmentally variable outdoor ponds. One of the main challenges is mitigating disease outbreaks that lead to culture crashes. Drawing on predictions from the "dilution effect" hypothesis, in which increased biodiversity is thought to reduce disease risk in a community, we tested whether algal polycultures would reduce disease risk and improve feedstock production efficiencies compared to monocultures. While the positive benefits of biodiversity on disease risk have been demonstrated in various systems, to the best of our knowledge this is the first test in an algal biofuel system. Here, we present the results of a before-after-control-impact (BACI) experimental design to compare mean monoculture (control) and polyculture (impact) yield, stability, and productivity before and after fungal infection when grown in 400-L outdoor raceway ponds. We found that polycultures did not experience a reduction in disease risk compared to monocultures or differ in production efficiencies throughout the course of the 43-day experiment. Our results show that polyculture feedstocks did not improve productivity, stability, and disease resistance compared to that of a monoculture. Determining whether these results are generalizable or represent one case study requires additional outdoor experiments using a larger variety of host and pathogen species.

Estimating the Potential Energy Yield from the Use of Woody Invasive Species as Feedstocks for Biomass Gasification in Southeast Michigan

STUDENT: Julia Magee, MS (SusSys), ME (Mechanical Engineering)

ADVISOR: Dr. Jose F. Alfaro

LOCATION: Ann Arbor, Michigan, USA

Small-scale biomass gasification presents a promising opportunity for distributed renewable energy generation, particularly in rural areas. The use of woody invasive plant species as feedstocks facilitates this generation without the reliance on dedicated energy crops or agricultural residues from monocultures, particularly in Michigan. Further, an opportunity is created to manage the ecological harm caused by woody invasive plant species while simultaneously co-producing biochar, which has the potential to sequester carbon and act as a soil amendment. The potential electrical energy yield from gasification must be understood and contextualized both with respect to the scale of impact, and a cost-benefit analysis. In this work, honeysuckle and buckthorn collected in southeast Michigan were used as separate feedstocks for biomass gasification. They were used in a small-scale Imbert gasifier and separate trials captured the percent composition of the produced syngas. The LHV for syngas produced using honeysuckle was found to be 6.6 ± 2.4 MJ/kg and 6.0 ± 1.8 MJ/kg for syngas produced using buckthorn. The gasification efficiency for the conversion of dry honeysuckle to syngas was 56 ± 23 % and 51 ± 18 % for the conversion of dry buckthorn to syngas. Finally, given assumptions about the amount of these species available in Michigan, a potential 0.34 – 0.37 TWh of energy could be yielded from honeysuckle or buckthorn respectively, enough to supply electricity to over 6,500 homes in the state for a year.

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

STUDENT TEAM: Shannon Blair, MS (GDS); Lola Chen, MS (EJ, BEC); Stephanie Hefelfinger, MS (SusSys, EPP); Heeseung Kim, MBA, MS (BEC); Catherine Mullin, MBA, MS (BEC); Erin Seguin, MBA, MS (SusSys)

ADVISOR: Dr. Gregory Keoleian

LOCATION: Lakeville-Middleboro, Massachusetts, USA

Climate change poses a significant risk to agriculture. At the same time, food systems are among the top sources of anthropogenic greenhouse gas emissions. Ocean Spray Cranberries, Inc. (OSC), which produces cranberry-based foods and beverages, seeks to reduce its carbon footprint. This research aims to enable OSC to understand its current output of Scope 1 and 2 carbon emissions, develop ambitious yet appropriate greenhouse gas emissions reduction goals, and identify emissions mitigation strategies. We also conducted a preliminary accounting of grower-owner emissions, which are classified as Scope 3 emissions. To achieve these objectives, we conducted a greenhouse gas inventory using 2019 data collected from the manufacturing and receiving facilities, and from cranberry farmers; the data were input and analyzed in Accuvio sustainability reporting software. We also conducted interviews in 2020 with 10 of OSC's manufacturing facilities. Additionally, we completed a literature review and research to benchmark competitor climate-action commitments and identify sustainable financing strategies. Following our analysis, we had three key findings: The majority of OSC's Scope 1 and 2 emissions come from purchased electricity and natural gas consumption; manufacturing facilities have notably higher Scope 1 and 2 emissions than receiving facilities; and existing company-wide standards for projects' returns on investment impede the approval of sustainability projects. These findings led us to target mitigation strategies to reduce use of electricity and natural gas at manufacturing facilities, while underscoring the need to factor in hidden costs associated with carbon emissions when assessing sustainability interventions.

Steelcase Scope 3 GHG Inventory

STUDENT TEAM: Prachiti Dhamankar, MS (SusSys); Julia Kehoe, MS (EPP), MBA; Elliott Schwab, MS (EPP), MBA

ADVISOR: Dr. Ming Xu

LOCATION: Grand Rapids, Michigan, USA

CLIENT: Steelcase

As a leader in corporate sustainability, Steelcase, Inc., a multinational $3.7B office furniture company, is committed to reducing its carbon footprint by setting science-based targets aligned with a 1.5°C climate scenario as set forth by the Paris Agreement. As such, the objectives of this Master's Project included the development of a scope 3 greenhouse gas emissions inventory, a set of strategic communications for internal and external stakeholders, and a supplier engagement strategy, each in support of Steelcase setting and achieving a set of scope 3 science-based targets for the decade ahead. To accompany the launch of Steelcase's science-based targets, the team began creating and producing a six-part webinar series to educate and engage Steelcase's suppliers to set their own emissions inventories and science-based targets. The team developed the following recommendations to facilitate and support Steelcase's achievement of these goals: • Build on improvements in data management practices by further transitioning from spend-based to supplier-specific methods and developing supportive processes • Balance the trade-offs between increasing granularity of data with the associated costs • Bolster the scrap tracking initiative and implement strategies to minimize waste-to-landfill • Facilitate understanding and engagement across the organization • Expand supplier engagement infrastructure beyond the webinar series • Support policies and initiatives that decarbonize manufacturing and transportation

Transportation Greenhouse Gas Emissions Baseline and Associated Policy Recommendations for the Ann Arbor 2030 District

STUDENT TEAM: Tess Fields, MS (EPP); Jeffrey Pritchard, MURP, MS (SusSys); Sivah Akash, MS (GDS)

ADVISOR: Dr. Geoffrey Lewis

LOCATION: Ann Arbor, Michigan, USA

CLIENT: Ann Arbor 2030 District (Jan Culbertson)

The project establishes the Ann Arbor 2030 District transportation baseline using a survey administered to the District members. The survey methods and greenhouse gas inventory calculations determined by the project team focus on commuting emissions for individuals employed by Ann Arbor 2030 District members. The transportation baseline is determined by assessing the greenhouse gas emissions based on the per-passenger fuel or electricity consumption of the vehicle used. The distance travelled, mode split, fuel type, and average fuel/electricity consumption are obtained from survey respondents or are determined by the research team using local or national data, and are used to determine the emissions per commuter. Policy recommendations from literature reviews and survey response data are provided based on the potential for emissions reductions. A survey was administered to employees regarding commuting patterns before and during the COVID-19 pandemic to establish a baseline for transportation emissions and to study how the pandemic affects transportation emissions. Results indicate that a shift in transportation modes from the high-intensity mode of driving alone in gasoline-powered vehicles to a lower-intensity mode of working-from-home is a valuable strategy for the Ann Arbor 2030 District to meet the goal of reducing transportation-related emissions at least 50% by the year 2030, based on a 2019 baseline. The report also provides 2030 Districts with a toolkit for establishing and tracking emissions associated with commuting.

Investigate technical, policy and business approaches to addressing stewardship and circularity for end-of-life for PV system

STUDENT: Aniket Yadav, MS (SusSys)

ADVISOR: Dr. Geoffrey Lewis

LOCATION: Michigan, USA

CLIENT: Michigan Energy Options

Renewable energy plays a vital role in limiting the catastrophic impact of climate change, and solar energy is one of the important renewable energy sources that the world is relying on. This industry has seen tremendous growth in the last decade with China and the USA taking the lead role. However, this growth is predicted to create a big problem of photovoltaic (PV) panel waste by the second quarter of the century when the global PV waste is projected to reach 60-78 million tons. This project explored the existing technologies, policies, and practices related to end-of-life management (EOL) of crystalline silicon (c-Si) based PV panels around the world to recommend these for the state of Michigan. The literature review was the main source of collecting information. Through this project, it is concluded that major PV markets except for the EU lack PV EOL management policies. In the lack of national PV EOL management policies, Washington has established their policies, and some other states such as New York, New Jersey, and North Carolina are also following suit. For the state of Michigan, an extended producer responsibility- based policy is recommended. Full Recovery End of Life Photovoltaic process to recover the highest mass percentage of materials with the least waste, and the process developed by Arizona State University to achieve the highest material value are recommended for effectively recycling c-Si PV panels in Michigan.

Conservation + Restoration

Impacts of local and regional environmental characteristics on breeding colonies of Yellow-legged Gulls (Larus michahellis) in the Southern Aegean

STUDENT: Rachael Carlberg, MS (CON ECO, GDS)

ADVISOR: Dr. Johannes Foufopoulos

LOCATION: Southern Aegean Sea, Greece

In island ecosystems seabirds act as keystone species, influencing patterns of biodiversity through their nutrient deposits and nesting behaviors. The Aegean Sea (Greece, NE Mediterranean Basin) is an area of high biodiversity and endemism which contains important seabird communities. Among them is the Yellow-legged Gull, Larus michahellis, a generalist gull species native to the western Palearctic. Over the past several decades populations have increased rapidly despite rising impacts of human activities on nesting islands. Through this research we aim to identify the variables impacting the density and locations of Yellow-legged Gull colonies. Censuses of 131 nesting colonies were completed in the Cyclades Island cluster and surrounding islands of the Southern Aegean Sea. We also gathered data on variables known to influence seabird colonies, including physical islet characteristics, resource availability (largely focused on landfill and fisheries activity in the area), and human disturbance. We used generalized linear models to determine how islet-level factors and regional resource availability impact the distribution and density of breeding colonies. We found a strong relationship between islet area and breeding colony density, with smaller islets containing much higher densities of Yellow-legged Gulls. We also detected a negative effect of rat and feral grazer (rabbit and goat) presence. On a regional scale, the presence of nearby landfills and fishing vessels were found to be related to Yellow-legged Gull colonies, showing that these anthropogenic food resources act as an important part of the species diet. Our results suggest approaches to manage Yellow-legged Gull populations in the Mediterranean Basin.

Evaluation and Adaptive Management of the Huron River Watershed Council Natural Areas Assessment and Protection Project

STUDENT TEAM: Ashley Lorinsky, MS (ESM); Paul Christianson, MS (CON ECO, GDS, EPP); Colin Welk, MS (GDS); Gavin Mcgregor, MS (ESM, BEC); Allyson Holman, MS (ESM); Vanessa Decker, MS (ESM, GDS)

ADVISOR: Dr. Sheila Schueller

LOCATION: Ann Arbor, Michigan, USA

CLIENT: Huron River Watershed Council

Natural areas are critical to ecosystem services and resilience as well as the conservation of biodiversity. Many natural areas in Southeast Michigan have already been anthropogenically altered and remaining natural areas are under threat of development, fragmentation, and habitat degradation. In 2006, the Huron River Watershed Council created the Natural Areas Assessment and Protection Program (NAAP) to map, assess and conserve the watershed's remaining natural areas. The program collects GIS and field-based data on ecological integrity, which it shares with decision-makers to better inform the prioritization and management of natural areas. However, in spite of the program's longstanding work, it has never undergone a thorough review on its methods or impact. We systematically reviewed and recommended improvements for three main areas of the program: 1) the field-based ecological integrity assessment; 2) data management and integration; and 3) engagement and impact. Overall, our three-tiered approach to evaluating NAAP revealed that although its methods remain largely in line with industry practices, they could be greatly improved by the products of our project. We updated data gathering protocols and provided a template for integration of GIS and field data, and we interviewed and surveyed individuals and organizations that use NAAP products to generate recommendations based on user feedback. Together these recommendations and new approaches will improve the efficiency, accuracy, usability and long-term impact of this important natural areas protection effort.

Comprehensive pollinator planning and outreach for U-M Central Campus: Raising awareness, enhancing habitat, and celebrating achievements

STUDENT TEAM: Savanna Delise, MS (ESM, EJ); Zoe Bliss, MS (BEC, ESM); Zhelin Li, MLA, MS (ESM); Rachelle Roake, MLA; Beth Weiler, MS (ESM)

ADVISOR: Dr. Sheila Schueller

LOCATION: Ann Arbor, Michigan, USA

CLIENT: U-M Office of Campus Sustainability & UM Grounds Services

Pollinator populations are threatened due to habitat loss and fragmentation, harmful land management practices, and a lack of awareness of the benefit and diversity of native pollinator habitats and species, especially in an urban setting of a university campus. University green spaces have the potential to support a wide variety of pollinators in an institutional setting where outreach and educational opportunities abound. However, university green spaces come with unique challenges to supporting pollinator habitat as well, including: harsh site conditions, high aesthetic expectations, high standards of human safety, and ease of maintenance. Supporting pollinators on campuses therefore requires a commitment to more sustainable landscaping practices and a shift in cultural norms that is supported by the surrounding community. Though U-M Grounds Services and the Office of Campus Sustainability are already committed to and implementing sustainable practices on campus, such as limited chemical use and the restoration of habitat, they needed a comprehensive effort related to pollinator habitat and education, both to provide habitat for declining pollinator populations and for community engagement. We addressed these needs through a multi-faceted approach to 1) assess and enhance pollinator habitat on campus; 2) identify and build outreach and education opportunities related to pollinators; and 3) establish a support network to continue these efforts as part of a national Bee Campus certification program.

Human-Leopard Conflict and Coexistence in Northern Kenya

STUDENT TEAM: Alan Ching, MS (ESM); Anna Urso, MS (EJ); Joyce Choi, MS (ESM, EJ); Robert Hart, MS (EJ); Laura McNeil, MS (EPP)

ADVISOR: Dr. Neil Carter

LOCATION: Laikipia County, Kenya

CLIENT: San Diego Zoo Wildlife Alliance

Livestock depredation by leopards is a common occurrence in Northern Kenya. Oftentimes, to defend themselves and their resources, it is common that pastoralists and ranchers resort to lethal methods leading to the killing of leopards in the area. Human-wildlife conflict is one of the leading issues causing leopard declines. Our primary objective of this project is to assist San Diego Zoo Wildlife Alliance and promote coexistence of leopards with the pastoralists communities located in Laikipia County, Kenya. To do this our goals were to i) analyze historical context of our study area and bring awareness to historical practices that increases risk of human-leopard conflicts; ii) promote the use of non-lethal management strategies; and iii) identify any socio-ecological and environmental variables that may increase risk of human-leopard conflict. Utilizing livestock-leopard conflict report data obtained from our clients, we conducted statistical analyses to identify the relationship between husbandry practices, landscape variables, and several socio-ecological factors and the amount of damage incurred during a conflict. Some of the results we obtained include: i) Leopards tend to attack and target sheep and goats over other livestock; ii) ideally, at least three different protective measures should be used to reduce damage caused during a conflict; and iii) risk of attack and amount of damage done increase closer to rivers and transitional boundaries between habitat types. Human-wildlife conflicts, such as livestock depredation, are a rising issue and are becoming more commonplace. As such, we need to find and identify effective methods to coexist with wildlife.

Azteca sericeasur nest patterns analysis in a conventional and organic coffee farm

STUDENT: Teresa Dorado, MS (ESM)

ADVISOR: Dr. Ivette Perfecto

LOCATION: (Ann Arbor, Remote Analysis) Data from Chiapas, Mexico

Spatial patterns in ecology have an important role in the temporal dynamics of a system. Farm management can further impact these patterns as species habitat change with varying management. Extensive studies have analyzed the spatial patterns of Azteca sericeasur, an arboreal nesting keystone species, in an organic shade coffee farm in Chiapas, Mexico. However, less is known about the nesting dynamics in a conventionally managed farm. Here, I analyze the dynamic clustering patterns over time of A. sericeasur in a conventionally managed coffee farm and a certified organic coffee farm. I explore the spatial patterns of A. sericeasur through a cluster analysis to determine the impact of nest clustering on mortality over time. Using Ripley's K analysis, I find there is clustering of ant nests at both farms but only at a small spatial scale in the conventionally managed farm. In addition, older nests in the conventional farm that died were observed to be more isolated from live nests. Nest location is dependent on tree availability and interactions of A. sericeasur with other species. This study has implications for coffee farm management, as it provides a useful comparison of the nest patterns observed over time.

Increasing Resistance and Reducing Vulnerability to Invasive Species at Sleeping Bear Dunes National Lakeshore

STUDENT TEAM: Bethany Louria, MS (ESM, GDS); Daphne Onsay, MS (ESM); Stephanie Peters, MS (SusSys); Emma Sloan, MS (BEC, ESM); Sara Steenberg, MLA, MS (ESM); Gabrielle Vinyard, MS (ESM)

ADVISOR: Dr. Sheila Schueller

LOCATION: Ann Arbor and Empire, Michigan, USA

CLIENT: Sleeping Bear Dunes National Lakeshore

Invasive species pose a significant threat to long-term ecosystem health. Current invasive management strategies at Sleeping Bear Dunes National Lakeshore (SBDNL) focus on reducing or eliminating single species; however, this reactive approach is often costly, time intensive, and is not successful long-term. Practitioners are interested in preemptive, resistance-based management. Our project provides recommendations for implementing resistance-based management practices at SBDNL and any similar site. We first conducted a literature review to determine the characteristics related to plant community vulnerability and resistance. We then conducted a fragmentation analysis and analyzed vegetation monitoring data to identify potentially vulnerable sites to prioritize for resistance-based management at SBDNL. We concurrently interviewed invasive species management practitioners to understand their perceived challenges in transitioning to resistance-based management. Literature shows native seeding and minimizing disturbance to be effective in preventing future invasion. Data analysis shows that in SBDNL, balsam mixed-conifer forests are significantly more likely to have more invasive species than pine forests (p-value = 0.0135) and sugar maple/beech forests (p-value = 2.92e-05). For every 1 species increase in native species, the probability of an increase of 1 species of invasive increases by 4.23%. The fragmentation analysis identifies two major sites in SBDNL to prioritize for management and monitoring: Benzie Corridor and the beachfront near Glen Arbor. Interviews reveal that resistance-based management is not often applied in practice despite a widespread desire to do so. Practitioners list the need for access to research, funding, communication with other practitioners, and better education and outreach efforts.

Landscapes of Extinction: physiography as a factor in Greek reptile extinctions during a period of climatic change

STUDENT: Sam Kalb, MS (ESM)

ADVISOR: Dr. Johannes Foufopoulos

LOCATION: Naxos, Greece, and surrounding islands

Reptiles are some of the most vulnerable organisms to climatic change, and in the age of anthropogenic climate change, understanding the relative importance of the many factors in the reptile extinction process is increasingly vital. The islands surrounding Greece present a prime opportunity to examine extinction processes since the height of the last ice age, and to investigate the influence of a wide variety of factors. We seek to fill a gap in this research by characterizing the role of physiography, non-biological landscape features, in this process. We reconstruct patterns of reptile extinction on Greek islands using bathymetry and parsimony, and then use GIS and a statistical model to parse the relative importance of a variety of physiographic variables on the prevalence of extinctions on these islands. Preliminary results suggest a high importance for topographic heterogeneity, which can provide numerous different microclimatic conditions that can help a variety of species persist, as well as dominant slope aspect, with north-facing slopes experiencing a significantly cooler climate than south-facing slopes even on the same island. Understanding the physiographic factors most associated with extinction can help conservationists to identify the areas most at risk as the climate grows warmer, potentially assisting in management decision making.

Evidence for the importance of invasive Dreissena veligers as a novel prey item for larval fish

STUDENT: Ellary Marano, MS (ESM)

ADVISORS: Dr. Karen Alofs; Dr. David "Bo" Bunnell Jr.

LOCATION: Great Lakes region

The establishment of invasive Dreissenid mussels in the Laurentian Great Lakes has had far reaching effects, from changes in the physical structure of habitat to changes in zooplankton community composition. Adult dreissenids are believed to have indirectly contributed to reductions in prey fish growth by reducing densities of important prey items available to larval prey fish such as Diporeia and zooplankton. However, the effects of larval dreissenid mussels (also called "veligers) on fish are relatively unknown. There is potential for native and naturalized larval fish to take advantage of veligers as a novel prey item. To assess the importance of veligers in larval fish diets, we examined the stomach contents of three species of larval fish collected from Lake Huron in July of 2017: burbot (Lota lota), rainbow smelt (Osmerus mordax), and bloater (Coregonus hoyi). Using Vanderploeg and Scavia's E*, preference for available zooplankton prey items was evaluated. Results indicate that veligers are rarely selected by rainbow smelt or bloater but are in some cases highly preferred by burbot. Further, the results of a mixed model analyzing the different factors that contribute to veliger preference indicated that small and medium sized larval burbot had more positive preference for veligers than larger larval burbot, indicating that veligers could be an important prey item while larvae are gape limited and unable to consume larger zooplankton. Thus, it is necessary to consider the ability of native and naturalized species to adapt to the effects of dreissenids when engaging in invasive species management.

Predicting Dreissena spp. presence and biomass as a function of Lake Huron characteristics

PRESENTER: Jennifer Wardell, MS (ESM, GDS)

ADVISORS: Dr. Catherine Riseng; Dr. Peter Esselman

LOCATION: Lake Huron, USA

Dreissenid mussels (Dreissena polymorpha and Dreissena rostriformis bugenis) have had huge effects on the areas they have invaded, changing the benthic habitat structure in addition to the overall food web and nutrient cycling on a lake-wide scale. The severity of these impacts depends on dreissenid distributions and their biomass, which vary dramatically across the lake. To accurately manage and understand the lake ecosystem, it is important to be able to not only quantify dreissenid presence and biomass, but also predict their ranges based on different environmental factors. Sample site data from the 2017 CSMI survey from Lake Huron and datasets for ten different explanatory variables were obtained and explored for possible trends. In addition, models were created with the goal of predicting dreissenid biomass on a lake-wide scale and representing these results cartographically. This objective was attempted and potential models are presented, however, good results were not obtained. As a result, a model that can predict dreissenid presence with moderate performance was created instead. In the future, many data limitations will need to be rectified since the performance of these models was greatly limited by the available datasets for Lake Huron. With the use of advanced technology to obtain the necessary data, I am confident these techniques can be used to create a robust, predictive model for dreissenid mussel biomass in the future.

Information + Education

Kiwanis Environmental Education Preserve: Phase 2

STUDENT: Yanning Gao, MLA, MS (ESM)

ADVISOR: Dr. Allen Burton

LOCATION: Ann Arbor, Michigan, USA

CLIENT: Kiwanis Club of Ann Arbor Foundation, Inc.

In 2017, the Kiwanis Club of Ann Arbor Foundation purchased a 17-acre property to the west of Ann Arbor at 100 N. Staebler Road, Scio Township. This property has a 7.6-acre vegetated area that includes a small pocket of wetlands including two ponds. It was historically used for agriculture followed by a book manufacturing facility, and was poorly managed. Upon acquiring the property, the Kiwanis sponsors, Margaret Krasnoff and Dan Devers, envisioned this parcel as an opportunity to pursue and practice environmental education. Ever since, they have been pushing their vision to bring the Kiwanis Environmental Education Preserve (KEEP) into existence. During Phase I (2019 – 2020), a SEAS Masters Project conducted a census and inventory of vegetation and wildlife, a baseline characterization of existing ecosystem types, and modelled stormwater runoff from the Kiwanis warehouse and parking lot. Phase II will continue the vision and expand the project by completing the site inventory, refining preliminary designs for the KEEP parcel, develop educational materials and displays, and begin the restoration and educational process. It will result in a package of landscape design that will be built mostly by volunteers in the future and will help visitors from all ages to better experience the KEEP. Management options and education module suggestions will also be provided as reference to initiate the next phase of work.

Food

The Farm at St. Joe's Oakland: Therapeutic Landscape Design for a Hospital-Based Wellness Initiative

STUDENT: Katharine Shiffler, MLA

ADVISOR: Dr. Raymond de Young

LOCATION: Pontiac, Michigan, USA

CLIENT: The Farm at St. Joe's

The Farm at St. Joe's is recognized as a national model in the "green care" movement; the hospital's farm is home to a small staff of growers, educators and horticultural therapists who provide food and innovative programming for patients and health care providers. In recent years, The Farm has grown exponentially to provide more produce and more services for the Ann Arbor and Ypsilanti communities—prioritizing the immediate needs resulting from the COVID-19 pandemic. The Farm at St. Joe's was ready to replicate its successes in other Michigan communities. To begin, the Farm's staff needed help designing a 1.5 acre site adjacent to St. Joseph Mercy Oakland in Pontiac, Michigan. An outcome of this collaboration is a robust and unified design for a new hospital farm and outdoor environment informed by site-specific factors, community input and contemporary research on therapeutic landscapes. Shiffler created a master plan articulating project phases, a planting plan, and planning documents to assist the organization's future landscape projects. She also coordinated many practical aspects of the site's initial construction process, installing the first phase in Fall 2020. As a result of the momentum of the design and planning process, The Farm hired a full-time staff member to oversee the Pontiac landscape moving forward.

Cover Crop Adoption & Government Conservation Agriculture Programs in Michigan

STUDENT: Alison Surdoval, MS (EJ)

ADVISORS: Dr. Jennifer Blesh; Dr. Meha Jain

LOCATION: Michigan, USA

Industrial agriculture is a leading cause of environmental degradation globally. Agroecology, or ecologically-based agricultural systems and practices such as cover cropping, offers an environmentally-sustainable alternative. Cover crops have been shown to improve soil quality, retain and supply vital crop nutrients, reduce runoff, and enhance crop growth, among other valuable agricultural functions. Despite these benefits, cover crops cover only 7% of cropland in Michigan. Funded through the Farm Bill, the Environmental Quality Incentive Program (EQIP) incentivizes conservation practices on working lands. Although overall funding for EQIP is small compared to subsidy payments for commodity crops, EQIP funding for cover crops increased from $15 M in 2009 to $56 M in 2015. Given the ecosystem benefits that cover crops provide, their growing popularity in farmer networks for soil health, and the recent increase in government cost-share payments, it is worth examining whether these trends correlate to changes in cover crop presence on the landscape. This research uses spatial and statistical analysis to examine the relationship between field-scale cover crop prevalence, conservation agriculture program participation, and environmental outcomes in Michigan. Initial results indicate that participation in government cover crop programs is increasing, but overall participation remains low. Disaster Assistance may play an important role in cover crop uptake in the face of a changing climate. The majority of agricultural fields in Michigan do not have winter crop cover, and winter crop cover prevalence has not changed substantially from 2008 to 2019. The research contributes to larger conversations around sustainable agriculture.

Securitized scarcity or insecure abundance?: A case study on the strengths and weaknesses of agroecology in southeast Michigan

STUDENT: Ayana Curran-Howes, MS (EJ)

ADVISORS: Dr. Sara Adlerstein-Gonzalez; Dr. Ivette Perfecto

LOCATION: Southeast Michigan

There is growing consensus that agroecology practiced by the new peasantry is needed to move communities toward food sovereignty and improve the sustainability, equity, economic viability, and climate resilience of farming. However, agribusiness interests subsume public funding, policy supports, and agricultural knowledge creation in the globalized food system. Furthermore, case studies of agroecological transformation remain sparse. In the heart of the Midwest, this case study provides a narrative of alternative agriculture, illustrating the strengths and weaknesses of agroecology in a landscape and country dominated by agribusiness interests. Through interviews with small-scale diversified farmers and farm support actors, I assessed which elements of the FAOs 10 principles of agroecology and which peasant values are being practiced and supported in southeast Michigan. From this I identified what barriers remain for scaling up agroecology and increasing value of adopting peasant values. Farmers all sold in direct-to-consumer markets and are increasing diversity, resilience, efficiency, and synergies across their farm on their own. This is aided by coproduction of knowledge and investments in the solidarity economy. All principles need to be strengthened, but recycling, responsible governance, and culture and food traditions were the least prevalent agroecological principles, with the lattermost principle being limited by the diversity of interviewees. Farmers were not invested in internalizing recycling processes, most notably for seeds and compost, and bottom-up responsible governance was deemed aspirational, not practical.

Sustainability + Development

Evaluating Social Capital as a Driver of Improved Cookstove Adoption in Lusaka, Zambia

STUDENT: Shannon Lloyd, MS (EPP, GDS)

ADVISOR: Dr. Pam Jagger

LOCATION: Lusaka, Zambia

This thesis evaluates the role of social capital in adoption of improved cookstoves in Lusaka, Zambia. While being an economically stable, relatively peaceful country, Zambia has seen low rates of improved or clean cookstove adoption. Improved cookstoves provide positive health benefits specifically to women and children under five, as well as require less fuel. The data used in this research is from the baseline data collection and rapid assessment done by the Energy Poverty PIRE in Southern Africa (EPPSA) research team and collaborators. Social capital was operationalized by taking the survey questions from baseline data collection and grouping them into similar categories as bridging, bonding, and linking; popularized by Putnam (2000) and Szreter and Woolcock (2004). The dependent variable, adoption, is defined as only having purchased the stove, this analysis does not address sustained use of the stove. The descriptive statistics showed that female-headed, adopter households had higher social capital values across all social capital variables included; it was also found that 60% of the households included in the analysis were considered adopters. Having a female-headed household was highly significant and increased likelihood of adoption across all three models (Full Sample, VITALITE, and Supamoto). Finally, as a population, people of presumably higher economic status had higher likelihoods of adoption, as indicated by two physical capital variables which increased the likelihood of adoption: owning your home and number of durable goods. These results show areas where cookstove firms could specifically target their strongest marketing populations.

Highlighting Women's Voices in a Climate Change and Livelihood Narrative: A Case Study in a Rural Fiji Community

STUDENT: Adriane Kline, MS (SusSys, BEC), MPH

ADVISOR: Dr. Jose Alfaro

LOCATION: Republic of Fiji

Climate change has wide implications for human health and also affects social and environmental determinants of health (for example, shelter, drinking water, food security). The Republic of Fiji, a developing island nation in the South Pacific, is particularly burdened by climate change. This is due to sea-level rise, increasing temperatures, and an increase of extreme climate events compounded by livelihood strategies that rely on healthy ecosystems. Population groups such as women, residents in rural areas, and disadvantaged communities are disproportionately affected by health impacts linked to climate change. Small-scale, community-centered studies are needed to understand local perspectives and livelihood systems, in order to facilitate equitable and culturally appropriate adaptation measures. This study promotes the voices of women in Yalobi Village, a rural Fiji community, by explaining their livelihood strategies, how their health is impacted by climate change, and their adaptive capacity. This mixed-methods study involved a quantitative survey (n=48) and qualitative interviews (n=10). Study participants exhibited a reliance on their natural environment demonstrated by their dependence on surrounding ecosystems for food, income generation, medicine, and cultural obligations. Their greatest concerns are the impacts of future climate change on food security, income generation, water access, and culture. The primary climate change threats of concern are sea-level rise, stronger tropical cyclones and changing weather patterns. Traditional gender roles and responsibilities prompted differing impacts for women and men in Yalobi Village. Community-based study methods should be applied to climate change adaptation planning to ensure local voices are heard and efforts are community-led.

Waste Resource Management

Environmental Payback Periods of Reusable Alternatives to Single-Use Plastic Kitchenware Products

STUDENT: Hannah Fetner, MS (SusSys)

ADVISOR: Dr. Shelie A Miller

LOCATION: Ann Arbor, Michigan, USA

Many consumers are transitioning away from single-use plastic products and turning to reusable alternatives. Oftentimes this change is being made with the assumption that these alternatives have fewer environmental impacts; however, reusable products are frequently made from more environmentally-intensive materials and have use-phase impacts. This study used LCA to look at the GWP, water consumption and primary nonrenewable energy use associated with reusable alternatives for single-use plastic kitchenware products, and determined environmental payback periods. Payback periods are calculated for each reusable alternative and defined as the number of times a consumer must re-use an alternative in order for the environmental impact per use to be equivalent to the environmental impact for the single-use product. The research explored the sensitivity of the results to different consumer washing and reuse behaviors, as well as local conditions such as overall transportation distances and the carbon intensity of different electricity grids. Product types studied included straws, sandwich storage, coffee cups, and forks. Environmental impacts associated with the reusable alternatives were highly dependent on the use phase due to dishwashing, making payback period sensitive to washing frequency and method, and for GWP, carbon intensity of the energy grid (used for water heating). For single-use products, the material/manufacturing phase was the largest contributor to overall impacts. Using Monte Carlo Analysis, it was found that nine of the twelve reusable alternatives were able to breakeven in all three environmental indicators.

Dynamic plastic flow and stock in the United States: Evaluating pathways towards zero plastic pollution by 2050

STUDENT: Mengqing Kan, MS (EPP)

ADVISOR: Dr. Ming Xu

LOCATION: USA

The United States (U.S.) is the second-largest consumer of plastics in the world, which directly leads to a large amount of plastic waste. Due to low recycling and incineration rates in the U.S. in 2018, 53% of plastic waste was discarded (landfilled or mismanaged). Scientific studies have proved that pollution from discarded plastics has a significant negative impact on the natural environment. This study aims to explore feasible pathways for the U.S. to achieve zero plastic pollution by 2050. We first developed a dynamic MFA model to assess the flow and stock of nine commonly used plastic polymers in seven commodity sectors with five end-of-life pathways in the U.S. for almost seven decades (1950 – 2018). The results show that national plastic pollution increased from 176 thousand metric tons in 1950 to 34,393 thousand metric tons in 2018. Plastic packaging contributed the most to plastic pollution because it has a shorter lifespan and a higher discard rate compared with plastics in other sectors. We then developed six scenarios to estimate plastic pollution reduction from 2019 – 2050 through seven initiatives including: 1) adapting a national plastic grocery bag ban; 2) reducing plastic consumption; 3) improving the lifespan of plastic products; 4) increasing waste recycling rate; 5) abandoning waste export; 6) avoiding mismanaged waste leakage; and 7) increasing waste-incineration rate. Even though each initiative can reduce plastic pollution to different extents, the U.S. cannot achieve the zero plastic pollution target by 2050 through implementing one initiative solely. Thus, a combined scenario that implements multiple initiatives is needed to help the U.S. to achieve the goal.

Viability of Leveraging Spent Coffee Grounds

STUDENT TEAM: Alicia Quilici, MS (EJ, EPP); Youssef Machkhas, MS (SusSys), MEng (Energy Systems Engineering); Jocelyn Marchyok, MS (SusSys), ME (Mechanical Engineering); Siwei Tang, MS (SusSys) Sondra Halperin, MS (SusSys)

ADVISOR: Dr. Shelie Miller

LOCATION: Ann Arbor, Michigan, USA

CLIENT: Kevin Jones, Starbucks

Starbucks is one of the largest coffee chains in the world, with over 28,000 stores in 75 countries, as millions seek their Frappuccinos and Peppermint Mochas. Since Starbucks is world renowned, it comes with a large social responsibility. They ensure that their coffee is grown ethically and sustainably, and aim to be leaders in minimizing their environmental footprint. Currently, Starbucks is curious if composting their spent coffee grounds (SCGs) is the best method to use, or whether there is an alternative that has a lower environmental impact and cost. In this project, we looked at the life cycle of four different alternatives to utilize the SCGs: PHA, anaerobic digestion, pyrolysis, and fertilizer. We analyzed these methods by utilizing Simapro 9.1 as well as reading literature reviews. We performed two distinctive analysis, comparing each alternative to the market solution they would be displacing (Corn, Natural Gas, Biochar, and Composting consecutively) and we compared each alternative to the current practice of composting. We used a yearly scale of 10,924.3 short tons of SCG, data provided by Starbucks. Our results indicated that Starbucks should continue composting their SCGs, and in a few years when (hopefully) the grid gets cleaner, they should consider turning SCG into PHA and/or using it for anaerobic digestion. Our team gained valuable insight from this project, and we were thankful for the opportunity to work with them.

A Tool for Evaluating Environmental Sustainability of Plastic Waste Reduction Innovations

STUDENT TEAM: Connie Chow, MBA, MS (BEC); Dengfeng Qin, MS (SusSys); Ruimin Yang, MS (SusSys)

ADVISORS: Dr. Gregory Keoleian; Dr. Michael Mazor; Dr. Martin Heller

LOCATION: Ann Arbor, Michigan, USA

CLIENT: Morgan Stanley

Plastics and their byproducts are littering our cities, oceans, and waterways, and contributing to health problems in humans and animals. Since plastics have become significant in our economic and social activities, it is urgent and essential to make progress in plastic waste reduction. However, a sole plastic waste reduction innovation does not guarantee or equate to sustainability performance. In this Master's Project, the team at the School fo Environment and Sustainability investigated the plastics industry, with the objective of developing a sustainability assessment tool for evaluating plastic reduction innovations to support investment decisions. The team reviewed sustainability assessment literature and studied significant opportunities and constraints among plastic waste reduction strategies. Through this work, the Plastic Waste Reduction Innovation Sustainability Evaluation Tool was created, setting educational guidelines around the criteria for both investors and other potential users. General guidance was presented for evaluating basic sustainable business models focusing on the company's mission & vision, circular economy attributes, and potential scale of the waste reduction innovation. More in-depth tools included third party certifications and life cycle assessments that require expertise to conduct. Innovations were classified into four categories: reuse & refill, alternative materials, innovative design and recycling; and specific guidance criteria were presented to highlight key drivers of sustainability performance in each category. Those innovations addressing wider sets of criteria are expected to be more preferrable. Feedback from the assessment will also be useful for companies themselves to focus efforts on those criteria they have not addressed.

Water

Implementing Natural Infrastructure in the Upper Mississippi River Basin: Lessons from Iowa

STUDENT TEAM: Joseph Dierdorf, MS (EPP); Madison Goff, MS (BEC, EPP); Dana Van Huis, MS (GDS)

ADVISOR: Dr. Sara Hughes

LOCATION: Des Moines and Cedar Rapids, Iowa, USA

CLIENT: Environmental Defense Fund

The Upper Mississippi River Basin (UMRB) suffers from poor water quality and the increasing frequency of flooding. One potential solution to these issues is the implementation of natural infrastructure (NI). The project focuses on Iowa with the potential for the recommendations and findings to be expanded to the entirety of the UMRB. The project has five objectives and corresponding chapters as follows: evaluate the potential for hydric soil to be a wetland proxy; evaluate the exposure of socially vulnerable communities to nitrogen pollution and flooding; understand the social and political conditions for successful NI implementation; identify policy opportunities for expanding NI; and, propose priorities for future NI research and advocacy. This project's methods include linear regressions, inferential statistics, interview methods, and utilizing ArcGIS Pro and NVivo. Chapter I demonstrated the potential of the hydric soil proxy which reduces the time and costs for identifying restorable wetlands nationally. Chapter II found that there are statistically significant associations between socially vulnerable communities, nitrite/nitrate, and flood risk. Chapter III identified key conditions for collaborative conservation through case studies of the Des Moines Water Works lawsuit and Middle Cedar Partnership Project. Chapter IV identified opportunities in five topics: administrative barriers, long-term planning and funding, coalition/trust building, environmental justice, and political agenda-setting. Finally, Chapter V connects the hydric soil proxy, social vulnerability atlas, and case study comparison findings to policy implications. Additionally, this section highlights what recommendations this team of researchers had for future research and advocacy.

Assessing Nutrient Management Strategies to Control Harmful Algal Blooms in Lake Erie

STUDENT TEAM: Emily Dusicska, MS (ESM); Sierra Rae Green, MS (ESM); Carol Waldmann Rosenbaum, MS (ESM, GDS); Kathy Sun, MS (ESM); Xinjie Wu, MS (CON ECO)

ADVISORS: Dr. Subba Rao Chaganti; Dr. Michael Fraker; Dr. Casey Godwin; Dr. Sara Hughes; Dr. Henry Vanderploeg

LOCATION: Ann Arbor, Michigan, USA

Harmful algal blooms (HAB) have impaired Lake Erie's western basin water quality since the 1960s. Drivers of HABs are still the subject of debate and are likely the result of interactions among several biotic and abiotic factors. The problem is twofold: (1) uncertainty in the specific causes of HABs leads to inapt management solutions; and (2) managing a cross-boundary watershed requires collaboration and agreement on apt solutions from multiple stakeholders as well as many U.S. states and Canadian provinces. In this study, we use Bayesian hierarchical modeling (BHM) to investigate the relationships between nitrogen (N) and phosphorus (P) and phytoplankton biomass, cyanobacterial biomass, and microcystin concentration. We used both a within-lake and an across-lake approach and examined whether the inferences from western Lake Erie differ from the ones using multiple lakes across the country. We found that while P is still the primary driver of HABs in Western Lake Erie (WLE), the great variability between stations and months suggests that even within-lake, there may not be a single relationship characterizing phosphorus effects on HABs. We also interviewed 29 stakeholders actively involved in western Lake Erie's watershed. We analyzed the stakeholders' values, attitudes, and policy preferences to understand their differences or similarities and their effects on management decisions. We found that although stakeholders agree on the urgency of the problem, the different opinions and preferences of each interviewee may complicate the decision-making process in a highly collaborative watershed.

Great Lakes Ice Cover: Enriching Database and Improving Forecast. Part A: Extending Data Record Back to the 1890s, with Identification of Key Teleconnection Patterns

STUDENT TEAM: Danielle Cohn, MS (GDS); Miye Nakashima, MS (GDS); Inigo Peng, MS (GDS)

ADVISOR: Dr. Ayumi Fujisaki-Manome

LOCATION: Ann Arbor, MI, USA (remote)

CLIENT: NOAA Great Lakes Environmental Research Laboratory (GLERL)

The Great Lakes are essential to millions in North America for water, income, and more. An integral part of the lakes' annual cycle is winter ice cover. An extended historical ice-cover record could be used to improve our understanding and forecasts of ice cover. A new teleconnection, ABNA, may have a correlation with Great Lakes ice cover and be used in ice forecasts. ArcGIS was used to georeference historical ice charts and approximate 1963-72 AMIC. These estimates and 1973-83 reports were used to model AMIC based on CFDD or NMDD. These models were then used to hindcast ice cover for 1898-1983. Similar models were developed for 2009-20 using CFDD. The ABNA was recreated for 1980-2015, then expanded to determine its influence on Great Lakes AMIC. GIS-calculated AMIC for 1963-72 was consistent with original reports for Lakes Michigan and Erie, but differed by ≥10% for Ontario and Huron. Historical ice cover is best modeled by individual lake; recent ice cover is similar, and shows stronger correlation with CFDD than NMDD. The ABNA index shows moderate correlation with either CFDD- or NMDD-based AMIC for each lake. Original AMIC estimates for 1963-72 were calculated and compared using GIS. NMDD was used for Superior, Michigan, and Ontario, and CFDD for Huron and Erie; thus continentality or depth may be influencing AMIC. Recent ice cover showed little to no correlation between maximum CFDD and AMIC dates; AMIC may be becoming more difficult to predict. The ABNA index may be used in future AMIC forecasts.

Great Lakes Ice Cover: Enriching Database and Improving Forecast Part B: Prediction using Machine Learning Models - LSTM and XGBoost

STUDENT TEAM: Lian Liu, MS (GDS), MS (Data Science); Santhi Davedu, MS (GDS)

ADVISOR: Dr. Ayumi Fujisaki-Manome

LOCATION: Ann Arbor, Michigan, USA

CLIENT: NOAA Great Lakes Environmental Research Laboratory

St. Marys River is a key waterway in the Great Lakes, and the massive Soo Locks and dredged channels constructed in it support navigation activities. This navigational lock system is closed annually from late January to late March due to the development of ice cover over the river. A notable year-to-year variability in ice condition exists in these transition periods, posing a challenge to safe and effective planning of shipping and icebreaking operations around the region. Most of the ice prediction for the Great Lakes done in the past are applied statistical and numerical modeling methods. St. Marys River area is not covered by these traditional models, including NOAA's Great Lakes Operational Forecast System, due to the focused geographical area and complex physics in the river system. Machine learning models have the potential to detect the internal mechanisms among data and can contribute to a higher prediction accuracy. Our study intends to explore these models. To support decision making by the Great Lakes shipping community, we will build the capability of the forecasting of ice cover on St.Marys river using Machine Learning models, namely LSTM and XGBoost, and compare the models' prediction skills. Two supervised Machine learning methods, namely Long Short-memory (LSTM) and Extreme Gradient Boost (XGBoost), were built and trained by using the four weather stations data around the St. Marys River from the Coastal Marine Automated Network and the satellite-based ice coverage data from the NOAA Coastwatch Great Lakes node. When the models' prediction was conducted for the next seven days, they accurately forecasted ice cover during the stable phase and for the whole year. For both the models, as per the evaluation metrics, the model skill tended to be worse in freezing and melting phases when compared with the mid-winter period because of highly dynamic conditions. The differences between the original and predicted ice-on/off date are within 3-5 days. LSTM has a higher prediction accuracy than XGBoost. Both the models have the potential to be used as a good reference for the shipping community to help plan operations.

Crosscutting Themes

A Framework for Implementing Resilience Hubs in Ypsilanti, Michigan

THEME: Climate + Energy, Cities + Mobility + Built Environment

STUDENT TEAM: Desmond Kirwan, MS (BEC); Grant Faber, MS (SusSys); Paige Porter, MS (BEC); Trever McCarty, MS (BEC)

ADVISOR: Dr. Raymond De Young

LOCATION: Ypsilanti, Michigan, USA

The imminent combination of increasing natural disasters due to climate change, degenerating national support systems, and declining natural resources suggests an ever-increasing need to focus on local resilience and adaptation rather than mitigation alone. Our team proposes resilience hubs—centers that provide physical, social, and emotional resources to neighborhoods before, during, and after natural hazard events—as a solution to these issues. With the nearby city of Ypsilanti, Michigan as our area of focus, we first began by investigating the history of the city and engaged with relevant stakeholders including the Ypsilanti Sustainability Commissions and the Urban Sustainability Directors Network. Our team conducted analyses using geographic information systems (GIS) to identify optimal locations for hub placement with an emphasis on environmental justice and equity. Additionally, we created and piloted survey and interview tools to be used by future research teams in order to implement resilience hubs. With financial challenges often posing as a barrier to climate resilience projects, we also identify a variety of potential funders and creative funding mechanisms to ensure the vitality of resilience hubs beyond municipal funding resources. Using the aforementioned methods, we conclude that the city can greatly benefit from the services a hub can provide and suggest pathways for implementing hubs in the coming years. We offer suggestions on community building, identifying key stakeholders, and establishing trust with local residents for further research as well as outline a five-year plan envisioning the city as a leading example in the future of climate resilience.

The impacts of record lake-level rise and interacting stressors on black tern (Chlidonias niger) nesting in Lake St. Clair, Michigan

THEME: Conservation + Restoration, Water

STUDENT: Jennifer Fuller, MS (ESM)

ADVISORS: Dr. Karen Alofs; Dr. Johannes Foufopoulos; Dr. Andrew Gronewold

LOCATION: St. Clair Flats, Michigan, USA

CLIENT: National Audubon Society

Global climate change is expected to interact with existing environmental stressors and increasingly impact wildlife populations. Few case studies of this phenomena exist however, especially in wetland ecosystems. The black tern (Chlidonias niger) is a migratory shorebird that nests on floating vegetation in large freshwater wetlands. Great Lakes breeding colonies have experienced heavy population losses and abandonment and have fallen by almost 90% since 1991. Like many marsh bird species, black terns face multiple stressors, yet the exact scope of these threats remains unclear. Record lake-level fluctuations generated by global climate change is likely both important and ill-understood. This study focuses on one of Michigan's largest black tern colonies, located in Lake St. Clair. To understand the potential drivers of these declines and inform species management, we analyzed long-term hatching success data regarding both proximate ecological, and large-scale hydrological and geospatial habitat features. Landcover and bathymetric data were collected using remote sensing classification and were evaluated relative to nest success via stepwise binomial general linear models. Results were then applied to land cover maps to estimate change in habitat characteristics tied to nest vulnerability. Between 2013 and 2020, the colony's population and nesting success collapsed in tandem with a record rise in lake-levels. Nests with significantly lower hatching success were surrounded by deeper water, more dense, monotypic vegetation, and were closer to the wave-exposed open area of the main lake. All these characteristics shifted unfavorably with rising lake levels, leading to progressively reduced nesting habitat availability, a 56% reduction in hatching success and a 77% estimated population decline. The ideal combination of interspersed native plant communities and floating nest material for successful breeding was unable to shift upland as the lake margins were either developed or invaded by Phragmites australis. Subjected to progressively deeper and unstable habitat, nests likely failed more frequently due to inclement weather and aquatic predators. Our results demonstrate that the interaction between climate change-driven lake-level rise, invasive species and coastal development are increasingly eliminating safe nesting habitat for black terns. The resilience of other coastal wetlands under these circumstances is worth investigating more broadly in the Great Lakes. We conclude that management must account for multiple stressors in mitigating habitat loss and protect as much wetland refugia as possible so black terns and other marsh birds can adjust to continued hydrologic extremes.

Bridging the Implementation Gap: Designing a Course of Action with Michigan Public Advisory Councils

THEME: Education + Information, Conservation + Restoration

STUDENT TEAM: Isabella Bledsoe, MS (EJ, GDS); James Polidori, MS (EPP); Emily Rau, MS (ESM); Paige Schurr, MS (BEC)

ADVISOR: Dr. Paul Seelbach

LOCATION: Michigan, USA

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

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) enlisted the help of three past masters' capstones through U-M SEAS to research how Michigan Public Advisory Councils (PAC) can maximize their effectiveness within the Michigan Area of Concern (AOC) program. These capstones produced 24 recommendations. As the fourth capstone project, we worked alongside PACs and EGLE to translate these recommendations into concrete implementation plans. Through individual interviews and community conversations with PAC members, we identified the desired objectives for 10 Michigan PACs and outlined how to implement these objectives. Using this information, we created an implementation plan for each PAC that documented organizational structures and action items to achieve within the next five years. We also provided EGLE with recommendations on how to further support the PACs' efforts to implement their desired objectives. We then conducted a formal qualitative analysis that analyzed our interviews with PAC members. The analysis showed that while PAC members varied in their interview responses, a majority of PACs expressed their interest in implementing recommendations related to community education, life after delisting, and PAC recruitment. We also found that PAC members felt they had made the most progress toward recommendations related to PAC structure, community education, and partner organizations. Finally, we developed four recommendations to strengthen PACs' capacity and durability: (1) including underrepresented communities in the AOC program; (2) building external funding sources; (3) guiding PACs through the delisting process; and (4) building collaborative state PAC meetings.

Digital Media, Data, and Dialogue in Dismantling the Illegal International Trade of Wildlife

THEME: Conservation + Restoration, Education + Information

STUDENT TEAM: Aditya Benyamin: MS (BEC, ESM), MPP (Public Policy);
Ryan Horwitz: MS (GDS), Certificate in Science, Technology and Public Policy

ADVISOR: Dr. Rebecca Hardin

LOCATION: Global

CLIENT: The Last Animals Foundation

The struggle to conserve endangered species is often framed as military or punitive legislative and policy action. We worked with The Last Animals Foundation (TLAF), formed from Kate Brook's documentary, to change that framing, using the film to advance environmental education and formalize data visualization tools. We structure our materials according to Paolo Freire's levels of relational knowledge production outlined in Pedagogy of the Oppressed. (1) For young learners, through literature review and consultation with multiple partners in the U.K. and Indonesia, we synthesized environmental education policies, the educational use of films, and conservation priorities in the Leuser ecosystem in Indonesia. That synthesis informed the development of a curriculum that builds secondary school students' understanding of wildlife conservation and related environmentally sustainable career options. (2) For the media and an engaged public, we developed a case study sharing tactics that fostered increased global impact for the film, using ESRI's StoryMaps. Users immerse themselves in the film's story, learn about outreach work, and see the result of that work in the forms of public engagement (through interactive maps) and policy outcomes (through explanations and videos). (3) For specialists and scientists, we partnered with a team of U.S. and foreign government agencies led by prominent conservation biologist Dr. Samuel Wasser to produce an ivory seizure network application to assist in prosecuting the heads of transnational crime organizations driving elephant poaching and the ivory trade. This work is in review at a prominent scientific journal and being presented at international conferences.

Variability of the value of Vehicle-to-grid across vehicle and time in future California grid

THEME: Climate + Energy, Cities + Mobility + Built Environment

STUDENT: Meiye Wang, MS (SusSys)

ADVISOR: Dr. Michael Craig

LOCATION: Ann Arbor, Michigan, USA

Electric vehicles (EVs) are gaining momentum across the global as a strategy to combat climate change, however, uncontrolled charging of EVs can create pressure on electricity grid. Along with smart charging (V1G), Vehicle-to-grid (V2G) technology presents an opportunity for a new way of vehicle grid integration that enables vehicles to send electricity back to the grid, creating the potential for vehicles to provide grid services, including electricity generation as well as regulation-up and regulation-down capacity. This study aims to quantify the economic value of V2G in the 2025 and 2030 California grid using a vehicle simulation model and a grid Unit Commitment Economic Dispatch model. Scenarios on different renewable penetration and future battery cost are included to account for uncertainty in future energy and battery development. Results show V2G-enabled EVs can generate an average of $25-60 more annual profit than V1G. Most profits come from the vehicle providing electricity and a small amount from regulation-down capacity. From 2020 to 2030, the economic value of V2G increases gradually; the result also shows tradeoffs exist between renewable deployment and V2G value. V2G can generate a moderate amount of economic benefit given access to electricity and the ancillary service wholesale market, which need further policy support and third-party business cases.

Governing ecosystem adaptation: an investigation of governance network level adaptive capacity

THEME: Conservation + Restoration, Education + Information

STUDENT: Matt Sehrsweeney, MS (BEC, ESM), MPP (Public Policy)

ADVISOR: Dr. Paige Fischer

LOCATION: Pacific Northwest USA: 1) Nisqually Watershed, Washington; 2) Rogue Basin, Oregon; 3) Siskiyou County, California

The impacts on ecosystems wrought by climate change have significant implications for the communities that steward ecosystems and depend on their services. Because ecosystems often span ownership boundaries, they are often managed by dispersed sets of public and private actors known as governance networks. Understanding the adaptive capacity of governance networks is a critical task if we are to understand the ways in which these ecosystem impacts might be mitigated; however, little research has examined adaptive capacity at the governance network level. Furthermore, most research on adaptive capacity seeks to evaluate it deductively across a framework of high-level indicators (e.g., social and financial capital), without attending to the underlying conditions that contribute to the variation in these measures. To address these gaps in my understanding of governance network level adaptive capacity, I conducted a case study analysis of three governance networks in the Pacific Northwestern U.S., investigating both the key features of adaptive capacity across the three regions, and the socio-political conditions underlying these features. Using a set of 50 interviews with actors engaged in ecosystem management across the three regions, I found evidence that three key features of adaptive capacity were particularly relevant: social capital, access to resources, and leadership. Furthermore, I found that these features, in turn, were shaped considerably by four key underlying conditions: political power, legal power, institutional support, and land protection. In investigating these underlying conditions that shape adaptive capacity, this study begins to answer the call of political ecologists to analyze the systemic causes of vulnerability and adaptive capacity.

"The Gasoline of the Future:" Electric Vehicles, Points of Continuity, and Making Green Capitalism

THEME: Sustainability + Development, Cities + Mobility + Built Environment

STUDENT: Roshan Krishnan, MS (EJ)

ADVISOR: Dr. Bilal Butt

LOCATION: Remote interviews across the USA

Electric vehicles (EVs) are key to U.S. plans to transition to a green economy that is powered by renewable energy rather than fossil fuels. There has been extensive research documenting the adverse socio-ecological impacts of resource extraction for EVs, including water shortages driven by lithium mining on Indigenous lands in South America and child labor in cobalt mining in the Democratic Republic of the Congo. However, little research has attended to the ways that automakers and utility companies shape the adoption of EVs through the use of corporate narratives and strategies. In this thesis, I introduce the concept of points of continuity, whereby specific aspects of the gasoline vehicle user experience are mimicked by the EV industry to increase adoption of EVs. This desire to adopt behavioral similarities between gasoline and electric vehicles allows for existing patterns of automobile production and consumption to be maintained. However, in order to establish points of continuity, EV industry actors must navigate material constraints imposed by the physical properties of electric power. Through this case study, I demonstrate that the production of points of continuity is a method through which the environmental violence of green capitalism is maintained.

Tradeoffs and synergies among ecosystem services, biodiversity conservation, and food security in coffee agroforestry

THEME: Conservation + Restoration, Food

STUDENT: Bella Mayorga, MS (GDS, ESM)

ADVISOR: Dr. Ivette Perfecto

LOCATION: Puerto Rico

Coffee, a major export of tropical countries, offers a unique opportunity to examine how different management practices can lead to a variety of outcomes in food security, ecosystem services, and biodiversity conservation. Our study examined this intersection to identify tradeoffs and synergies using compiled data from Puerto Rico. At the island level, we analyzed data on coffee yield and area sown under shade or sun management. At the farm level, we analyzed management variables, non-provisioning ecosystem service variables, and biodiversity variables. At the island level, we found that area sown was the most significant predictor of yield, suggesting no obvious tradeoff between yield and shade in coffee farms. At the farm level, canopy cover was negatively correlated with ground cover and positively correlated with crop richness, suggesting a synergy between agroforestry and food security. We detected mostly synergies resulting from agroforestry management and no tradeoffs among ecosystem services and biodiversity. Shade canopy cover significantly increased total carbon storage, coffee plant biomass, hurricane resistance and bird species richness. Shade canopy height had a similar positive effect on total farm carbon storage while crop richness had a positive effect on farm resilience following Hurricane Maria. Ground cover was positively associated with soil carbon storage and pest-controlling lizard abundance. Additional understanding on the associated tradeoffs and synergies in this system generated by our study will help inform further development of agroforestry management strategies that support both ecosystem functioning and local livelihoods.

Assessing Equity and Environmental Justice in the Great Lakes Restoration Initiative

THEME: Conservation + Restoration, Water

STUDENT TEAM: Helena Garcia, MS (ESM); Logan Murphy, MS (EJ); Tiffany Wu, MS (ESM, GDS); Briana Wendland, MS (EJ, EPP)

ADVISOR: Dr. Paul Seelbach

LOCATION: Great Lakes Region

CLIENT: Healing Our Waters—Great Lakes (HOW) Coalition

In the last decade, the Great Lakes Restoration Initiative (GLRI) has demonstrated significant economic and ecological success, with much progress being made towards delisting Areas of Concern (AOCs). Despite this economic and environmental success, there is little documented evidence to evaluate if the GLRI has served to minimize environmental risk and remediate legacies of environmental inequities. Groups like the Healing Our Waters—Great Lakes (HOW) Coalition, who work to educate members of Congress and the public about the far-reaching benefits of GLRI funding, have begun investigating how the GLRI both considers and impacts social equity in its restoration work. Our study begins this inquiry into emphasizing social equity across the GLRI and aims to illustrate how equity needs to play a critical role in the continued revitalization of the Great Lakes region. This research used a case-based approach and studied four different AOCs in Michigan—White Lake, Muskegon Lake, the Rouge and Detroit Rivers, and the River Raisin—to form recommendations for HOW's GLRI advocacy work. Semi-structured interview methods were used to build a clearer understanding of how communities perceive equity outcomes and considerations. In addition, ArcGIS was used to map the distribution of GLRI restoration projects with social demographics for each study AOC community to illustrate social equity patterns and disparities. Our final recommendations delineate actions the HOW Coalition can pursue with community organizations across the Great Lakes region, as well as equity considerations the HOW Coalition should prioritize through their GLRI advocacy work with Congress.

Greek Paths of Culture: Reimagining Ancient Trails in the Rhodope Mountains

THEME: Conservation + Restoration, Education + Information

STUDENT TEAM: Josie Whelan, MS (BEC); Kevin Bechard, MLA, M.ARCH

ADVISOR: Dr. Johannes Foufopolous

LOCATION: Xanthi, Greece

CLIENT: Greek Society for the Environment and Cultural Heritage

Within the Rhodope Mountains of Greece there lies an incredible amount of biodiversity and historically significant trails. However, due to a lack of expertise and funds, this area does not have user-friendly materials detailing information of flora and fauna within the area. The Greek Society for the Environment and Cultural Heritage created the Greek Paths of Culture project to preserve the history of the ancient walking trails within Greece. Many are located in areas not frequented by tourists, but locals are interested in both preserving the area and scaling up options for sustainable tourism. Our team will be utilizing 3D images to create renderings of historical sites within the area to be used on educational brochures, and ready-to-use social media templates and posts. Educational materials will accompany these and will serve to inform both locals and tourists about the history of the region. These deliverables will add to the already existing Greek Paths of Culture project and highlight the importance of preserving cultural and environmental history in rural Greece, while increasing the number of people who are familiar with its unique offerings.

Advancing Sustainable Growth in the Grand Traverse Region through the Power of People and Metrics

THEME: Education + Information, Water

STUDENT TEAM: William Aycock, MS (GDS); Victoria Graves, MS (SusSys); Megan Houle, MS (ESM); Christine Purdy, MS (SusSys)

ADVISOR: Dr. Paul Seelbach

LOCATION: Grand Traverse Region, Michigan, USA

CLIENT: Grand Traverse Regional Community Foundation

The Grand Traverse Regional Community Foundation serves five counties across Northwest Lower Michigan and is recognized for their role in gathering regional actors. In 2019, they mobilized interdisciplinary leaders to form a Community Development Coalition whose aim is to guide collaborative and intentional growth throughout the region. However, the Coalition faces lingering hesitancy resulting from the inaction of prior collaborative efforts. Consequently, the Coalition's success hinges on their ability to shift from planning to action in a coordinated and impactful way. To support these efforts, we researched strategies for initiating and sustaining long-term progress toward Coalition goals. We interviewed leaders from six Great Lakes coastal communities and members from the local Grand Traverse region, then evaluated our findings using a qualitative data analysis software. To synthesize our research, we created a series of case studies that outline common themes for success in collaborative efforts across other Great Lakes coastal communities. We then organized themes from the Grand Traverse community into strengths, weaknesses, opportunities and threats surrounding Coalition efforts. Our findings informed the following recommendations for Coalition action and implementation: (1) establish an active and direct approach to diversity, equity and inclusion; (2) intensify efforts to unify action; (3) build and optimize coalition partnerships and collaborative efforts; (4) enhance communication and engagement with the public; and (5) be creative with data tracking and progress sharing. While these recommendations are designed for the Coalition, their implications can be leveraged in other collaborative efforts across the Great Lakes region.

Mnomen: Building Relationships and Assessing the Feasibility of Anishinaabek - Centered Wild Rice Restoration on University of Michigan Properties

THEME: Conservation + Restoration, Food

STUDENT: Samantha Stokes, MS (EJ)

ADVISOR: Dr. David Michener

LOCATION: Southeast Michigan

The lands currently occupied by U-M are within the traditional homelands of the Anishinaabek. The cession of nearly 4,000 acres of these lands via the 1817 signing of the Fort Meigs Treaty provided for the creation of our university. Land cessions such as these, violent removals, murder, enslavement and forced assimilation were methods the settler colonialist government used to gain control of the land now called the United States. The trauma of this process and the disruption of lifeways caused by such policies is felt today by the over 573 tribal communities still living within a society that limits their interaction with ancestral lands and foodways. The question we must now deal with as academics working for a colonial institution is how we reconcile these historic realities and with our work, repair relationships and further justice and equity for the native people of this land. The Mnomen Initiative seeks to do this by fostering partnerships between Anishinaabek community members and U-M that build respectful, mutually beneficial relationships around the central goal of restoring "the good berry" to the landscape. The first stage of The Mnomen Initiative seeks to begin making this vision a reality by assessing the social and ecological feasibility of Anishinaabek-centered Mnomen restoration on U-M properties.

Assessing Barriers to Climate Smart Subsistence Agriculture in Northeastern Namibia Under Potential Climate Scenarios

THEME: Climate + Energy, Food, Sustainability + Development

STUDENT TEAM: Marissa Lazaroff, MS (EPP); Kiana Lindsay, MS (EJ); Lynn Socha, MS (EPP, SusDev)

ADVISOR: Dr. Avik Basu

LOCATION: Windhoek, Namibia

CLIENT: United Nations Framework Convention on Climate Change (UNFCCC)

Global climate change threatens the livelihoods of subsistence farmers in northeastern Namibia but there is uncertainty about how these impacts will be experienced. Therefore, this study examined impacts climate change may have on Namibian subsistence agriculture and the barriers farmers may face in adapting their agricultural practices. Based on a review of regional climate features, four future climate scenarios were developed for Namibia (Extreme Heat, Drought, Shortened Wet Season, and Extreme Rainfall and Flooding). To better understand existing Namibian agricultural practices as well as potential financial and sociocultural barriers to climate adaptation, a literature review, expert stakeholder interviews, and a survey of 205 Namibian farmers were carried out. The study indicated that there are substantial barriers preventing subsistence farmers from implementing climate smart agricultural technologies including: financial challenges, limited resource access, lack of information, social inequity, and crop-based obstacles. Recommendations were formulated for key stakeholders including the United Nations Framework Convention on Climate Change (UNFCCC), governments, NGOs, and farmers to address these barriers and strengthen capacity building in subsistence farming communities. Additionally, a Climate Scenario Planning Toolkit integrated findings from this project into a participatory workshop in which farmers can learn about and plan for adapting to possible climate scenarios. Finally, these recommendations and resources will assist the UNFCCC to support future adaptation processes in Namibia and potentially across southern Africa.

The Impact of Renewable Energy versus Fossil Fuel Energy on Human Development

THEME: Climate + Energy, Sustainability + Development

STUDENT: Elena Essa, MS (SusSys), MEng (Energy Systems Engineering)

ADVISORS: Dr. Jose Alfaro; Dr. Michael Moore

LOCATION: Remote

As the effects of the climate crisis grow more severe annually, countries around the world have increased their commitments to increasing renewable energy consumption to mitigate greenhouse gas emissions. While renewable energy consumption greatly reduces emissions, it is wondered if renewable energy or fossil fuel energy consumption contribute differently to country development. This study aims to understand differences in relationships between fossil fuel energy consumption and development versus renewable energy consumption and development. The Human Development Index (HDI) framework is used as a proxy to represent country development to incorporate a more holistic approach to quantifying development instead of merely using gross domestic product (GDP). Using a sample of low-to-middle income (LMI) countries, methods include statistical regression analysis to understand these relationships. Results show that there is a negative, linear correlation between fossil fuel energy consumption and HDI. There is not enough evidence to suggest a regression relationship, linear or otherwise, between renewable energy consumption and HDI. The results add to the growing body of research that shows that the benefits from fossil fuels do not dominate over renewable energy. Countries will continue to increase consumption of renewable energy for global decarbonization and to increase access to energy.

Assessing and Communicating Climate and Water Ecosystem Services of the City of Ann Arbor Greenbelt Program

THEME: Conservation + Restoration, Water

STUDENT TEAM: Jackie Edinger, MS (CON ECO); Jessica Einck, MS (CON ECO); Sebastian Kasparian, MS (GDS); Lavran Pagano, MS (CON ECO, EI)

ADVISORS: Dr. Sheila Schueller; Shannon Brines

LOCATION: Ann Arbor, Michigan, USA

CLIENTS: (1) City of Ann Arbor Greenbelt Advisory Commission and Office of Sustainability and Innovations; (2) The Conservation Fund

It is difficult to quantify and report on the ecosystem services that justify further acquisitions and land conservation efforts and to do so without the need for future field data collection. Our objective was to provide the City of Ann Arbor Greenbelt Program with the ability to assess and report on the ecosystem services of individual properties over the total acreage already protected, as well as each new or potential property acquisition, especially in terms of climate regulation services through carbon storage, and water quality services through reduced pollutant loads. To measure carbon storage, we developed separate geoprocessing tools for the aboveground (trees and shrubs) and belowground (soil) components to estimate the carbon storage of Greenbelt properties using a combination of field-collected tree data and LiDAR remote sensing data. To address water ecosystem services, we determined which aspects of water quality are quantifiable and recommended an existing web-based tool for the Greenbelt to use. We found that the 71 properties in the Ann Arbor Greenbelt collectively store 50,258,767 kg of carbon belowground as soil organic carbon and 32,969,612 kg of carbon aboveground as biomass in tree trunks and branches. We demonstrated the feasibility of measuring ecosystem services using existing GIS and remote sensing data, providing the Greenbelt Program with a way to continue to assess specific ecosystem services without further field data collection. Ultimately, this project meets the Greenbelt Program's need to report the value of land protection beyond acreage.

Early signs and patterns of a secondary outbreak of American leaf spot disease in an organic coffee farm in southern Mexico

THEME: Conservation + Restoration, Food

STUDENT: Chenyang Su, MS (ESM)

ADVISORS: Dr. Ivette Perfecto; Dr. John Vandermeer

LOCATION: Data from study site at Finca Irlanda, Chiapas, Mexico

American leaf spot disease caused by Mycena citricolor and coffee leaf rust by Hemileia vastatrix are important coffee fungal diseases that can cause severe yield losses. While coffee leaf rust received much attention from the recent regional outbreak in Latin America, here we report on an associated pattern of American leaf spot with the presence of coffee leaf rust as well as its patterns associated with various shade trees in a coffee farm in southern Mexico. Based on seven months of sampling for disease incidence and severity of both American leaf spot and coffee leaf rust, we show that the incidences of the two diseases are not independent. Chi-square analyses of contingency tables of coffee leaf rust and American leaf spot presences show significantly fewer coffee plants infected with both diseases and more plants infected with only one of the diseases than expected at random. The resulting patterns of infection suggest that there may be trade-offs in controlling these pathogens, where the resistant varieties to the coffee leaf rust that were planted in response to the recent outbreak may be more susceptible to American leaf spot. T-test and chi-square analyses on American leaf spot and coffee shade trees show significant differences in disease incidence and severity by tree types, with higher prevalence under nitrogen fixing trees. These results suggest that management strategies for the control of coffee fungal disease should not rely on planting homogenous resistant varieties and must take into consideration the community of pathogens and plants.

Enhancing the Legacy of California's Marine Protected Areas through Bottom-Up Collaboration

THEME: Conservation + Restoration, Education + Information

STUDENT TEAM: Gwyndolyn Sofka, MS (EPP); Kimberly Guo, MS (BEC); Julia Hassen, MS (BEC), MSW (Social Work); Celina Horbat, MS (EJ); Kathryn Maloney, MS (EPP); Dani Triebwasser, MS (EJ, ESM)

ADVISOR: Dr. Steven Yaffee

LOCATION: California, USA

CLIENT: California Marine Protected Area Collaborative Network & Resources Legacy Fund

California enacted the Marine Life Protection Act in 1999 to create a network of Marine Protected Areas (MPAs) along the California coast. Through an eight-year process that engaged stakeholders, scientists and policymakers, 124 MPAs were designated. A network of collaboratives was formed to ensure that MPA management continued the bottom-up engagement of a diverse set of stakeholders in implementation. These collaboratives, and the Collaborative Network (CN) that supports them, have been an integral part of MPA management ever since their formation in 2012. The CN is an ongoing experiment in collaborative governance and has been recognized as a key element in resource management. Our project analyzes the fourteen collaboratives, the CN, the Tribes, the State, and the relationships between them to delineate the benefits and challenges of this arrangement, and identify the best practices of collaborative governance. Extensive qualitative interviews with key stakeholders informed case studies of each collaborative. We used these case studies to distill themes in benefits, facilitating factors, and challenges of the collaboratives. We identified multiple facilitating factors that have enabled the benefits of the collaboratives. We also found several challenges that frustrate their progress. We offer a set of 20 recommendations to help collaboratives and the CN improve implementation of their collaborative governance model. This report can be used to help improve the effectiveness of the collaboratives and the CN, while also informing organizations that wish to implement a similar approach elsewhere.

Life Cycle Greenhouse Gas Emissions for Last-mile Parcel Delivery by Automated Vehicles and Robots

THEME: Climate + Energy, Cities + Mobility + Built Environment

STUDENT: Luyao Li, MS (SusSys)

ADVISOR: Dr. Gregory A. Keoleian

LOCATION: Ann Arbor, Michigan, USA

Increased E-commerce and demand for contactless delivery during the COVID-19 pandemic have fueled interest in robotic package delivery. We evaluate life cycle greenhouse gas (GHG) emissions for automated ground delivery systems consisting of a vehicle (last-mile) and a robot (final-50-feet) in a suburban setting. Small and large cargo vans (125 and 350 cubic feet; V125 and V350) with internal combustion engine (ICEV) and battery electric (BEV) powertrains were assessed for three delivery scenarios: (i) conventional, human-driven vehicle with human delivery; (ii) partially automated, human-driven vehicle with robot delivery; and (iii) fully automated: connected automated vehicle (CAV) with robot delivery. The robot's contribution to life cycle GHG emissions is small (2-6%). CAV auxiliary loads offset operational benefits from automated driving. Compared to the conventional scenario, full automation results in 7% lower GHG emissions for the V350-ICEV but 5% higher for the V125-BEV. Conventional delivery with a V125-BEV provides the lowest GHG emissions, 160 g CO2e/package, while partially automated delivery with a V350-ICEV generates the most at 450 g CO2e/package. Sensitivity analysis shows delivery density and fuel economy are key parameters determining GHG emissions for all scenarios, while CAV power requirements and efficiency benefits have a smaller impact on automated scenario emissions.

V2G-capable shared autonomous electric vehicles fleet: Economic viability and environmental co-benefits

THEME: Climate + Energy, Cities + Mobility, Climate + Energy

STUDENT: Zitong Liao, MS (SusSys)

ADVISOR: Dr. Ming Xu

LOCATION: Ann Arbor, Michigan, USA

The pursuit of energy efficiency, increasing consumption of non-renewable energy related to fossil fuels, and concerns about the impact of climate change are some of the primary motivators for the introduction of electric vehicles. Battery electric vehicles (BEV) may be used in potential commercial autonomous taxi fleets; in addition to saving energy and maintenance costs, the introduction of these electric vehicles will also provide fleet operators with possible vehicle-to-grid (V2G) service opportunities. This study investigates the life-cycle total cost, greenhouse gas emissions, and energy consumption of automated shared vehicle fleets consisting of internal combustion engine vehicles and electric vehicles with 100-mile short-range and 250-mile long-range capable of achieving the same level of service. The results show that the 250-mile long-range electric vehicle fleet with V2G service has significant advantages in cost, emissions, and energy consumption.

Monitoring and leveraging hydrologic restoration in the Shiawassee Flats estuary

THEME: Conservation + Restoration, Water

STUDENT TEAM: Julie Dellick, MS (ESM,GDS); Jon Gorter, MS (EJ,BEC); Anna Greenberg, MS (ESM,EPP); Xinmiao Liu, MS (ESM), MLA; Maria Salem, MS (ESM)

ADVISORS: Dr. Paul Seelbach; Dr. Karen Alofs

LOCATION: Shiawassee National Wildlife Refuge, Saginaw, Michigan, USA

CLIENT: U.S. Fish and Wildlife Service

The Shiawassee National Wildlife Refuge, located in Saginaw, Michigan, is a floodplain where four tributaries merge to form a coastal wetland. The Shiawassee floodplain system has long been disconnected from the river channels with miles of dikes. This landscape alteration shifted the land cover from lowland forests and wetlands to agricultural and urban development—which has disrupted the Refuge's ecosystem services and degraded the habitat quality for both vegetation and wildlife. In line with the goals of the Refuge staff to protect this crucial wetland habitat, our project focuses on the second year of ecological monitoring to understand the effects of restoration work on this ecosystem. The ecological monitoring consists of both traditional fieldwork and the exploration of utilizing an ARIS sonar camera to further inform the restoration work. In this second year of monitoring, we recorded increases in habitat quality in some units, which provides evidence of the progress of the Refuge's habitat restoration efforts. In addition to ecological monitoring, we created educational material to inform the public on the importance of this ecosystem.

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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. With the highest research volume of all public universities in the country, U-M is advancing new solutions and knowledge in areas ranging from the COVID-19 pandemic to driverless vehicle technology, social justice and carbon neutrality. Its 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. The university also boasts a world-renowned intercollegiate athletics program and 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. U-M's alumni body is one of the largest in the world and includes a U.S. president, scientists, actors, astronauts and inventors.

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.

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Editing: Nathan Geisler, Denise Spranger, Jennifer Taylor

Statement on the Anishinaabe Land Transfer
The University of Michigan is located on the territory of the Anishinaabe people. In 1817, the Ojibwe, Odawa, and Bodewadami Nations made the largest single land transfer to the University of Michigan, ceded in the Treaty of Fort Meigs, so that their children could be educated. We acknowledge the history of native displacement that allowed the University of Michigan to be founded. Today we reaffirm contemporary and ancestral Anishinaabek ties to the land and their profound contributions to this institution.