Community Farm Technological Capacity Building in the Upper Peninsula of Michigan

Final Report

Comprehensive Economic Recovery Initiative – Technical Assistance Projects

Jean Hardy Bohaczek

Assistant Professor, Department of Media & Information

Director, Rural Computing Research Consortium

jhardy@msu.edu

Submitted with the support of the staff and volunteers at Partridge Creek Farm.

Executive Summary

The COVID-19 pandemic exposed widespread issues with affordable and healthy food access, a foundational issue for economic and community development in rural regions. Rural regions of Michigan, particularly the Upper Peninsula (UP), have long faced issues with food access due to the region's cool climate, short growing seasons, and poor soil quality. Community-oriented agricultural organizations like Partridge Creek Farm (PCF), the community partner highlighted in this report, are working to expand food access and address the fragile food distribution networks of the region. To assist with their work expanding food access and education in Ishpeming, we partnered with PCF to develop and install an advanced soil monitoring system, providing technical assistance for their staff through a combination of educational and technological capacity building. Building on PCF's existing technological capacity, we sought to expand their ability to provide real-time data about the growing conditions of their crops. This work will contribute to future increased yields of fresh, healthy produce for the local community, enabling PCF to make data-driven decisions about what crops are most appropriate for their growing conditions. Contained herein, we also provide guidance for others seeking to implement similar practices on selecting appropriate technology, incorporating new technology into existing practices, harnessing local technology champions, and avoiding "data-driven mission creep."

Acknowledgements

The author would like to thank May Tsupros, Dave Lawler, Liz Armstrong, Malena Michaelson, Dan Perkins, Jesse Semph, and Dale Honeycutt for their input and participation, as well as Nat Hooper, Emma Gilbert, Matt Hall, and John Melcher for feedback on the project at various stages. Some of the cloud services used in the sensor project were donated by Datacake. This project is supported in part pursuant to the receipt of financial assistance from the United States Department of Commerce – Economic Development Administration. The statements, findings, conclusions, and recommendations are solely those of the authors and do not necessarily reflect the view of any federal agency or Michigan State University.

Introduction

The COVID-19 pandemic exposed massive issues with supply chains that continue today. This is especially true for access to affordable and healthy food, a foundational issue for economic and community development in rural regions. Rural communities in Michigan's Upper Peninsula (hereafter, the UP) are a particularly salient case for expanding access to local food, not only for the duration of the pandemic, but for the foreseeable future in order to promote increased economic and community development. The UP has long faced issues with food access due to the region's cool climate, which results in shorter growing seasons, and its poor soil quality, which requires increased soil remediation and monitoring, among other things. While the UP can (and does) import the vast majority of its fresh food from outside the region, its distance from agricultural markets and its smaller market capture leads to higher cost and lower quality fresh food, especially produce. These issues with food access have increased during the pandemic, and been exacerbated in times of job loss and economic instability, which have further disrupted already fragile food distribution networks in the UP's communities. Community farms in the UP and throughout Michigan are working to address affordable access to local, quality produce during the pandemic. One of these community farms in the UP is the farm at the center of this project, Partridge Creek Farm (PCF), located in Ishpeming, Michigan.

Due to the climate of the Ishpeming area, with its long winters and an average of over 100" of snow a year, it's imperative that community farms like PCF have access to the tools and data that allow them to maximize their short growing season. Of growing importance is access to digital tools to monitor soil quality and agricultural inputs and outputs over time, and the data infrastructure and knowledge to make use of that data. Current market innovations in digital agriculture are often expensive and inaccessible to small scale producers. This results in community farms needing to bootstrap their own solutions through a combination of off the shelf hardware (e.g., advanced soil/pH sensors), software (e.g., GIS), and databases. Due to the community-oriented nature of PCF's work, it's also necessary for these systems to reflect the capacity, capability, and processes of collaboration that are the center of the sustainable mission of the organization.

The project described in this report brought together PCF staff with partners at Michigan State University to develop an advanced soil monitoring system, providing technical assistance for their staff through a combination of educational and technological capacity building. This project sought to expand PCF's ability to provide real-time data about the growing conditions of their crops, resulting in future increased yields of fresh, healthy produce to their local community, enabling them to make data-driven decisions about what crops are most appropriate for their growing conditions. The remainder of this report is as follows: first we introduce Partridge Creek Farm and their work in the City of Ishpeming. Next, we describe the project in more detail, including the project timeline and data collection. Finally, we describe in detail the three phases of the project and make recommendations for what others interested in data-driven community agriculture need to consider in taking on a project such as this.

Partridge Creek Farm – Ishpeming, Michigan

Partridge Creek Farm was founded by Dan Perkins in Ishpeming, Michigan in 2013. It is a 501(c)3 non-profit with the mission to build a healthy, prosperous, and empowered local community through food and wellness education. Ishpeming is located in the center of Michigan's Upper Peninsula and was founded in 1873 due to local iron ore deposits. The City became one of the centers of iron ore mining in the United States in the late 19th and early 20th century. While the success of the mining industry allowed Ishpeming to develop and thrive, its population peaked in the early 20th century at approximately 13,000 residents and as of 2020 is home to 6,140 residents. Today Ishpeming is home to the US Ski & Snowboard Hall of Fame and Museum, and much of its public life and reinvigorated downtown core revolves around outdoor activities such as mountain biking. According to data provided to PCF by Feeding America, as of 2020, 18.1 % of the Ishpeming population was considered food insecure. According to the Michigan Department of Education, as of the 2021-2022 school year, 65% of children attending Ishpeming's elementary school qualified for free/reduced lunch. Further, as of 2019, 43% of Ishpeming residents were considered "living in poverty" or "asset limited, income constrained, employed" (also known as ALICE).[1] PCF works in Ishpeming to reduce food insecurity, supporting food-based economic development, and providing education to the next generation on sustainable food systems through hands-on farming. This includes a 28 week-long experiential, hands-on Farm-to-School educational program for all 5th and 6th graders in Ishpeming during the school year. During the program students learn the importance of fresh food from seed to table including 8 weeks of healthy cooking, in partnership with MARESA and Marquette Food CO-OP, that culminates with student created recipes being implemented school wide into the cafeteria.

[1] https://www.unitedforalice.org/county-profiles-mobile/michigan

Much of PCF's activities and programming occur during the summer months, including a Farm-to-School Summer Camp and 16 "Community Days" held weekly that include a healthy cooking/activity demonstration and that provide volunteer opportunities for community members to work in the gardens. As of 2022, PCF maintains five agricultural sites in Ishpeming, including:

- The Incubator Garden, located at Grace Community Church and Cognition Brewery
- Inspiration Orchard, heralded by community members in the "Inspiration Zone"
- The "Carpet Garden", located next to Carpet One Specialists
- The Elks Community Garden, located next to the Ishpeming Elks Club
- The School Garden, located across the street from Ishpeming Middle/High School

In the 2021 year, these sites provided over 4,000 pounds of fresh produce for the community. In addition to these agricultural sites, PCF also runs a compost program where they divert food waste from partners throughout their county, offering vermicompost and topsoil for the public to buy.

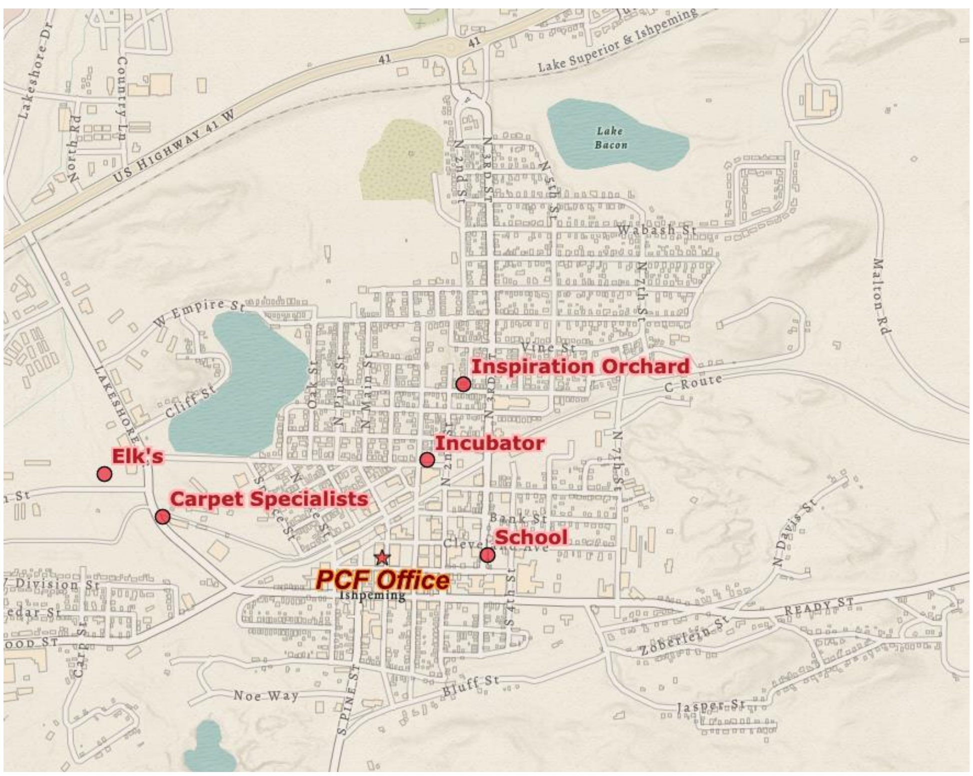

Figure 1: A map of PCF's sites in Ishpeming.

Recently, PCF was provided a 3.75-acre brownfield site next to Ishpeming Middle/High School and the Jasperlite Senior Housing development. This site will be home to the new intergenerational Community Care Farm that will serve as the foundation of an elevated and expanded Farm-to-School and Ag CarTech program, in partnership with the Ishpeming School District. This will also expand PCF's ability to provide year-round access to fresh, affordable, and cultural relevant food. As this growth happens, technology efforts will be utilized to maximize yields and potential in order to grow more food for more people. As we step into a future where environmental and food distribution impacts are unknown, Partridge Creek Farm and Ishpeming are positioning themselves by building community resilience.

Existing technology and data practices

Partridge Creek Farm is fortunate to have local technology champions that recognize the value of digital technology for the day-to-day work of the organization, and who have sought to develop capacity for the adoption of new technology. In previous years, local volunteer and GIS expert, Dale Honeycutt, worked with interns at PCF to develop a database used to crop varieties, planting times and locations, and harvest amounts and times. These databases are used to populate a public facing GIS portal, called the SeedPacket App, that allows for not only the visualization of PCF's garden sites on a map, but allows for a public-facing information source providing background about the garden site, the location and produce planted in each bed, and other data points about the produce (e.g., planting date, grow days, and when to harvest).

Figure 2: Screen capture of the School Garden on the Seed Packet App.

The Project

The goal of this project is reflected in its name: Community Farm Technological Capacity Building in the Upper Peninsula of Michigan. Our goal, in other words, was to further the technological capacity of Partridge Creek Farm, in turn providing insight into how other community farms might also do so. Based on the existing technological capacity of PCF, there was no reason for our project to reinvent the wheel. We wanted to complement existing technological practices, while providing opportunities for PCF to create and incorporate new forms of data externally for their public facing digital platform (the Seed Packet App) and internally for their own tracking purposes. Of growing importance for agriculture, especially in regions like Ishpeming with short growing seasons, is access to digital tools to monitor soil quality and agricultural inputs and outputs over time, as well as the data infrastructure and knowledge to make use of that data.

A long-term goal for this project is not only provide real-time data about the growing conditions of PCF's crops, but to increase yields of fresh, healthy produce for their local community, enabling PCF to make data-driven decisions about what crops are most appropriate for their growing conditions. This optimization process will also hopefully enhance their ability to provide educational opportunities in Ishpeming and surrounding communities. By increasing education and exposure to their work, PCF increases a demand for healthy local food, therefore creating opportunities not only for expanding their work, but furthering job creation in the local and UP-wide food system.

The project began in January of 2022 and continued through June of 2022. It went through three phases: Phase One – identifying data needs and technical requirements; Phase Two – site evaluation, sensor testing, and developing workflows; and Phase Three - evaluating our results and determining next steps. While this particular iteration of the project is over, work will continue to move forward to expand the use of the sensors, buy new ones, and incorporate data into PCF's work. The people involved in this process included:

- Liz Armstrong, GIS intern at PCF
- Jean Hardy, Primary Investigator (PI) of the project and Assistant Professor at MSU.

- Dale Honeycutt, volunteer GIS expert at PCF
- Dave Lawler, volunteer data specialist at PCF
- Malena Michaelson, GIS intern at PCF
- Dan Perkins, Founder of PCF
- Jesse Semph, Community Gardens Manager at PCF
- May Tsupros, Director of Programs and Partnerships at PCF

Data collection

To best understand the existing practices of PCF, how the organization adopted the new technology, and to recommend best practices for others, PI Jean Hardy collected qualitative data with PCF for the six-month duration of the project in 2022. This included: conducting preliminary meetings with PCF staff in January and February; an all-hands meeting on March 25 with PCF staff and volunteers to discuss adoption strategy; three days of ethnographic fieldwork in Ishpeming in April, including interviews with May, Dave, Dan, and Jesse, along with a walking tour of PCF's garden sites; attending two PCF task force meetings; and attending meetings with the technology working group (i.e., Liz, Dave, and Malena) in June of 2022 as details about the soil sensors were finalized and the sensors were deployed in the field.

Phase One: Data Needs and Technical Requirements

From January through April 2022, we worked to understand the specific data needs of PCF, the technological requirements necessary for a soil sensor system, the corresponding capacity of the organization to actually operate the system, and identified and purchased the appropriate technology that would serve those needs and requirements while leaving them open to potential changes in the future. The PCF team held the perspective that this was primarily a "pilot" deployment, and that our job was to best understand how to do it and build the appropriate base to expand the work in following years. This is reflected in a major emphasis on existing capacity and foundational data needs.

Data needs

The most important data points for PCF to track were soil temperature, soil moisture, sunlight, and soil nutrients and pH. The table below shows what each could be used for.

Sensor type	Sensor use
Soil temperature	Used to detect the subsurface temperature of the soil. Would allow for more precise and real-time data about soil temperature that would help PCF determine: planting dates based on best temperature for germination rates, understanding cover crop and mulching benefits, yield forecosting, and troubleshooting plant pest and disease issues.
Soil moisture	Used to detect the moisture levels of the soil. This data is used to determine watering needs and alongside sunlight data can be used to estimate rates of evaporation.
Soil nutrients and pH	Used to detect soil nutrients such as nitrogen, phosphorous, and potassium. This data is used to determine if soil additives are needed for a particular garden plot, as different plants have different nutrient needs.
Soil pH	Used to detect the pH levels of the soil. Improper pH levels lead to an inability for plants to absorb nutrients.
Sunlight	Used to detect length and intensity of sunlight in a particular garden plot. This data is used to determine which plants are most appropriate for planting in a particular area, as some plants are more tolerant to shade and/or full sun than others. This data can also be used alongside soil moisture data to estimate rates of evaporation.

While each data source could be useful for PCF's work, part of the motivation behind the adoption of the sensors was saving the organization money in the long-term. PCF operates as a non-profit entity, and hopes to dedicate as many resources as possible to its programming and to offset the cost of fresh produce for those in need in Ishpeming. For example, in one meeting, the gardens manager (Jesse) noted that PCF spent over $200 year just on strips to evaluate the nutrient and pH levels in soil. In Summer 2021 there were issues with the watering system at one of their garden sites that resulted in PCF owing the local water utility over $1500. This event, and associated issues with water conservation in a changing climate, were major motivating factors beyond just "What data can the sensor provide?" that were important to consider for the project.

Technological requirements and capacity

PCF has an existing system for tracking and visualizing some forms of data. This includes a series of cloud-based spreadsheets where employees and staff kept planting and harvest logs for each of the garden sites. Built off those logs is a GIS system and the corresponding SeedPacket app that visualized some elements of that data (e.g., planting and harvesting times) for public knowledge and educational purposes. Given existing technological tools and systems, we decided that a new soil-based sensor system needed to complement the current system, which had been developed through a multi-year process, rather than create a whole new system for tracking the sensor data. In other words, the end goal would be to have the data created by the sensors at some point interface with the data that was created for harvest logs.

While the organization has technology champions and interns with advanced technological skill that allow them to do things like develop and operate a GIS system, there is no guarantee that those people will always be around. Because of this, we determined that, in the beginning, we needed a system that was relatively "plug and play." This means that we needed a system that required as little advanced programming or computer hardware skills as possible to set up and operate.

A related concern was how the data would get from the sensors back to the office. Traditional soil monitoring systems, such as a soil pH strip testing kit, require you to go out to a garden bed, conduct a test, interpret the results, write them down, and then log the resulting data appropriately. PCF wanted a system that could transmit the data wirelessly from the garden bed where the sensor was installed back to the office or to a cloud-based system. This would mean that the data would be collected, no matter if there was a staff member, intern, or volunteer there to collect it. Further, the system needed to be battery-operated, as most of the sites do not have electrical connections. Due to lack of electricity, and related costs, this also meant that a wi-fi based system would not be feasible.

Selecting and purchasing

By knowing what kind of data PCF needed, the technological capacity of the organization (e.g., skillset), and the desired capabilities (e.g., wireless data transmission that isn't wi-fi, battery operated) we were able to identify what sensor systems were feasible for the budget. Sensor systems that are typically marketed to commercial agricultural ventures and provide real-time data over a wireless connection were too expensive for this non-profit community farm. It's possible to develop custom solutions using different computer hardware, but PCF needed something that was more “plug-and-play.” Dave Lawler, one of the volunteers who helped get the project off the ground, had experience using a SenseCAP sensor for tracking CO_2 for growing mushrooms. This sensor, created by a company called Seeed (yes with three ‘e’s), was weatherproof, at a lower price point than typical commercial sensors, and operated wirelessly using LoRaWAN.

Based on the qualities of the sensor that fit the needs of PCF, plus Dave’s existing experience, we decided that the Seeed sensors would be our best choice. During the March all-hands meeting, we decided to purchase three moisture/temperature sensors and two light intensity sensors.

> LoRa stands for “long range” and is a radio-frequency based technique for transmitting simple data. LoRa uses license-free radio frequency bands to transmit data, can do so at a 10km radius relatively easy in rural areas, and since the data has low complexity, it also operates with relatively little power necessary. LoRaWAN is the actual network layer protocol that makes the data transmission possible, telling the devices connected to LoRaWAN how to operate and transmit data. To use LoRaWAN, at least in this case, all you need is a sensor that can connect to LoRa and a gateway that uses an Internet connection to transmit the data from nearby sensors.

The light sensors chosen were the SenseCAP Wireless Light Intensity Sensors, which measure the intensity of light and are fully enclosed with a battery for outdoor use, which lasts up to eight years (see picture below). The moisture/temperature sensors chosen were the SenseCAP Wireless Soil Moisture and Temperature Sensor, which measure soil volumetric water content and temperature and are fully enclosed with a battery for outdoor use, with lasts up to six years.

Figure 3: Light intensity sensor (left) and soil moisture and temperature sensor (right).

Phase Two: Site Evaluation, Sensor Testing, and Developing Dataflows

From April to June of 2022, we worked to determine which site(s) were going to be best for using the sensors, tested the sensors in the PCF office and in the field after they arrived, and began developing initial data and workflows for getting the data off the sensors and to the GIS intern and others that would be working with the data.

Site evaluation and selection

Due to budget constraints and the "pilot" nature of this project, PCF purchased five sensors from Seeed, including two light sensors and three moisture and temperature sensors. A CO_2 sensor was also donated to PCF. Given the water use issues that occurred at the Elks Lodge site in Summer 2021, the technology working group and the staff at PCF were able to very quickly come to a consensus that the Elks Lodge site was the best site to serve as the primary pilot site for the sensor deployment. By deploying light and moisture sensors at the Elks Lodge, PCF would be able to get a better understanding of their water usage and how light and moisture are related to water needs and evaporation. In addition to the four sensors that would be deployed at the Elks Lodge, conversations among staff and volunteers resulted in two sensors being located at the compost site and one at the school site.

Prior to installation at the Elks Lodge site, the technology working group's hypothesis was that the hügelkultur mounds would be the best place for the sensors.[2] But their mounds are used for perennials, and they wanted to create data that would most benefit their cash crops, which are largely annuals. They reoriented to raised beds, where they grow annuals, and consulted with Jesse, the garden manager, to determine which beds would be the best. They decided on two beds, one growing carrots and one growing peas. Their reasoning was to see how the coverage of a tall plant, such as peas, would affect the water retention of the soil versus a crop such as carrots that has a low shading effect on the soil. They decided to place a moisture/temperature sensor in each bed, with a light intensity sensor on the sides of the bed to understand the amount of light each bed received during the day. This would, in theory, help them understand why certain beds dry out faster than others.

The soil moisture/temperature sensor to be deployed at the site across the street from Ishpeming Middle/High School would also help better understand evaporation. There are two raised beds at that site with tomato plants, one shaded and one not. While there weren't enough sensors to deploy them in both beds to document difference, one was placed in the bed without shade. Though they expect placement to change as they create a more definitive plan for research.

[2] Hügelkultur mounds are a permaculture technique used to build natural raised garden beds in the shape of mounds.

The last site they decided to put sensors is their compost site, where they are deploying a CO_2 sensor and a moisture/temperature sensor. Consulting with the person who runs their composting program, they selected a newer 2.5-month-old compost pile. In the long run, they hope to understand: 1) if new or old compost piles retain moisture better, 2) how moisture levels assist or inhibit the breakdown of organic matter, 3) how quickly compost piles heat up during the day, 4) how temperature fluctuates over time as compost piles break down, and 5) what kind of CO_2 levels are released from new versus old piles.

Sensor testing and developing dataflows

When the technology working group first started meeting, they faced some roadblocks. There was very little information online about the usage of the sensors for small-scale farming operations, so they initially set them up in the PCF office to both learn how to successfully set the sensors and LoRaWAN network up, and to develop the process through which they would get the data off the sensors. The primary concerns during this process were properly connecting the sensors to the LoRaWAN network and checking to make sure that the sensors were returning data. Part of this process also meant setting up LoRaWAN hotspots, the devices that would connect to an existing LoRaWAN network creator called the Helium LongFi Network, and provide the network coverage that the sensors would connect to in the field. They chose Helium as the network platform to relay the data because it was relatively user friendly and allowed them to triangulate hotspots across town to create the appropriate network. One of the downsides of using Helium is that it chargest for a continuous flow of data using data credits. While the credits are not expensive, in the long run if they set up many sensors it could get expensive, though Helium offers grants that organizations such as PCF can apply for to offset costs.

Once the sensors were properly set-up and the technology working group was able to determine they were connected to the LoRaWAN system, they did background research on the best data dashboards for visualizing sensor data. Their LoRaWAN provider, Helium, has a series of posts on their website on "Integrations," including different cloud-based clients that can aid in data visualization. Returning to the technological capacity of the organization, they needed to make sure that this system needed to be relatively easy to use. They picked a platform called Datacake that describes itself on its website[3] as a "multi-purpose, low-code IoT [Internet of Things] platform that requires no programming skills and minimal time to create custom IoT applications." The

[3] https://datacake.co/

technology working group found a blog post that documented exactly how to set up the Seeed sensors on Datacake.[4] With this in hand, they were able to set up their Datacake platform (pictured below) and start collecting and visualizing data centrally. Datacake allows for two devices to be connected for free, and charges per device beyond that. The team emailed Datacake to describe the project and were able to get additional devices connected for free given their non-profit status and community-oriented work.

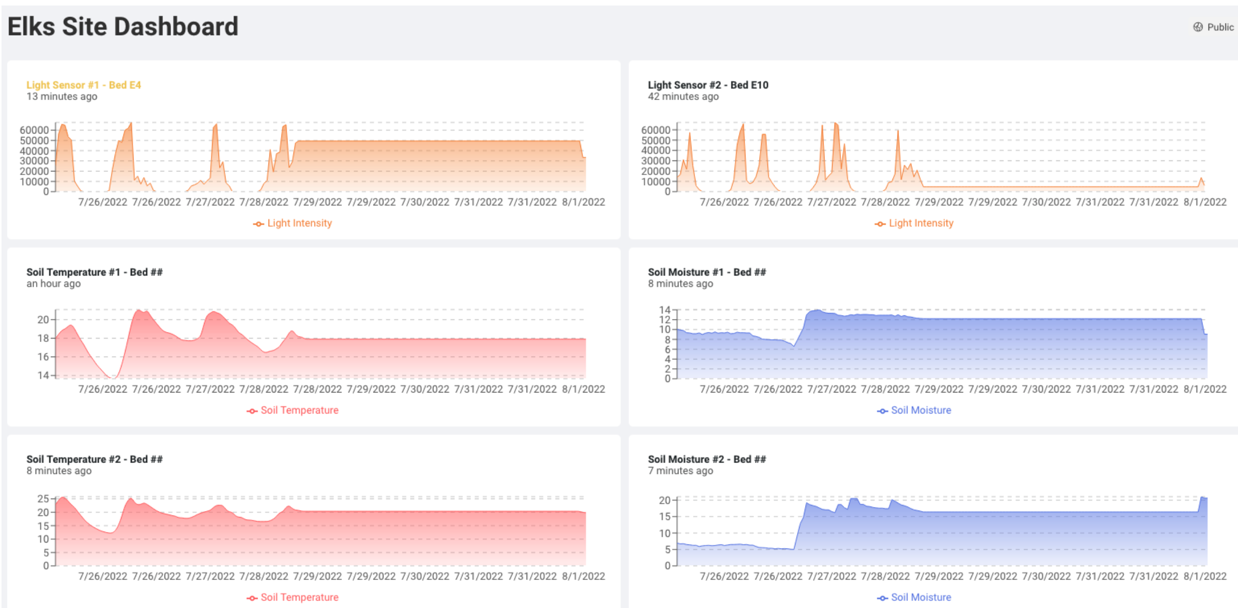

Figure 3: A screenshot of the Elks Site Dashboard the technology working group created on Datacake. You can see starting on July 29 that there were three days where the system was down and data transmission didn't change.

[4] https://www.balena.io/blog/connect-seeed-soil-temperature-sensor-balena-helium-hotspot-datacake/

Installation and troubleshooting

Installation wasn't as simple as just sticking the sensors into the soil and expecting them to work. As described above, there are a handful of moving parts that are required to properly connect the sensors and receive the data. In particular, the LoRaWAN hot spots needed to be located within appropriate proximity to the sensors to provide a strong enough LoRa signal so that data could be successfully transmitted received from the sensors. The technology working group had to troubleshoot the location of the hot spots at first to ensure that all three sites where the sensors were going to be deployed would be able to get a signal. Installation itself was relatively simple, with the moisture/temperature sensors being put directly into the soil and the light intensity sensors mounted on the sides of garden beds, though as of time of writing the team is still working on troubleshooting the optimum locations for providing appropriate and quality data.

Figure 4: Picture on prior page is of an intern installing the moisture sensor onto the garden bed. Above picture on left is of light intensity sensor and picture on right is of the soil moisture sensor in the ground under the peas at the Elks Lodge site. Picture below is of intern installing moisture/temperature sensor at compost site.

Installation at the compost site was different than other locations because there are no raised beds. This meant they couldn't mount the sensors with screws like they had at the other sites. Instead, they used a metal T-post (pictured to the right) to place a sensor in the middle of the compost pile. The temperature and moisture sensor was zip tied to the post, and the probe was placed underneath a thick layer of compost so it was completely covered. To measure CO_2 appropriately, the CO_2 sensor had to be placed inside of the CO_2 release tube that runs the length of the compost pile. Members of the technology working group zip-tied the sensor inside of the tube at one end so that the prob could sit inside of the tube.

Phase Three: Evaluating results and next steps

We held a meeting on-site in July 2022 to evaluate the completed activities and brainstorm next steps. Overwhelmingly people were excited about the project and the impact that it could have on

PCF's work. The major issue that came up over and over again was how much the team, especially the technology working group, underestimated the amount of time and troubleshooting it would take to set up the system. Neither Liz nor Malena, the two interns working on the project, had used this type of hardware before. While they both had a background in coding, coming to PCF with skills in GIS, there was a learning curve. In particular, the biggest issue was setting up the sensors so they would appropriately transmit the data. When describing the process of connecting the sensors' dataflow to Helium and Datacake, Malena described a process of having to disconnect and reconnect multiple times to the Datacake website, and having to edit their dashboard over and over again as they figured out how to connect everything.

Decision making and communication also took longer than they thought it would. The technology working group wanted to ensure that people like Jesse, the garden manager, and Aaron, the compost guy, were able to provide context and input on where the sensors should go. While this may have resulted in longer times for installation, they believe that it was worth it to ensure buy-in in the organization and an end product that would reflect the true needs of the organization. Throughout the duration of the project, the technology working group maintained central documentation in a Google document of the resources they were using and the steps for each stage of installation (e.g., turning on the sensor, connecting a sensor to Datacake). They also tracked progress and links on a collective Trello project management board.

Moving forward, PCF had clear next steps for how they wanted to continue using the sensors:

- In the immediate future, they wanted to experiment with placement of the sensors to determine what locations provided the most accurate data.
- The sensors seemed like the perfect tools to conduct experimental tests within their gardens to determine the best growing practices for their particular climate. In particular, the team present at the final meeting discussed conducting two experiments next year: one to understand the role of cover crops such as clover, hay mulch, and woodchip on the soil moisture retention and impact on a cash crop such as tomatoes; and another on shaded vs. non-shaded growth of a cash crop such as tomatoes. The hope is that they would be able to learn more about growing in their particular micro-climate and incorporate those findings and resulting recommendations into the SeedPacket App. Hopefully over time they'd be able to expand their sensor network and conduct many types of experiments in their work.

- Lastly, the interns weren't able to connect the sensor data to their GIS system this summer due to timing issues mentioned above. One major goal moving forward will be to figure out how to appropriately export the data so that it can be integrated on their GIS system to display it on the SeedPacket App for public education.

Considerations for Others

Agriculture is becoming increasingly digital. While not everyone is going to want to, or should need to, adopt the most recent digital agriculture tools, for those who do we have a handful of recommendations for consideration when approaching new digital adoption. While these recommendations are most likely beneficial to small community farms and gardens, we expect that smaller commercial farms running on slimmer margins and who can't afford the fanciest new technology will also find opportunity in these takeaways.

1. SELECT THE APPROPRIATE TECHNOLOGY

We propose four things to consider when selecting digital agriculture technology:

- <u>Existing technology</u>: The introduction of new digital technology should complement or replace existing technology whenever possible. For example, PCF had an existing GIS system they used to track location of crops and planting dates. The data provided by the soil sensors would complement this information and allow PCF in the future to develop connections between growing conditions and yields. While the current sensor system does not replace any existing technology, there is hope that future sensors could focus on pH and other nutrients, so that the organization could save money on test strips.
- <u>Skill levels:</u> Organizations and firms considering the adoption of new digital agriculture technology need to first evaluate what kind of skill levels exist within their current staff and dedicated volunteer base, and then make their purchasing decisions accordingly. While PCF had existing skills in its Board, its intern pool, and in its staff to navigate the GIS system, they did not have the kind of skills necessary to build a sensor system from the ground up. Because of this, and through the dedicated assistance of a volunteer who had experience with the technology, they chose an affordable soil sensor system and corresponding data dashboard provider that were relatively "plug-and-play." The chosen systems also had plenty of documentation and how-to guides online that would help guide their process.

- Longevity: The third thing to consider when selecting technology is how long it's going to realistically last and how often parts of it will have to be replaced. Many organizations don't have labor hours to be constantly repairing sensors or replacing batteries, so choosing devices that are long-lasting is important. In PCF's case, they were most concerned with battery life. Their farm sites are spread across the City of Ishpeming and having to constantly replace batteries or charge sensors was not realistic. The sensors they chose have a multi-year battery life and can be modified to send data less frequently to save on battery life as well. It is yet to be determined how the harsh winters are going to affect battery life if they decide to keep them outside for the duration of winter.
- Geography: The last thing to consider when selecting technology is geography. The distance to agricultural sites will determine what kind of sensor network is feasible. For home gardeners who are considering sensors, a wi-fi enabled system on an existing home wi-fi network could be feasible if the distance between a wi-fi router and the sensors was short enough. The dispersed and distant nature of the farm sites in the case of PCF required a long-distance solution, which is why LoRa was chosen. Some other sensor systems utilize, and usually charge a monthly fee for, access to 3G or 4G cellular systems for transmitting data across long distance. For PCF's purposes, a LoRa system was the most cost-efficient and met their geographic needs.

2. INCORPORATE NEW TECHNOLOGY INTO EXISTING DATA PRACTICES

Most agricultural ventures have extensive data collection practices, from soil nutrients to yields to weather conditions. Because digital agriculture systems are primarily meant to provide data, it's important to determine 1) what data is most needed, and 2) what data provides the largest returns (monetarily or otherwise).

- The first thing to consider with respect to data is what data is most needed. Are there existing gaps in data access? Is some data much more difficult to get with existing analog practices? In the case of PCF, they chose to start with soil moisture and temperature sensors and sunlight sensors. At the beginning of the project, soil moisture, temperature, and sunlight were not measured at all.

- The second thing to consider is what data is going to provide the largest return in the long run. When selecting new technology to adopt, prioritize technology that creates data that provides the largest returns. Returns don't need to be about making money, but can be about saving money and time. In the case of PCF, a sensor for soil moisture was important to help them save future money on their sites that utilize municipal utilities for their water. The soil moisture sensors also generally help prevent water waste. Further, by choosing sensors that are wireless, they are also able to collect data from multiple sites without having to actually go into the field every single day to collect the data. This provides a major return on labor hours and allows them to collect data they otherwise wouldn't have been able to because they didn't have the labor to do it.

3. HARNESS LOCAL TECHNOLOGY CHAMPIONS

Our third recommendation is to identify and harness local technology champions that are passionate about the organization's work. This is especially relevant for non-profit farms and community gardens. Technology champions look like community members who either 1) have advanced technological skills that organizational staff does not have, or 2) are willing to develop and/or cultivate technological skill to serve the organization's mission. Before this project started, PCF had two dedicated, long-term volunteers who acted as technology champions and drove the technological capacity of the organization. Both of these technology champions were key to helping with the adoption of the digital agriculture sensors.

If an organization doesn't have or isn't aware of existing technology champions, they may consider incorporating asks into their community outreach material. For example, if an organization surveys its volunteers in an onboarding process, they should consider adding questions about the kinds of technological skills, specialized or otherwise, that volunteers could bring to the organization. An organization might also consider doing special outreach campaigns on social media and elsewhere to find and bring on board local technology champions who are willing to donate their time and skills.

4. AVOID DATA-DRIVEN MISSION CREEP

Our final consideration is related to the problem of digital technology as a shiny, new object. Shiny, new objects create shiny, new data, which results in shiny, new opportunities for your organization. It’s tempting to see all the opportunities that new technology can offer an agricultural venture or non-profit: new data that was never able to be collected before, new workflows to create to best utilize new data, opportunities to monetize data streams for alternative revenue, and lots of different ways to take the data being produced and create new measurements for outcomes, yields, and conditions. New technology can open an organization up to a lot of different directions that aren’t necessarily serving their stated mission, and organizations should be cognizant as to not get overly distracted by the *possibilities* of the shiny, new objects and focus on how new technology can best serve their existing mission.

When we started this project with PCF, they were at a point in their organization where their scope of work was growing rapidly. They had recently received some large grants to expand onto a 3.75-acre brownfield site across the street from Ishpeming Middle/High School and right next to a new senior living facility. Due to these opportunities, the organization was already grappling with what their vision and mission for PCF looked like and how they were going to be able to best serve their community with the new opportunities they had. It could have been very easy for mission creep to settle in, and for PCF to see the new digital agriculture sensors as an opportunity to quickly expand their work in many different directions. In early conversations, we identified this as a potential outcome because it was something that PCF was dealing with already in their other areas of growth. By identifying mission creep as a potential threat, we were able to hone in and develop boundaries for the implementation of the digital agriculture sensors so they best served the existing mission of the organization: to produce high quality produce for Ishpeming residents.