Fact Sheet:
Maine Greenhouse & Covered Agriculture Program

Topic:

Wireless Telemetry for Maine Farms; the intersection of small and mid-sized farming, artificial intelligence, data driven decision making, and traditional food production

January, 2021

IN THIS ISSUE:

- FARMER DESIGNED WIRELESS BIO-SENSOR NETWORKS
- INTEGRATING FARM MICRO-CLIMATE DATA WITH UTILITIES; an "Internet of Things" Approach.
- CROSS DISCIPLINARY RESEARCH PROGRAM: Maine Agriculture Apps Project Agriculture, Sustainablity Sceince, Computer Science and New Media at UMaine/UMPI
- CASE STUDY: Soil/Atmoshpere Sensor Network Development WasteNotWantNot, LLC
- OPPORTUNITIES FOR INTEGRATING "STEM" & AGRICULTURE: From "Maine Agriculture in the Classroom" to Higher Ed Research; Areas for research and development

MESAS
The Maine Sustainable Agriculture Society

Advances in low cost wireless telemetry allow farmer to add detailed environmental monitoring, automation of utilities and useful applications for artificial intelligence to the small farm tool kit. The following provides an overview of research, development and field trials on Maine farms and research stations.

Wireless telemetry tools for climate monitoring, greenhouse and high tunnel climate control integrate user controllable data streams to provide detailed bio-feedback to the farmer. Data sets can also be integrated with the automation of certain utilities. This tends to improve sustainability by helping farmers limit excess utility bills, while increasing climate stability, and thus crop quality, crop yeilds, pest management and more. These are particularly useful tools for extended and off-season production where inefficient climate control or crop loss can be very costly. Wireless telemetry for agriculture is also an important nexus between generations of farmers and STEM educators

Bio Sensors for Environmental Monitoring

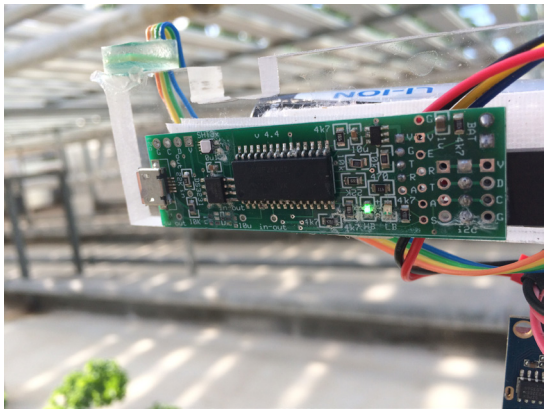
The air, water and soil sensors can add regular environmental data streams to a farmer's decision making toolkit. For greenhouse and high tunnel growers, as well as broadacre farmers, environmental sensors can increase our understanding of microclimates in production spaces as well as specific real time happenings in the air, soil and water. They can interact with utilities, send alerts to farmer's phones, and even help pinpoint an imbalance in your soils. All with using only a tiny fraction of power compared an average WiFi home router.

Applications in Production

The same device that provides information and data from sensors also sends data to a database or internal storage device. Date can almost instanly be sent to a mobile or web app where the user engages with it. The user can then program on/off or variable control messages to utilities such as fans and vents, irrigation, hot water manifold valves, and more. These applications allow for mobile engagement and monitoring of utilities and their effect on the production.

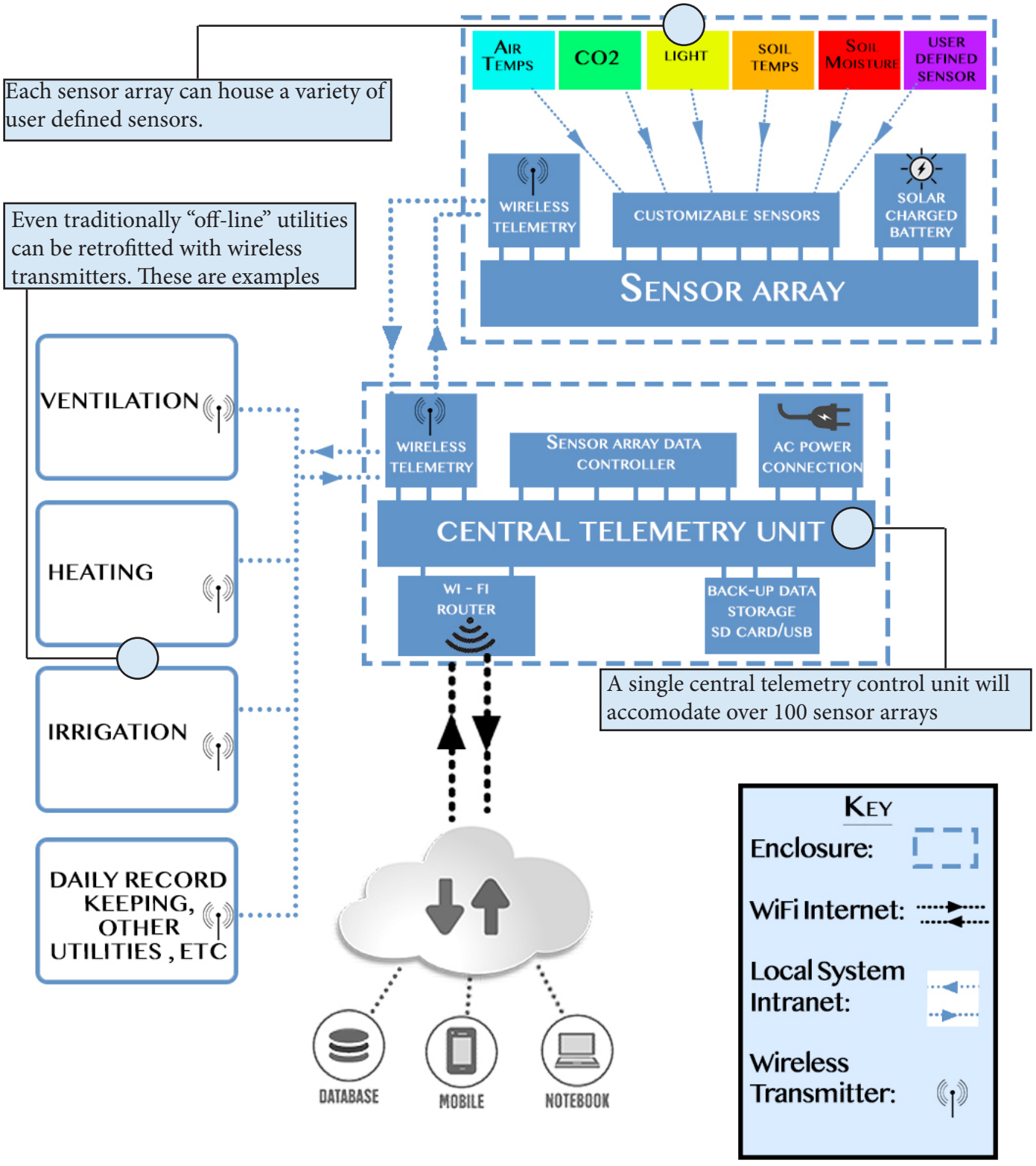
Farmers already rely on devices such as soil probes and thermostats, so integrating two way telemetry into untilities such as heating and ventilation controllers, watering timers, and soil analysis not only provide additional feedback, but allows the farmer to modify utilities based on data in real time or on a schedule.

The traditional approach to greenhouse climate monitoring took a "centralized sensor" approach. Low cost sensor array systems allow for many more sensors arrays that provide regular insight. This allows for new applications for bilogical monitoring that are helpful for decision making - such as with measuring nitrogen cycling, or tracking problematic insects or even tracking helpful bees and pollinators.



Prototyping tech: *This prototype wireless sensor array system is currently getting a facelift as enclousres, sensors, power supply and circuitry will get a new enclosures before the untis the next phase of demonstrations.*

Wireless Sensor Ecosystem and Signal Flow (illustrations not to scale)



Farm Sensor Data: *In MESAS' prototypes, sensor arrays operate with extremely low energy draw allowing power needs to come from a solar charged battery. This allows for a "wireless field sensor" approach that can allow for many wireless sensors in a greenhouse or even out in the field to send data to a central telemetry command unit with little to no servicing required through a year. This central command telemetry unit can then stores data and - if connected to WiFi - regularly sends its data stream to a computer database or cloud. The software front end displays data and can control utilities from a mobile device.*

CASE STUDY: WASTE NOT, WANT NOT LLC

Wireless Telemetry Development on Maine Farms

Technical notes:

- The current prototype's central telemetry control module can control up to 60 sensor arrays reliably and theoretically, up to 200.
- The central telemetry control module needs wifi and standard AC power to send data to a host platform. But the remote arrays utilize rechargeable batteries and small solar panels.
- The central telemetry control modules synchronize all the sensor arrays so that data is reliably timestamped to 1 second accuracy. Each remote communicates its data with the central module in a predetermined time slot.
- The scalability of this technology allows for hundreds, even thousands, of arrays to be deployed on a single site. This would require upgraded central telemetry command module compared to the existing prototypes.
- Sensor arrays can operate through walls at up to 1000feet from central unit and over 2000 feet using low-range radio wireless transmitters

Coding Used:

- C++ programming for the central modules
- MySQL database and language for data storage
- JSON formatting for sensor data transfer
- BASIC programming for the PIC microprocessors (similar to Arduino processors) on the remote arrays.

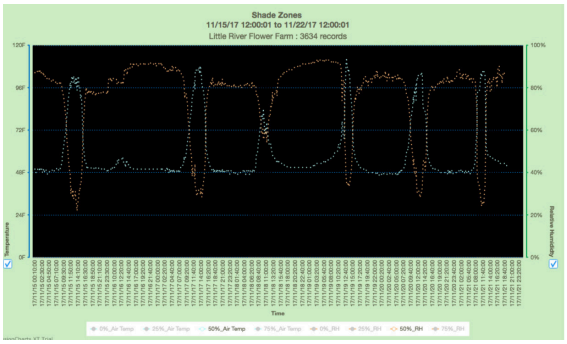
Market Goals:

Target cost to end user for a greenhouse or tunnel kit that includes 8 wireless sensor arrays, 1 central telemetry command module and a web/mobile app : $600-800

Integrations and switches for two way communication and control of utilities are built on top of this cost.

*Field demonstrations of the sensor system prototype supplied steady and reliable data that was used to test the radiant root zoneheating system used in field trials in Bux*ton.

The first prototype light sensors were measured for accuracy against the Apogee Quantum Flux handheld PAR sensor unit.



This prototype graph tracked real time and historical data in a searchable tool. The current R & D team is working with UMaine System partners to redesign graphics and user interface from the ground up as shown in research the program summary below. Relative humidity here being analyzed against average air temp.

(Waste Not Want Not case study, cont'd)

Development notes:

Data interpolation accommodates occasional missing data or sensor-down situations.

For current prototypes WiFi access is prefereable. In the absence of local Wi-Fi, cell reception is all that is needed to run the system by utilization of a local hot spot. In the absence both WiFi and cell reception, the sensors still work and send data to the central telemetry control module. There is stored or manually transfered.

The initial prototype used 2400 milliamp/hour battery which lasted for 3 days between battery changes. With successive prototypes, energy efficiencywith improved to lasting over 2 months without re-charging. The addition of solar chargers for the battery on the sensor arrays improved that drastically; auto-charging elminates seasonal battery maintenence even during long periods of low light. For future development, more efficient batteries at more cost effective pricing than our prototypes will be likely.

Immeadiate next steps:

- Web development, and app development is needed to make the data more understandable and useful to the end user.
- Bee keeper's kit. Insect monitoring kit
- Instant data request function that temporarily interrupts the sync cycle to request data instantaneously for emergency response during erratic weather and make real time data (minus equipment latency).
- Integrate new sensor technologies into systems. The system has been built utilizing an I2C bus, which most low cost sensors can accommodate. That makes expansion of the sensor array eminently feasible.
- Per- and polyflouroalkyl substance spectrometry integration
- Marine grade enclosures
- Broadacre configuration. Low range radio capability; Low range radios can be integrated into the circuitry and are very low power, yet can communicate over long distances. Although not actually tested to this range yet, it is likely that distances of over 1 mile between remotes sensor arrays and the central collection module are possible.

CROSS DISCIPLINARY RESEARCH:

Maine Agriculture Apps Pilot Program

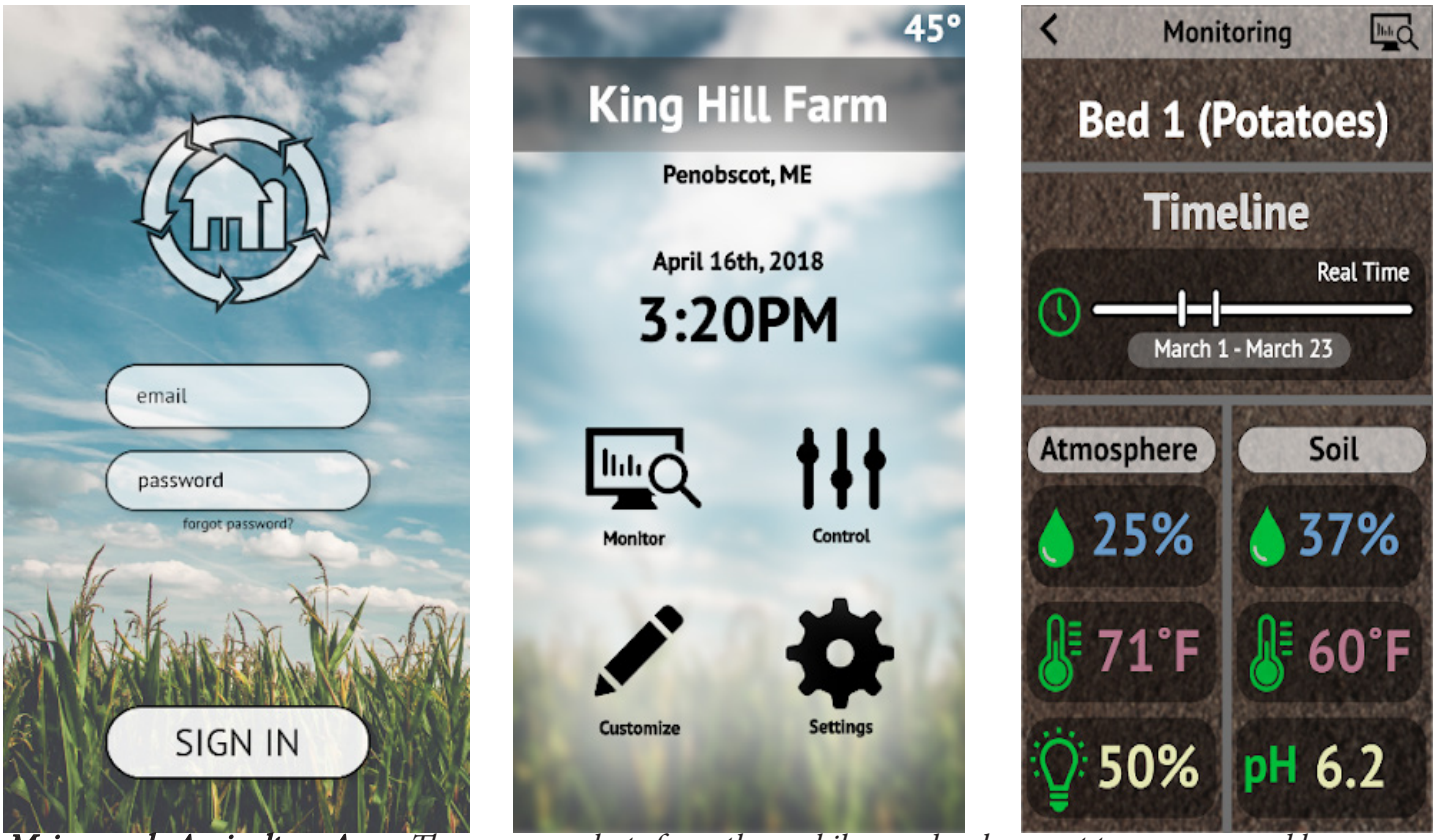
In 2018, a collaboration between the University of Maine System researchers, students and the Maine Sustainable Agriculture Society began a collaboration to analyze data sets and develop graphic user interfaces for active data streams.

Teams from acriculture, computer science and new media set out to build a simple and customizable mobile app that works with Apple and Android devices. The program brought researchers and students from computer science, tech, engineering and agriculture together to test prototype sensor systems in the field and with small farm businesses througout the Northeast.

The prototype wireless system described above was presented as a problem solving opportunity for students from Sustainability Science at UMPI and from the New Media Program at the University of Maine.

UMaine System New Media and Sustainability Science students engage farmers to hear their story and work to building tools that improve sustainabilty on Maine farms

The pilot program was a success and a follow up program is currently in development. Better data and metrics for measuring efficacy of production, heating and energy use along with marketing and customer engagement has helped some farmers lower utility bills and maintain cash flow, retain labor during winter and increase direct sales.



Maine made Agriculture Apps: *These screen shots from the mobile app development team were used by students to discuss how technology and agriculture skill sets can connect to benefit rural economies and on small scale family farms.*

Program Development Concept; Cross Disciplinary STEM Curriculum for Agricultural Classrooms

The Maine Agricultre Apps Program piloted cross - disciplinary educational app tool that is useful for farmers. Using the same infrastrucutre of the wireless sensors system and app tools, Maine's schools garden and Agriculture in the Classroom leaders can provide new opportunities for school districts and educators seeking better integration of agricultre and garden curriculum into Science Tecnology Engineerings and Mathmatics (STEM) curricula.

School greenhouses and science classrooms may find useful application for evironmental monitoring tools. Whether through lesson plans that encompass technology, math, science, engineering or through traditional greenhouse lessons such as earth science, monitoring tools and related apps allow for teachers and students to stay in relationship to growing spaces or greenhouses without leaving the classroom. Greenhouses still need a lead grower and caretaker/service person, however lessons plans keep students engaged to a greenhouse ecosystem. Wireless data streams provide opportunies for meaningful lesson plans that link hard science and even math to nature based learning and **'ecosystem awareness'** that can include climate monitoring, soil sceince, environmental engineering and much more.

Ecosystem awareness links technology, ecosystem science, sustainability science and agriculture

- Ecosystem science (e.g. bio-accumulation, geology and geo-morphology, pollination etc)
- Bio-physics; how dynamic chemical changes - especially those from human impact - effect ecosystem health
- Heating and energy conservation tools; knowing how to reduce our carbon fuel useage demands that we undestand how we use fuels with greater level of detail compared to current awareness
- Basic wireless telemetry; Internet of Things (IoT) devices and Raspberry Pi, Arduino & PicMicrocontrollers
- Sensor science; how do sensors function what metrics are needed to sense differen aspects of air, soil, water, etc
- Convservation assessments and emissions monitoring
- Wabanaki cultural history and indigenous ecological traditions, land claims, impact of historic repropriations
- ...and more, get creative!!

Agriculture in The Classroom meets STEM Crossover Curriculum:

Know a greenhouse school garden champion? Nominate them for our Maine School Greenhouse and Technology program development advisory team.

MESAS is working to covene education professionals who currently - or in the near future will be - engaging students in agriculture and greenhouse learning opportunities. Schools that currently have, or schools that are planning to have year round greenhouses on their campus are envouraged to sign up for our mailing list. We are currently accepting nominations to our development team! Scholastic focus on STEM fields in Maine's Schools and across Higher Ed, a marraige between Bio-Sensor monitoring for greenhouses and agriculture infrastructure allows for an exciting opportunity to design STEM curricula that focus on sustainable agriculture.

Other Noteable Environmental Monitoring and Greenhouse Climate Control Systems
Rainwise, Trenton ME - Weather Stations
Powerwise, Buckport ME - Building energy and heat monitoring
Ceres Greenhouses, Boulder, CO - Automation controller and greenhouse design/build firm
Growlink, Denver, CO - Monitoring and automantion
Wadsworth Controls, Arvada CO - Climate controls, heat and light curtain systems, vent automation

Additional Resources:
For more info on solar greenhouse technologies see National Center for Appropriate Technology "Solar Greehouses" Fact Sheet. For info specific to Maine see UMAINE Cooperative Extension Season Extension Bulletin

Need help budgeting for new tools and infrastructure? Check out ME SAS' draft editable Enterprise Greenhouse Budget Planning Tool. Use the tool to plug in and calculate cost, depreciation, estimated payback and even carbon emissions for whole farm accounting. This draft of the tool comes pre-loaded with a model budget.

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M E S A S
The Maine Sustainable Agriculture Society

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W W W . M E S A S . O R G

Into greenhouses, tunnels, heat, energy, and tools for Maine and the region? Be sure to sign our mailing list to get updates timely announcements on events programs, farm tours, educational opportunities, membership and the seasonal ME SAS Newsletter. For more info please e-mail: mainesustainableag@gmail.com

Co-Developing Maine's Agriculture and Arts Economies

A living laboratory to accelerate climate smart agriculture & sustainability science implmentation through small business technology transfer

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TILTH
ARTS & AGRICULTURE

Overview

Small and family farms in Maine and nationally are historically cornerstones of rural community development. This research focused on novel arts agriculture co-development over the past decade and developed an economic development framework for Small Business Technology Transfer programming that acclerates climate smart agriculture and sustainability science implementation while centering farmers & food

Analysis

Incentivizing long range public/private partnerships that center arts and small farm talent and innovation together, in a codevelopment strategy along with new media, agriculture, engineering and food systems talent pools and infrastructure, is better for society than single discipline short range or venture targeted economic development pathways. In this way, arts based economic development serves a supportive link between " 7 technology areas" led by Maine Technology Institute. Implementing codevelopment strategies in rural communities may have implications for rural development and Maine's entrepreneurial ecosystem, and portions of MCED's 10 Year Strategy.

In some communties this codevelopment is supporting the retooling of Maine's small and family farm sector and relative rural community centers while broadcasting and capitalizing their value beyond the reach of Maine's specialty and commodity products alone.

Collaborators

Blue Hill Heritage Trust
MRC Center
Crown O Maine
American Rescue Plan Maine Project Guide
Magic Food Bus
UMaine New Media

Research Implementation; a living laboratory for participatory action research and small business development

Participatory Action Research & Implementation Living Laboratory
10.5 acre public facing farm and infrastructure

Integrated Environmental Humanities & Arts
programming, symposia and summer stage relational to research outcomes

Business Development Programs:

- **Tilth Accelerator Program;** 2 year business development
- **Tilth Artist in Residence Program** 2 week - 9 month project support

Outcomes

Project outcomes led to the development of the **Living Laboratory** research program **Fair Mount Farm**, and the incorporation of Fair Mount's umbrella organization Tilth Arts and Agriculture, in **Blue Hill, Maine**. Tilth serves as a mission driven community development hub, and a model for piloting public private partnership and technology transfer projects through participatory action research. Program targets are outcomes of soil and water conservation and sustainabilty science innovation and meet a growing need to accelerate implementation and economic development.

Tilth uses **environmental humanities** and **arts** programming relative and adjacent to climate smart agriculture infrastructure program targets to accelerate the transfer of proven **climate smart agricutlure** and **sustainability science** in the pubilc research sector into **positive cultural & socioeconomic responses** from the small business sector.

Tilth Accelerator Program Targets:

- **Diurnal Heat Sinks & HVAC in Year Round Soil Based Greenhouses**
- **Field PFAS Bioremediation with Nanocellulose, Fungi & Biochar**
- **A Maine Small Farm 'Wireless Sensor Network Common Server'**
- **Digital Farmers Markets for Maine's Small & Family Farms**
- **CoDevelopment of Arts & Food systems in Maine Economic Development**

Anticipated outcomes from field demonstration and participatory action research at the Fair Mount Farm living laboratory, help filter viable **Tilth Accelerator** programs that target U.S. Small Business Administrations Small business technology transfer funding that specifically centers **CoDevelopment of environmental arts, humanities, tourism and stem innovation relative to the small and family farm sector** as a rural economic development framework that implements innovative research.

Service Provider and Business Consulting Programs