COVEYOU FARMS LLC

Innovative soil, water and energy conservation portable high tunnel vegetable production system for season extension small farm applications

Conservation Innovation Grant Final Report

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Executive Summary

The Purpose of this project as highlighted in the grant agreement is for Coveyou Farms LLC to design, install, demonstrate and evaluate a portable high tunnel growing system. This project was intended to demonstrate improvements to the production systems available to small farmers who grow produce for local and regional consumption. These enhanced production systems provide for water conservation, soil building and rotation and even demonstrates an energy efficiency element that reduces costs but also allows for newer technology to be used in the field where grid electricity is not available. The net result of applying these new technologies to the small farm is to make vegetable production more

viable and sustainable for the many people transitioning their farms to local food production. The Goals of the project are:

- Demonstrate that an innovative moveable high tunnel growing system can be used to improve the soil quality in high tunnel vegetable production.
- Demonstrate that new commercially available soil moisture sensors can be used to improve the efficiency of irrigation systems in high tunnel environments
- Demonstrate that innovative irrigation pond and system design can allow for an energy free irrigation water supply for drip irrigation systems.
- Demonstrate that solar DC powered air movement fan systems can be beneficial in preventing early season frost damage within moveable high tunnels.
- Demonstrate that fertilizer dosing irrigation systems can be used to better manage fertilizer applications in high tunnel vegetable production.

A significant amount of learning was accomplished through this demonstration project. The high tunnels were constructed as planned with a simple bottom rail system employed to provide ease of movement. A robust attachment system of the tunnel to the rail was designed and proven to hold up through a number of tunnel moves. A movement approach that is quick and efficient was developed and used numerous times to demonstrate the tunnels ease of movement. Soil building and preparation were performed as planned allowing not only a soil rotation and better deep tillage soil preparation options but also a lower cost structure of soil building that allowed the use of conventional equipment. The irrigation dosing fertilizer injectors were found beneficial to not only continuously feed nutrition to the plants but also in supplying calcium and other organic minerals directly to the plant root zone. The soil moisture sensing system was installed and evaluated with mixed results. We still believe this system has great potential for the high tunnels but the improvement in water management from

sensing the soil moisture is traded off by the complexity of the water delivery system providing water to the controlled tunnel. Further work in simplifying and enhancing this system will continue after this project completes. The frost protection system was designed and fabricated. We believe this system has merit and warrants additional study. The results were inconclusive with additional testing and system enhancements planned for the seasons ahead.

The details behind many of these project goals were shared at the Northern Michigan Small Farm Conference attended by several hundred regional farmers each year as well as through a USDA extension bus tour field trip allowing farmers from around the state and region to hear first-hand details of these systems. We view that the main benefactor of this type of project are the fellow farmers who can observe, learn, and apply features of these systems to their own operation. It is these technologies that will allow farmers to enhance their production systems. Our 2010 growing season used most of these technologies and resulted in our having tomatoes available in the local farmers market for three weeks prior to any other conventionally grown produce producer in the area. The volume of produce sold in those three weeks represents a movement from small farms just being able to make a profit to improving the potential of those farmers to truly make a sustainable living.

This project was completed within the budget planned and ongoing improvements to the systems will be funded from our farm resources. The timeline was stretched out by a year to allow all activities to get completed. There were some regulatory hurdles that resulted in a delay but the real challenge is being able to make the progress desired in these projects during the very busy growing season.

On the whole we view this project demonstrated a method of growing local produce that is now the cornerstone of how we operate our farm. This technology is an integral part of our operation and we believe others who embrace this technology will value what it brings to produce quality, labor needs,

soil and plant health, irrigation efficiency and overall improvement to the sustainability of small local produce farms.

Introduction

This project to explore soil, water and energy conservation through the use of portable high tunnel vegetable production systems during season extension initiatives on small farms was carried out by Coveyou Farms LLC of Petoskey, Michigan over a number of years starting in 2008. Coveyou Farms LLC is a 139 year old family farm in the northern portion of Michigan's Lower Peninsula that focuses on growing produce and other items for sale to the local and regional community. This project was funded solely through the resources of Coveyou Farms LLC and the USDA CIG grant program. The results and findings of the demonstration project were shared with regional and state farmers through the Northern Michigan Small Farm Conference and through on farm tours with USDA extension coordination. Additionally, it is our desire that some of the findings relating to moveable high tunnels become incorporated into the USDA high tunnel practice documentation that can used by a larger range of small farmers across the country.

The purpose of this project was to design, install, evaluate and document an innovative soil, water and energy conservation portable high tunnel vegetable season extension production system for small farm applications. The Goals of the project are:

- Demonstrate that an innovative moveable high tunnel growing system can be used to improve the soil quality in high tunnel vegetable production.
- Demonstrate that new commercially available soil moisture sensors can be used to improve the efficiency of irrigation systems in high tunnel environments

- Demonstrate that innovative irrigation pond and system design can allow for an energy free irrigation water supply for drip irrigation systems.
- Demonstrate that solar DC powered air movement fan systems can be beneficial in preventing early season frost damage within moveable high tunnels.
- Demonstrate that fertilizer dosing irrigation systems can be used to better manage fertilizer applications in high tunnel vegetable production.

Project Background: Small and midsized farms across America are transitioning to grow vegetable crops for local sales including the direct marketing to the public as a means of increasing revenue and ultimately sustaining family farms. A challenge to production in many northern portions of the country is the short growing seasons where crops get damaged by early spring or fall frosts. High tunnels are used extensively in European countries and Asia and are now gaining visibility in America. A key benefit of high tunnels is the ability to bring the farmer higher market prices by allowing product to mature faster and be available for sale earlier in the spring prior to typical field crop production. A higher quality product is possible due to the shielding of crops from wind, excessive moisture and cold weather damage. High tunnels are a steel frame covered with a poly plastic film. Historically, these high tunnels have numerous foundation stakes that permanently secure the unit to the field. Crops are grown directly in the soil beneath the tunnel year after year. This fixed system makes it economically impractical to employ soil building practices like crop rotation and using cover crops resulting in challenges to maintaining optimum soil quality and keeping the soil free of harmful diseases and pests. This project was to demonstrate a mobile high tunnel system that can be easily moved to an adjacent field that has been allowed to use common crop rotation and soil building practices. This new system will allow small farmers to have the opportunity to grow crops in an

improved soil structure as well as enable good crop rotation practices and all the benefits these practices bring to agricultural production.

The vegetable product growing in the soil under the high tunnel is shielded from natural rainfall. Irrigation is the only means of getting water to the crop. Drip irrigation methods are ideal for this type of growing system. Optimum plant growth, crop yield and crop quality can be obtained when water and fertilizer applications are maintained at optimums levels. Fertilizer can be provided as needed through the irrigation water in precise fashion limiting the risk of nutrient leaching deep into soils or water supplies. In normal field applications water and nutrient levels cycle with rainfall, irrigation schedules and fertilizer applications. The high tunnel environment provides the unique opportunity to monitor and control the soil moisture levels. New commercially available soil moisture sensors were planned to be demonstrated in this project to activate the irrigation system throughout the day as needed resulting in lower water use. Having a water source with at least a 15psi pressure is needed to run this type of automated drip irrigation system. Spring fed irrigation ponds provide an opportunity to have a supply of water continuously available. The naturally sloping terrain of many farms provides an opportunity to use the head pressure of existing manmade irrigation ponds and systems to provide water to different fields at lower elevations without the need for pumping at all.

The plastic film of the high tunnel protects the crops from a certain level of frost injury; however, at some point the temperature will drop to a damaging level. Every day of delayed freezing into the fall is another day of harvest potential. Similarly, every day earlier in the spring that crops can be planted results in increased production and improved profit margins from getting crops to the market earlier.

Air movement in the tunnel was planned to be explored to see the benefits of protecting crops from frost damage.

Review of Methods

This section will review the details of what was implemented in this project. The first goal was to demonstrate that an innovative moveable high tunnel growing system can be used to improve the soil quality in high tunnel vegetable production. To accomplish this goal a moveable high tunnel was developed that allows the structure to be easily slid from one section of a field to an adjacent field. The high tunnel structure chosen was 24' x 96' in size of a gothic shape. We used a 1-5/8" x2-1/2" oval shaped tube for our arch assembly that came prefabricated. All steel was 14 gauge in this project to assure the strength for our snow loads and the added stress of moving the tunnels. Our earlier work with ground staked tunnels resulted in some significant wind damage over the years. This structure was designed with 2" square steel tubing instead of the standard 1.5" tubing to give more rigidity to the structure. All connections were made with bolts vs. self taping tek screws since we have found the tek screws to work themselves out over the months of constant wind vibration. The high tunnel structure was secured to two rails running the full length of the tunnel. The rails were made of 2x3" 14 gauge galvanized steel with a swedged end to allow for interlocking connections between the 24' long rail sections See Figure D-1. These rail sections were bolted together. Also, note that the rails extend about 3' beyond the house in each direction to provide an attachment point for a chain or cable that will be used to pull the tunnel. Since the tunnels can be pulled in either direction this extended rail is on both ends of the tunnel.

Figure D-1; Bottom 2x3” rail with endwall bottom cross member

A 3” angle iron bracket was cut and drilled to allow attaching the high tunnel to the rail. See Figure D-2 below for a picture of the attachment bracket.

Figure D-2; Bolted angle iron attachment Bracket

The same 2x3” steel tube was used as the base of the endwalls. This tube setting on end provides the strength to hold up all the endwall vertical studs. It’s height off the ground was varied between test trials of tunnels and it is desired to have this endwall bottom rail sit approximately one foot above the soil to allow soil and vegetation to slide under the endwall as it is pulled forward. This endwall cross member can be seen in figure D-1 and is a critical component of the design since it bears much of the stress during tunnel movement.

A number of methods of moving the tunnels were explored. Pulling the tunnels with the rails directly on the soil works well however it was determined that raising the tunnels up with a heavy bar and

block will allow putting a round pole under the rail to act as a roller. This roller allows the tunnel to slide forward with less horsepower required. The tunnel raised on rollers is shown in Figure D-3

Figure D-3 Tunnel Ready for pulling to new location

The actual pulling of the tunnel can be accomplished in multiple ways. A chain attached to each rail will allow the tunnel to be pulled by a tractor. The original plan was to include a ski attachment to the front of the rail. We found that this ski is not needed since there is always a fair amount of upward pull on the front of the rail. Pulling the tunnels with two tractors, one attached to each rail works fine, however, a coordinated pull is needed to assure one side does not get in front of the other. Cables attached to each rail coming to a center single pull point puts too much lateral stress on the endwall as the cable tries to pull the two rails to the center. The preferred method that we found was to use a

wide disk which allows the tunnel to be attached to a single tractor with cables or chains connected to the front of the rails. The disk turns the soil lightly as it pulls the tunnel forward removing all tire tracks and compacted soil. Figure D-4 shows a disk attached to the tunnel pulling it forward.

Figure D-4 Pulling a tunnel forward with a single tractor and disk

This moveable tunnel system has worked very well for multiple seasons. Its relative simplicity coupled with the robustness of the heavy rail system should result in a system that can be long lasting and require minimal upkeep. It takes about 30 minutes to actually pull a tunnel with this method. Most of that time is spent assuring that no soil is catching on the endwalls or shuttling the log rollers from back to front. A 2-3 person crew is all that is needed, however, these tunnels can be moved with by just a single person.

The tunnels weigh just short of 3000 lbs and originally we envisioned we would need to anchor screw the tunnel down or place large concrete blocks on the ends of the rails to hold it down from the wind. We have not had any issues with wind and presently do not anchor any of these tunnels due to their weight and the difficulty for wind to get under the plastic to provide lift.

The moveable tunnel allows for crop rotation. A better term may be soil rotation. High value crops like tomatoes will be grown in a tunnel every year. In reality the crop stays with the tunnel each year. Tomatoes can be grown in that same tunnel every year maximizing the benefit of the investment in the structure. The movement of the tunnel now allows the rotation of the soil eliminating the disease and pest pressures that come from continually growing in the same soil. Outside of soil cover cropping we have found the added benefit of ease of tillage and ease of adding compost and soil minerals. With a standard ground staked tunnel it is difficult to get equipment inside the tunnel to till the ground. It is also difficult to add compost or other minerals since getting the material into the tunnel would require a lot of hand work with a wheelbarrow or the use of a small tractor that would compact the soil. The ability to use conventional tillage tools including deep tillage tools and open access to dump compost by the tractor scoop saves a significant amount of labor with this moveable tunnel system.

The moveable tunnel allows for the tunnel to be used for multiple crops in a growing season. Chard, Kale, Broccoli, peas or other cold hardy crops can be planted within the tunnel while snow is still on the ground outside. These plants can grow and flourish during the early spring within the tunnel. When the tunnel provides enough frost protection for early tomato plants the tunnel can be pulled forward to the prepared tomato field leaving the cold hardy crops to continue growing without the

tunnel protection and the tunnel can then be transplanted out with tomatoes for the main summer season. Similarly in late summer another adjacent field can be prepared and planted with late fall and winter produce and when the tomato crop is finished in late November the tunnel can be pulled over the winter crops to provide protection and allow those crops to be held for harvesting into the winter. This technique has been used with the tunnels and provides significant promise for making farm sustainability ever more feasible for the smaller operations that focus on providing produce for their local communities.

Irrigation benefits are another goal of this demonstration project. The tunnel keeps all natural rain off the plants and thus irrigation is required. Drip on its own is not new and is the technology of choice in moveable tunnels. The plants in the tunnel benefit from not having rain or moisture on their leaf surfaces and fruit helping to prevent disease pressure. Drip irrigation provides the water needed without getting the foliage or fruit wet and builds on the ability to improve both plant and fruit quality. The insertion of fertilizer injectors to provide a constant feed of nutrients throughout the growing season is an added benefit. The implementation on the high tunnels has a dosing fertilizer injector capable of dosing nutrients at the ppm level into the water supply. We precede the inlet water with a filter to protect the injector from any foreign material in the water supply. Prior to the filter is a solenoid valve to allow automated control of the water supply. The water supply in our demonstration case is a spring fed pond that is used for irrigation water on the farm. Another goal of the demonstration project is the implementation of soil moisture sensing within the root zone of the plants within the moveable tunnel and the coordinated application of water when the plant root zone requires water. Effectively opening the solenoid valve to irrigate the crop up to the point that the soil

sensor indicates that a pre determined level of soil moisture has been obtained. Soil moisture systems were investigated, procured, installed and trialed in our demonstration project.

There are a few features in this project that make soil sensing unique and not standard. Our tunnels are in an agricultural field where AC line power is not available. The reality is that the sensor or controller will not have access to AC line power. DC power could be provided but even that adds complexity. Second is the fact that the tunnels move season to season and year to year. We won't be able to bury wiring due to the fields being tilled. Third is that any wiring outside of the tunnels is in open agricultural growing fields that have tractor and tillage equipment passing around the tunnels during the season. Complexity of connecting to the sensor and the solenoid activation wiring is important. Many sensors need a wire from the controller to each component in the system including moisture sensors, solenoids, temp sensors and any other monitors. If there were 5-10 of these high tunnels in the field then each wire would be multiplied by the number of tunnels. Having independent controllers in each tunnel is one option, but then it takes away the benefit of having a central location where we can monitor conditions in all the tunnels without having to physically observe each tunnel. Ideally a solution that had wireless reporting and control would be the ideal application. Commercial technology that is wireless was not economically viable at the time we purchased the system. Most of the wireless systems required AC line power and we needed a system that could run only from DC power in the field. We purchased and installed a Baseline system because it provided the best overall solution for our moveable tunnel system. The key benefit is it's use is the fact is does not require a power supply in the high tunnels and the fact that a single wire provides the DC power needed and a digitally encoded reference for each sensor or solenoid on the single control line. In this way a single controller communicates on the single wire to dozens of sensors and each sensor has its unique address and individual control.

We installed the Baseline system with the controller in an area of our barn that was easily accessible. A single control wire was run from the barn in an 8” deep buried trench to the high tunnel range along the edge of our tilled fields and along the edge of our 8’ high deer fence. The branches from the main wire are run up the fence posts and then are suspended in the air using a high tensile wire to span the distance over to the tunnels. The capacitive reading moisture sensors are buried in the plant row about 6” below the soil level directly in the plant row. A temp sensor is also put in a couple of the tunnels to monitor air temperature. Both sensors and the water control solenoid are connected to the single wire. Figure D-5. Shows a picture of the sensor itself.

One of the challenges with this system is that water pressure needs to be available all the time to the high tunnels. Our irrigation pond supplies water to our complete farm with it running typically once a day for a few hours. Our plan was to use the water capacity of the 6" main line that rises over 100' from pond level and is 1000' long to provide the head pressure and water volume to supply the tunnel ranges at the lower level. We have realized in implementation that the dual redundancy of putting in a second supply line for the tunnels is an unplanned challenge but did resolve with the additional investment in getting the supply lines to that portion of the field. To maintain the water in the supply line all other fields need to be turned off shortly after the pump stops running or the reserve water will drain out of the system. We were not successful in achieving this element of the management of the system and need to work a more regimented schedule of irrigating along with more timed solenoid shut off systems to assure adjacent fields that can bleed off irrigation water are disabled. We still believe that the overall benefits of controlled irrigation with soil moisture sensors is a valuable tool in improving fruit quality and further work in refining this system in the seasons ahead is planned. Figure D-6 shows the potential of well managed cherry tomato plants in a moveable high tunnel with good water control. Cherry tomatoes will split if receiving too much water, however, plant and fruit quality will be limited if receiving too little water. This picture shows tomato plant rows 100' long, 8' tall full of prime fruit with very minimal cracking or waste that were harvested from July through November.

Keeping these high tunnel valuable crops producing as long as possible is a goal of every produce grower in northern climates. Frost on the cool fall nights usually kills most tomato crops prior to all the fruit ripening. The tunnel covering provides a good level of protection resulting in over 2 weeks of additional harvesting time compared to field grown crops. The elimination of rain and moisture from sitting on the leaf and fruit surface itself extends the life of the plant and the protection from frost extends the season as well. We have found it is usually only a couple of clear cold nights in October

or November that damage or kill the plants. There are often many nice warm growing days after this killing frost event. Another goal of this project was to explore the benefits of circulating the air within the tunnel to prevent damaging freezing air to hurt the plants. A system using small 7" diameter high flow DC powered fans was designed and assembled. The six fans are spread throughout the high tunnel and temporarily hang on the trusses with a wiring harness that can plug into the main supply line. The fans run from a large deep cycle battery that is recharged with a solar panel. This system benefits were not able to be confirmed in this last growing season. We plan to improve the system in two ways to determine net benefits. The system as it exists does not have a temp sensor that can activate when it comes on. Running this system based on projected low temperatures is not accurate enough to assure the system is running when needed. To truly test this system we need to determine a way to activate it from the temp sensor that is already in the high tunnel. At that point when the sensor determines the temperature is below a certain level the fans can be activated. It has yet to be determined that the additional air flow makes a significant improvement in protecting crops. Further studies are needed in this area and we will continue to explore this approach in the seasons ahead.

Outreach and Sharing of Results

The results of this demonstration project have been shared in multiple ways. A presentation was given at the yearly Northern Michigan Small Farm Conference in Grayling, MI in January of 2013. This conference brings over 600 small farmers from around the region together. Our presentation on these conservation innovation technologies was standing room only with many rating in the post presentation review that the material presented was very applicable to their operation and that many replied they would consider using these ideas in their farm practices.

The second main outreach activity took place in August of 2012 with a USDA NRCS planned bus tour bringing farmers from around the state and greater Midwest to see innovative farms. This walking tour and first hand being able to answer questions from the many farmers was another good way for people to take away the insight and knowledge developed in this project.

In addition to these formal presentations on the technology there have been many individuals who have asked for insight or I have shared what we are doing with conservation innovation technologies on the farm.

I believe the next step in outreach would be to work with our State of Michigan NRCS staff to incorporate findings from this project, especially the moveable high tunnel techniques, into the state practices for high tunnel development.

Deliverables

This project has four deliverables. Note that some of these deliverables were modified from the original contract and are noted here.

1. During the period of the award, the grantee is will make a presentation sharing details of this project at the Michigan Small Farms Conference in January of 2012. The presentation will provide a forum for technology feedback and sharing with other producers;

   The presentation for the 2012 small farm conference was not acceptable due to the timing of session choices for that year. The presentation was accepted and given at

the 2013 Small Farm Conference with a positive acceptance. We view this deliverable as being accomplished.

2. Design and install a portable high tunnel growing system that improves soil quality and management of water and fertilizer application to vegetable crops;

   A portable high tunnel growing system was designed, constructed and demonstrated the soil rotation potential as well as incorporating water and fertilizer application methods as described in more detailed in the methods section of this report. We view this deliverable as being accomplished.

3. Demonstrate a high tunnel frost mitigation system utilizing an electrically powered water pump system; and

   A high tunnel frost mitigation system was designed and built that runs off of solar generated DC power. The details and conclusions of this demonstration are described in the methods and conclusions section of this report. . We view this deliverable as being accomplished.

4. Document the design, installation, operation, and effectiveness of the project in a manner that it can be transferred to and used by others.

   The communication of our demonstration project findings have been described in previous Outreach section along with this final report. We do hope that some of the findings described in this final report can be incorporated into the NRCS high tunnel practice documentation. We view this deliverable as being accomplished.

Findings, Conclusions and Recommendations

This project demonstrated the use of some newer technologies that can help small farms grow produce with improved techniques that conserve and manage water resources better and can improve the plant and soil quality. On the whole the goals of the project were met with additional work still needed to fully validate a few areas. The following conclusions and recommendations are made from this project:

Moveable high tunnels are a viable tool in early season produce production on the small farm. The present USDA NRCS practices do not speak much to or encourage highly the use of moveable high tunnels. I believe the experience and techniques developed and demonstrated in this project can be used across the nation for farmers looking to install a high tunnel. The moveable high tunnel as designed brings the following benefits to the farmer:

- Simple rail structure that can be used with most high tunnel frame assemblies
- Simple attachment bracket to the rail system
- Benefits of a rigid frame to minimize wind, snow and movement damage
- Easy to use movement experience with log rollers and using disk tools to pull the tunnels
- Multi season use to maximize the tunnel investment over 2-3 different crops each year.
- Soil rotation improving plant soil quality and decreasing disease pressure
- Easier soil preparation with conventional tillage equipment
- Easier to add soil compost and minerals than conventional tunnels

We recommend that the high tunnel USDA NRCS practices be updated to encourage farmers to explore installing moveable high tunnels when they are looking to make an investment in a tunnel.

Some of the design techniques and movement techniques could be added to the NRCS practices to build off from the work performed in this project.

High tunnel irrigation using drip and dosing fertilizer injectors has been confirmed as a growing practice that results in high quality fruit. The moveable tunnel system is fully aligned with the use of drip irrigation and fertilizing dosing injectors. Even farms that grow organically can benefit from the dosing injectors as a way to incorporate expensive fertilizers and minerals directly into the plant root system.

Soil moisture sensing and control of irrigation water was explored in this venture and continues to show good promise. It does come with added complexity in the farm operation and although saves time and effort in the portion of water management that involves checking in on the plants during the day but it does add time and effort in managing the available water supply to remote fields. We believe the emerging technology is very encouraging, however, there are practical challenges involved with the time it takes to set up in the spring (a very busy time on the farm) and the management of a continuous supply of water. Farms that have pressurized water available at their site would not have the water availability concerns. More work is needed to optimize the ease of use of this technology to warrant the benefits especially in applications without AC power and without a constant water supply. We believe for certain water sensitive crops the benefits of controlled water still validate the need for this technology. We plan to continue this exploration in the seasons ahead.

Frost damage management within tunnels using circulating air fans is a technique that still requires further study. We were not able to draw any conclusions from this approach and technology to date. We do believe for this system to be practically acceptable a better method of temperature monitoring

and remote starting would be beneficial. The actual benefits to the plants are also not confirmed from our initial work. Further testing in the spring and fall seasons is planned and will continue until conclusions can be made.

It is our hope and intention that others in the farming community will be able to benefit from this demonstration project and be able to build upon this work to further the use of this technology in the future.