

carolina farm   
stewardship association

# High Tunnel Micro-irrigation Guide: A Practical Guide to Understanding and Implementing Micro-irrigation in High Tunnels

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## Introduction

High tunnels can be a great resource for farmers. The season extension capabilities provided by high tunnels can open up new opportunities and price premiums in the local market place. However, producing in high tunnels is different from field production and can be difficult to master. Although plants have the same water needs in both field and high tunnel production, irrigation requirements are very different. Due to the lack of rain fall, high tunnels require greater irrigation amounts. These irrigation amounts can be tailored to a crops water needs that change throughout its growth cycle. This controlled irrigation is what sets high tunnel production apart from field production in regards to matching crops and water needs.

Micro-irrigation can be defined as any irrigation system that frequently dispenses water in small amounts. This irrigation is often used on small farms and works well in vegetable production. Micro-irrigation helps to maximize high tunnel production through specialized watering schedules. Developing micro-irrigation plans in high tunnels can be affected by soil type and texture, plant water needs, microclimate considerations, and the type of micro-irrigation system employed. This handbook will provide a practical process to establish irrigation practices for various crops to be grown in a high tunnel.

## Soil

According to the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) conservation practice standard 325, High Tunnel System, the high tunnel is an enclosed structure where crops are grown in the '*natural soil profile*'. Thus, understanding soil properties are important in determining specific irrigation needs for crops produced in the high tunnel. Many soil factors affect irrigation needs. Determining soil type, texture, drainage, and water table levels can impact the amount of required irrigation. Soil type can vary based on geographical location, landscape, and geology. To find out your soil type, visit the [United States Department of Agriculture \(USDA\), Web Soil Survey](#). The Web Soil Survey serves as a resource to anyone interested in learning about the known properties of a specific soil type, including those relevant to its crop production capability. The site will generate maps that display the various soil types of a specific area. Figure 1 shows a soil map generated for the Lomax Incubator Farm in Concord, NC. The full soil report can be found in [Appendix A](#). The map includes lines that show approximately where certain soil types exist. Information included in the full report consists of soil type, composition, estimated slope, and other characteristics. For example, the majority of Lomax Farm is delineated as CuB2 which is Cullen clay loam, 2 to 8 percent slopes and moderately eroded soils.

In addition to utilizing the NRCS Web Soil Survey as a soils and crop management decision making resource, the NC State University Department of Soil Science maintains the [North Carolina Realistic Yield Expectations \(RYE\) database](#), which provides crop yield expectations under well managed conditions per soil type for many prominent NC production

and forage crop varieties. Understanding realistically achievable crop yields in well managed conditions may help facilitate producer decision making in irrigation management practice establishment.



Figure 1. Soil map of Lomax Incubator Farm generated from USDA Web Soil Survey (2016).

Knowing the soil type is important, but be aware that the soil in a tunnel can sometimes differ from mapped soil descriptions. Discovering the soil composition and texture in a high tunnel, along with knowing the general soil type of an area, helps to determine water holding capacities and drainage abilities. During the grading process for high tunnel construction, much of the top soil layer is sometimes removed which can affect soil texture. Other factors that impact high tunnel soil texture are past land use, soil amendments, mulching practices, tillage, and irrigation.

Soils are made up of three main texture types: 1. Clay 2. Silt and 3. Sand. Figure 2 shows the soil texture triangle which is used to determine soil texture. For example, a soil containing an estimated 35% Clay, 25% Sand, and 40% Silt would be classified as a clay loam. The main consideration in soil texture and irrigation requirements is water holding capacity and drainage.

Soils with larger particles, like sand, have increased drainage capacity. In contrast, soils with high clay content and small particle sizes drain slowly and typically have higher water holding capacity. This information will determine irrigation duration and frequency. For example, lettuce being grown in sandy soil will require more frequent watering with short duration. Soil texture will also impact plant spacing in regards to irrigation. Soils high in clay content will distribute water more widely as compared to sandy soils, see Figure 3. Therefore drip tape emitter spacing may need to be closer in sandy soils to provide an optimal amount for each plant root system. Also, sandy soils may require more drip lines per bed to optimize water distribution. Soil texture can be identified through lab testing or visual observations. You can also contact your local Cooperative Extension office for help with soil testing.

For more information on soil texture and how to determine the texture of a soil visit [Colorado State Cooperative Extension](http://colorado-state-cooperative-extension.org). The resource provides some “at home” methods to determine soil texture.

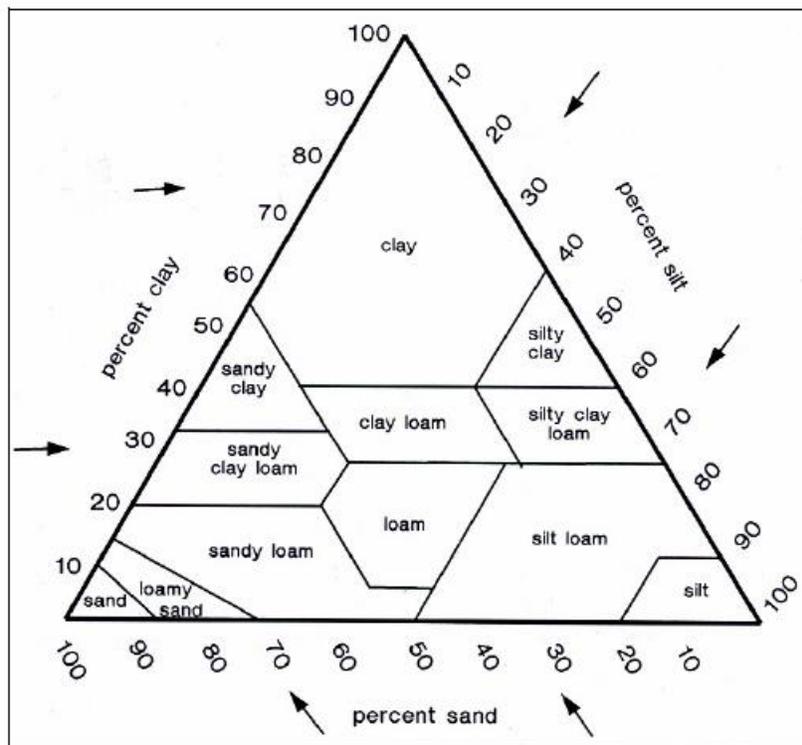
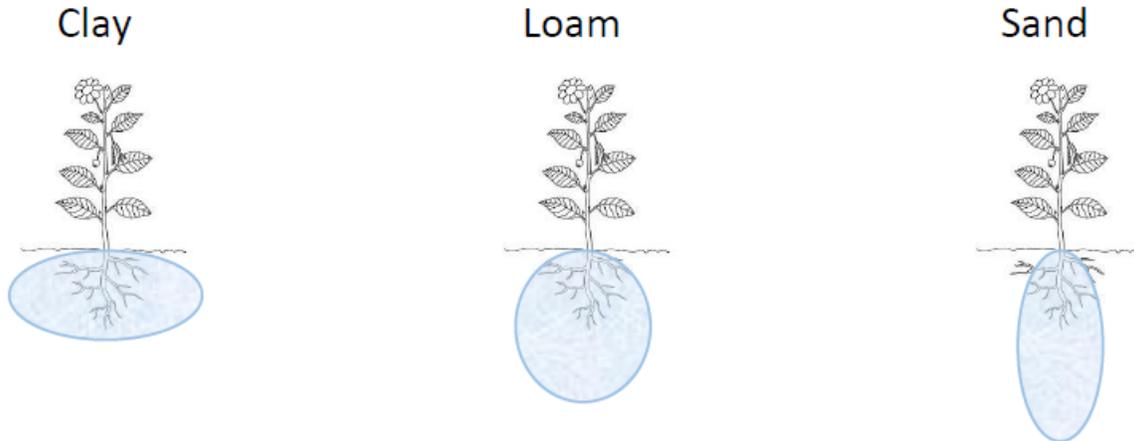


Figure 2. Soil texture triangle as displayed by Cornell University (2007). Arrows on sides indicate axis direction in triangle.

## Water Distribution and Soil Texture



*Figure 3. Representation of water distribution in clay, loam, and sand soil textures.*

Another soil related factor that impacts irrigation in high tunnels is the location of the water table. The water table is the depth at which naturally occurring ground water can be found. Water table depths vary depending on geographical location and can typically be determined by visual observation. Water tables that are within the plant root zone can provide some or all of the needed water for that crop. Therefore, understanding the water table depth may reduce or eliminate the need for irrigation. Causing fluctuation in the water table through irrigation can impact plant health. Nguyen and Walker (2005) studied the impact of irrigation on water table levels. The authors found that some irrigation practices can raise water levels and in turn cause water logging of plant root systems. Should water table levels rise through a plants root zone, damage and death can occur in certain crops. Although water table level may not be a factor for most, all farmers producing in high tunnels (and fields) should be aware of its depth and the potential impacts that may have on irrigation practices.

## Soil Wetness

The goal of irrigation, regarding soil moisture, is to saturate the soil around a plant's root system to field capacity. Plants must efficiently uptake water at soil wetness between field capacity and the permanent wilting point. Field capacity is when all excess water has drained from macro pores in the soil. The permanent wilting point is when the soil has little moisture, which causes plants to wilt and unable to regain turgidity. When checking soil moisture, soil should be moist yet still have open macro pores. The amount of water that is needed to reach field capacity for a specified area depends on soil type, texture, and microclimate factors.

## Plant Water Needs

All crops have different water needs. The water needs depend on species, variety, root depth/development, evapotranspiration rates, and other traits. Total water needs are also impacted by production time. Due to species and varietal differences, only crops with similar needs should be planted in the same row. For example, melons require more water than peppers. If both crops are planted in the same row, with the same irrigation line, in order to provide the needed water for melon plants, overwatering of peppers will occur. Become familiar with planned crops to understand water needs of each specific crop/variety.

Many crops have critical growth periods where certain amounts of water are needed. Typically, young transplants require less water as compared to mature plants. Water needs increase as the plant grows. This is not only due to general plant growth but also the increased surface area where evapotranspiration takes place. Most fruiting crops will require more water during flowering periods and while fruit is developing. Determining what the crop will require throughout its production time will increase crop success and minimize risk of water stress. To find optimal irrigation amounts for various vegetable crops visit [Vegetable Crop Irrigation](#) by North Carolina Cooperative Extension.

Finally, a plant's root structure will impact irrigation. For example, plants with deep root systems benefit from a longer watering duration as compared to plants which have shallow root systems. One goal of micro-irrigation is to only irrigate where the plant root system occurs. This maximizes water use by the plant and minimizes water loss. As discussed earlier, depth of irrigation is impacted by soil texture. Therefore, one must consider both soil texture and root system depth when determining duration and frequency of irrigation. Figure 3 shows a representation of plant cross-sections as displayed in *Bio-Intensive Approach to Small-Scale Household Food Production* (IIRR, 1993). The figure shows that different crops have different root structures. To learn more about critical growth periods and root system development of specific crops visit [Root Development of Vegetable Crops](#) by Weaver and Bruner.

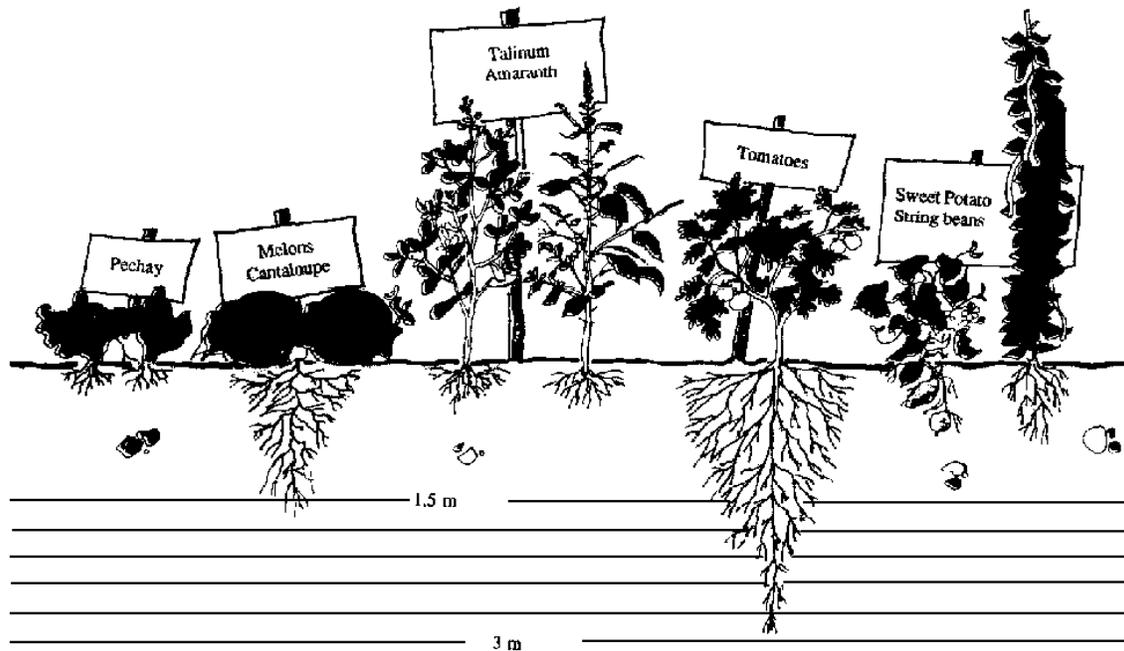


Figure 4. Representation of plant cross-sections provided by International Institute for Rural Reconstruction (1993)

## Microclimate Considerations

Environmental conditions greatly impact irrigation. Because high tunnels are protected structures, the internal microclimate has an effect on irrigation. Hot summer months tend to increase the need for irrigation due to evaporation from soil and increased plant evapotranspiration. Be sure to consistently check soil moisture during the summer months and increase irrigation frequency as needed. In early spring and late fall high tunnels can experience high humidity which can reduce or change irrigation needs. Pay close attention to leaf wetness and mold development during these times and be careful not to overwater or create unnecessary air moisture. One practice to reduce humidity during irrigation events is to increase ventilation.

Mulching also has an impact on irrigation needs. The most commonly used mulch in agriculture is plastic mulch. When used in conjunction with drip irrigation, the plastic is placed on beds over the irrigation lines and secured on either side of the bed. Plastic mulch helps to regulate soil temperature, reduce weed pressure, and minimize water loss through evaporation. When water loss is minimized, irrigation can be more easily managed. In a high tunnel setting, plastic mulch is most commonly used in warm season crop production. Other types of mulch that lend similar benefits are landscape fabric, straw, bark, and paper.

Irrigation can be used to achieve goals not related to plant water needs. For example, saturating the soil in early fall can reduce soil temperature and induce seed germination of cool

season crops. In order to saturate a soil, run irrigation for longer periods of time until beds are completely moist, or at field capacity.

Water retention and leaf wetness can be affected by the time of day that the irrigation is run. If overhead irrigation is used in the afternoon/evening, water loss due to evaporation is increased and leaf wetness is prolonged. Long periods of leaf wetness can lead to disease. If any type of irrigation is run during the heat of the day, loss from evaporation is going to be high. The best time to irrigate is typically in the morning. If a second watering is needed determine the best time based on your crop and microclimate/weather conditions. Setting up an irrigation timer can assist in consistent watering enacted at specific times during the day.

Finally, water can retain heat. Beds irrigated to field capacity will retain heat through periods of cold. Making sure that all beds have an adequate amount of moisture during the day can influence the air temperature throughout the night. This is specifically beneficial during colder months. By closing the high tunnel and allowing saturated bed to slowly release heat, a more stable (and warmer) air temperature can be achieved.

## **Types of Micro-irrigation**

There are several micro-irrigation systems that can be used in high tunnels. The micro-irrigation system needed is determined by the crop and conservation goals. The two main systems included in this handbook are drip irrigation and overhead irrigation. Drip irrigation is more commonly used because of its ability to conserve water by placing it directly in the plant's root zone. Overhead irrigation is more desirable if an even water distribution is needed throughout the tunnel. Overhead irrigation can be installed in a high tunnels truss system, at the ground level, or by using stakes and sprinkler heads. Overhead irrigation is commonly used for cover crops, lettuce, and seed germination within high tunnels. In any case, being able to have a seasonal irrigation set up is desirable so systems can be easily changed based on crop needs.

Drip irrigation is typically comprised of a header pipe at the front of the tunnel and one to three drip lines that run down each bed. Drip line, also called drip tape, is a long flat plastic tube with emitters or holes at varying distances. Common emitter spacing's are 6, 8, 12, and 18 inches. When the irrigation is turned on, water fills the flat irrigation line and begins to drip from of each emitter at a regular rate. Each drip line is connected to the header pipe via a fitting (typically a barb adaptor valve). Please note that most drip lines can only sustain water pressure of 12-15 PSI. To adjust water pressure, install a pressure reducer. A filter must also be installed to avoid clogging emitters with any particles that may exist in the water source. A backflow preventer may be helpful as well to avoid contamination of the main water source. Additionally, some areas may have local water codes that require the use of a backflow preventer. Finally, drip lines must be laid out with emitters facing upward. This also reduces

risk of emitters being clogged. Figure 4 shows an example layout of a drip irrigation system typical of high tunnel production.

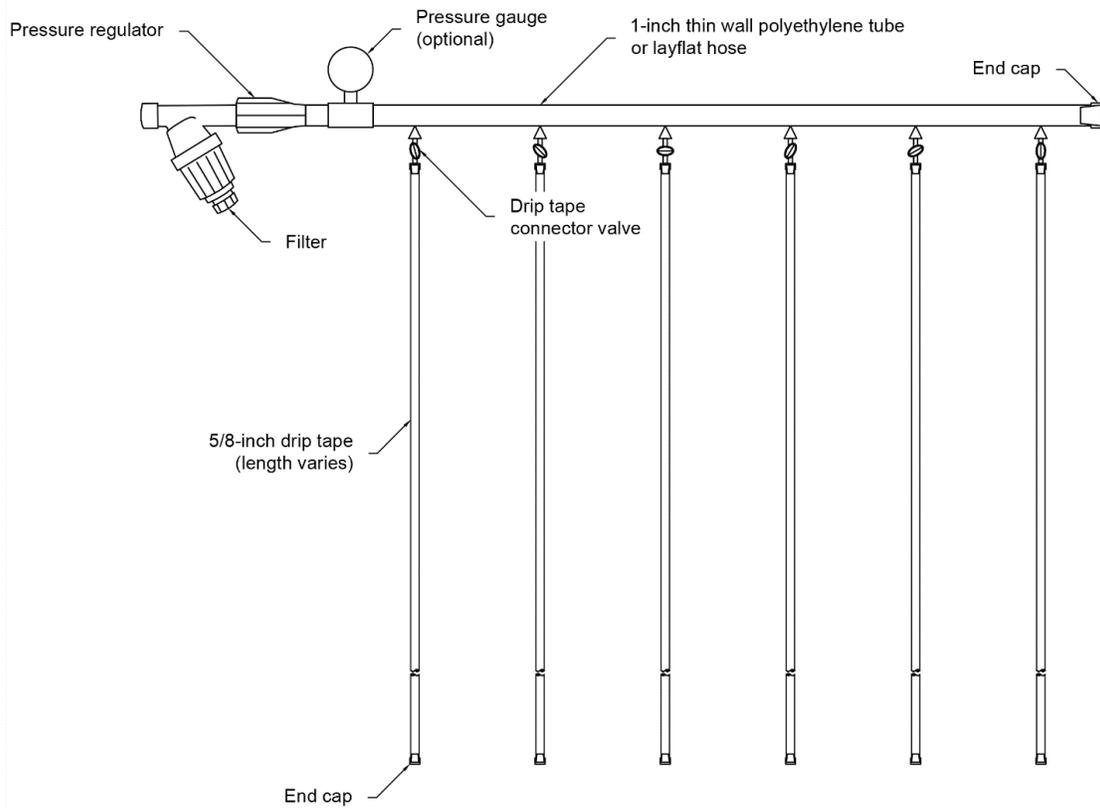


Figure 5. Drip irrigation example layout

Overhead irrigation is a “blanket term” for any type of irrigation system using sprinkler type heads. As stated before, sprinkler heads can be installed at ground level, in upper high tunnel bracing, or anywhere in between. The type of head used is determined by desired water amount and area to be watered. These systems require header pipe, tubing, sprinkler heads, and an attachment to secure sprinkler heads in place. You may also need a pressure reducer/regulator, filter, and backflow preventer. Figure 5 shows an overhead irrigation system installed in a high tunnel. Overhead irrigation is typically used for cover crops although it can be used for lettuce and other direct seeded crops as well. Using overhead irrigation for some vegetable crops can cause high leaf wetness and increase disease risk. This type of irrigation is also less water efficient as compared to drip and should be used only when necessary and there is adequate water supply.

The USDA NRCS provides additional technical guidance on design and implementation of micro-irrigation and surface/subsurface irrigation systems in its [Field Office Technical Guide \(FOTG\)](#) conservation practice standards developed for each of these irrigation techniques. Conservation Practice Standards are included in Section IV of the FOTG.



*Figure 6. Overhead irrigation system in a high tunnel*

## **Irrigation Capabilities**

The capability of a micro-irrigation system will depend on water source, water pressure, and materials used. Most micro-irrigation systems require a specific water pressure. Water pressure can be easily reduced through the use of a pressure regulator. Low water pressure is not as easily adapted. Increasing the elevation of a water source or using a pump can increase water pressure. Usually spring fed water sources and any water source from a holding tank may have low water pressure. If using pumps, be aware of the pressure the pump is creating as excessive water pressure can cause damage to the irrigation system.

Something else to consider with irrigation set up is the flow rate capabilities of a header pipe. Header pipes can be connected directly to a water source or to a water hose. The hose distance from the water source to the header pipe can affect pressure and in turn flow rate. Also, the diameter of a header pipe in contrast to the number of drip lines can impact flow rate and water distribution. An irrigation system with six beds and two 5/8" drip lines per bed would benefit from a 1" diameter header pipe. A larger diameter header pipe can more effectively supply a larger number of drip lines. A smaller diameter header pipe may not have an adequate flow rate to provide equal distribution of water to multiple drip lines. Having a 1"

header pipe in a high tunnel irrigation system would give the flexibility to use few or many drip lines.

Another helpful tool to use in micro-irrigation is a pressure gauge. Pressure gauges can be installed at a header pipe or at the end of a drip irrigation line. In some cases, the pressure can vary within an irrigation system. By checking the pressure at the end of a dripline, you can ensure that there is a constant flow through the entire system.

## **Fertilizer Injection**

Injecting fertilizers, or Fertigation, is easy in micro-irrigation systems. Specifically, drip irrigation systems are ideal for Fertigation. There are many organic and conventional products that can be used in Fertigation, however the fertilizer needs to be completely soluble to avoid clogging the emitters. Injectors have varying capabilities in regards to function. Talk with your irrigation supply professional before purchasing in order to best match your needs with an injector.

## Calculations

Many farmers and gardeners create their irrigation schedules based on checking plant health and soil moisture. This model works well for those experienced in plant production and many see success by basing their irrigation need from visual observations. However, having the ability to calculate irrigation amounts has benefits. Calculating irrigation amounts can help avoid over or under watering certain crops. Also, through calculating and planning irrigation amounts you can provide adequate water amounts during critical crop times to maximize production. A few pieces of information are needed to be able to calculate water amounts and create irrigation plans.

- 1. Square feet of irrigated area. This can be calculated per tunnel or per bed depending on micro-irrigation system.**

Consider a 30' x 96' high tunnel with 6 beds. Each bed is 2.5' x 90'.

$$2.5ft \times 90ft = 225ft^2 \text{ per bed}$$

$$225ft^2 \times 6 \text{ beds} = 1,350ft^2 \text{ for total irrigated area}$$

- 2. Desired water amount. This could be in total gallons, weekly gallons, or inches of rain. Most available information will provide amounts in inches of rain. Note that this may change through the plant's production cycle and thus new calculations generated.**

Lettuce plants require  $\frac{1}{7}$  inch of rain per day (Sanders, 1993) which adds up to one inch of rain per week. This needs to be converted to gallons per day. We know that one inch of rain on one acre equals 27,154 gallons of rainwater. We also know that one acre equals 43,560ft<sup>2</sup>. Therefore, one inch of rain on 43,560ft<sup>2</sup> equals 27,154 gallons of water.

$$27,154 \text{ gallons} \times \frac{1}{7} = 3,879.14 \text{ gallons}$$

This means that 3,879.14 gallons equals  $\frac{1}{7}$  inch of rain on one acre. This amount will change based on the total square feet being watered! So now we use the 1,350ft<sup>2</sup> from above.

$$\frac{3,879.14 \text{ gallons}}{43,560 \text{ ft}^2} = \frac{X \text{ number of gallons}}{1,350 \text{ ft}^2}$$

Cross multiply to solve for X!  $\frac{3,879.14 \text{ gallons} \times 1,350 \text{ ft}^2}{43,560 \text{ ft}^2} = 120.22 \text{ gallons}$

This means that we need 120.22 gallons of water each day in order to irrigate our lettuce, produced on 1,350ft<sup>2</sup>, to reach  $\frac{1}{7}$  inch of rain.

- 3. Output of irrigation system. This information is displayed on most products. There will be math involved, see below. For drip irrigation, the output per emitter, emitter**

**spacing, and length of lines used are required. For sprinkler, the output per head at a specific water pressure and number of heads used are required.**

Figure 6 is an example of a tag that would be located on a roll of drip line. The important information to know is the emitter spacing which is 12 inches, the gallons per hour (GPH) which is 0.24GPH (per emitter) and recommended pressure per square inch (PSI) which is 10PSI (15 max PSI). Be sure to check the PSI of your irrigation system, this will affect the use of pumps and/or pressure reducers. The below calculations reflect a systems regulated to 10PSI.

Flow Rate	Spacing	Length
0.91 L/H	.3 m	2743 m
0.24 GPH @ 10 PSI	12 in	9000 ft
<b>Maximum Pressure 15 PSI</b>		

Figure 7. Drip line information

If we determine how many GPH our entire irrigation system is dispensing, we can determine the length in minutes or hours that we need to run the irrigation.

Consider the needs of the lettuce and soil. Assuming we plant three rows of head lettuce at 12 inch in-row spacing on a clay-based soil. Three drip lines, one for each row of lettuce would be best. Since the lettuce is spaced at 12 inches and we have 12 inch emitter spacing, one head of lettuce can be planted at each emitter. This model will maximize water use and conservation. Determine the total number of emitters used in the high tunnel. We know that each bed is 90' and has three drip lines.

$$90 \text{ ft} \times 3 \text{ drip lines} = 270 \text{ ft of drip line per bed}$$

$$270 \text{ ft of drip line} \div 1 \text{ ft emitter spacing} = 270 \text{ emitters per bed}$$

$$270 \text{ emitters per bed} \times 6 \text{ beds} = 1,620 \text{ total emitters}$$

Now multiply the total number of emitters by the 0.24 gallons per hour at 10 PSI listed on the tag.

$$1,620 \text{ total emitters} \times 0.24 \text{ GPH} = 388.8 \text{ GPH for the entire system}$$

From above we know that we need 120.22 gallons of water a day. And now we know that in one hour, our system will put out 388.8 gallons of water in one hour.

$$\frac{60 \text{ minutes}}{388.8 \text{ gallons}} = \frac{X \text{ minutes}}{120 \text{ gallons}}$$

Cross multiply to find X minutes!  $\frac{60 \text{ minutes} \times 120 \text{ gallons}}{388.8 \text{ gallons}} = 18.52 \text{ minutes}$

Now we know that we need to run our irrigation for 18.52 minutes every day in order to water the lettuce  $\frac{1}{7}$  inches daily which adds up to one inch of rain per week.

#### **4. Weather or microclimate information.**

Although we know that we need to run the irrigation 18.52 minutes, this amount may need to be adjusted due to microclimate factors. If this is summer lettuce production with no plastic mulch, the amount may need to be increased to around 30 minutes to mitigate the effects of evaporation. This could be divided into two 15 minute cycles per day. These adjustments will need to be made based on weather information and visual observations. Late fall lettuce production would not be subject to excessive evaporation and thus irrigating for 18-19 minutes once a day would be most appropriate. In some cases, lettuce would not require daily irrigation due to microclimate conditions.

#### **5. Soil Texture**

Soil texture will influence the amount and duration of irrigation as well. For example, in clay soils the calculated 18.52 minutes once a day would be a good protocol to follow. However, if the soils have high sand content the irrigation amounts may need to be increased and divided between two cycles a day, potentially two 10 minute watering cycles a day. In some cases, lettuce will not require daily irrigation due to soil texture.

## **Conclusion**

Fitting a micro-irrigation system to a specific high tunnel environment can be easy and effective. Combining knowledge of the soil, microclimate and plant needs can result in a micro-irrigation system and plan geared towards healthy plants and maximum productivity. Various systems and layouts can be installed in high tunnels to fit specialized production needs to match various crop requirements. More resources on irrigation are listed in this guide to help determine soil information, crops needs, and other factors impacting high tunnel micro-irrigation. For further help, consider applying for [High Tunnel Consulting](#), a free service provided to all CFSA farmer members.

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## Additional Resources

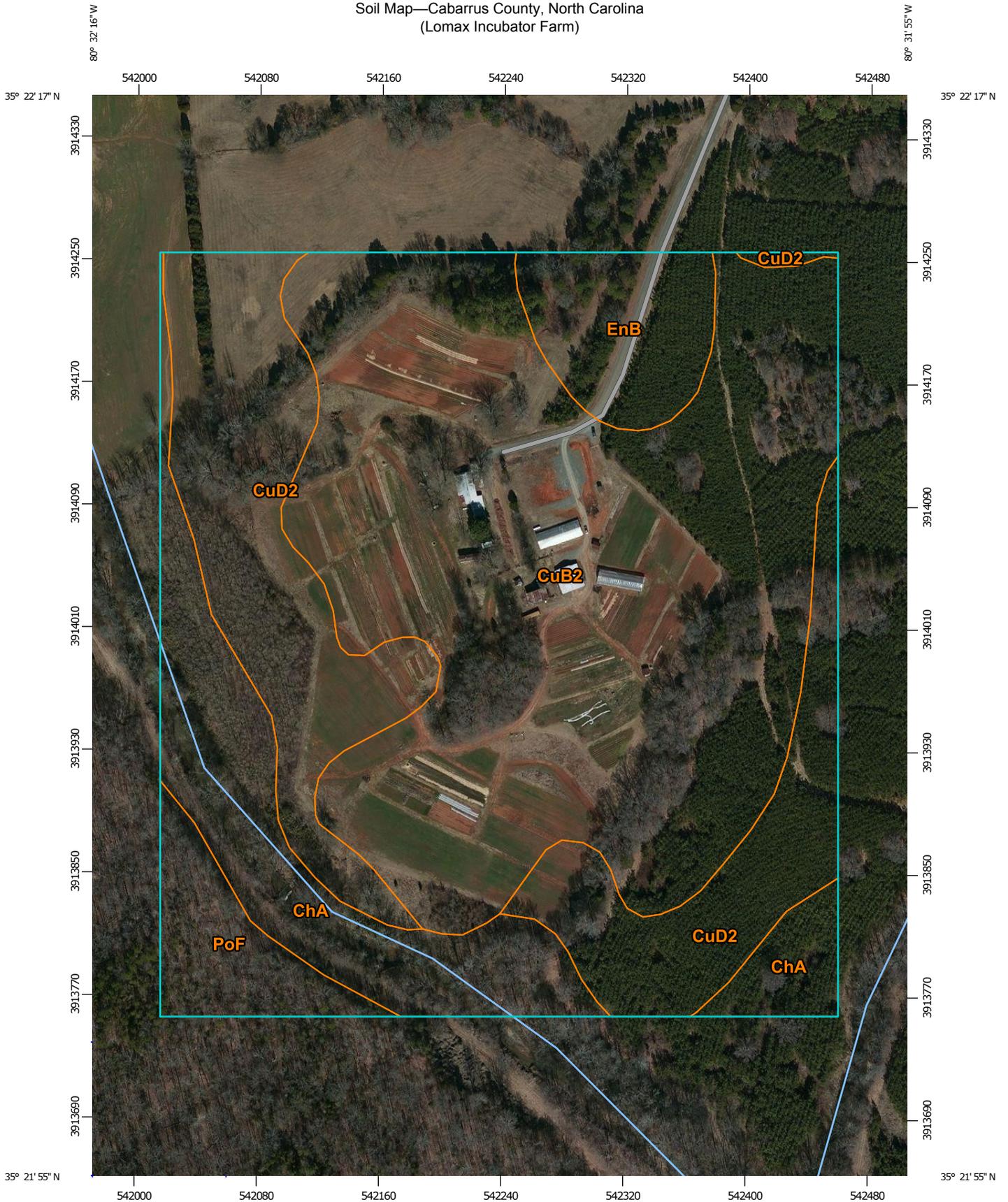
- Examination and Description of Soils  
[http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2\\_054253](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253)
- Web Soil Survey  
<http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>
- Northeast Region Certified Crop Advisor, Study Resources  
<https://nrcca.cals.cornell.edu/soil/CA2/CA0212.1-3.php>
- Root Development of Vegetable Crops  
<http://soilandhealth.org/wp-content/uploads/01aglibrary/010137veg.roots/010137toc.html>
- Vegetable Crop Irrigation  
<https://content.ces.ncsu.edu/vegetable-crop-irrigation>
- Drip Irrigation Consideration in High Tunnel Production Systems  
[http://extension.missouri.edu/webster/documents/presentations/2013-05-21\\_HighTunnelWorkshop/2013-05-21\\_High\\_Tunnel\\_Drip\\_Irrigation-BobSchultheis-screen.pdf](http://extension.missouri.edu/webster/documents/presentations/2013-05-21_HighTunnelWorkshop/2013-05-21_High_Tunnel_Drip_Irrigation-BobSchultheis-screen.pdf)
- Rainwater Catchment from a High Tunnel for Irrigation Use, a PDF  
[www.sare.org/content/download/66033/929147/PM3017.pdf?inlinedownload=1](http://www.sare.org/content/download/66033/929147/PM3017.pdf?inlinedownload=1)
- Irrigation Watering Strategies  
<http://hightunnels.cfans.umn.edu/management/irrigation/irrigation-watering-strategies/>
- SARE High Tunnel Topic Room  
<http://www.sare.org/Learning-Center/Topic-Rooms/High-Tunnels-and-Other-Season-Extension-Techniques>
- Natural Resource Conservation Service  
<http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/>

## References

- Cornell University Cooperative Extension. (2007). Soil texture. Retrieved from [http://water.rutgers.edu/Rain\\_Gardens/factsheet29.pdf](http://water.rutgers.edu/Rain_Gardens/factsheet29.pdf)
- International Institute of Rural Reconstruction. (1993). *Bio-intensive Approach to Small-scale Household Food Production*. Silang, Philippines: International Institute of Rural Reconstruction.
- Natural Resources Conservation Service. (2016). Web soil survey. Retrieved from <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>
- Nguyen, H. T., Walker, J. P. (2005). The effect of irrigation schedules on water table depth and root zone soil moisture. *The Modelling and Simulation Society of Australia and New Zealand*, 1286-1292.
- Sanders, D.C. (1993). Vegetable crop irrigation. Retrieved from <https://content.ces.ncsu.edu/vegetable-crop-irrigation>

## Appendix A Below

Soil Map—Cabarrus County, North Carolina  
(Lomax Incubator Farm)



Map Scale: 1:3,440 if printed on A portrait (8.5" x 11") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84



## MAP LEGEND

### Area of Interest (AOI)

 Area of Interest (AOI)

### Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

### Special Point Features



Blowout



Borrow Pit



Clay Spot



Closed Depression



Gravel Pit



Gravelly Spot



Landfill



Lava Flow



Marsh or swamp



Mine or Quarry



Miscellaneous Water



Perennial Water



Rock Outcrop



Saline Spot



Sandy Spot



Severely Eroded Spot



Sinkhole



Slide or Slip



Sodic Spot



Spoil Area



Stony Spot



Very Stony Spot



Wet Spot



Other



Special Line Features

### Water Features



Streams and Canals

### Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

### Background



Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service  
Web Soil Survey URL: <http://websoilsurvey.nrcs.usda.gov>  
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cabarrus County, North Carolina  
Survey Area Data: Version 14, Sep 9, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Feb 11, 2011—Feb 13, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

## Map Unit Legend

Cabarrus County, North Carolina (NC025)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
ChA	Chewacla sandy loam, 0 to 2 percent slopes, frequently flooded	7.5	13.6%
CuB2	Cullen clay loam, 2 to 8 percent slopes, moderately eroded	29.3	53.3%
CuD2	Cullen clay loam, 8 to 15 percent slopes, moderately eroded	12.8	23.4%
EnB	Enon sandy loam, 2 to 8 percent slopes	3.0	5.5%
PoF	Poindexter loam, 15 to 45 percent slopes	2.3	4.3%
<b>Totals for Area of Interest</b>		<b>54.9</b>	<b>100.0%</b>