# No-Till Systems at Dilmun Hill: Building Soil Health and Utilizing Marginal Land

Dilmun Hill Student Organic Farm, Cornell University

Final Report 2013

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Project Overview:

This season, the project team installed and evaluated two novel no-till strategies: a no-till permanent raised bed system and a no-till forest gardening system. The first installation was constructed to evaluate no-till methods for annual crops (figure 1). The second approach, the forest gardening system, was constructed to evaluate no till methods for perennial crops (figure 2). This project, through both installations, targeted conversion of marginal land into productive crop gardens.

Throughout project implementation, a critical goal was to strengthen the knowledge base for organic no-till production, and to disseminate that knowledge through on-site workshops and anecdotal results. Specifically, we sought to provide knowledge of these transformative organic farming strategies to Cornell students, faculty, the local community, and a broader online audience of individuals throughout New York State and the Northeast. As our project comes to an end, we feel confident saying that we were able to provide particularly rich educational opportunities for smaller-scale gardeners. In many urban and periurban farms and backyards the lack of access to high quality or sizeable tracts of land, and the lack of access to sufficient capital or labor resources, discourages individuals from growing their own food, however this project was successful in providing a model for small-scale gardeners to sustainably produce food on marginal land.

Part One: The No-Till Market Garden (Emily Burrichter)

Why convert to no-till or reduced tillage?

There were two issues we faced in our market garden that we thought were significant constraints, and which we wanted to address through a new design scheme and management plan. The first was compaction, which had become a real problem in recent years with more and more volunteers, classes, managers, and visitors walking through the garden. According to the Cornell Soil Health Manual, the likely causes of soil compaction are traffic when soil is wet, tilling wet soils, heavy equipment and loads, and uncontrolled traffic. It can result in poor seedling emergence and stand establishment, poor water infiltration and increased occurrence of erosion and runoff, reduced root growth, less active microbial communities, and reduced aeration. We had been noticing many of these effects in the garden, at least those that showed direct effects. Root crops were unable to penetrate the soil to grow harvestable yields, seeds would not germinate due to soil crusting, and standing water was unable to infiltrate through the compacted soil. This is a soil health issue that needed to be addressed to promote sustainable production at our current location.

Another constraint that we began noticing, and which is also tied to soil compaction, was the occurrence of runoff and erosion. Because of the nature of the landscape, which is sloped on 3
sides of the market garden, our site is more vulnerable to these occurrences. In addition, our poor soil health contributed to the erosion. The objective of this project in the market garden was to try to mitigate these issues through design and management. The design was implemented this season (2013) and the management, which is based on no-tillage, will be an ongoing process.

**New and Improved Design**

The new design of the garden started with changing the direction of the beds. Prior to this season, the beds were laid out parallel to RT 366, meaning they were lined up with the slope rather than against it. Consequently, water runoff and soil erosion became an issue. If we got a heavy rain, water would collect in the walkways and flow right down the hill, taking precious topsoil soil with it as it travelled. An easy fix to this problem is to lay out the beds so that they are contoured to the slope. This way, when water lands on the garden and collects, it is slowed down by the beds and has more time to infiltrate the soil.

The second major design challenge was to follow those contour lines to form 4 foot raised beds and 2 foot walkways in between. This process had to be well thought out and carefully planned since the system was being converted to no-till, and therefore the fundamental design would be permanent. We thought 4 foot beds would be more appropriate than the more narrow beds formerly in the market garden because the wider beds lead to fewer walkways, and an overall greater amount of bed space and more efficient utilization of the area.

![Figure 1. First day of transplanting! May 2013](image-url)
Implementation

The design process began last winter when we laid the groundwork for changes we could implement to address our soil health issues. After deciding on a reduced tillage system, we had to make decisions about how it would fit into our current structure and landscape. Managing a no-till system is something that will be a learning experience for all future market garden managers, so setting up a simple, easy-to-maintain design was important. We also brainstormed ways we could share our experience with organic no-till gardening with the community. That’s when we started talking to local schools and organizations that may be interested in coming to learn about our project, both the no-till market garden and the developing permaculture garden. In May 2013, we began the first stages of physically transforming the space. We spent a weekend in Mid-May mapping out the contours in the garden, and then used flags to mark the outline of the beds to follow. Steve McKay, farm manager at the HC Thompson Research Farm from Cornell University Agricultural Experiment Station came to form the beds, which consisted of primary tillage as well as rototilling before using the bed maker to form 4 foot beds. Once this was complete, we could start transplanting our seedlings into the garden and spreading wood chips in the walkways. There was also ⅓ of the garden that was seeded in cover crop for the season due to poor soil structure and aggregation. Below is a basic schematic of the timeline from our grant proposal submission to implementation.

Results

Part of the inspiration for this project was the seemingly lack of information on no-till small-scale vegetable production. We figured many gardeners and small farmers must be facing similar soil health problems similar those at Dilmun and so we wanted to experiment with the potential for this kind of system. The lack of information added a challenge to our project, but it also provided a perfect environment for experiential learning, one of the core tenants of Dilmun’s mission. From whole landscape design to protecting the smallest critters in the soil, this project proved to be holistic and expansive in its learning potential.
Our specific objectives outlined in our proposal were as follows:

**Specific Objectives**

**Research:**

- Assess the annual productivity (performance yields) of two no-till systems: a permanent raised-bed annual crop garden and a permaculture perennial-based food forest. Compare the performance of each no-till system to the performance expectations of comparable tilled organic production systems.
- In each system, monitor select chemical, physical, and biological parameters to assess soil health and landscape water dynamics, including: organic matter content, microbial activity, water percolation, soil compaction, and site biodiversity.
- Assess selected biological methods for excluding weeds from no-till garden areas.

We will be addressing the first objective by comparing records of past vegetable yields (as fresh weight) to those we will be getting starting next season, which will be considered the first season in no-till. This expectation will be made clear to the managers of the garden, so we are able to consistently get data to compare.

For the second objective, we are collaborating with the CSS 2600 Soil Science class to obtain soil data on organic matter content, water percolation, soil compacting, as well as other physical and chemical characteristics. As for the biology of the soil, which is where we expect to see a significant amount of change following the switch to no-till, we will be recording qualitative data. This may include observations of greater soil organisms such as earthworms and other decomposers, as well as more efficient organic matter turnover and nutrient recycling. As for the soil erosion problem we established before the start of this project, we observed some interesting trends. It was a fairly wet season, compared to 2012, and so the conditions for observing water infiltration and soil erosion were fairly good. We found that, in general, there was an improvement in water infiltration. However, the problems we did see were in the beds and walkways furthest down the slope. In the walkways where we planted the Solanaceae crops, we observed frequent puddling. This was probably due to water infiltrating higher up in the garden and flowing down to lower elevations at the East end of the garden. Although there is definite improvement in water infiltration from previous years, we are hoping that it continues to improve as organic matter builds up and soil health improves.

The third objective alludes to the common challenge in no-till systems, which is weed management. Since neither herbicides nor tillage are options in our system, we had to be creative about our weed management strategy. In the two major pathways through the garden that divide it into three sections, we decided to have sod to prevent weeds from establishing. In the walkways between each of the beds, we put down a heavy layer of wood chips to keep weeds under control. Finally, in the beds, we decided that adding substantial enough organic amendments in combination with hand weeding would be sufficient. Part of the plan is to seed
cover crops in the beds at the end of every season to add biomass and keep the soil covered in the spring for weed suppression. Below is a visual of our crop rotation for last season and the layout of the garden.

Another important aspect of the new design was the installation of sod in the two major pathways that divide the garden into three major sections, as seen in the image above. The sod was generously donated by Saratoga Sod, and was implemented to prevent weeds from establishing in those wide pathways and to improve the aesthetic value of the garden. It also proved to be a tough lesson in how to install sod! Below is a picture of the sod being laid down by Dilmun’s four female managers!
The Future of the Project

The responsibility for the maintenance and data collection of the garden will fall to the annual market garden managers. The annual maintenance requirements include adding wood chips to the walkways, composting the beds, and cover cropping the beds at the end of the season. In terms of data collection, many of the basic soil tests are measured by Professor Russell-Anelli’s Soil science class and can be used to help us monitor our soil health. The managers are responsible for obtaining this data and compiling it to publish in the Farm Report at the end of the season. Other data collection will include observations on overall soil health and crop growth.

We consider this project a huge success, not only did we complete what we needed to do to convert the garden to no-till and begin improving soil health, we also found unforeseen benefits from the changes we’ve made. The beds are easier to access with tools and wheelbarrows, the layout is more conducive for giving tours and it is generally more aesthetically pleasing. We are excited to see how the garden progresses from here, and the effects we will see in both soil health and crop growth.
Part Two: Hillside Perennial Garden *(Liz Camuti)*

*Why Hillside Farming?*

While Dilmun actively cultivates about an acre of annual crops annually, much of the 11 acres the farm is situated on are unused or used very infrequently. Most of these underused areas are situated on very steep slopes. We recognized that this is the situation for many landowners and farmers in the Northeast — rarely is an entire tract of land in ideal condition for our traditional means of food production. Rather than leaving these sloped lands untouched, we pulled on the principles of permaculture to design and construct a hillside demonstration garden that not only produced food but was more resilient to the soil erosion commonly associated with hillsides. Figure 3 is the garden site in the initial stages of installation.

We also chose our location due to its proximity to the front of the farm (more on that choice later). Not only did we want to call more attention to the farm, which is often overlooked by
passer-bys but we also chose the steepest slope on the land and the one that was most readily accessible. Figure is the new garden in the initial stages.

Figure 2. The initial design for the new garden

Figure 3. The garden in the beginning stages
Installation

I. Contoured Swales

In order to prevent soil erosion on the hill, the first thing we did was dig out contoured swales. These harvesting swales were laid out and dug along contours (which we marked with a laser level), which created long, skinny reservoirs that interrupt and capture soil-eroding water runoff as it flows downhill. After the swales stop the runoff water they hold it in place where it can then soak into the ground to create an underground reservoir.

In order to build these swales, we used our BCS walk behind tiller. After marking the contours with a laser level we made several passes with the BCS while threw dirt down the hill, as we went, easily making berms downhill which we would plant into. After we were finished with the BCS, with the help of a few volunteers we further dug out the swales to prevent them from eroding back into the earth then filled the ditch area of the swales with cardboard and wood chips to prevent plants from growing in these ditches. While we would eventually grow plants in the berm areas of the swales, the ditches served their ecological purpose within the landscape while also serving as pathways through the garden.

We consider these contoured swales our most permanent and successful piece of this project. Not only will they remain intact with little maintenance in years to come, but they have proved successful even in this first year of installation. We experienced a very wet summer and even when other, higher elevations experienced flooding, there were no signs of flooding in this very low area of the farm (where there had been in previous years). Our next indicator will be the
growth of the trees we planted that we will see over the next couple of years. We expect them to 
thrive as the swales help create an underground reservoir.

II. Perennial Plants

a. Perennial Vegetables
We were able to purchase some different varieties of perennial vegetables from Jonathan 
Bates of Paradise Lot in Amherst, MA and from Sean Dembrosky, the owner of Edible 
Acres in Trumansburg, NY. With the help of two of our PI’s Ken Mudge and Steve 
Gabriel, we were also able to take cuttings from the Cornell Orchards and propagate 
them.

From Jonathan Bates we purchased:
5 sea kale plants
5 perennial arugula plants
10 alpine strawberries
5 maximillian sunflowers
3 welsh onions, 3 egyptian onions, 3 bunching onions
5 ground nuts

From Sean Dembrosky we purchased:
1 Curly Willow Tree
1 Carpathian Walnut Tree
1 Blackberry
2 Raspberry Transplants
2 Malibar Spinach Seedlings
1 Bolivian Rainbow Pepper Seedling
2 Skirrets
2 Peruvian Purple Potatoes

Cuttings from McDaniels Nut Grove (to be planted in the garden in Spring 2014):
    Seaberry
    Elderberry
    Juneberry
    Gooseberry

We also purchased some miscellaneous flowers from the Cornell Cooperative Extension. We 
consciously tried to purchase only perennial varieties of plants so as not to have to till 
and replant every year on the steep slope. As it is a teaching garden, it was important for 
us to incorporate lesser known varieties of popular annual crops such as carrots and 
potatoes, so that we could teach people how to farm in a less invasive way (without
having to till and replant crops every year). We were surprised with how well these perennial varieties did in the garden, even after a late frost threatened to kill them right after transplanting. Everything that was damaged by the late frost bounced back or regrew and was thriving by mid-July.

b. Polycultures

Building polycultures is the practice of planting a community of interrelated, interdependent plants, mimicking the complex relationships that are found between plants in nature. In the case of food producing crops, a perennial polyculture tries to set up conditions where you can almost continually eat or of your garden. The faster growing plants protect the tender ones from the sun and the thickness of these planting clusters eliminates weeds while functioning as a living mulch to keep the soil moist and cool.

While building and planting the garden, we experimented with numerous polycultures (listed below). We did extensive research on permaculture plant databases and blogs to figure out what kinds of functions different polycultures could serve and which plants could depend on each other — this mainly involved picking plants at different levels (groundcover, vine, root crop, shrub etc.) and understanding how they would benefit one another with their different functions.

As the different plants within each polyculture grow and spread out, as perennial plants do, we are interested in seeing how they will interact with each other and act in symbiosis. As with most projects based in perennial plants, it may be years until we have a fully functioning ecosystem with visible interactions among them. However, in this first year we have been impressed with their vigor and think the future is promising.

Example Polyculture Found in the New Garden:

<table>
<thead>
<tr>
<th>Perennial Three Sisters</th>
<th>Full Sun</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Helianthus</td>
<td>tuberosis</td>
<td>Sunchoke</td>
<td>Edible tubers, scaffold for groundnut; tall herb</td>
<td></td>
</tr>
<tr>
<td>Apios</td>
<td>americana</td>
<td>Groundnut</td>
<td>Edible Tubers beneficial insects, n-fixing; vine</td>
<td></td>
</tr>
<tr>
<td>Stachys</td>
<td>officinalis</td>
<td>Wood Betony</td>
<td>Ground cover, beneficial insects; good tea plant. Helps relieve headaches, makes a good tonic</td>
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</table>
Other Polycultures in the Garden:

<table>
<thead>
<tr>
<th>No Weed Asparagus</th>
<th>Full Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>officinalis</td>
</tr>
<tr>
<td>Fragaris</td>
<td>x annanasa</td>
</tr>
<tr>
<td>Phaseolous</td>
<td>coccienus</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Eccentricity Polyculture</th>
<th>Perennial Snack Patch</th>
<th>Stir Fry Polyculture</th>
<th>Hidden Feast Polyculture</th>
<th>Annual Necessities</th>
</tr>
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<tbody>
<tr>
<td>Curly Willow</td>
<td>Sea Kale</td>
<td>Perennial Arugala</td>
<td>Skirret</td>
<td>Garlic</td>
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<tr>
<td>Amaranth</td>
<td>Alpine Strawberries</td>
<td>Welsh Onion</td>
<td>Peruvian Purple Potato</td>
<td>Leeks</td>
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<tr>
<td>Nasturium</td>
<td>Egyptian Onion</td>
<td>Walking Onion</td>
<td>Jerusalem Artichoke</td>
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<tr>
<td>Yarrow</td>
<td>Perennial Arugala</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welsh Onion</td>
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III. Black Locust Stairs

In order to make the garden both more interesting and more accessible, we added several sets of Black Locust log stairs. We bought 14 logs for $100 from a friend. We chose Black Locust because the wood is resistant to rot and will hold up with little maintenance as stairs. This simply addition truly transformed the garden into an enjoyable, defined space that groups were interested in exploring.
Ethan and Liz prepare the Black Locust logs by stripping off the bark.

IV. Trellising

It quickly became apparent that our choice of location — though visible and intriguing from the road — had some drawbacks. Mainly, when leading groups it was often hard to hear over the noise of the road and we have in the past had complaints from drivers saying activities at Dilmun were driving distractions. To combat these issues, Ethan built two trellis systems that are to be used for growing hops. The trellises are still visible from the road and create intrigue but help combat the noise and screen out distractions that the location can cause. In early spring 2014, we will be transplanting hops to the trellis system from our Growing Mosaics Garden where they have become invasive to this new garden. This fits in with our mission to create functional, aesthetically-pleasing and environmentally sustainable solutions to challenging agricultural landscapes.
Jonathan Bates Workshop

With money from TSF, we were able to bring Jonathan Bates, contributing author of “Paradise Lot: Two plant geeks, one-tenth of an acre, and the making of an edible garden oasis,” to Dilmun Hill on May 13, 2013. Drawing on his experience working with his 10-year-old edible forest in Holyoke, MA, Jonathan used the principles of permaculture design to lead a hands-on workshop about the uses of uncommon fruits and perennial vegetables, and the benefits of different plant guilds. Workshop participants worked with Jonathan to craft their own polycultures in Dilmun Hill's new permaculture garden.
We purchased plants from Jonathan ahead of time and he brought them to the farm where we did an hour lesson on the benefits and uses of these perennial crops. In the second hour, volunteers / workshop participants worked with Jonathan to design and plant their only polycultures in this new garden. Overall, we had about 15 participants at this free workshop and considered it a great success. Though we were hit with a frost the next week, all of the plants Jonathan brought survived and the knowledge we gained through the workshop stuck with us throughout the rest of the installation phase.

**Ben Falk Workshop**

On October 25, 2013, with the help of TSF funding, more than 40 farmers, gardeners and students joined us at Dilmun Hill for an interactive tour with permaculture expert and author, Ben Falk of Whole Systems Design in VT. The tour was followed by a presentation in the Plant Science building which more than 70 people attended leaving standing room only.

![Ben Falk leading an interactive tour at Dilmun Hill](image)

Given our project this year Ben’s tour and presentation ended up being the perfect culmination to everything we had worked on. He walked around the farm point out places we could expand our project and using Dilmun as an example for teaching people to create closed loop no-till systems. Ben illustrated how daunting issues of our time, such as dwindling energy resources and climate
change, require us to reexamine core agricultural principles. Ben explained that our focus must shift to absorb extreme climate events such as droughts and heavy rains, rather than setting the stage to further aggravate them. It was an honor that, with the implementation of our no-till project, Dilmun Hill was able to serve as an example of an agricultural landscape that is setting the stage for a new agricultural revolution of sorts — one that mimics nature and is adaptive to climate change.

More information about Ben Falk’s tour and lecture — which were free and open to the public — can be found here: http://events.cornell.edu/event/reading_the_landscape_for_resiliency_tour_talk_with_ben_falk

**New Groups at the Farm**

As a result of our work with this project, we were able to attract several new groups to the farm. HORT 4940: Permaculture Design Course came to visit Dilmun and learn about the basics of permaculture design through the new garden and our permanent raised beds system. CSS 4140: Tropical Cropping Systems also used Dilmun Hill for the first time this year to learn about terracing and polycultures that are used in traditional agriculture in developing nations. The New Roots School also had several high school classes come out to the farm for the first time — most notably in conjunction with a landscape architecture studio that was designing a permaculture garden for the Ithaca Children’s Garden. Using the new garden, we were able to teach the students about different kinds of plants and design elements they would want to incorporate into their designs for the Ithaca Children’s Garden project.

**The Future of the Project**

After our workshop with Ben Falk, we were brimming with ideas for expanding this project. The way Dilmun is currently designed, our Zone 1 — or highest area of use — is situated far away from the main space where people congregate — the barn — due to the steep uphill slope that lies between the two. While we will be graduating in May, we hope that the new managers will take the opportunity to expand the hillside farming aspect of this project to other areas of the farm and thus, create an ecological farm that efficiently uses all available space in a sustainable way.
Pictures of the New Garden toward the end of the season.

Thanks for making this possible, TSF! We really appreciate it.

— Dilmun Hill Student Farm (Emily and Liz)