The Growing Mosaics Garden: Examining Permaculture in a Student Research Environment  
Dilmun Hill Student Organic Farm  

2011 Report

Principle Investigators and Cooperators

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Introduction

Dilmun Hill is the student organic farm at Cornell, run entirely by and for students. Day to day decisions are handled by paid student managers (5 managers were hired in 2011) while the steering committee of around 15 students develops long term planning. Our mission is to empower students to learn about ecological agriculture in an experiential context. In the spirit of our educational mission, we have research goals in addition to production goals. The eastern half of the farm was formerly orchard land that was sprayed with lead arsenate, a common insecticide prior to the development of synthetic organic pesticides. Both lead and arsenic persist in our heavy clay soil, so this land will remain contaminated into the foreseeable future. Major exposure pathways for these heavy metals include breathing in airborne dust (e.g. dust created by tillage) and consumption of the soil, either through contamination on hands, or on food crops grown in the soil. For this reason, the contaminated half of the farm is unsafe for traditional field agriculture, and is the site of various research projects, including the Growing Mosaic Garden (GMG), a permaculture project.

The GMG has evolved and expanded in scope and complexity since it began with TSF funding in 2008. The original project is an alley cropping experiment that demonstrates an agroforestry technique applicable to the Northeast, and examines the production of two crops: maples for coppicing to produce logs for shiitake mushroom cultivation, and hybrid hazelnuts. In 2009, we added a perennial polyculture garden to two of the alleys in block 3 (see map in Appendix A). First conceived as an edible forest garden, the GMG has shifted its focus to providing beauty, cut flowers, and ecosystem services, in response to concerns of lead and arsenic contamination in food from the site. In 2010 we implemented the Achillea beneficial insect study in block 4. This study examines the potential of yarrow to attract beneficial insects to control pests. In 2011 two managers hired with TSF funding (Elizabeth Burrichter and Peter Christine) continued developing the GMG, expanding the perennial polyculture garden and adding kale to the Achillea beneficial insect study.
At this stage the permaculture project at Dilmun can be thought of in terms of three components that are integrally connected spatially and conceptually: 1) an alley cropping component; 2) a polyculture evolution component; and 3) Achillea beneficial insect study component. We will discuss the 2011 outcomes of these three components with respect to the specific objectives established in the 2011 TSF grant proposal.

**Meeting Specific Objectives**

**Alley Cropping, Coppice Management and Species Selection**

*Provide data to help consumers differentiate between Root Pruning Method (RPM) and bare root seedling production systems in red and sugar maples for coppice management systems that produce substrate logs for forest mushroom production.*

This portion of the alley cropping experiment examines the effect of RPM on two different maple species: Sugar maple, *Acer saccharum*, and Red maple, *Acer rubrum*. In 2008, 20 replicate seedlings of each treatment were planted in a replicate design.

We measured each tree for height and diameter at breast height in the middle of the growing season. As in previous years, Red maples performed better than Sugar maples, and RPM trees in general performed better than conventional seedlings. This indicates that effects of RPM propagation persist at least four years (on our site). A critical question that remains is the long term (10+ year) performance of RPM trees compared to conventional seedlings, especially considering that RPM trees cost 3-5 times more than conventional seedlings.

Figure 2. RPM vs. non-RPM Maple tree diameters
This year we also pruned the trees to give them a more upright shape with a straighter, less branched trunk. This makes for more aesthetically pleasing trees in the garden and will make the logs more useful for mushroom production, as they will be coppiced for this purpose in the 2012 season.

*Continue data collection on 2008 cover crop and mulch treatments for hybrid bush hazelnuts.* 2011 was the first year of nut set for the hazelnuts, so in addition to measuring height of bushes (diameter was eliminated as all bushes now have several main stems), we collected data on nut yield. Each bush in this planting is genetically distinct, as they are all seedlings of a cross between the locally adapted American hazelnut and the highly productive European filbert. The genetic diversity is evident in the range of production. In late September, students of Ken Mudge’s Practicum in Forest Farming class gathered and counted all the nuts from each bush. By this time many of the nuts had fallen, which made the gathering a bit more complicated. Most bushes did not bear any nuts; of those that did, number of nuts ranged from 1 to 119. The nuts were dried with a forced air drier weighed in the lab. The nuts will have to be analyzed for heavy metal content to ensure they are safe for consumption. Then, future analysis can investigate shell-nutmeat ratio, and taste. The most promising bushes will be vegetatively propagated to facilitate a larger trial.
Figure 4. Total Hazelnuts produced per bush

Figure 5. Total nut weight per bush
Maintain alley cropping as a complement to the existing forest farming (MacDaniels Nut Grove) and vegetable crop farming systems at Dilmun Hill for agroforestry research, education and outreach.

In addition to this year’s involvement of the Practicum in Forest Farming class in the hazelnut harvest, we are currently establishing a new connection with the MacDaniels Nut Grove related to mushroom cultivation, both log grown shiitake cultivation and woodchip Stropharium beds. This new integration will demonstrate a larger continuum of agroforestry applications of mushroom production. Also this year we further diversified the alley cropping system in Block 4 by adding kale as an annual cash crop, as detailed below under Achillea Beneficial Insect Study.

**Polyculture evolution in the Growing Mosaics Garden**

*Develop student garden managers’ leadership, outreach, and horticultural skills.*

Manager testimonials:

Peter Christine – Agricultural Science ’13

Working in the GMG has been a great experience for me. Working intimately with the garden every day for a season, I learned so many things about the plants and the human systems that support them (and what can go wrong with the human part) that would be impossible to even conceive of otherwise. Having a leadership role in the garden forced me to develop my ability to make decisions and to coordinate groups of volunteers. Dilmun Hill as a community has been very supportive of me personally and given me a context in which to grow and develop my communication and cooperation skills.

Elizabeth Burrichter -- Plant Sciences ‘12

Dilmun Hill has taught me more than any other job I’ve had. I learned not only ecological and agricultural concepts in a hands-on way, but also developed managing and communication skills that relate to both scientific research and managing a farm. The constant evolution of this project each season, in response to environmental constraints, has been a very welcome challenge to learn from for the past season and a half. I greatly appreciate the opportunity to work so closely with a piece of land for multiple seasons and watch as the site develops within the context of Dilmun Hill organizationally as well as ecologically.

*Maintain a field classroom for Cornell courses and community workshops to learn about permaculture.*

Throughout the growing season, a broad diversity of workshops, youth groups, and classes made use of the GMG as a teaching garden for observation exercises. The site serves as an example to promote thinking about alternative land use strategies.

Cornell University classes that visited the GMG during the 2011 growing season included: Practicum in Forest Farming, Soil Science, Sustainable Landcare, Exploring the Small Farm Dream, and Horticulture Science. Additionally, the first year students in the Environmental Science major visited the GMG.

In addition to Cornell classes, the GMG was a venue for workshops with the NY Master Gardeners, the 4H career explorations conference, and the Youth Growth Summit. On October 1st, we collaborated with Steve Gabriel of the Finger Lakes Permaculture Institute to host an
introductory permaculture workshop for the general public. When exposed to the GMG, students are better able to understand principles of permaculture, including selection of elements with multiple functions, integration of all elements of the system based on needs, outputs, and properties, and fostering synergy to decrease waste and work. These design principles can be applied across a wide scale of human activities from small gardens to expansive bioregions.

In addition to formal workshops, the GMG welcomes visitors to explore at all times. Although the garden is not in a very prominent location for most traffic, occasional day hikers and dog walkers pass through the farm and enjoy the garden. The garden also serves as a resource for the students who volunteer at work parties. By helping with the construction of the raised beds, planting, weeding and mulching, students learn basic horticultural techniques that apply both to permaculture and to any gardening project.

Figure 6. Students doing an observational exercise in the GMG

*Strengthen Dilmun Hill as a site for networking and experimenting with alternative land management systems.*

Hosting events at the GMG is not simply a one-way flow of knowledge. We learn from workshop participants, and the system evolves with input from a variety of parties. One outcome of the October 1st workshop was the development of a new serviceberry guild experiment designed by Steve Gabriel, director of Finger Lakes Permaculture Institute. This same group of plants will be planted in several other locations, including MacDaniel’s Nut Grove and the Cornell Plantations, in the hopes that the success of the guild will be evaluated based on the various microclimates in which it’s planted.
The garden is extremely biodiverse. The ground cover, shrub layer, and overstory all consist of several different species that provide various ecosystem services, including attracting beneficial insects, accumulating soil nutrients, providing habitat for wildlife, and creating microclimates for other types of plants to thrive. The GMG is maintained as an example of the many different ways the plants grown in agricultural systems could also be planted in more dynamically

Figure 7. An example of a diverse ground cover in the GMG

Empower students to design gardens that explore the functionality and profitability of edible, medicinal and ornamental polycultures.
Throughout the season we learned vast amounts of information about the workings of the garden through observing the stages of plant growth and succession. In an attempt to crystallize this knowledge and make it available to future managers and users of the site, we created a phenology calendar to track the timing of growth stages of the different plants in the garden. We also updated the plant list spreadsheet created last year with new plants, and created a small guide for a select number of plants for visitors.

In managing the existing garden, we were constantly faced with numerous questions about the best management decisions for the garden. We spent a large portion of time weeding at the beginning of the year. Ideally, the garden should be self-maintaining, and not require weeding. However, since the garden is still in the establishment phase, we considered the effort to reduce competition justified. Still, we frequently discussed which weeds were worth pulling and which should be left. Many weeds are beautiful and useful, if for no other purpose than to occupy niches not yet filled by crop plants. Nonetheless, we consistently removed invasive species like seedling honeysuckle, buckthorn and multiflora rose, as well as weeds that could produce seeds and cause problems in other areas, such as thistles and dandelions.
A major activity of the season was implementing the design for the expansion of the garden that was outlined by last year’s managers. In addition to the physical work of building new raised beds and planting and caring for new polycultures, this process required a lot of last minute problem solving as constraints of plant availability, weather, and materials for constructing beds impacted the implementation of the plan. Along the way, we discovered problems in the established plan, chiefly that we didn’t have enough plants to provide sufficient density to outcompete weeds. This led to the need for more on-the-spot garden design, using available cover crops, and divisions of plants from last year’s plantings. As the garden progressed, yet more unforeseen challenges became apparent; for instance, one corner of the garden has become infested with bindweed, which will be impossible to control through pulling. Future managers will no doubt be faced with more decisions and plans as to how to either control such problems, or somehow use them to benefit the garden.

Figure 8. New beds build and planted, designed by former managers

Create a cut flower operation that can help to support the garden financially. Each week we made bouquets of flowers from the GMG, as well as wildflowers from around the farm, to sell at the market stand. Also, we sold bouquets in front of the Cornell Store at convocation. Unfortunately, the bouquets, while a great aesthetic success, were less than lucrative. Poor timing at the convocation sale resulted in most of the bouquets being wilted by the time crowds of potential buyers were passing through the store. At the market stands, the flowers were appreciated as a way to add color to the stand, but were rarely sold. This experience has provided the impetus to explore other ways of generating a financial yield from the GMG, chiefly, examining the possibility of safely producing food products from perennial plants on the site such as hops, hazelnuts, herbs and berries. We will also continue to explore various other
ornamental crops, such as the red twig dogwood (*Cornus sericea*), a potentially lucrative non-timber forest product.

Figure 9. Flower arrangement for sale at Market Garden stand

**Achillea Beneficial Insect study**

*Quantify the benefits of wildflower inter-planting by planting kale to compare quality of a cash crop interplanted with different Achillea varieties, and Determine if individual yarrow varieties attract different numbers or diversity of beneficial insects and pollinators.*

Last season’s managers planted five different cultivars of yarrow in a randomized block pattern with five replications (See map in Appendix B). This spring we rototilled strips between the yarrow rows and planted Winterbor kale seedlings which had been started in the greenhouse in March. The very wet spring, combined with our very poorly drained soil, resulted in waterlogging. The high moisture and favorable habitat provided by the surrounding sod caused heavy slug pressure. A combination of slugs and waterlogging led to high mortality in the initial planting, eliminating some of the replications. Fortunately, Abby Seaman had extra kale plants from an experiment of a similar variety, Ripbor, and we replaced all the kale with this variety. To reduce the problems of waterlogging, we redug the plots with a shovel and shaped them into berms to increase drainage, and incorporated more compost. We installed a drip irrigation system for the kale but it was rarely necessary throughout the season due to the soil’s extremely high water holding capacity.

Throughout the summer we scouted the kale plants twice a week for pests and beneficials. We chose three leaves of each plant randomly and assessed them for damage, as well as counting the number of eggs, larvae and adults of a variety of arthropod species present. Although we rarely saw slugs, as we worked in the day, most of the damage was clearly the result of slugs, as
evidenced by the distinctive size and shape of the holes, as well as residual mucus from the slugs walking over the plants.

To better assess the potential causes of any trends we might observe in scouting the kale, we swept the yarrow with an insect net once per week while it was in bloom. Each yarrow plant was given one full sweep with each pass, and in the control blocks the weedy sod was given four full sweeps, so as to have an equal number of sweeps for each treatment. For each collection, two managers worked in parallel, moving down the row so as to minimize the effects of disturbance as insects left the plants being swept. All samples were transferred into plastic bags and frozen for later identification and analysis.

When the yarrow blooms began to senesce in July, we cut back all the plants evenly in an attempt to induce a second flush of growth. Unfortunately a period of drought began at this time, which put the yarrow at a competitive disadvantage to the surrounding weeds. For this reason, the yarrow never fully bloomed again for the season. Nevertheless, we continued scouting the kale to see how the effects might change over time.

Statistical analysis was performed, but tests showed no significant difference between pest or beneficial populations on kale by variety of yarrow. We did, however, gain some interesting results when comparing the difference in populations between the yarrow flowers when they were blooming, and when they were not.

Figure 10. Average Number of Insects on Kale With and Without Yarrow Blooms Present

Note: The lady beetle and lacewing eggs are beneficial insects for the field population, while the ICW eggs and larvae, mites, and flea beetles are kale pests.
The population of flea beetles on the kale increased once the yarrow blooms were removed in late July (see Figure 10). The presence of the flowers could have caused the smaller the number of flea beetles earlier in the season. This could be attributed to the populations of predatory insects and beneficial parasitic wasps attracted to the flowers, having a nearby source of food on the kale--flea beetles. However, the increase in flea beetles later in the season cannot be definitively assigned to the absence of the yarrow since changes in population could have been related to other external factors changing over the season. Although we did not take data on the cause of damage to the leaves, our observations suggest that the majority of the damage was caused by slugs, and that the pests recorded in Figure 10 incurred little damage. The fact that they never reached a damaging population size suggests that beneficial insects were adequately controlling these pests throughout the entire block.

This information concerning the importance of attracting diverse insect populations, as well as potential yarrow varieties that could be more effective at doing this, will be useful in discussions with classes and any other visitors of the site at Dilmun Hill, as well as any recommendations made to diversify farm landscapes.

*Develop students’ research skills.*
Abby Seaman worked with us to develop a plan for gathering data, both the scouting and sweeping. Michael Hoffman generously allowed the use of his lab and equipment (dissecting scopes and camera) for identifying insects in the sweep samples and documenting the results, under the guidance of Jeff Gardner. Richard Hoebeke had previously agreed to help with the identification, but unfortunately retired before we were ready to analyze the samples. Fortunately Alex Traven, one of the market garden managers, had taken an insect biology class and was able to help us with identification.

*Expand Dilmun Hill’s biological resources for pest management.*
Although the effectiveness of yarrow as an attractor of beneficial insects has yet to be confirmed, the presence of the project inspired discussion on the topic of conservation biological control around the farm. Perennials such as yarrow are unlikely to play a major role in the annual systems of the farm; however, the market garden managers this year experimented with intercropping nasturtiums and marigolds with annual crops. Additionally, a bed of bolted basil was allowed to remain in the field long after any potential harvest, since we observed that the flowers attracted bees and numerous other beneficial insects.

**Project Evolution**

This season we grappled with a variety of questions related to the goals and direction of the project. Unforeseen circumstances made certain components of the plans from last year impossible or impractical. More fundamentally, throughout the summer we constantly questioned permaculture itself. What is permaculture? Why is this system permaculture, and not something else? Is permaculture even a horticulturally/agronomically/ecologically/socially valid goal? This questioning helped to inspire a variety of changes in the direction of the GMG project as a whole and in its various components, particularly the polyculture evolution and Achillea beneficial insect study components.
Polyculture evolution:
Our failure to produce income from growing flowers provided impetus to diversify and focus more on food crops. We have already introduced serviceberry (which was part of the original plan) and some paw paw and persimmon seedlings in the nursery bed that can be planted out in the garden next season. Past testing has suggested that strawberry is a safe crop to grow with the current system. However with many of the other perennial edible crops it is still unclear if heavy metals might accumulate in the harvested portion. Accordingly, we are making plans to transition the research focus of the GMG project from a plant pest interaction study to one that addresses issues of perennial food crops on contaminated soil.

We also intend to expand our resources for ornamental production, incorporating plants that may have a more readily available market, such as red twig dogwood.

Achillea Beneficial Insect Study:
The limitations experienced in 2011 suggest that site conditions in block 4 cannot satisfactorily answer the questions set out in the original grant proposal; it is simply too small. All the treatments were quite close to one another, such that the entire field would be considered one patch from the point of view of the insects of interest. Additionally, there were many confounding variables. The kale and yarrow grew in a sod of grass and forbs, in between tree rows, making it impossible to prevent wildflowers from blooming in the sod, despite frequent mowing. In order to test the efficacy of yarrow only, we would have to till the entire site and start with a simple yarrow/kale system. This, however would be unacceptable based on the goals of the site, both from the point of view of a permaculture research plot, and from the point of view of the farm’s best management practices policy for contaminated soils, which mandates complete soil cover at all times.

With these limitations in mind, the project should be considered more along the lines of a system study, which could compare kale grown in a flowering perennial sod matrix with kale monocultures. Unfortunately, properly constructing such a systems study would be difficult, if not impossible, given the constraints of space, financial resources, and management continuity faced by Dilmun Hill. Accordingly, we decided that the focus of the Achillea beneficial insects trial should not be the production of data, but rather a resource for outreach and education on alley cropping, permaculture, and ecological pest management. Consequently, we are using the insect samples we gathered over the summer not just for data, but also as an educational resource. We have photographed samples, pinned insects and used a dissecting scope to photograph the insects that are too small to see clearly with the naked eye. These materials will be available for students and community members visiting the farm year round.

Whole GMG evolution:
As we questioned the nature of permaculture, we developed the concept of integrating permaculture more into the farm as a whole, rather than isolated in a single demonstration plot. To this end, we conducted a site assessment of the farm based on the guidelines Steve Gabriel created for the Practicum in Forest Farming class. The site assessment project is yet ongoing; however, we have already created a whole farm map, which is now posted at the entrance to the farm to orient visitors to the variety of projects occurring at the farm.
Conclusion

The GMG has continually changed in scope and focus since its inception in 2008. At times we were frustrated during the 2011 season with failure to generate income from cut flowers, or to generate usable data from the Achillea Beneficial Insects study. In retrospect these seeming failures were opportunities for growth: our growth as managers as well as the growth of the GMG itself. Major lessons from the 2011 season include:

- The current ornamental species in the GMG do not lend themselves to lucrative cut flower production, so future plantings should diversify income potential by planting new ornamentals, and exploring the possibility of safe production of perennial food crops on contaminated sites.
- Confounding variables and lack of space make our site unsuitable for agroecological studies; accordingly the yarrow trial would be more appropriately used as an educational site.
- Permaculture is inherently integrative, and thus cannot be satisfactorily demonstrated as an isolated garden plot. Accordingly, it should be part of the responsibility of future managers to pursue the integration of the GMG and permaculture principles in general into the farm as a whole.

Literature Review

The following literature was read in book clubs, consisting of student managers, faculty, and the organic farm coordinator, throughout the season, informing our approach.


Appendix A. Map of Dilmun Hill
Appendix B. map of Block 4