Effects of controlled disturbance within early-successional northeastern forest habitat: Evaluating soil quality, plant production, and economic feasibility

Final Report for FNE12-751

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State: Massachusetts
Project Leader:

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Bug Hill Farm

Project Information

Summary:

The majority of landowners in the Northeast region, including farmers, have some forestland on their property, whether it is maintained as native woodland or managed as a woodlot. Bug Hill Farm is among a generation of startup farmers in this region who may be forced to consider methods for starting or expanding their operations in marginal forestlands.

The main research objective of this project was to discover a viable means to expand perennial berry production into land that had been allowed to grow as forest for several decades, while minimizing disturbance to local ecosystems. This objective was achieved by means of examining changes in soil quality as a direct effect of experimental land management and cultivation techniques. Secondary objectives included measuring plant growth as an indicator of health and future production value, and economic analysis of the costs associated with the execution of each treatment, in order to determine which cultivation methods produce the best balance between production value, cost-effectiveness, and environmental sustainability.

Our methods included establishing small plantings of perennial woody berry crops — chokeberry, elderberry, and honeyberry — into early-successional habitat which had received treatments of varying levels of soil disturbance. All plots were clear-cut, and then each received one of three treatments: Control plots were cleared, tilled, and planted, as for traditional agricultural use; Hugelkultur plots were partially cleared and trenched, and then beds were constructed using a specialized high-carbon sheet composting method known as ‘Hugelkultur’ before planting; Early-Successional plots received only the initial clear-cut, then plants were placed in openings between existing vegetation which was allowed to partially regenerate. Regular soil tests were performed on each plot throughout the experiment.

Our results seem to indicate that soil health was most increased by the Hugelkultur treatment, which saw a gain of 7.67% in soil health ratings over the course of the

experiment. The Early-Successional treatment showed an increase of 5.00% in soil health ratings, and the Control treatment showed an increase of 4.67%. Plant health, as measured by growth, mirrored the soil health increases for each of these plots, with plants showing notably increased vigor under Hugelkultur treatment, and slightly increased vigor under Early-Successional treatment. However, the economic analysis revealed that the Hugelkultur treatment was almost twice as expensive as the Control, and almost four times more expensive than the Early-Successional treatment. Our initial assessment is that the Early-Successional treatment is potentially the most economically viable option for producing woody perennial berry crops from land dominated by forest or shrub cover, although a longer-term assessment would be necessary to verify continued performance as plantings mature.

Our project outreach included twelve on-site workshops, targeting primarily students from local colleges and agricultural programs. Our results will also be disseminated through the farm's own website, and through the UMass Extension Fruit Program's Massachusetts Berry Notes newsletter which reaches agriculturists and horticulturists throughout the state.

Introduction:

The Northeast region is heavily forested (see Carpenter, 2007; Butler et al., 2007; [Refer to the attached Bibliography for cited references]). The majority of landowners in this region, including farmers, have some forestland on their property, whether it is maintained as native woodland or managed as a woodlot. Prime agricultural land is difficult to acquire for start-up farmers due in part to lack of availability and prohibitive costs. However, as population pressures continue to increase, many of the next generation of farmers in this region may need to consider beginning their operations on marginal forestlands. Bug Hill Farm is among this generation — more than two-thirds of our land is forested. The primary challenges that such farmers face is striking a balance between the following considerations:

- the high costs and concerted labor required to cut, stump, clear, till, plant, drain and/or irrigate agriculturally-marginal, forested land for productive use;
- the ability to produce a productive and profitable harvest; and
- the need for mitigating environmental impacts such as habitat destruction, ecosystem fragmentation, soil erosion, and agricultural runoff.

Bug Hill Farm, owned and operated by Kate Kerivan since 2005, is situated in the small hill town of Ashfield, MA, at an elevation of 1,700 feet. Bug Hill Farm is a values-driven enterprise, established out of a desire to become a model for environmental, agricultural, and social sustainability. Our mission has been to serve as an educational center for visitors interested in the complementary aspects of ecological restoration and sustainable small-scale farming. The farm has 45 acres of native middle-aged forest and wetlands, of which only five acres have been cleared and are currently under production. We are USDA-certified organic and cultivate a diverse selection of berry crops, including: currants, gooseberries, strawberries, wild blueberries, blackberries, elderberries, summer- and fall-fruiting raspberries, and heirloom tomatoes. The farm has a Forest Stewardship Plan and is classified in Chapters 61 and 61A—managing the woodlands and fields for native plants and wildlife habitat including native pollinators. We have partnered with the Natural Resources Conservation Service to restore native high bush blueberries on the property and to fell trees on the ten acres of forest nearest to the farmstead in order to create an area rich in early-successional forest species that promotes biodiversity and serves primarily as wildlife habitat.

Kate Kerivan acted as the Project Leader for this grant project. Other notable project collaborators include: Sonia Schloemann, University of Massachusetts Extension Educator and Fruit Production Specialist and the project's technical advisor; Devon Castillo, who designed and wrote the grant and assisted with some of the early-project execution and with reporting requirements; and Diego Irizarry-Gerould who performed a large amount of the maintenance and data collection. Several farm workers and interns assisted with the execution and maintenance of the project, including Emily Forse, Ellen Green, Matthias Nevins, Mike Dale, Shelby Howland, Tomas Pickering, Abbot Dodson, Anne Preston, and Casey Robinson.

This grant project was designed utilizing techniques of agroforestry and permaculture in an effort to allow us to expand berry production into marginal, forested areas of our property while still managing these areas for the overall health of local forest ecosystems. More specifically, we established small, experimental plantings of perennial woody berry plants that are common in transitional ecosystems into early-successional shrub-/scrub-dominated forestland in order to determine which cultivation methods will produce the best balance between production values, cost of production, and environmental sustainability. Our intention was to explore utilizing perennial berry crops in natural successional habitat as a twist on reduced- or no-tillage practices and traditional agroforestry intercropping models. Our experiment is distinguished from similar projects by monitoring successional soil processes on land that had been allowed to grow as forest for several decades before disturbance.

The main research objective of the experiment was to examine changes in soil quality as a direct effect of experimental land management and cultivation techniques, viz. maintaining land in an essentially arrested state of early-successional woodland and utilizing the high-carbon waste produced by such management practices in the construction of specialized sheet compost-cum-raised beds known as 'Hugelkultur'.

Succession is the ecological process describing plant community change over time. The term 'early-successional' used throughout this report and this project denotes a plant community (or a species native to such a community) that exists somewhere in the natural transition from cleared land to meadow to shrub thickets, before the plant community returns to a juvenile forest ecosystem. In traditional agricultural settings, fields are maintained for high productivity through prevention from successional return to natural vegetation (see LS98-094; Loomis & Connor, 1992). Humans manipulate the successional process via: designed disturbance of natural succession (e.g. tillage); controlled colonization (e.g. sowing), and controlled species performance (e.g. weeding) (see Luken, 1990; SW03-056). The effects of successional processes on soil quality are measurable in the soil's microbiota and nutrient content. Generally, agricultural soils (highly disturbed) have a fungal to bacterial biomass of 1:1 or less, while forest soils (least disturbed) have ten times or more fungi than bacteria (see Lowenfels & Lewis, 2010). The balance of soil microbiota directly affects the amount and form of nitrogen available to plants in the soil. In bacterially dominated soils ammonium ($NH4$) is converted into nitrate ($NO3$) by specialized bacteria. As fungi begin to dominate, the acids they produce lower the pH and greatly reduce the amount of these bacteria; thus, more of the nitrogen remains in ammonium form (see Lowenfels & Lewis, 2010). Trees and shrubs that are normally considered transitional in successional development — such as those utilized in this experiment — tend to do well in bacterially dominated soils when they are young because they can easily utilize nitrates, but as they mature their preference changes to ammonium nitrogen (see Lowenfels & Lewis, 2010).

Hugelkultur — a technique based on European agroforestry practices — can be viewed either as a type of raised bed or a specialized method of high-carbon sheet composting. Woody debris is piled and compacted, layered with compostable materials, covered with soil, and planted. The wood is intended to act like a sponge as it decomposes, quickly soaking up excess water and releasing it slowly over time. The decomposition process of the compostable materials also raises soil temperature within the mounds which may boost plant growth, especially in colder climates. Due to these properties, hugelkultur plantings are thought to require fewer inputs than traditional plantings (see Hemenway, 2001). Hugelkultur also provides a means to keep high-carbon forestry waste-products sequestered in a functioning ecosystem as an alternative to the common methods of burning or landfill disposal (see Schahczenski & Hill, 2009).

We chose specific woody perennial berry plants for our project based on their role as transitional, early-successional species and pollinator habitat value. Their performance under conditions similar to those which were created in our experiment has been confirmed by independent research, including the results of past SARE projects. Black chokeberry (*Aronia melanocarpa* (Michx.) Ell.) and American elderberry (*Sambucus nigra* L.) have both been successfully grown in a non-traditional agro-forestry system as understory plants to orchard trees (see FNC08-718). Honeyberry (*Lonicera caerulea* L.) has also been demonstrated to grow and produce well under orchard tree shading, and can be successfully double-cropped (see FNC01-343; see also Bors, 2009).

Our intention in designing this project was to use the results of the experimental plantings to develop a plan for expanding berry production into the early-successional habitat acreage and possibly even into the understory of other forested sections of the property, while—if possible—continuing to provide wildlife habitat, promote biodiversity, and reduce the farm's carbon footprint. The information and data generated by our project may be beneficial to any landowner that is considering utilizing forested land for agricultural production. Our results may be of use in determining:

- land-use potential for production of perennial berry crops;
- the degree of land preparation and soil disturbance necessary for such operations;
- potential benefits of non-traditional berry production techniques such as intercropping with other agroforestry products and hugelkultur production;
- and potential means for recycling waste products of site clearing, timber harvesting, and other agro-/forestry waste products.

- Bibliography and Additional Resources

Project Objectives:

The main research objective of this project was to examine changes in soil quality as a direct effect of experimental land management and cultivation techniques, viz.

- Establishing small plantings of perennial woody berry crops that are common in transitional ecosystems — chokeberry, elderberry, and honeyberry — into early-successional habitat which had received treatments of varying levels of soil disturbance;

- Maintaining land in an essentially arrested state of early-successional development to increase biodiversity and habitat for wildlife, including native pollinators; and
- Recycling the high-carbon waste produced by such management practices through the construction of specialized sheet compost-cum-raised beds known as ‘Hugelkultur’.

Secondary objectives included measuring plant growth as an indicator of health and future production value, and economic analysis of the costs associated with the execution of each treatment.

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Research

Materials and methods:

The basis of our experiment was to create an experimental planting utilizing three different types of treatments (‘Control’, ‘Hugelkultur’, and ‘Successional’), which represent varying levels of soil disturbance (high, moderate, and low, respectively). Nine adjacent 50’ by 50’ plots were delineated out of forestland that had recently been felled for the purpose of creating early-successional habitat. All plots were situated on a uniformly level site which was chosen to minimize pre-existing environmental variables. Each plot was assigned one of the three treatment types, for a total of three plots for each treatment. Please see the attached diagrams labeled “Plot Location Diagram” and “Plot Layout Diagram” for further clarification.

Due to economic constraints and the difficulty of executing stump-removal in small, isolated parcels without disturbing surrounding areas, it was necessary for our control plots to be situated adjacent to one another, alongside a 1.5-acre area that had already been scheduled for stumping. Although this presented difficulties for randomizing the order of our plots, true randomization may be less critical in our experiment since our results were determined by change over time within plots, rather than comparing absolute values of soil quality. The experiment was conducted over the course of three- to four- years to account for the slow and gradual nature of the changes in soil health and composition which we were monitoring and for uncontrollable environmental variables like weather. A project extension was requested and received early-on, due to our need to cope with a severe local drought event and a lack of sufficient labor resources needed to complete the project setup.

SETUP

'Control' plots represent a high level of soil and root disturbance. Plots received the following treatment:

- Stumps were ground-down and woody debris was removed by heavy machinery;
- Land was plowed and seeded with a cover crop of oats and field peas;
- Cover crop was allowed to grow for one month;
- Plots were tilled again; and
- Planted with berry crops.

The debris removed from these plots was utilized to construct hugelkultur beds in the second plot set.

'Hugelkultur' plots represent a moderate level of soil and root disturbance. Hugelkultur plots received the following treatment:

- Topsoil, stumps, and woody debris was removed in broad furrows, measuring approximately 3 feet wide by 50 feet long by 3 feet deep, and piled alongside, using heavy machinery;
- Furrows were filled to a depth of 1–2 feet with remnants of stumps, logs, and other woody debris which were cleared from the 'Control' plots and 'Hugelkultur' plots and supplemented with woody materials from adjacent non-experimental parcels. Particularly large or heavy materials were moved using a tractor, other materials were moved by hand;
- Woody materials were covered with a layer of compostable materials—a mixture of compostable ingredients was gathered from control plot waste and adjacent parcels and supplemented with purchased green hay;
- Organic materials were covered over with the topsoil removed during creation of the furrows;
- Berry crops were planted directly into the resulting mounds. See attached diagram for further explanation of basic hugelkultur construction.

After the disturbance of initial construction, 'Hugelkultur' plots were maintained in the same manner as the 'Successional' plots (see below).

'Successional' plots represent a minimum level of soil and root disturbance. Plots were maintained as early-successional habitat via the following treatment: stumps and other woody debris and native plants were not removed and were maintained in an essentially arrested state of early-successional development by selectively cutting back regenerating trees and shrubs upon reaching approximately 4 feet in height to maintain spatial and temporal heterogeneity. Berry crops were planted between existing stumps and young and regenerating shrubs and trees.

All plots were planted with three species of woody perennial berry crops, chosen for their production value and ability to grow naturally in early-successional habitats — specifically: native black chokeberry (*Aronia melanocarpa* (Michx.) Ell.) 'Viking', American elderberry (*Sambucus canadensis* L.), and honeyberry/haskap (*Lonicera caerulea* L.), 'Tundra' and 'Borealis'. Ten of each species was planted in each plot, in rough rows; honeyberry rows received five specimens of each cultivar to aid in cross pollination.

Our experiment was designed to incorporate agroforestry practices that embody the four ecological principles of natural ecosystems highlighted by Olson et al. (2000): 1) spatial and temporal heterogeneity was achieved through maintaining early-successional habitat as an intermediary between forest and field; 2) controlled disturbance of soil and successional processes was the primary determinant of structure and function in the system; 3) the ecosystem was selected and designed to be dominated by woody perennials, including selected crops; and 4) ecosystem performance and efficiency was increased by structural and functional diversity through the addition of crops that serve as food sources and habitat for native pollinators and through management for crop production (see also LS05-174).

Once the plots were established, any additional treatment not specifically noted above was replicated identically for all plots. Such treatments included regular care and maintenance of berry plants and early-successional habitat, weeding around berry plants, and application of pelleted lime around the base of each plant.

PERFORMANCE TARGET MEASUREMENTS

OBJECTIVE 1 – SOIL HEALTH

A baseline soil test was made before any plot modification began, in the spring of 2012. Soil testing was then performed regularly throughout the course of the experiment to evaluate change over time. Samples were taken in the fall of 2012, the spring and fall of 2013, and the spring of 2015.

Soil sampling methods followed the protocols outlined in the *Cornell Soil Health Assessment Training Manual*, 2nd Ed., 2009, p. 18-19. Each plot was sampled at five (5) randomly chosen locations, using a soil core sampler and a penetrometer to measure subsurface compaction. Testing and analysis was performed via the Cornell Soil Health Assessment comprehensive package, which included analysis of:

- Particle size distribution and texture
- Wet aggregate stability
- Available water capacity
- Surface hardness
- Subsurface hardness
- Organic matter
- Active carbon
- Standard fertility test, (pH, Buffer pH (lime requirement), organic matter and Modified Morgan extractable phosphorus, potassium, calcium, magnesium, aluminum, iron, zinc, and manganese.)
- Potentially mineralizable nitrogen

Cornell's soil test reports were issued with quality ratings for each category, along with suggestions for improvement in low-ranking categories.

OBJECTIVE 2 – PLANT HEALTH

Plants were not expected to produce a harvest within the first couple of years due to the maturation rates of the chosen perennial species. Plant growth was measured as an indicator of future production values, by measuring shoot growth at the end of the project. Elderberry and Aronia growth were both assessed by measuring the average number of stems per plant and the overall length of each stem. Honeyberry growth habit differs significantly from Elderberry and Aronia growth habits, in that it forms a compact, densely-branched shrub—growth was assessed by measuring the overall height of the plant and by measuring the diameter of the canopy in two orientations, due to the inherent difficulty of counting and measuring individual stems.

We had originally intended to measure root health by randomly selecting and digging up plants from each plot for assessment, but our technical advisor determined that this step was unnecessary and that plantings would be better left intact for future growth and production data.

OBJECTIVE 3 – COST ANALYSIS

We attempted to maintain records of the cost of constructing and maintaining each of the different plot types, although this presented some small difficulties as we were not able to sufficiently log the separation in time and costs for the contractors who performed the initial land clearing, stumping, trenching, and movement of materials for the 'Control' and 'Hugelkultur' plots. Therefore, in order to estimate our costs, we have run two separate scenarios wherein the cost of major land preparation for the Hugelkultur plots was estimated at one-half-, and one-quarter- of the cost of land preparation for the Control plots, respectively. These estimations were made based on observations of the relative amount of time and labor that went into each treatment, and we believe them to be reasonable estimates. This consideration does not extend to the Early-Successional treatment, as it required no additional major land preparation.

The only other cost estimate that we weighted for the analysis was the cost of planting into each of the treatment types. Although the time and labor necessary for planting was almost identical for each of the three treatments, we slightly weighted the cost of planting into hugelkultur and early-successional plots as it was slightly more difficult to work around the buried woody debris in the hugelkultur mounds and the existing plants and roots in the early-successional treatment.

The costs for applying each treatment was broken down into cost per 50' x 50' plot, and then extrapolated to determine an estimated cost per acre for each plot type, in order to determine which treatment is the most economically feasible.

- Plot Location Diagram
- Plot Layout Diagram

Research results and discussion:

OBJECTIVE 1 – SOIL HEALTH

Please refer to the attached diagrams labeled "Soil Health Data Charts" for visual representation of the data discussed in this section. We have also included a copy of our raw data for anyone interested in running their own analysis, in an Excel database labeled "Soil Health Data".

Soil Health Test results taken over the course of three- to four-years following the initial treatments of ‘Control’ (clear cut and stump pulling), ‘Early Successional’ (clear cut only), and ‘Hugelkultur’ (clear cut, trenching and filling w/ stump material, compost and soil), showed varied results. From the widest view, the change in the Soil Health Index Overall ratings from Spring 2012 to Spring 2015 showed the greatest improvement in the ‘Hugelkultur’ plots at an average increase in the Soil Health Index of +7.67 compared to +5.00 for the ‘Early Succession’ plots and +4.67 for the ‘Control’. Cornell’s Soil Health Index is scored out of a maximum of 100 points; therefore, these scores represent 7.67%, 5.00%, and 4.67% improvement, respectively. While not a large difference and possibly not statistically significant, the level of improvement was still notable because it was confirmed by improved growth observations for each of the three berry types grown in those plots (See Objective 2, below). The mean stem height and number for both Elderberry and Aronia were greater for the ‘Hugelkultur’ plots compared to the other two treatments. For Honeyberry, the mean canopy diameter and canopy height was also greater in the ‘Hugelkultur’ plots compared to the other treatments.

Finding key soil health indicators that explain the improved growth seen in the ‘Hugelkultur’ plots is not easy. Many of the measured indicators showed a high degree of variability (e.g., surface hardness, active carbon, extractable potassium, etc.), some showed little change over time (e.g., organic matter content and extractable phosphorous – although both have some unusual readings midway through), and yet others move in a counterintuitive direction (e.g., aggregate stability). Some measures indicated improvement in all treatments (e.g., available water holding capacity and potentially mineralizable nitrogen). However, none of the measured indicators clearly point to a reason why the ‘Hugelkultur’ plots would exhibit improved plant growth. This may be because the impact of the treatments cannot be shown in a three-year time frame. It may also be because the key is an interaction between two or more of these measures (e.g., organic matter, water holding capacity, and potentially mineralizable nitrogen), or possibly a factor that was not measured for, such as soil temperature changes or fungal and bacterial biomass or species composition. It is also worth noting two things: 1) that the soil organic matter was universally high in all plots right from the start of the project, which is unusual for common agricultural soils, and 2) the soil pH was universally low in all plots, which brought down the available micronutrients. This could have been easily remedied with earlier additional lime applications.

OBJECTIVE 2 – PLANT HEALTH

Please refer to the attached diagram labeled “Plant Growth Performance” for visual representation of the data discussed in this section.

Elderberry (*Sambucus canadensis*)

Control specimens averaged 1.63 stems per plant, with stems measuring an average of 10.23-inches in height. Contrast those measurements with hugelkultur specimens, which averaged 4.03 stems per plant, with stems measuring an average of 24.7-inches in height. The successional specimens fell between those two extremes, averaging 2.07 stems per plant, with stems measuring an average of 16.33-inches in height. Based on these results, elderberries clearly favored hugelkultur production and languished under control treatments. The elderberries, which are normally given to much taller growth habit than Aronia and Honeyberry actually underperformed growth measurements for both of the other species under control conditions.

Aronia (*Aronia melanocarpa*, ‘Viking’)

Control specimens averaged 3.17 stems per plant, with stems measuring an average of 13.0-inches in height. Hugelkultur specimens saw a slight increase in performance, averaging 3.4 stems per plant, with stems measuring an average of 17.07-inches in height. Successional specimens were a close match to the control group, averaging 3.13 stems per plant, with stems measuring an average of 13.23-inches in height. Based on these results, it appears that the Aronia showed a slight preference for hugelkultur production over the other two methods, both of which showed almost identical results.

Honeyberry (*Lonicera caerulea*, 'Tundra' & 'Borealis')

Control specimens had an average canopy height of 15.03-inches, with an average canopy diameter of 12.03. Hugelkultur specimens averaged 18.87-inches in height and 16.7-inches in diameter. Successional specimens averaged 17.73-inches in height and 12.33-inches in diameter. Based on these results, it appears that Honeyberry also shows a preference for hugelkultur production, with perhaps a slight preference for successional treatment over control conditions.

OBJECTIVE 3 – COST ANALYSIS

Please refer to the attached table labeled "Plot Setup Cost Analysis" for a more detailed breakdown of the factors that were accounted for in estimating setup costs. Please note that the estimated costs discussed below include only the cost of the treatment application (Control, Hugelkultur, or Early-Successional), and do not include the cost of crop plants or maintenance costs incurred after the initial setup is complete.

Beginning with relatively flat and uniform semi-mature forestland, all of the treatments required an initial clear-cut, which was performed prior to the start of this project. We included the cost of the clear-cut in our calculations, however, because it would likely be a necessary startup cost for other landowners considering application of these methods. We estimated these costs at $2,000 per acre based on our costs and conditions, but it could cost more depending on the slope and accessibility of the site to be cleared.

Based on our estimates, creating 'Control'-type, traditional agricultural land from forested land would cost the average landowner approximately $13,000-$14,000 per acre, or more depending on the level of soil remediation required for their particular location. These costs would be mitigated for landowners starting from non-forested land.

We estimate that the cost of creating a 'Hugelkultur'-type production system from forested land would cost the average landowner approximately $22,000-$24,000 per acre, or more depending on the cost of labor for creating the hugelkultur mounds. This is almost double the cost of the Control treatment, and although the plants in the hugelkultur appear to have increased growth performance so far, the initial gains seem to be far outweighed by the cost. The ultimate expense of this treatment surprised us, as we had hypothesized that the Control plots would be more expensive due to the cost of major land clearing and preparations, however after the major land preparation was done the hugelkultur mounds ended up requiring a great deal more labor and effort to construct than we had initially envisioned. These costs could be mitigated to a small degree for landowners starting from non-forested land or where raw materials are abundant, such as following major construction or land renovation projects.

We estimate that the cost of creating an 'Early-Successional'-type production system from forested land would cost the average landowner approximately $6,000 per acre, or more depending on the degree of difficulty and cost of the initial clear-cut. This is about half the cost of the Control treatment, and according to our results, plant and soil health was slightly greater in the Early-Successional treatment than in the Control treatment plots.

The cost of ongoing upkeep and maintenance for each of the treatments throughout the first three years was almost identical. The Control plots required more attention for weeding and trimming early-on, possibly due to an activation of the latent seed bed after the soil disturbance, but we found that after that initial push, the upkeep and maintenance evened out across each of the treatments.

Based on these early results, it would appear that the most economically feasible option for startup farmers and landowners is the Early-Successional model which—although it underperformed the Hugelkultur treatment in plant and soil health—was far less expensive than either of the other treatments and saw slight improvement in plant and soil health over the Control treatment. Furthermore, the modest gains to plant and soil health in the Hugelkultur treatment do not seem to be worthwhile given the additional cost.

There are other considerations to take into account when determining the overall 'best' treatment even on an economic scale—for example, factors such as ease of accessibility, ease of harvest, and ability to apply intensive planting models may favor the more traditional Control treatment where those are desirable, such as in traditional intensive agriculture; factors such as reduced cost, minimal soil disturbance and reduced runoff, additional native pollinator and wildlife habitat, and the potential ability to intercrop with other agroforestry products may favor the Early-Successional treatment where those are desirable, such as in sustainable agriculture models, small farms, homesteads, and conservation areas; factors such as improved plant and soil health, improved drainage, increased carbon sequestration, semi-permanent installment, and the ability to grow a wider variety of crops than is possible in the Early-Successional treatment may favor the Hugelkultur treatment where those are desirable, and where costs are mitigated by implementation on a smaller scale or where abundant cheap labor or material is available such as in permaculture or educational installments, community gardens, or some small farms and homesteads.

IMPACTS

The data analysis indicates that the hugelkultur treatment showed the greatest increase in overall soil health, which was also reflected by increased plant vigor in hugelkultur plots. However, demonstrating the benefit to plant growth of following a 'Hugelkultur' regimen may not be the most interesting finding since the cost of following this regimen is high and may not be realistic for many growers. It also appears that the difference between the 'Control' plots and the 'Early Succession' plots is minimal, which suggests that the process of pulling stumps before planting may not be justified by the plant growth response. This is a somewhat tentative finding because there may be other reasons to pull stumps (e.g., ease of access, etc.), but if that is not a high priority, following an 'Early Successional' regimen may be justified.

The implication here is that for young, small-scale startup farms interested in these crops, it may be less expensive and more beneficial to employ agroforestry techniques for diversified production of berry plants with early successional habitat, which could be coppiced and managed for the production of cordwood, thatch, fodder, or other timber products or possibly even for maple sugar production if the University of Vermont's recently designed sapling vacuum systems become a viable option for production.

This project has provided enough information that the farm can move forward with planning an expansion of our berry production into the early-successional habitat acreage and possibly even into the understory of other forested sections of the property. We will likely focus on utilization of production techniques similar to those used in the 'Early Successional' plots, due to the decreased cost of land preparation, the lack of any notable decrease in plant health compared to the 'Control' plots, and the farm's easy access to existing early successional habitat. Utilization of 'Hugelkultur' techniques may also be viable on a smaller scale, such as in our kitchen garden or educational gardens, although the costs and labor associated with creating production-scale Hugelkultur for berry crops would be prohibitive.

- Soil Health Data Charts
- Soil Health Data
- Plant Growth Performance
- Plot Setup Cost Analysis

Participation Summary

Education & Outreach Activities and Participation Summary

PARTICIPATION SUMMARY:

Education/outreach description:

Bug Hill Farm has hosted twelve (12) on-site workshops to present the project goals and methods and our data and results. Workshops were advertised on our website and through contacts with local colleges and agricultural organizations. Topics varied by workshop, but included: hands-on hugelkultur construction classes, instruction on permaculture and agro-forestry techniques employed in the project, ecology and successional patterns, construction and maintenance considerations (including cost and benefit analysis) for hugelkultur and early-successional production models, and selecting plant species to promote native pollinators and other wildlife.

Workshops averaged 10-20 participants each. Workshop participants included University of Massachusetts and Greenfield Community College students, students participating in permaculture apprenticeships and workshops offered by third-parties, and other interested individuals.

A copy of this report has been submitted to our project Technical Advisor, and will be published and/or publicized in the Massachusetts Berry Notes newsletter and on the UMass Extension – Fruit Program website (ag.umass.edu/fruit).

Our report and data sheets will also be made available on our website (www.bughillfarm.org).

Project Outcomes

Assessment of Project Approach and Areas of Further Study:

This project did yield some interesting findings, although a longer term evaluation might yield even more interesting data as the plantings mature. For example, will the 'Hugelkultur' treatments continue to outperform the other plots as the plantings mature over the next ten- to fifteen- years? Will the 'Early Successional' plots continue to keep pace with the 'Control' plots, or will the performance gap increase as the existing natural vegetation matures and competes with the crops for resources? The results that we produced also raised some other questions that we were not able to answer definitively, such as: What exactly produced or contributed to the increased soil quality and plant growth in the 'Hugelkultur' plots?

Potentially beneficial revisions to our methods or future research opportunities might include:

- Increased application of soil amendments to optimize soil health throughout the course of the project, while monitoring the amount and cost of inputs to each plot;
- Choosing alternative soil testing methods and parameters, such as tests that would determine soil microbial species composition and/or bacterial to fungal biomass ratios. Additionally, less frequent soil testing may still yield valuable results and would significantly mitigate project costs;
- Experimentation with inter-planting berry crops into land that is already being managed for coppiced wood products;
- Modeling the success of early-successional intercropping over a longer-period of time, such as the amount of time that would be required for a full successional transition from clear-cut to juvenile forest.

Potential Contributions

The findings of this project are valuable even though they are conditional—a longer term evaluation would be needed to make any more definitive claims about this work. Nevertheless, this project made some interesting inroads into the question of how best to utilize reclaimed forest land for perennial fruit production.

Information and data generated by our project may be beneficial to agriculturists and landowners that are considering utilizing forested land for agricultural production. Our results may be of use in determining:

- land-use potential for production of perennial berry crops;
- the degree of land preparation and soil disturbance necessary for such operations;
- potential benefits of non-traditional berry production techniques such as intercropping with other agroforestry products and hugelkultur production; and
- potential means for recycling waste products of site clearing, timber harvesting, and other agro-/forestry waste products.

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