COPPICE AGROFORESTRY
Resprout Silviculture for the 21st Century
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Coppice Design Case Study
Wellspring Forest Farm
Trumansburg, NY
Final, 4/13/2015

This material is based upon work supported by Sustainable Agriculture Research and Education in the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2013-38640-20895. Any opinions, findings, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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INTRODUCTION

As we muddle our way through the oil peak, into climate chaos, and towards whatever our future will bring, we need to examine new ideas and re-examine old ones, testing them on the ground to see how they might help us bring our best to that future. This case study is intended as a sketch of patterns and possibilities that test what we have learned so far about coppice and pollard systems against a particular piece of ground. It is based on the best available data and a small investment of time and energy, but in no way do we pretend to have all the information we need to make the ideas developed here successful. In fact, part of the point of doing this sketch is to help us identify the gaps in our knowledge and feel our way as far as we can into filling those gaps. We hope in that process to be of service to you, our case study clients, and pray we do not lead you astray.

With that in mind, it is important to note that, while plenty of experience with resprout silviculture exists in Europe with European species and our observations give us faith in the resprout ability of North American woody plants, we have little research or experience supporting the ability of most if not all of the North American species mentioned herein to be *managed* as coppice, and even less on their use as pollards. Few studies appear to have been done on these practices on this continent, and the studies we have found have limited utility for the kinds of practices we discuss here. We have learned much in working on this sketch, but we still have much to learn. In moving towards the ideas laid out below, proceed with caution and scale up at a reasonable pace. Test species, practices, and systems at small scale before committing large amounts of land, money and labor to this design scheme.

This report begins by elucidating some of the farmers' Goals, proceeds through a brief Site Analysis and Assessment, and then proposes two Design Schemes.

DESIGN GOALS

• The farm embodies the idea of "farming in the image of a forest."
  - The farm hosts mostly wooded land in 10-20-50-100 years.
    ~ The existing forest systems function in a healthy manner.
  - *The farm's yields and products arise primarily from wooded ecosystems.*

• The farm design combines a permaculture homestead and a commercial operation with a handful of integrated interacting systems that leave home self-sufficiency central.
  - The farm supports a lifestyle, not necessarily a commercial operation—that balance may shift over time.
    ~ any income covers costs for the homestead so the farm system's products are free for the homestead;
    ~ commercial farm systems might eventually be 1/3-1/2 of income stream; also 1/3-1/2 of time spent on homestead rather than commuting.
      * (in NY state when 1/3 of income from farm one gains additional benefits)
    ~ for example, want sheep here, scaling up until it works and hits the balance that works for them (ducks scaled way up, then down to 20 or so because that worked best; they love 8 sheep, would they love 10 or 20?)
  - The enterprises focus on product niches that sell easily, have low establishment costs and high retail value, but also integrate into the farm system.
    ~ Ithaca is a main market, but the whole area's interest in local products is increasing.
      * Get product into Schuyler County—fair share, but there's more need for good food there—maybe product sells in Ithaca and Schuyler gets fair share extra/surplus?
    ~ Integration: for example, meat ducks eating slugs and snails to reduce sheep parasites, etc.
    ~ mushrooms, duck eggs, maple syrup, lamb coming on line.
    ~ $\pm$ 1,000 mushroom logs right now
    ~ bulk harvest, bulk processing, then store and sell over time—elderberry, pawpaw pulp

• Key potential coppice products:
  - Sheep fodder, especially for winter storage—a portion thereof:
    * Currently 8 sheep, assume 20 sheep.
    * Feed needs (cursory assessment):
      - According to shepherds Al Miller[1] and Ellen Dumas,[2] hay feeding per day ranges from 3-5 lb/sheep/d to 4-6 lb/sheep/d—6 if lactating.
      - During winter, most ewes will go from maintenance through gestation and into lactation, so the average dry matter intake (DMI) as % body weight (BW) for each life stage is a reasonable the number to use to estimate total DMI for the winter season. According to Schoenian, *average DMI as % BW from maintenance through lactation is 3%.*[3]
      - Steve and Elizabeth have Katahdin sheep with a weight range of 60-80# x 3% Body Weight = up to 2.4#/d DMI. Growing lambs (DMI = 4.4%BW) in the 66# range need about 3# DM/d. *Assume 3# DM/sheep/d for the sake of argument and to be conservative.*
      - 3# DM/sheep/d x 180 d winter = 540# DM per sheep per winter, x 20 sheep = 10,800# DM, or 5.4 tons DM.
      - Ideal protein content varies depending on life stage, but ranges from 9-15% Crude Protein. [4]
  - Mushroom logs: currently there is so much oak to thin in the woods in the region, that there's not much point in trying to grow logs via coppice. Nonetheless:
    * Need 200-400 3' bolts per season—4-5" ideal diameter—shiitakes prefer sapwood, most logs avail. have high heartwood content, so moving a lot weight they won't decompose.
    * Red alder has a lot of sapwood, good for mushroom wood.
    * Poplar for oyster production: 8-10" diameter maybe 12" diameter, 2 ft long
  - Firewood: 2-3 cords/year: 0.5-1 cord/ac/yr current annual increment = 2-6 acres/year for total system; a mixed-species cant ideal for various firewood qualities for different times of year/burning needs
  - Other than that polewood needs would be token:
    - trellis material, posts, and stakes
    - bioengineering materials
    - nursery material: plants to help reforest other people's places in the region based on what works for them—sideline at this point

SITE ANALYSIS AND ASSESSMENT

AREA: Total property area: ± 9 acres. Main field 4.0 acres: zone 1-2 ridge top: 1.5 ac.; northern ridge top: 1 ac.; slope and bottomland: 1.5 acres, of which the bottomland is about ¼ ac.

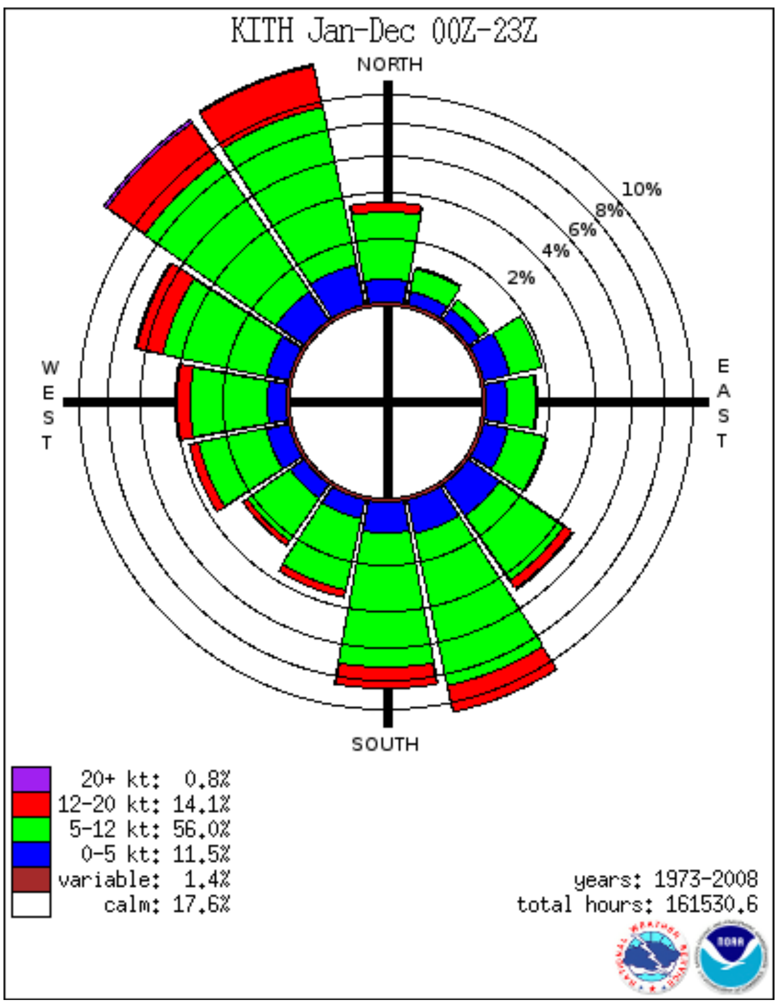
CLIMATE

Average annual precipitation: 34 inches/year; average monthly precipitation is above 3 inches per month throughout the growing season, but never near 4 inches per month; drops to a low of ± 1.7 inches/mo. in Feb.[5]

→ Irrigation probably not necessary in average years, but increasing water storage in the soils may be of benefit in droughty conditions.

→ Planning for the likelihood of increased variation in precipitation conditions is necessary given climate chaos. Stronger and more intense storms, as well as longer and deeper droughts are both likely. Design for increased retention for drought AND increased drainage in wet periods. Select species tolerant of both drought and wet feet for this site.

Figure 1: Ithaca, NY wind rose, courtesy www.erh.NOAA.gov.



USDA plant hardiness zone: 5b (-15° to -10°F)[6]

Arbor Day plant hardiness zone: 6 (0° to -10°F)[7]

→ Site is probably not yet in a solid, consistent zone 6. Design for a general warming trend in future, but with punctuated cold events.

Average Annual Wind Speed at 80 m high: 5.5-6.5 m/sec.[8]

Prevailing Winds: Northwest and southeast. Wind speeds of 5-12 knots have comprised 56% of the total period 1973-2008.[9]

→ Given the site's location on the regional high ground, wind speeds are fairly high. The prevailing directions bode challenges, given the site's exposure to cold northwesterlies and the blocking of cooling southeasterlies from the neighbor's trees on higher ground to the south and east. Livestock need wind protection, as do agricultural crops.

LANDFORM

Ecoregion: The site lies in the Northern Allegheny Plateau ecoregion near the south edge of the highland plateau between Seneca and Cayuga Lakes. This places it at the southern edge of the Finger Lakes Uplands and Gorges land type where it transitions to the Glaciated Low Allegheny Plateau. The site is underlain by soft shale bedrock overlain by till, on this site a mix of calcareous and non-calcareous loamy till derived from horizontally bedded, erodible shale, siltstone, sandstone, and limestone. Overall the landform consists of rolling hills, open U-shaped valleys cut through the plateau by erosion and glacial action, and low mountains.[10] This site lies on the high ground of the rolling hills.

→ Horizontally bedded bedrock probably limits water infiltration into the bedrock and contributes to water logging of soils in wet seasons, especially where runoff from higher ground hits level-ish areas, as in this site's eastern panhandle. The softness of the bedrock holds some hope for deep-rooted trees and shrubs being able to penetrate, but such species are more likely to be limited by the landform than aided. Taprooted trees should probably be avoided in most of the site.

Elevation: ± 1,410-1,470+ ft.[11] Some hills up to 600 feet higher than the property rise away to the south, but deeper valleys also lie south and west of the property. Relief north and west of the site is mostly similar or lower in elevation.

• The lowest part of the property, ±1,410 ft elevation, lies in a valley at the western edge of the main field just below the northwest property corner. This valley rises gently to the southeast, leaving the property near the southwest corner at ±1,430 ft. elevation. The ridge top parallel to and east of this main valley ranges from ±1,420 – ±1,450 feet elevation from north to south, giving a relief of 10-20 feet or more on the slope between them. The land then mostly rises gently to the east to it's high point at a bit over 1,470 feet. The neighboring properties to the east and south rise further.

→ The landform does not protect the site from prevailing winds: it is rather exposed at the neighborhood level.

Slope aspect(s): The neighborhood has a generally northwest facing slope overall. The site has gentle northerly and northwesterly slopes, as well as steep northeast and southwest facing slopes on either side of the western valley that drains northwesterly.

→ Aspect and elevation will reduce soil temperatures, indicating possible need to design with plants more hardy than the hardiness zone indicates. Do not plant marginally hardy species!

Soil types: The site consists of three similar soil types: Appleton silt loam (ApB), Conesus silt loam (CsB), and Erie silt loam (ErB). The Appleton soils form the core of the site mostly on the main ridge and neighboring slopes, with Conesus to the west on valley slopes and bottom, and Erie in the concave-sloped panhandle to the east. Appendix 1 contains a basic soil report describing these soil types. Table 1 summarizes their key characteristics relevant to this case study. Seasonal wetness most limits uses of these mostly young, moist newly developing soils (mesic inceptisols).

Table 1: Summary of key soil type characteristics of Wellspring Forest Farm, Mecklenburg, NY.

Characteristic	**Conesus CsB**	**Appleton ApB**	**Erie ErB**
General Area:	Western Valley Pasture	Central Ridge Top	Eastern Panhandle
Parent material	Loamy till derived from shale with varying components of limestone, sandstone, and siltstone.	Calcareous loamy till derived mainly from limestone, sandstone, and shale.	Loamy till derived from siltstone, sandstone, shale, and limestone.
Depth to restrictive feature	>80"/200 cm	>80"/200 cm	10-21"/25-53 cm: fragipan
Depth to water table	18-24"/45-60 cm	6-18"/15-20 cm	6-18"/15-20 cm
Drainage Class	Moderately well drained	Somewhat poorly drained	Somewhat poorly drained
Available water storage	moderate	moderate	very low
Hydrologic Soil Group	B/D	C/D	D
Farmland classification	Prime Farmland	Prime Farmland if drained	Statewide Importance
Frost action	Moderate	High	High

All three soil types have surface layers of silt loam, but the underlying textures vary. Appleton soils contain gravelly silt loam and gravelly loam starting at 8 inches/45 cm from the surface. Conesus soils have silt loam to 56 inches/142 cm, with gravelly silt loam below that, making it a better agricultural soil. Erie soils switch to channery silt loam at only 3 inches/8 cm depth, with channery silty clay loam at 15 inches/38 cm. While all three soils have a seasonal high water table not too far from the surface, Erie has the highest at 6-18 inches/30-45 cm. The pH of all three soils ranges within pH 6-7, though Appleton is listed as calcareous and the others are not.

→ All three soils have decent fertility, given their loamy texture and their moderately low to moderate cation exchange capacity, in the range of 12-15 meq/100 g, which allows them to hold nutrients fairly well. Key limitations of all three soils are the high water tables, which can limit rooting depth, and the fragipan in the Erie soils, which limits rooting even further.

→ One should avoid deep-rooted tree species in this design. For most of the site, select plants that can tolerate wet feet at least part of the year. The moderate to high frost action means that fall-planted trees are best well mulched to limit heaving of plants during the winter months.

→ In the Erie panhandle area, plants selected should be either wet tolerant or shallow-rooted and able to survive on small high ground patches. Focus planting on higher ground patches. Consider creating mounds, swales, or hugel beds in the Erie soils so as to grow a wider range of plants.

→ Deepest rooted species should be grown on Conesus soils in the western third of the site.

WATER

• The site drains to the northwest, eventually into Taughannock Creek. The two perennial streams on site have only dried up in one very dry year so far in the farmers' experience. Warren Pond, at the north central portion of the site, overflows southwest across the site to a new small pond and thence into a swale running mostly south along the slope. This drainage path bisects the best farmland on site, and complicates access and circulation, but also offers passive irrigation opportunities on a portion of the best soils.

• Two-thirds of the site's soils are somewhat poorly drained, with only the western Conesus soils being moderately well drained. Therefore, excess water retention is probably more a problem than drought, most of the time.

• Most soils here are moderate to high runoff soils, only slightly erodible, with mostly moderate (Appleton and Conesus) or very low (Erie) water storage capacity.

→ Focus on wet tolerant species, once again, except on the Conesus soils to the west, where soils drain somewhat better. For less wet-tolerant species, consider building berms associated with earthworks to plant them upon, especially in the eastern Erie soils, but also perhaps in the Appleton soils in the farm's core.

→ Erosion is only an issue on roads and trails, where simple prevention techniques should work. Elsewhere, as long as soil is vegetated this should not be a problem.

MARKETS

• The site lies 20 minutes drive from Ithaca and Watkins Glen (12 miles each east or west); Trumansburg is 8 miles away. This provides equal access to both major markets in the region—Ithaca is a larger and more developed market with higher demand for local products; Watkins Glen is less developed in terms of local food but coming on, but there's also more need there. Ithaca/Tompkins County had 2010 population of 102,000, and 2010 median family income of $53,000. Watkins Glen/Schuyler County had a 2010 population of 18,000, and 2010 median family income of $41,000.

- The markets for products grown on the farm and sold locally appear to be good. The coppice products in question for this case study here are not direct market products, but support either the homestead itself or, more importantly, the on-farm production of items brought to market.
- The leading concern Elizabeth and Steve have is the hay market, which can be volatile and hay can be in short supply. This could severely impact the cost and viability of sheep production.
- Firewood is fairly easy to come by in the local market, as there are many acres in need of timber stand improvement. While Steve and Elizabeth feel it would be nice to grow their own firewood, this feels less critical than winter animal fodder.
- Mushroom logs, similarly, are relatively easy to come by in the region, for the same reasons firewood is. However, there appears to be greater doubt about the stability of this market as an input than the firewood, partly because there are somewhat more exacting criteria for mushroom logs than for firewood. Mushrooms produce better on trees with more sapwood than heartwood, for example, and the logs must be green, not dry, for the spawn to take.

→ The design should focus on generating leaf hay for winter animal fodder, but provide flexibility in producing mushroom logs and/or firewood, as well.

ACCESS & CIRCULATION

- Onsite, the most critical access and circulation nexus appears to be the triangular area between the new small pond, the hard corner of the existing driveway, and the proposed house site southwest of the Warren Pond. Some key flows intersect within this triangle:
  - Overflow from Warren Pond flows across the site to the small pond, and thence into the swale, while the swale and the slope it sits upon impede access to the lower western portion of the site's best ag soils; this creates a chokepoint in the path to the site's most productive soils;
  - Vehicle and livestock/pedestrian access from the upper ridge farm core must cross through the nexus to get to the majority of the best soils and the house site;
  - Essential daily and seasonal workflow patterns will cross the nexus from the house site to the greenhouse and gardens.
- A secondary nexus occurs at the top end of the existing drive near the yurt, where vehicles and materials flows access the maple woods and the Erie panhandle beyond, with potential to access the neighbor's woods to the south. This is, however, another place livestock will have to go through to get to the eastern panhandle in the current layout. This is a longer path and also provides

opportunities for mischief along the way, as they will pass by the gardens, automobiles, and various other accoutrements of farm life.

- The main access path through the eastern panhandle lies in the lowest and wettest part of that area, limiting its usefulness and potentially causing problems with soil damage and traction in muddy conditions.

→ The pattern of flows indicates that livestock should mostly remain in the western fields and not frequently travel to or from the eastern panhandle area except perhaps a few times each year, and stay in their new quarters for a period.

→ The main nexus should be very carefully and thoughtfully designed to ensure it does not become a bottleneck in the farm plan. Should probably avoid placing agroforestry components there in this design until the scheme for that zone is clear.

→ Consider redirecting livestock and traffic flow for a more direct route to the panhandle from the main western pastures so they only have to go through one nexus along the way.

→ Consider moving the main panhandle access to higher, drier ground to the north.

VEGETATION AND WILDLIFE:

Potential Natural Vegetation: According to the Ecoregions mapping, this region was historically dominated by Appalachian oak forest (white oak, red oak, some northern hardwood forest at higher elevations).[12] However, Küchler's maps of Potential Natural Vegetation show the area covered by Northern Hardwoods (*Acer-Betula-Fagus-Picea-Tsuga*) forests. Many of both of these sets of species will resprout, and some have some usefulness for fodder (mostly the maples, ashes, and birches) or for fuelwood or mushroom logs (oaks, hickories, ashes, maples). However, on this site these species are either in low numbers on the margins, are being used for their highest multiple functions now (the sugar maple grove), or they are not in evidence in general (e.g., in the panhandle). Useful coppicing plants do not dominate the site or even cover a large percentage of the area.

→ Most woodies to be used for resprout silviculture will need to be planted, not brought into production from what exists. Hence, we can choose the optimal species from the world at large and not necessarily pull from existing species.

Existing Vegetation: The wooded area in the land's southwest corner is not part of this case study, nor is the triangular sugar maple stand just east of the farm core.

- The bulk of the vegetation within the area of interest is pasture, with some initial plantings of black locust, honey locust, and red alder alleys on the northern flat zone of the western pasture. All of these are high protein leaf hay crops. Purple osier willow (*Salix purpurea*) has been planted along the existing swale, and reportedly has very high crude protein levels: about 24% (see Appendix 1). Black locust and alder have performed well so far in these plantings, and support the idea of planting more. Honeylocust has not performed well, and the literature also indicates it is not a great leaf fodder crop due to its slow regeneration rate, though the pods have good value.

- The eastern panhandle is, as Steve called it, "an interesting scrubbiness" of white pine and hawthorn with various shrubs of mostly unremarkable character (except a few alders) that can mostly tolerate wet feet. Steve and Elizabeth would like to keep some hawthorns and pines there, and want more of a mosaic of vegetation.

→ Existing vegetation in the pastures offers initial opportunities for leaf hay or coppice production and no stumbling blocks for sheep fodder. Coppice/pollard species for the pasture are best chosen from the available flora of the world to optimize production and yield. The species chosen so far are good for multiple uses. Build on the black locust and alder successes, but also consider additional alder and willow species where these are viable.

→ From a vegetation standpoint, the panhandle is pretty much the optimum place to experiment with coppice systems, as the vegetation there is mostly of little value for conventional forestry or agriculture, and one won't have to try to transform existing healthy forest. The wetness is an issue, though, and may throw off any estimates of growth rates or yield significantly.

- **Pasture productivity now:** Main field: 2.5 acres of pasture; 250-400 #/acre DM / inch grass growth—assume 300#/acre-inch for this farm x 2.5 acres = 750 # DM per inch of grass on this pasture = 3,000# DM on this farm with 4" growth. At 3#/sheep/d, that = 1,000 sheep days/20 sheep/herd=50 herd days of DM on this pasture. Assume 180 d pasturing season/50 d=3.6 rotations/year of 4" growth. Totally doable, and these are conservative numbers.

→ No need for summer fodder, except in severe drought years, for which it would be good to have a backup source of fodder. Overhead pollards could be that.

→ May be able to get some hay off this pasture in good years after soils have improved or if our assumptions are too conservative compared to reality. Preserve ability to mow for hay in the design: alleys, not scattered fodder trees.

DESIGN SCHEMES

Summary: We offer below two design options for coppice on this site: Pollard Pastures, and Pollard Pasture and Coppice Blocks. The overall intent here is to design simple but versatile systems with the highest chance of working well for production. Diversity is not the focus.

OPTION 1: POLLARD PASTURES

Design Concept:

- Both the main western pasture and the eastern panhandle contain 30-foot wide pasture alleys formed by pollard trees grown for fodder and/or small woody material cut on 3 year rotations. An access spine runs through the center of the western pasture to facilitate flock movement options through different runs of alleys depending on site conditions, while an access surround offers tractor and flock turning room. Panhandle access runs along the drier north edge of the panhandle, then through the north-central area of the maple woods to shorten sheep access between pasture blocks. A multifunctional coppice windbreak just south of the new small pond protects the greenhouse, nursery, and gardens from winter winds.
- See Appendix 3 for the Wellspring Forest Farm "Pollards & Pasture Design Concept" or look at file WFF App3.Pollards&Pastures.150413.pdf (11 x 17 color) for a graphic representation of this design.

- **Western Pasture and Pollards:** This area holds the best soils on the site, and productivity here should be maximized. Steep slopes inhibit this to some degree, requiring care in design and management. Orienting tree rows close to contour will work well on these slopes to limit erosion hazards. Though this orientation means windbreak effects will *not* be maximized, the pollards will still reduce wind speeds for the animals and to some degree across the site as a whole. This also aligns the alleys mostly north-south, which should help maximize sunlight on the pasture sward. How much shading is too much?

  USDA researcher Jim Neel is quoted as saying that a maximum of 25% percent shade is necessary to maintain forage production.[13] Others say that anything more than 55% shade will seriously limit pasture production,[14] or that "Silvopasture management often seeks to prevent understory light levels from declining below 50% of incident sunlight."[15] However, a number of studies and researchers have found that up to 40-60% shade has no effect or actually improves forage yield, not to mention forage quality, when combined with the proper selection of herbaceous forage species.[16, 17, 18, 19, 20, 21] This works by limiting grass overheating in summer and increasing Photosynthetically Active Radiation Use Efficiency (PARUE). Typically, cool-season grasses and legumes work best, especially drought-tolerant species that will also reduce water competition between trees and herbage.

  While alley width determines much of the shading regime for the underlying pasture, we have found little data correlating alley width and percent shade, especially for pollards. Various references offer various numbers for optimal between-row distances/alley widths for silvopasture. Forty feet/12 m is a common alley width,[22] but some studies use alleys as narrow as 16 ft./4.9 m. Wide alleys (80 ft./24 m up to 320 ft./96 m) most often occur when multiple tree rows are used in a single alley row.[23]

In West Virginia, Feldhake and his associates used 12 meter (39.4 ft.) alleys when they demonstrated no reduction pasture yield under black locust alley crops compared to unshaded pasture. The study had 8 m (26 ft.) tall black locust planted 1.5 m (4.9 ft.) apart within the row with a 5 m (16.4 ft.) canopy width along the row.[24] Trees were pruned up the trunk to 2 m (6.6 ft.), which allowed light to penetrate under the trees more easily. This configuration creates about 42% canopy cover overall, when the trees are in leaf. However, due to the complexities of the sun's movements and the configurations of alleys and landforms, the canopy cover percentage does not relate linearly to percent shade. In addition, black locust leafs out late in the spring, offering about 90% of full sun when the pasture experiences its first flush of growth. The species also tends to senesce early in the fall, and its small leaflets shade grasses less once they land than larger leaves would. In any case, Feldhake and friends found no decrease in pasture yield under such a system over the course of three years. Choices of pasture grasses have a major impact in this equation, too.

The farmers at Wellspring requested alleys 30 feet wide to facilitate pasture management by mob grazing with the sheep using portable electric fencing. The design here provides single tree-rows 30 feet/9 m apart to align with this.

A 30-foot between-row spacing/alley width with a 15-foot within-row tree spacing would result in maximum tree cover of approximately 40%, similar to Feldhake's study, *assuming all the pollards are at maximum growth extent in their cycle at once*, which should never be the case. This assumption means that the pollards achieve a full 15-foot diameter before cutting on their three-year cycle *and* that rows with trees at the same place in the rotation are adjacent to each other. Since the trees are on a rotation of three years, one third should always be early in their cycle and shading far less. The amount of shade actually created by this 40% canopy cover will also depend on many other variables, including tree species planted, canopy density and leaf area, pollard growth rates, cutting frequency, the pruned form of the pollards, and the configuration of the cutting rotations. Raising the height at which pollards are cut will increase light transmission, including PAR, under the pollards even with full canopies. Especially with north-south rows, the PAR should be sufficient under the pollard canopies for sward production to remain near or above full-sun levels. The pattern of pollard cutting will also affect shading intensity. If every third pollard is cut each year, then average light transmission will increase throughout the pasture, while if cutting takes place in solid blocks, each section of pasture will have a three year cycle of high light to less light until cutting occurs again. From a pasture management perspective, cutting every third tree would provide the most consistent growing conditions and productivity of the sward. From a labor perspective, cutting in blocks is probably much easier. It is safe to assume that in most cases, even at the above maximum canopy extent, actual shading will be significantly less than 40% overall.

Based on the one study we could find with usable pollard yield data, we assume 21 pounds dry matter production per pollard per year over a three-year rotation. The planting pattern above will provide 1,800 lineal feet of tree row in the western pasture, hence 120 trees at 15' spacing. If one third get cut each year, that means 40 trees are cut each year. We therefore estimate that this system of pollard and pasture on the western pasture area will yield 40 x 63# of usable leaf fodder, or 2,520 lbs DM per year—approximately 29% of yearly winter fodder needs for 20 sheep.

- We can recommend any number of species for this area of the site:
  - First choices would be more alders and black locust, as they have performed well so far there. However, black locust's thorniness can be a significant disadvantage. The focus should be on these species since you have experience with them already.
  - In addition, you might want to test the following species, at least around the edges of the property:
    - ~ Additional alder species: European gray alder (*Alnus incana* ssp. *incana*) or, in drier locations, Italian alder (*Alnus cordata*). European gray has more history as a fodder plant from what we can tell. The local species speckled (*A. incana* spp. *rugosa*) and smooth or mountain (*A. serrulata*) alders appear to be ill-equipped for coppice or fodder production: they either grow too crooked (speckled) or are too short, do not coppice well if at all, and have less forage value (smooth).
    - ~ White mulberry (*Morus alba*): This species is so well studied that it seems worth a try. The native *M. rubra*, red mulberry, might also be worth playing with, though we have found little to no data on this species as a fodder plant.
    - ~ Of the elms, European species are best known as pollards and fodder species, and appear to have higher crude protein content than North American species: *Ulmus glabra, U. minor, U. procera,* maybe *U. laevis*.
    - ~ Similarly, it appears that the European birches *Betula pendula* and *B. pubescens* have higher crude protein and digestibility than North American species.

- **Panhandle Pasture and Pollards:** With a similar spacing of trees and alleys, again running north-south, this ± 2 acres can hold about 124 trees, so 41 trees get cut per year, yielding about 2,583 lb DM per year, or about 30% of winter fodder needs for 20 sheep. This assumes that the species chosen for the pollards will yield sufficiently in the shallow-to-wet soils.

- The soils in this area remain wet much of the year. We therefore recommend red alder (*Alnus rubra*) or European gray alder (*A. incana* ssp. *incana*). A number of willow species could also serve: of the species for which we have data, *Salix caprea*, *S. babylonica*, and *S. fragilis* have solid crude protein content and digestibility over 50%, while *S. pentandra*, and *S. viminalis* have solid crude protein content but under 50% digestibility. However, the willows have fewer multiple functions for this farm—their firewood value is low and they probably would not work as well for mushroom logs as alders.
- Toward the northern edge of the space, one could try mulberry or elm, or *perhaps* black locust pollards instead of alder. But it is likely that alder or willow will do well throughout the stand except in the driest areas. The alder or willow can also double as craft material, and alder makes decent firewood or mushroom logs in a pinch, too.
- Between the western pasture and the panhandle, the pollards could yield as much as 60% of winter fodder needs for 20 sheep while also providing summer pasture with improved living conditions (more shade and less heat) and a backup source of fodder if the grass fails during a dry summer.

- **Multifunctional Coppice Windbreak:** This feature will serve as a windbreak for the greenhouse, nursery, and nearby gardens, while also producing usable coppice material for fodder, biomass, hazelnuts, garden stakes, small construction projects, crafts, etc. It would consist of six or seven rows of trees planted offset so each row "fills in the cracks" between the plants in other rows. The center row of the seven would consist of hazels planted primarily as a hedge for nut production, though it would be pruned to keep it narrow, and stems would be individually draw-felled for construction or craft materials at need or when mature from within each stool, without cutting the whole stool at once. This will result in a taller central portion of the windbreak—15-20 ft. tall and perhaps ten feet in width.

  Three rows six feet apart on the northern/windward side of the hazel hedge would grow hardy coppicing species for biomass and fodder, or perhaps craft. Kept lower through coppicing each row every third year on rotation, this creates a lower leading edge to the wind while also ensuring at least two rows have biomass at all times to break the cold northerly winds.

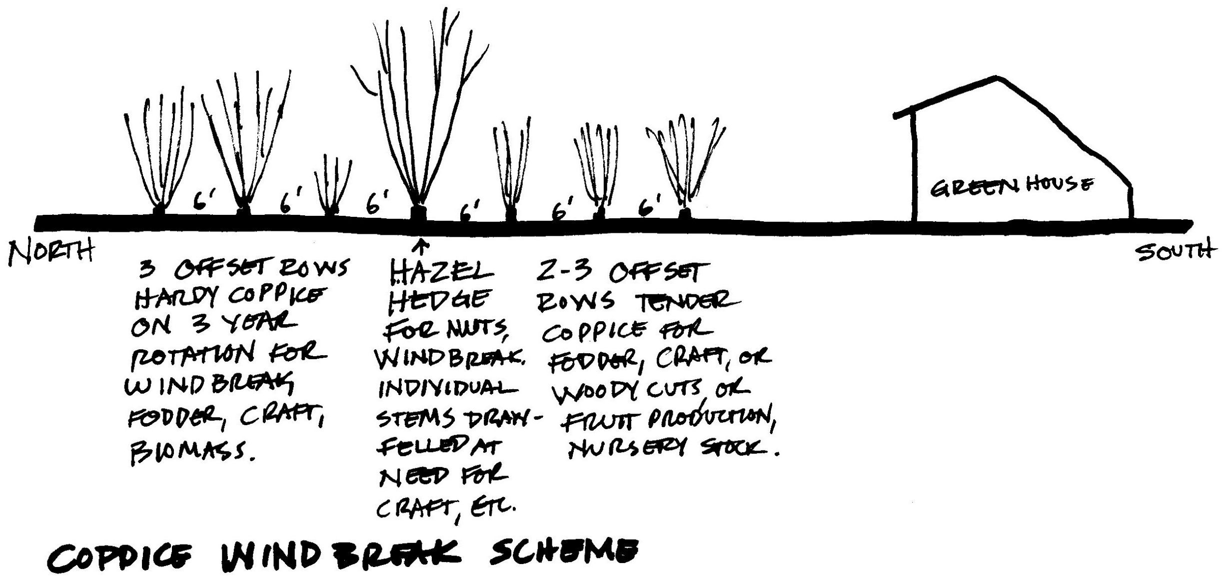


Figure 2: Coppice windbreak scheme for Wellspring Forest Farm.

Similarly, two or three rows six feet apart on the southern/lee side of the hazel hedge could grow coppice crops that are more tender for fodder, craft, or woody cut flowers. Alternately, the space could house fruiting or nursery crops that would also slow the wind.

Overall, the windbreak above would cover about a 40-foot wide swath of land, 32 feet if only two rows are used south of the hazel hedge.

Option 2: Pollards and Pasture West, Coppice Blocks East

Design Concept:

- The eastern panhandle has 8 coppice blocks of approximately 0.2 acres each with an access through the center of the panhandle for easy materials movement and a somewhat drier route. The main western pasture contains 30-foot wide pasture alleys formed by pollard trees grown for fodder and/or small woody material cut on 3-year rotations. An access spine runs through the center of the western pasture to facilitate flock movement options through different runs of alleys depending on site conditions, while an access surround offers tractor and flock turning room. Panhandle access runs along the drier north edge of the panhandle, then through the north-central area of the maple woods to shorten sheep access between pasture blocks. A multifunctional coppice windbreak just south of the new small pond protects the greenhouse, nursery, and gardens from winter winds.
- See Appendix 4 for the Wellspring Forest Farm "Coppice & Pollards Design Concept" or look at file WFF App4.Coppice&Pollards.150413.pdf (11 x 17 color) for a graphic representation of this design.

- **Western Pasture and Pollards:** See the previous scheme description for details on this aspect of this option.

- **Multifunctional Coppice Windbreak:** See the previous scheme description for details on this aspect of this option.

- **Panhandle Coppice Blocks:** This part of Option 2 focuses on the production of woody material for mushroom logs or firewood. The basic design pattern provides eight cants of 0.2 acres each (±83 x 110 feet = 9,130 sf) with stools at a 9-foot spacing and a new access lane down the center of the coppice blocks. This pattern can be easily modified to alter the rotation lengths and types of products harvested.
  For mushroom production, the farm needs an estimated 200-400 3' bolts per season with an ideal diameter of 4-5" each from species with a high sapwood content, such as alder. The estimated demand for firewood is 2-3 cords per year, ideally of mixed species to allow for varied wood use during different kinds of weather through the season. These two demands conflict in their design requirements somewhat. So, in terms of species selection, one can only optimize either mushroom logs or firewood production, not both, though suboptimal firewood or mushroom logs wouldn't necessarily destroy the system. Wet site conditions also limit species choices substantially in this area.
  To simplify, we have chosen red alder (*Alnus rubra*) as the design species for this site, due to the nudging of the farmers towards alder as a good mushroom log substrate, as well as their existing test plantings, the wet site conditions, and the available data. Some of the literature casts doubt on the ability of red alder to be used the way we discuss here; test at small scale before committing to this design, or use alternate species (see below).
- **Red alder (*Alnus rubra*): Species Characteristics:** Many factors make red alder an ideal species for coppicing. Some factors raise questions about whether it will work.
  - Red alder fixes nitrogen.
  - It tolerates wet soils.
  - "Alder stems have many suppressed buds."[25] These buds are critical to being able to coppice or pollard.
  - Red alder grows very fast: "In pure stands on good sites, it has been estimated that red alder can achieve annual cubic volume growth rates of 21 m^3/ha in pulpwood rotations of 10-12 years, and 14 m^3/ha in sawlog rotations of 30-32 years."[26] These two figures equal 300 ft^3/acre/year and 200 ft^3/acre/year, respectively, which equal about 3 cords/acre/year and 2 cords/acre/year (not including air space in the cords) respectively! The Mean Annual Increment of

red alder, the amount of wood added to a stand each year, appears to peak between ages 10 and 15.[27] Red alder (*Alnus rubra*) seedlings in Oregon test plantations at 2 m/6 ft. spacing grew to 8 cm (3 inches) in five years at one site, and achieved 11 cm (4.3 in.) in 12 years at another. A 2.7 m/8.9 ft. spacing yielded 14 cm/5.5 in. stem diameters within 12 years.[28] However, "growth rates differ markedly with site quality."[29] How these figures would translate to coppiced trees on established stools with multiple stems in New York state on these soils is hard to know, but they would probably be lower due to poorer site quality in the panhandle. One can assume that established root systems will increase growth rates, while multiple stems will spread that growth around and lengthen the time it takes for multiple stems to achieve a usable size. Nonetheless, this design will build off the above data to guide rotation lengths and spacing.

- Spacing appears to have a strong effect on diameter and height growth in red alder plantations, with wider spacing increasing diameter growth substantially. For faster yields of mushroom logs, wider spacing—at least 8 feet—is probably advisable with this species.

Table 2: Effect of spacing on diameter growth in selected age classes of red alder grown in an Oregon plantation. Derived from DeBell and Giordano, 1984.[30]

	1.2 x 1.2 m (6 x 6 ft.) spacing		2.7 x 2.7 m (9 x 9 ft.) spacing	
Age (years)	Dia. (cm)	Dia. (in)	Dia. (cm)	Dia. (in)
8	6-8	2-3	7-10	3-4
12	10-11	3.5-4.3	13-15	5-6

- On the questionable side, Constance Harrington's 1984 study of red alder indicates that stumps of trees older than five years of age have mortality over 10% after cutting. This work also indicates that the number of sprouts per plant, the height of the tallest sprout at year 1 and the diameter of the tallest sprout at year 1 fall rapidly after stump age 10.[31] This would appear to limit the coppice rotations to five years or less. However, it has been seen elsewhere that the age of first cutting can dramatically affect the ability of a stool to sprout consistently over a long period on longer rotations. Sometimes, at least, if a plant is first cut in its juvenile stage, it creates large numbers of dormant buds that then allow the plant to be coppiced longer and on longer rotations than if the first cut is later in the plant's life when its ability to generate new dormant buds is more limited. In effect, a first coppice cut in a plant's very early life can "train" it to coppice management for the rest of its life. Until someone tests this for this species (and others), we just do not know for sure.

The basic design scheme here assumes that, after establishment and training of the stools to coppice management, each of the eight cants would be cut on an eight-year rotation, one cant every year. At a 9-foot stool spacing, a 0.2 acre cant would have 112 stools, each yielding perhaps 1-3 poles. However, an eight-year rotation is not very likely to produce logs of an appropriate size for mushroom production, at least for red alder. It appears that at least 10-12 years would be needed for 4-5 in. mushroom bolts to grow, supporting the idea of a 16-year rotation and harvesting one cant every other year. Or the space could be divided into four cants of 0.4 acres each harvested every 3 years to get a 12-year rotation and more logs in each harvest. If each stool had between 1 and 3 shoots, then each harvest would yield 112-336 poles on a 0.2 acre cant, or 248-672 poles from a 0.4 acre cant, both within range of the desired log production for harvest years, if not excessive. However, it may be possible to get more than one 3' bolt on each pole, or even on some proportion of the poles, making the 0.2 acre cants and greater harvest frequency more viable.

Table 3: Variations on a 1.6-acre Copse Design for Wellspring Forest Farm. Assumes red alder (*Alnus rubra*) planted on 9-foot centers harvested either for mushroom logs or firewood. Pole diameters are either based on research, or speculations based on the literature (*italics*).[32,33] "± Cords/Harvest" assumes a current annual increment of 0.5-0.75 cords/ac/year, the low end of the regional conventional wisdom. "Ft^3/harvest" is based on the low end of the red alder annual increment found in the literature above, 200 ft^3/ac/yr, and does not include air space. Divide this number by 100 to get approximate number of stacked cords of firewood.

Cant size (ac)	**Total # Cants**	**Years Between Harvests**	**Rotation Length (yrs)**	**Stools per Cant**	**Est. Poles/ Harvest**	**± Pole Dia. (in)**	**± Cords/ Harvest (std)**	**Red Alder Ft^3/harvest**
0.2	8	1	8	112	112-336	2-4	0.8-1.2	320
0.2	8	2	16	112	112-336	*4-8*	1.6-2.4	640
0.2	8	3	24	112	112-336	*6-12*	2.4-3.6	1,296
0.4	4	2	8	248	248-672	2-4	1.6-2.4	640
0.4	4	3	12	248	248-672	4-6	2.4-3.6	1,280

The regional standard Cumulative Annual Increment (CAI) for forestland is 0.5 – 1.0 cords/acre/year, that is, each acre of forest produces ½ to 1 cord of wood per year (a cord is 128 ft^3 of wood and air space, or about 100 ft^3 of wood only). If we assume the panhandle will produce the low end of that, or 0.5-0.75 cords of wood/ac/yr, the eight cants on eight-year rotations would yield an estimated 0.8–1.2 cords of firewood at each harvest. If the rotation becomes 16 years, with one cant harvested every other year, each cant would yield 1.6-2.4 cords of wood, closer to the forecast needs. The eight-year material would likely have a diameter smaller than most wood stoves typically use, but would be quite appropriate in a rocket mass stove or masonry heater. The longer rotations *might* have a good diameter for typical stove wood if that is desired.

However, if we assume the greater annual increment measured for red alder cited above, and knock that down a bit due to the poorer site conditions (to 200 ft^3/ac/yr), the yields per harvest go up substantially: 0.2 acre cants on an 8 year rotation would yield 320 ft^3 of wood, which would be over 3 cords of firewood when stacked (with air space)! How many BTUs that wood will contain is another question entirely, and the key question when it comes to firewood. But that lies outside the bounds of this study.

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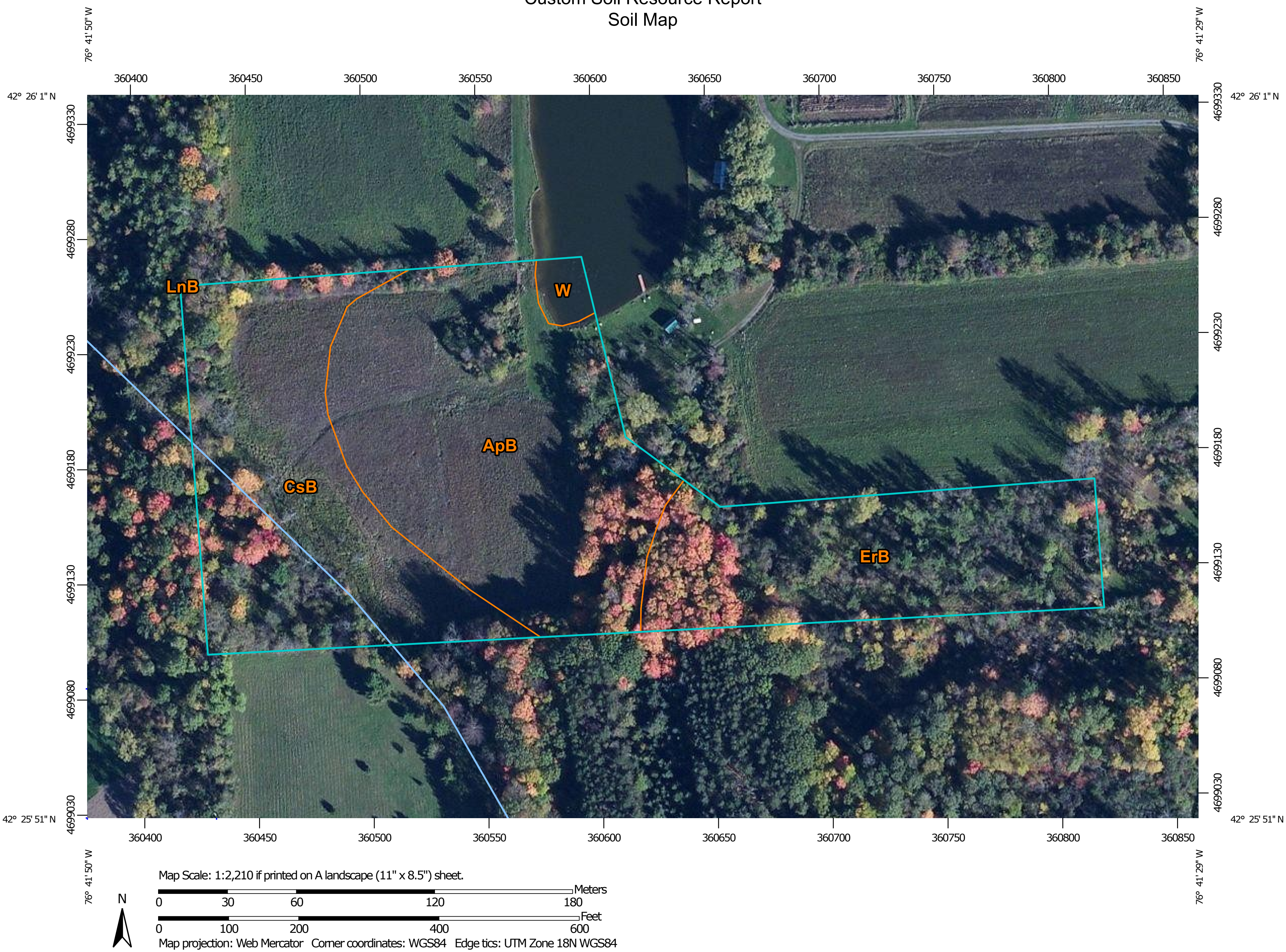
Custom Soil Resource Report
Soil Map



Appendix 1: Wellspring Forest Farm Coppice Case Study, April 13, 2015.
Dave Jacke and Mark Krawczyk, page 1 of 8.

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

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

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

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

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

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

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

Soil Survey Area: Schuyler County, New York
Survey Area Data: Version 10, Sep 16, 2014

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

Date(s) aerial images were photographed: Jun 2, 2010—Oct 8, 2010

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

Map Unit Legend

Schuyler County, New York (NY097)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
ApB	Appleton silt loam, 3 to 8 percent slopes	4.2	40.5%
CsB	Conesus silt loam, 3 to 8 percent slopes	3.3	32.1%
ErB	Erie silt loam, 3 to 8 percent slopes	2.7	25.9%
LnB	Lansing gravelly silt loam, 3 to 8 percent slopes	0.0	0.0%
W	Water	0.2	1.5%
Totals for Area of Interest		**10.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Schuyler County, New York

ApB—Appleton silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 9wjf
Mean annual precipitation: 32 to 40 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 120 to 160 days
Farmland classification: Prime farmland if drained

Map Unit Composition

Appleton and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Appleton

Setting

Landform: Drumlins, till plains
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Calcareous loamy till derived mainly from limestone, sandstone, and shale

Typical profile

H1 - 0 to 8 inches: silt loam
H2 - 8 to 17 inches: gravelly silt loam
H3 - 17 to 34 inches: gravelly loam
H4 - 34 to 60 inches: gravelly loam

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Available water storage in profile: Moderate (about 7.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: C/D

Minor Components

Conesus

Percent of map unit: 5 percent

Alden

Percent of map unit: 5 percent
Landform: Depressions

Unnamed soils

Percent of map unit: 5 percent

Erie

Percent of map unit: 5 percent

CsB—Conesus silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 9wk8
Elevation: 900 to 1,600 feet
Mean annual precipitation: 32 to 40 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 120 to 160 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Conesus and similar soils: 75 percent
Minor components: 25 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Conesus

Setting

Landform: Drumlinoid ridges, hills, till plains
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Crest
Down-slope shape: Concave
Across-slope shape: Convex
Parent material: Loamy till derived from shale with varying components of limestone, sandstone, and siltstone

Typical profile

H1 - 0 to 7 inches: silt loam
H2 - 7 to 41 inches: silt loam
H3 - 41 to 56 inches: silt loam
H4 - 56 to 77 inches: gravelly silt loam

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 18 to 24 inches
Frequency of flooding: None
Frequency of ponding: None

Calcium carbonate, maximum in profile: 15 percent
Available water storage in profile: Moderate (about 8.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B/D

Minor Components

Aurora

Percent of map unit: 5 percent

Lansing

Percent of map unit: 5 percent

Appleton

Percent of map unit: 5 percent

Mardin

Percent of map unit: 5 percent

Unnamed soils

Percent of map unit: 5 percent

ErB—Erie silt loam, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 9wkg
Mean annual precipitation: 32 to 40 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 120 to 160 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Erie and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Erie

Setting

Landform: Till plains, drumlinoid ridges, hills
Landform position (two-dimensional): Footslope, summit
Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Loamy till derived from siltstone, sandstone, shale, and limestone

Typical profile

H1 - 0 to 3 inches: silt loam
H2 - 3 to 15 inches: channery silt loam
H3 - 15 to 45 inches: channery silty clay loam

H4 - 45 to 55 inches: channery silt loam

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: 10 to 21 inches to fragipan
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Available water storage in profile: Very low (about 2.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: D

Minor Components

Chippewa

Percent of map unit: 5 percent
Landform: Depressions

Mardin

Percent of map unit: 5 percent

Appleton

Percent of map unit: 5 percent

Volusia

Percent of map unit: 5 percent

COPPICE AGROFORESTRY
Resprout Silviculture for the 21st Century
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Appendix 2: Crude protein content of leaves of selected woody plants, in Latin name order, based on scientific papers published through 2012. Data may contain percent crude protein (% CP) content of samples taken at various times of year, including dead or senesced leaves taken off the ground in autumn. Some samples in the dataset may have included twigs or young green shoots, but for the most part such data was excluded. Data for species with average leaf crude protein below 9.0% not shown. *Please note* the number of studies (# Refs) for each species in the right-hand column: this table is highly preliminary and narrowly focused! We desperately need much more research and practical experience to enhance the depth and breadth of understanding here.

Genus	***species***	**common name**	**Reported Leaf % CP Average**	**Reported Leaf % CP Low**	**Reported Leaf % CP High**	**# Refs**
Acer	*rubrum*	red maple	11.4	2.7	12.8	6
Acer	*saccharinum*	silver maple	14.0	11.7	16.3	3
Acer	*saccharum*	sugar maple	12.5	7.8	28.8	4
Ailanthus	*altissima*	tree-of-heaven	18.2	10.5	27.2	2
Albizia	*julibrissin*	mimosa	19.3	16.8	23.8	3
Alnus	*cordata*	Italian alder	15.9	12.1	19.7	1
Alnus	*glutinosa*	European black alder	15.2	9.4	19.7	4
Alnus	*incana*	European gray alder	20.1	17.6	25.0	2
Alnus	*rubra*	red alder	14.2	12.7	15.6	2
Amelanchier	*utahensis*	Utah serviceberry	12.0	11.0	13.0	1
Amorpha	*fruticosa*	false indigo	18.2	12.5	19.7	5
Betula	*allegheniensis*	yellow birch	23.5	12.5	34.4	1
Betula	*alnoides*	xi hua	19.4			1
Betula	*lenta*	black birch	13.5			1
Betula	*pendula*	European white birch	19.3	16.9	23.0	2
Betula	*pubescens*	downy birch	15.4	17.6	13.2	2
Caragana	*jubata*	shag-spine	20.3			1
Caragana	*korshinskii*	Korshinsk peashrub	17.0	13.3	19.1	3
Caragana	*microphylla*	litteleleaf peashrub	16.8			1
Castanea	*sativa*	European chestnut	14.5	12.4	17.0	3
Celtis	*occidentalis*	hackberry	11.5	8.7	13.5	1
Cornus	*stolonifera*	red-osier dogwood	14.4	11.3	17.5	2
Corylus	*avellana*	European filbert	10.5	8.5	12.1	1
Corylus	*cornuta*	beaked hazel	13.8	12.4	14.6	1
Elaeagnus	*angustifolia*	Russian olive	18.0	11.1	25.0	6
Elaeagnus	*umbellata*	autumn olive	17.9	13.8	21.9	1
Fagus	*grandifolia*	American beech	11.6	10.8	12.3	1
Fagus	*sylvatica*	European beech	16.1	11.9	17.5	3
Fraxinus	*americana*	white ash	14.4			1
Fraxinus	*pensylvanica*	green ash	9.9			1

(continued)

Leaf crude protein content of selected woody species, *in Latin name order.*

Genus	***species***	**common name**	**Reported Leaf % CP Average**	**Reported Leaf % CP Low**	**Reported Leaf % CP High**	**# Refs**
Ginkgo	*biloba*	ginkgo	11.9			1
Gleditsia	*triacanthos*	honeylocust	13.7	10.9	17.7	6
Hippophae	*rhamnoides*	seabuckthorn	19.7	15.6	21.8	4
Liquidambar	*styraciflua*	sweetgum	10.9	9.0	16.9	3
Liriodendron	*tulipifera*	tulip-tree	12.4	7.9	16.8	5
Morella	*cerifera*	southern bayberry	13.1	9.5	16.0	1
Morus	*alba*	white mulberry	20.5	10.7	35.9	24
Populus	*alba*	white poplar	14.8	13.0	16.5	2
Populus	*deltoides*	eastern cottonwood	12.0	5.6	18.5	5
Populus	*nigra*	black poplar	13.7	11.3	19.7	4
Populus	*tremula*	aspen	18.5	12.8	27.7	4
Populus	*tremuloides*	quaking aspen	13.8	5.4	26.9	5
Quercus	*alba*	white oak	9.2	3.4	12.9	3
Quercus	*nigra*	water oak	13.0	10.3	19.1	1
Quercus	*robur*	English oak	14.7	11.5	18.2	2
Quercus	*rubra*	red oak	11.7	8.7	13.9	3
Quercus	*stellata*	post oak	12.3	12.1	12.4	1
Quercus	*velutina*	black oak	9.5	8.6	10.3	1
Quercus	*virginiana*	live oak	9.5	9.1	10.2	1
Robinia	*pseudoacacia*	black locust	19.8	11.9	27.3	23
Salix	*babylonica*	weeping willow	14.5	6.9	24.8	3
Salix	*caprea*	goat willow	18.8	16.5	22.3	2
Salix	*fragilis*	crack willow	15.5			1
Salix	*humboldtiana*	Humboldt's willow	12.7	6.9	18.4	1
Salix	*nigra*	black willow	10.5	8.3	13.3	2
Salix	*pentandra*	laurel willow	18.3			1
Salix	*purpurea*	purpleosier willow	23.7			1
Salix	*udensis*	fantail willow	9.9	8.2	11.4	1
Salix	*viminalis*	basket willow	18.3			1
Sassafras	*albidum*	sassafras	13.5	5.5	28.3	2
Sorbus	*aucuparia*	rowan	14.6	14.3	14.8	2
Ulmus	*alata*	winged elm	13.0	7.3	27.6	2
Ulmus	*americana*	American elm	12.6	4.8	16.3	3
Ulmus	*crassifolia*	cedar elm	10.9	8.7	12.1	1
Ulmus	*glabra*	Scotch elm	17.6			1
Ulmus	*minor*	smooth-leaved elm	15.0	12.1	19.7	2
Ulmus	*rubra*	red elm	9.9			1
Zanthoxylum	*americana*	prickly ash	17.2			1

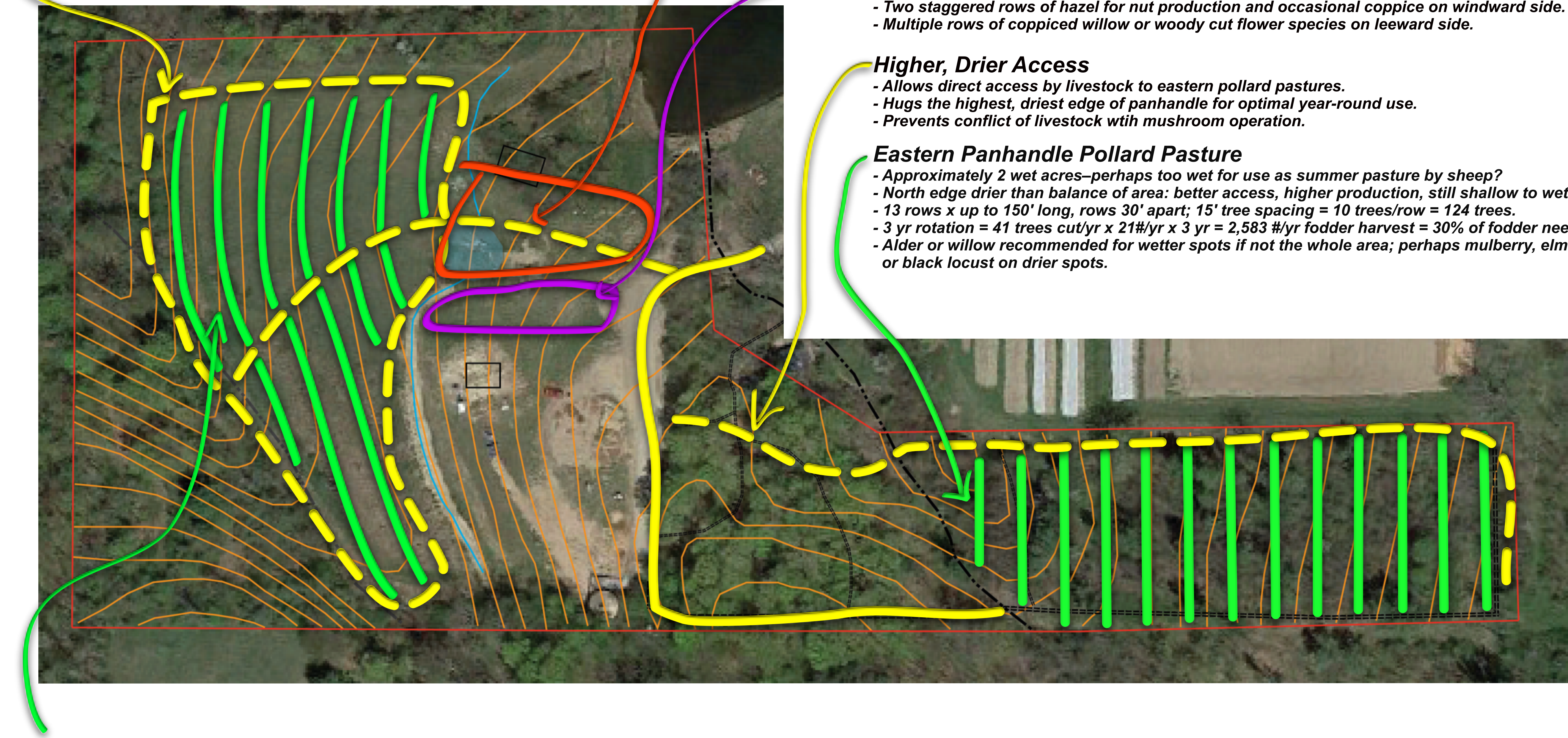
Access Spine & Surround
- Allows vehicle access to bottom of west field and around the pastures.
- Central spine allows changes in livestock grazing pattern mid-rotation.
- Work out details of intersection at nexus in the field / at closer scale.

Access & Circulation Nexus
- Design carefully so water, vehicles, livestock, and pedestrians can intersect functionally.
- Role of agroforestry components unclear until detailed design worked out.

Multifunctional Coppice Windbreak
- Protects greenhouse and nursery, as well as gardens uphill from N and NW winds.
- Two staggered rows of hazel for nut production and occasional coppice on windward side.
- Multiple rows of coppiced willow or woody cut flower species on leeward side.

Higher, Drier Access
- Allows direct access by livestock to eastern pollard pastures.
- Hugs the highest, driest edge of panhandle for optimal year-round use.
- Prevents conflict of livestock wtih mushroom operation.

Eastern Panhandle Pollard Pasture
- Approximately 2 wet acres–perhaps too wet for use as summer pasture by sheep?
- North edge drier than balance of area: better access, higher production, still shallow to wet.
- 13 rows x up to 150' long, rows 30' apart; 15' tree spacing = 10 trees/row = 124 trees.
- 3 yr rotation = 41 trees cut/yr x 21#/yr x 3 yr = 2,583 #/yr fodder harvest = 30% of fodder needs.
- Alder or willow recommended for wetter spots if not the whole area; perhaps mulberry, elm and/ or black locust on drier spots.



Pollards & Pastures
Design Concept
Wellspring Forest Farm

N

Mark Krawczyk and Dave Jacke
January 16, 2015
Base map courtesy Steve Gabriel.
1" = 100'

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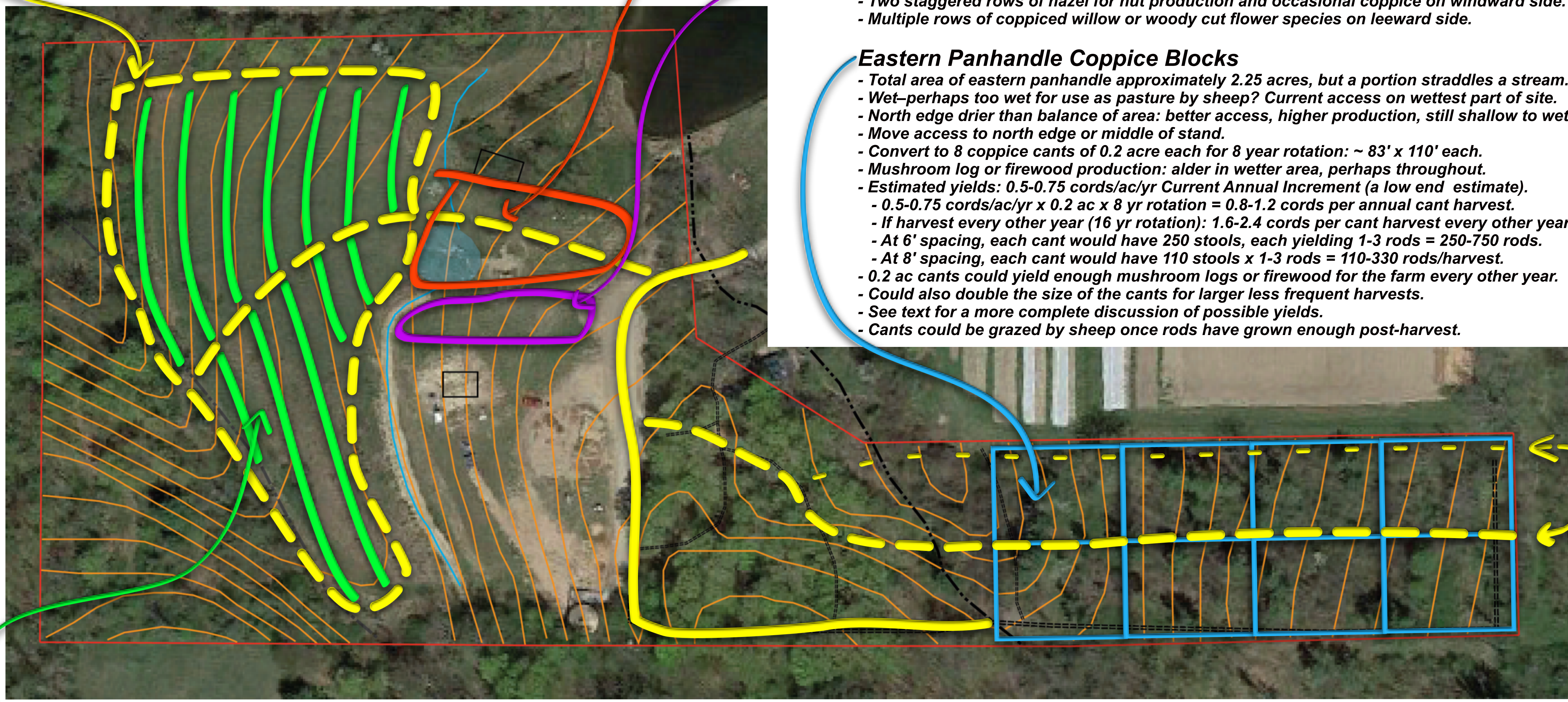
Eastern Panhandle Coppice Blocks
- Total area of eastern panhandle approximately 2.25 acres, but a portion straddles a stream.
- Wet–perhaps too wet for use as pasture by sheep? Current access on wettest part of site.
- North edge drier than balance of area: better access, higher production, still shallow to wet.
- Move access to north edge or middle of stand.
- Convert to 8 coppice cants of 0.2 acre each for 8 year rotation: ~ 83' x 110' each.
- Mushroom log or firewood production: alder in wetter area, perhaps throughout.
- Estimated yields: 0.5-0.75 cords/ac/yr Current Annual Increment (a low end estimate).
  - 0.5-0.75 cords/ac/yr x 0.2 ac x 8 yr rotation = 0.8-1.2 cords per annual cant harvest.
  - If harvest every other year (16 yr rotation): 1.6-2.4 cords per cant harvest every other year.
  - At 6' spacing, each cant would have 250 stools, each yielding 1-3 rods = 250-750 rods.
  - At 8' spacing, each cant would have 110 stools x 1-3 rods = 110-330 rods/harvest.
- 0.2 ac cants could yield enough mushroom logs or firewood for the farm every other year.
- Could also double the size of the cants for larger less frequent harvests.
- See text for a more complete discussion of possible yields.
- Cants could be grazed by sheep once rods have grown enough post-harvest.



Higher, Drier Access
- Better year round access!
- Straight runs for moving rods.
- Center lane within panhandle.
- Or, move it to north edge.

Pollard Alleys
Pollards for fodder production. Could be used for wood production for firewood, craft, etc.
In either case, wind and sun protection will increase animal health and decrease stress.
- 20 sheep @ 80# x avg. 3% body weight in dry matter (DM)/d x180 d winter = 8,640# DM/winter.
- 1,800 lf of pollard rows; 30' spacing between rows; trees planted 15' apart = 120 trees.
- 600 lf cut per year on a 3 year rotation = 40 pollards cut per year for leaf hay fodder.
- Assume 21# dry matter fodder production per year/tree x 3 yrs. x 40 = 2,520# DM/yr.
- 2,520/8,640 = 29% of winter fodder needs.
- We recommend red alder or black locust since it's what you have already tested and they seem to grow well.

Coppice and Pollard
Design Concept
Wellspring Forest Farm

Mark Krawczyk and Dave Jacke
January 16, 2015
Base map courtesy Steve Gabriel.
N
1" = 100'