CONCEPTUAL SITE DESIGN

FREEZE CREEK FOREST

Emigration Canyon, UT

ACKNOWLEDGEMENTS

Produced by Backyard Abundance
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Figure 1. Cover
Shiitake mushroom (*Lentinula edodes*), ginseng (*Panax quinquefolius*), and hazelnut (*Corylus americana*) are all high-value agroforestry crops.
Photos by dominik18s, Priya Jaishanker, Fred Meyer / CC BY ND

Figure 2. Above
Once established, the Chinese chestnut (*Castanea mollissima*) tree will yield food and habitat for decades.
Photo by Otto Phokus

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The pawpaw (*Asimina triloba*) is a mid-sized understory tree that yields potato-sized fruit in part shade or full sun.
Photo by Fred Meyer

AGROFORESTRY DESIGN STRATEGIES

Figure 4. Elderberries
Elderberry shrubs (*Sambucus canadensis*) yield fruit in full sun or part shade and prefer moist, well-drained soil.
Photo by Andy Rogers / CC BY SA

1 INTRODUCTION

Agroforestry is the growing of a combination of crops (plants, animals, fungi) and trees in forest-inspired agricultural systems. These systems benefit human communities through a greater connection to landscapes, improved stewardship of resources, and enhanced economic opportunities.[1]

Following best-practice agroforestry designs allow producers to overcome the significant time commitments, monetary investments, and risk associated with researching planting configurations, estimating implementation costs and payback, and experimenting with planting techniques.

This document provides a custom design of edible agroforestry practices to aid Freeze Creek Forest with the design, implementation, and management of environmentally-beneficial ecosystems that support personal income and community needs. Much information is summarized from existing resources.

Freeze Creek Forest is located on a 40-acre parcel in Emigration Canyon, UT approximately six miles east of Salt Lake City. The site is comprised of a 10-acre mature white Fir stand mixed with gambrel Oak, bigtooth Maple, and quaking Aspen. Chokecherry, blue Elderberry, and Utah Serviceberry are also found intermixed in this stand and the surrounding sage juniper grassland. The site forms a bowl with all aspects present with slopes exceeding 50 percent accounting for the majority of the parcel.

Figure 5. Aronia Berry
The black aronia berry shrub (*Aronia melanocarpa*) yields nutritious berries in a wide variety of soil types.
Photo by Fred Meyer

Overview of Site Areas

Alley Crop Orchard. Grow agricultural crops between strips of food-bearing trees and shrubs.

Edible Forest Edge. Maximize food growth potential at the edge of an existing forest.

Shady Edible Forest. Incorporate edibles and medicinals under the canopy of a forest.

Edible Riparian Buffer. Protect waterways from pollution and erosion with an edible low-land habitat.

Edible Windbreak. Protect crops, livestock, and buildings with a linear planting of edible trees and shrubs.

Homestead Orchard. Increase the value and yield of the land with intensively managed edible landscaping around agricultural accessory use structures.

Silvopasture. Silvopasture, the practice of combining forestry and animal grazing, is addressed in all designs. Most research separates silvopasture from other agroforestry practices, but given the maintenance value provided by animals across many settings, specialized techniques are described in each design. In addition, honeybee apiaries will be an integral part of each design.

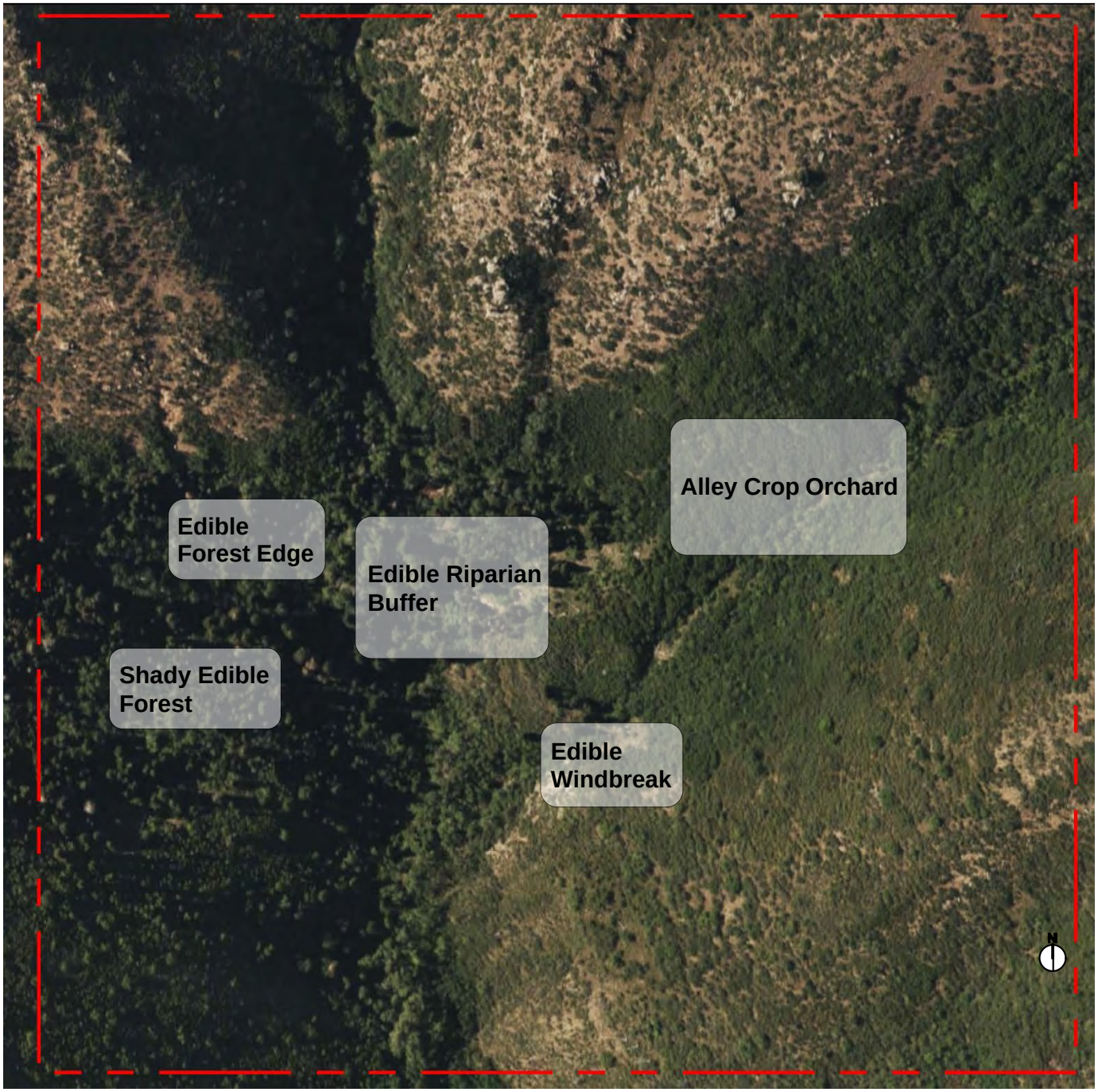

Figure 6. Realistic Designs
Locations on Freeze Creek Forest were used to provide realistic designs and plant selections. Freeze Creek is located at 6,400' MSL in northern Utah in hardiness zone 5b.

2 GOALS

Each design area attempts to meet a variety of important goals to ensure it maximizes value to the producer and the landscape.

Figure 7. Chestnut and Aronia Berry Tour
Tom Wahl, co-owner of Red Fern Farm, hosts educational field day tours of their family-owned tree nursery near Wapello, Iowa.
Photo by Fred Meyer

LOW MAINTENANCE

An established agroforestry system requires some management even if it was designed to mimic self-renewing, self-fertilizing, and self-maintaining properties of a diverse woodland. Leaving energy-intensive maintenance (seeding, planting, weeding, fertilizing, watering) to plant, insect, and animal allies frees up time for additional harvesting, processing, and resting. The grower's role is management—not maintenance—of the ecosystem, guiding it in a desired direction through periodic disturbances of mowing, thinning, pruning, and harvesting. Through these methods, growers become an integrated working part of nature, catalyzing healthy ecosystems that improve over time without constant oversight.

HIGH YIELDS

Food and profit often receive the most emphasis when designing and managing an agricultural landscape. Maximizing long-term success, however, means designing for additional yields that come from the development of an entire system, not just a single element.[2 3]

Agroforestry emulates nature's processes and patterns to decrease labor and financial inputs. While the food productivity of a single plant is considered, yields are additionally measured in terms of the entire system: labor saved, soil fertility increased, weeds suppressed, habitat created, carbon sequestered, beauty enjoyed.

For example, planting chives (*Allium* spp.) and gooseberries (*Ribes uva-crispa*) under the light shade of a pear tree (*Pyrus* spp.) creates a system of cumulative yields: chives accumulate calcium and potassium in the soil for use by the gooseberry and pear while also supporting pollinators and confusing pests with a strong smell, the pear protects the gooseberries from scorching sunny days, and the thorny gooseberry can help deter some animals from browsing the pear. These yields could not be achieved if the elements were planted separately.

Growing food and increasing environmental health are typically considered to be separate endeavors, but by holistically viewing the landscape as a system, edible agroforestry demonstrates that achieving both goals is possible on a single plot of land. The following yields can be realized and greatly increased through the integration of plants, wildlife, insects, and humans.

Food

Integrating a food-bearing plant into a polyculture may decrease its food yield due to competition with other plants for nutrients, water, and sunlight. A thoughtful layout can minimize this competition and promote collaboration so that the entire polyculture produces a crop that is greater than the individual plant. Forage for livestock is also a valuable yield that can be incorporated.

Money

Profit is obviously important but can be difficult to estimate due to many factors: seasonal weather patterns, maturity of perennial crops, soil fertility over time, fluctuations in regional market demand, value-added processing. Establishing annual crops in and around maturing perennial patches can help mitigate these factors.

For information about effective economic planning, see Economic Considerations in the Center for Agroforestry's *Training Manual for Applied Agroforestry Practices*.[4]

Soil Fertility

Industrialized agricultural systems assume soil will degrade over time and therefore attempt to simply minimize losses. Agroforestry systems seek to build new soil, mimicking nature's processes to indefinitely increase tilth and nutrient-holding capacity.

Water Management

Perennial plants are better than annuals at conserving water on the landscape. The persistent canopy created by trees and shrubs holds water for wildlife and insects while slowing rain impacts on soil. Perennial plant roots slow water flow year-round and turn soil into a moisture-retaining sponge. These features help create a drought-resistant landscape that eliminates erosion problems.

Materials

Food-bearing plants and their supporting species can have valuable secondary yields of materials. The trunk of a honey locust (*Gleditsia triacanthos*) can provide rot-resistant lumber and can serve as a living fence post when thoughtfully placed. Hazelnut (*Corylus americana*) wood can be used for basketry or burned for charcoal.

Habitat and Pest Management

The majority of insects and wildlife benefit perennial crops. Without birds and insects the expensive and time-consuming burden of pollinating and protecting crops falls exclusively on producers. Through proper plant selection and layout, we can provide homes and support for beneficial helpers while discouraging severe crop herbivory.[5]

Climate Change Mitigation

Pulling atmospheric carbon into soil and plants helps mitigate climate change. Perennial crops sequester vastly more carbon than annual crops due to their longer growing period and minimal soil disturbance.[6]

EFFICIENT HARVEST

Patches of the site are designed to accommodate a planned harvesting schedule with accessible pathways and physical "windows" into vegetation. Plant varieties are grouped based upon a common ripening period to minimize the fuel consumption and the time required to move through the site. Plants are spaced based upon equipment requirements to make reaching a patch and harvesting within it as efficient as possible.

RESILIENCY AND STABILITY

Mimicking a woodland's vegetation layers, density, and diversity are fundamental to creating resiliency and stability. Left unmanaged, the yields and functions of a well-designed agroforestry site stabilize or improve over the years even when faced with extreme drought, herbivory, wind, and other external stresses.

3 DESIGN STEPS

Designing a landscape that is based upon ecological principles requires thought, patience, and adherence to a good design process.

These following steps were used in creating the Conceptual Site Plans for each area.

1. Articulation of goals
2. Base mapping
3. Inventory and assessment
4. Concept designs
5. Plant list
6. Conceptual Site Plan

Figure 8. Drawing
Tracing paper on top of a base map is an inexpensive and effective method of creating landscape drawings from a variety of viewpoints.
Photo by Fred Meyer

ARTICULATION OF GOALS

The goal of Freeze Creek Forest is to create a living food forest garden for the public to enjoy and understand the role of silviculture in watershed conservation and carbon sequestration while advancing high-altitude, semi-arid agroforestry practices. The intent is to validate economic incentives of sustainable agriculture in harmony with environmental conservation.

BASE MAPPING

A scaled map of the site was created identifying elements that can and cannot be removed.

INVENTORY AND ASSESSMENT

Existing site elements were identified and documented for a thorough understanding of all limiting factors, landforms, water flow and erosion patterns, circulation paths, vegetation, wildlife and insect life, microclimates, frost pockets, wind speed and direction, pesticide drift, buildings, soil fertility, soil texture and drainage, aesthetics, sun and shade, and surrounding ecosystems. Usage zones were designed with frequency of areas are visited in mind.

During the design steps, these careful assessments helped in placing the right plant in the right place which will greatly improve chances for success while lowering maintenance chores.

Species Inventory

The function of existing vegetation on the landscape were inventoried, including all weeds, native species and exotic species. For each plant, sunlight conditions, soil types, common plant groups, and amount of shelter were noted. This research was used to guide the search for desired plants that have attributes similar to thriving plants on the land. This approach will greatly increase plant establishment, yields, disease resistance, pest tolerance, and drought-tolerance.

Existing edible and marketable plants, such as Elderberry and Serviceberry have been prioritized in the existing forest. These plants are expected to expand or establishing higher-yielding varieties to greatly increase chances of success.

Water Flow Patterns

An emphasis was placed on precisely identifying the contours of the landscape to better understand how to minimize drought. USGS contour maps were used for initial planning and design. Detailed maps will be created from USDA GIS data collected on site using Real-Time Kinematic (RTK) via NTRIP positioning correction transmission protocol for more precise maps and designs.

Eroded areas represent high-priority opportunities for catching and impounding large amounts of water for the benefit of nearby plants.

Limiting Factors

The site’s limiting factors and resources are key to designing resilient polycultures that produce high yields at desired times. Latitude, annual precipitation, landform, and biome are factors that cannot be easily changed. Plants were selected to match the site instead of attempting to alter the site so desired plants will thrive on it.

Plant selections will minimizing competition between plants for limited moisture, nutrients, or sunshine by using limitations as a guide.[9] For example, species with high drought tolerance or deep taproots, or both, were selected to not compete for scarce moisture.

The availability to harvest crops is another limitation. Time windows for harvesting throughout the seasons were considered and species and varieties selected that accommodate the schedule.

CONCEPT DESIGNS

Initial designs were sketched using free flowing bubble-like shapes and loose lines. The entire landscape with functional areas were created using the site inventory and assessment to inform this brain-storming. Each area is designed with a specific purpose that helps fulfill the producer's goals. The ecosystem of each area is intended to help define plant communities: forest, woodland, shrubland, prairie, wetland. Pathways are defined between areas to create an elegant flow throughout the landscape. Beneficial relationships are created between elements to increase their value; for example, a terraced swale on contour is used to hold and infiltrate rainwater.

PLANT LISTS

The design started with a desired plant list. The mature size of each plant, its optimal growing conditions, and its functions were identified. Plants were identified that suppress weeds (i.e., ground covers, fix nitrogen in the soil, accumulate nutrients, and/or attract beneficial insects and birds. Including these highly functional plants in the landscape means less maintenance because plants, animals, and insects perform this maintenance.

For each area in the concept design, desired plants were divided into individual plant lists using the designated ecosystem, desired functions, and limiting factors to guide decisions.

CONCEPTUAL SITE PLAN

For each area in the concept design, infrastructure elements, trees, and shrubs were first selected and then herbaceous plants and ground covers placed. The area’s plant list was used to place plants based upon desired harvesting schedules. Trees and shrubs were selected based upon their mature size to minimize future competition for sunlight.

Several conceptual site plans were created for different periods to show growth over time. For example, the alley crop contains mostly windbreak and soil anchor trees during its initial establishment. After 3-5 years, the widening tree canopy will help to establish perennial plans with the understory shielding harsh sunlight.

The Center for Agroforestry’s *Training Manual for Applied Agroforestry Practices guidelines were incorporated to develop the work plan, site assessment, and market plan* .[10]

4 ORGANIzING PATTERNS

Each agroforestry design shares an underlying framework of patterns that aid in the maintenance, yield consistency, stability, and resiliency of the system. Understanding these patterns allows plant substitutions and design changes to be made for different growing conditions and desired yields.

Figure 9. Ostrich Fern Fiddlehead
Young shoots of the ostrich fern (*Matteuccia struthiopteris*) are edible and can be prepared like asparagus.
Photo by Priya Jaishanker / CC BY ND

WATER MANAGEMENT AND LANDSCAPE CONTOUR

Plants need water to thrive, so a critical first step was to carefully create a water management plan. Topography, current soil moisture levels, annual rainfall, and each plant's water needs were considered and then a plan that distributes and infiltrates rainwater at specific locations was created. Establishing swales and ponds, keyline plowing, and placing pathways and plants on a landscape's contour are water management techniques that will form a strong foundation for perennial crops. See *The Keyline Plan* for information about keyline design and plowing to create a drought-resistant landscape.[11]

PATHWAYS

Decreasing management time requires that site designs accommodate light equipment, off-highway vehicles (OHV), wheel barrows, and other equipment. Path widths and turn-around headlands (space at the end of a field) are based upon existing and future equipment.

WOODLAND ECOSYSTEM

Achieving the many goals of an edible agroforestry system requires a high input of energy. This energy can come from our labor and a declining supply of fossil fuels or we can place a majority of the burden onto Mother Nature's strong shoulders. Understanding the ecological niche of plants is key to leveraging nature's free benefits.

Most orchard crops originated in woodlands. All design templates, therefore emulate a woodland ecosystem as a design foundation to ensure the broadest array of these crops will reside in familiar biological communities with desired sun, soil, nutrient, and water needs fulfilled. This ecosystem has a high level of ecological productivity, giving plants a home in which they will inherently thrive and maximize food yields without constant oversight.

Where existing mature forest stands are overgrown, tree spacing will adhere to the diameter plus ½ guide, that is the distance in feet between adjacent trees should be equal to 1½ times the tree diameter in inches. Upright, undamaged, full crowned trees will be retained where possible. Thining activities will be performed during late fall and winter.

Infested trees will be felled by early May, before the adult beetles emerge. Mechanical treatments include splitting, chippping, and peeling bark from infested trees to be burned are highly effective but also highly labor intensive.

NATIVES AND ECOLOGICAL ANALOGS

Whenever possible, species native to the property were selected to take advantage of their inherent ability to adapt to regional stresses and provide desired habitat for local wildlife and insects. If a native could not appropriately fulfill a needed function or fit within a space, an attempt was made to find an ecological analog: a species or variety that has a high degree of similarity with the native species. For example, the native saskatoon (*Amelanchier arborea*) may be too tall to grow alongside a semi-dwarf fruit tree in a Mountain West polyculture so the shorter Regent variety of the *Amelanchier alnifolia* species could be selected instead.

When selecting any species, especially non-natives, the plant's replication methods were carefully researched, which can vary depending upon the region and site conditions. Highly dispersive and expansive species were avoided.

Figure 10. Contour Planting
These newly planted fruit trees at Versaland Farm follow the contour of the landscape to slow rain water and help it infiltrate rather than run off.
Photo by Paul Trieu

Figure 11. Saskatoon Harvest
Saskatoons (also known as serviceberries and Juneberries) yield sweet berries in late June. They have few pest or disease problems. Native species can be found throughout much of the United States.
Photo by Fred Meyer

VEGETATION LAYERS

The vertical structure of a woodland is defined by several vegetation layers, all of which are capable of yielding food. Each layer interacts with the other layers to keep the entire system functioning. Resiliency in the woodland is increased with more vegetation layers due to redundant functions and additional availability of species niches.

The soil of healthy woodlands is composed of mycorrhizal fungi due to the constant presence of woody trees and shrubs. Therefore, to help orchard crops thrive, a fungal-dominated soil must be encouraged by establishing a large number of trees and shrubs with undiseased debris from regular pruning dropped directly to the ground. Interplanting species that can be exclusively used for mulch is recommended, such as the fast-growing, nitrogen-fixing black alder (*Alnus glutinosa*).

Tall Tree

Some woodlands may not have a tall tree layer or may only have only a few tall trees. The overstory defines the amount of sunlight available to lower layers and consumes the most nutrients and water in the woodland. Due to this fact, great consideration must be given to the amount of food yield desired in lower layers; a sparse overstory will increase food yields in lower layers (see “High-Yielding Upper Canopy” on page 13). Examples: bigtooth maple (*Acer grandidentatum*), chestnut (*Castanea mollissima*), heartnut (*Juglans ailantifolia*).

Low Tree

Understory trees are often shade tolerant, but fruit yields increase with more sun. Trees in this layer can be designed to replace tall trees from accidental or purposeful disturbances. Examples: elderberry (Sambucus cerulea), saskatoon (Amel-anchier alnifolia), pawpaw (*Asimina triloba*), pear (*Pyrus* spp.), apple (*Malus* spp.), hickory (*Carya ovata*).

Shrub

Just like understory trees, shrubs are often shade tolerant and add diversity and yields to the system. Examples: aronia berry (*Aronia melanocarpa*), gooseberry (*Ribes uva-crispa*), bush cherry (*Prunus japonica*), hazelnut (*Corylus americana*).

Herb

In addition to providing food and medicine, the flowers and vegetation of perennial herbs often support a wide variety of insects that assist in the pollination and protection of the system. Examples: ginseng (*Panax quinquefolius*), anise hyssop (*Agastache foeniculum*), purple coneflower (*Echinacea purpurea*), comfrey (*Symphytum x uplandicum*), rhubarb (*Rheum x cultorum*).

Ground

Low-growing, spreading perennials help suppress weeds and conserve moisture. Huge amounts of nutrients are stored and cycled in the herb and ground layers. Examples: Utah sweetpea (Lathyrus pauciflorus), Dutch white clover (*Trifolium repens*), garden strawberry (*Fragaria ananassa*), yarrow (*Achillea millefolium*), mushrooms.

Root

Plant roots can help condition poor soil sometimes to great depths. Examples: Jerusalem artichoke (Helianthus tuberosus), alfalfa (*Medicago sativa*).

Vine

Vines can grow in any layer using other layers for structural support. Pruning may be required to ensure they do not suffocate other vegetation. Examples: hardy kiwi (*Actinidia arguta*), grape (Vitis spp.), maypop (*Passiflora incarnata*).

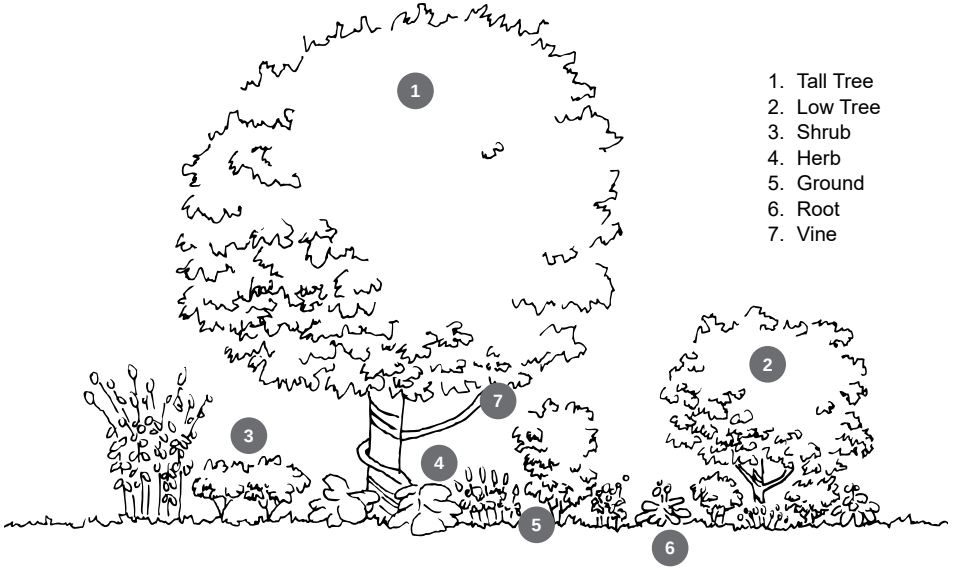

Figure 12. Vegetation Layers
Up to 7 layers can exist in an edible agroforestry planting.
Drawing by Fred Meyer

VEGETATION DENSITY

A woodland tree canopy ranges from 40% to 99% coverage (a forest has 100% coverage).[12] Most orchard crops yield more food with increased sunlight. The density of a woodland’s upper canopy, therefore determines the amount of food that can be expected to grow in lower layers.

High-Yielding Upper Canopy

To maximize food yields in the upper canopy, space trees so their mature crowns touch, but do not interlock. This design keeps the most sunlight in the upper canopy which may decrease yields in lower layers.

High-Yielding Understory

To maximize food yields in lower layers, focus first on providing required sunlight to understory plants and then integrate upper canopy trees. For example, space understory shrubs so their mature crowns do not interlock and then surround or bookend them with trees ensuring mature tree crowns do not shade the shrubs.

Increase Yields in New Orchards

Far more sunlight is available to the lower layers of a newly planted orchard. Establish fast-yielding crops between trees to provide yields while trees mature; for example, annual vegetables, French sorrel (*Rumex acetosa*), rhubarb (*Rheum x cultorum*), aronia berry (*Aronia melanocarpa*), and bush cherry (*Prunus japonica*) often provide food within two years after planting. As the canopy closes, sun-loving species can be replaced with shade-tolerant plants; for example, gooseberry (*Ribes uva-crispa*), and elderberry (*Sambucus canadensis*).

VEGETATION DIVERSITY

Physical and functional diversity in a woodland increases the ecosystem's stability, resilience, and self-maintenance.[13] Competition between plants with similar resource needs decreases yields. Resiliency and yields are maximized by using a variety of diverse plants which encourage harmony and cooperation.

Resource Partitioning

Varied plant heights minimize competition for sunlight. Plants with roots of varied depths are also utilized to partition the soil for nutrients and water; for example, taprooted comfrey (*Symphy-tum x uplandicum*), dandelion (*Taraxacum officinale*), and French sorrel (*Rumex acetosa*) are unlikely to sap resources from a nearby shallow-rooted fruit tree.

Polycultures

A well-designed, intercropped mix of plant species provides several benefits:

- Food yields increase due to decreased competition for similar sunlight, water, and nutrient resources.
- Disease problems decrease because parasites cannot jump as easily between different species.
- Herbivory is decreased because it is more difficult for pests to find desired plants.

Integrated pest management strategies often suggest avoiding monocultures of long rows and large masses of the same species.[14] When designing blocks or short rows of plants, try to increase harvest ease by keeping species with similar ripening times in the same patch.

Uneven Structure

A woodland with a level canopy height is not desired. Plantings of varied dimensions throughout all layers are established to promote air circulation, increase sunlight availability, and increase niches for beneficial insects, birds, and soil organisms.[15] Intermixing varieties of the same species creates varied heights and widths while also increasing disease and pest resistance. Within rows, plants are slightly offset rather than planted in a straight line.

Redundancy

To increase system resiliency, similar functions are fulfilled multiple times in different ways. If deer nibble all fragrant false indigo (*Amorpha nana*) to the ground, a backup ground cover of perennial Dutch white clover (*Trifolium repens*) exists to replace its nitrogen-fixing function.

FUNCTIONALLY INTERCONNECTED POLYCULTURE

Maximizing food yields is a primary focus, but to remain stable, resilient, and self-maintaining, a woodland ecosystem requires that its inhabitants fulfill other functions, not just producing food. Every area was designed to build soil, suppress weeds, cycle nutrients, support pollinators, and resist pests by leveraging inherent functions of plants and attracted animals. Elements in the ecosystem all work in an interdependent web of relationships, each fulfilling each other's needs and caring for one another. Ideally, a single plant, insect, or animal will provide multiple functions to the system, increasing chances for redundancy and other yields.

Soil Building Nutrient Accumulators

Plants that generate biomass filled with nutrients accumulated from subsoil or gathered from topsoil detritus are used to eliminate fertilizers. Comfrey (*Symphytum x uplandicum*), dandelion (*Taraxacum officinale*), French sorrel (*Rumex acetosa*), and Roman chamomile (*Chamaemelum nobile*) are examples of plants that build soil and reduce leaching losses by accumulating nutrients and then releasing them through root and foliage decomposition.

Nutrient accumulators are placed near the dripline of the mature outer canopy of food-bearing plants where feeder roots are commonly located.

Figure 13. Strawberry and Garlic Polyculture

This polyculture of strawberries and garlic yields more food per square foot together than it would if the plants were separated. The different leaves and root structures do not compete for sunlight or water.

Photo by Fred Meyer

Figure 14. Comfrey

The deep roots of comfrey bring up nutrients from the subsoil and do not compete with surrounding plants.

Photo by Fred Meyer

Nitrogen Fixers

Nitrogen is often the least available soil nutrient, but one that all plants need. Nitrogen-fixing plants sequester atmospheric nitrogen and then release ("fix") it into the soil where it can be used by surrounding plants. Good examples include leadplant (*Amorpha canescens*), lupines (*Lupinus* spp.), alfalfa (*Medicago sativa*), and clovers (*Trifolium* spp.).

Just as with nutrient accumulating plants, nitrogen fixers are placed near the mature outer canopy of food-bearing plants where feeder roots are commonly located.

Ground Cover Weed Suppressors

Ground covers can form a thick mat under crops and in pathways to make it difficult for weeds to gain a foothold. Ideal ground covers are low-growing, provide habitat for beneficial insects and soil organisms, do not harbor pests, eliminate erosion, do not compete with crop plants for water and nutrients, and decrease or eliminate mulching and mowing maintenance. Achieving all these goals can be difficult and trade-offs are often needed.

Vegetation under crop plants yield soil development, pollinator habitat, and reduced maintenance, but sacrifice some food yields due to competition for nutrients and water. Yields from the entire system are less important then trying to design for that balance. Permanent vegetation under crop plants that eliminate mowing, but also reduce food yields, were selected instead of maximizing food yields by replacing vegetation under crop plants with chop-and-drop mulch from native grasses.

When designing a ground cover mix, 2-4 species with both clumping to accomodate all weed niches and running habits in the each area. After a few years, the clumpers will appear to be islands in a sea of runners.

- Running species spread indefinitely, weaving among other plants filling in soil and sunlight gaps. Examples: dwarf yarrow (*Achillea tomentosa*), wild strawberry (*Fragaria virginiana*), sweet woodruff (*Galium odoratum*), peppermint (*Mentha spicata*), apple mint (*Mentha suaveolens*).
- Clumping species grow to only a specific width and typically spread slowly. Clumpers should be tall enough to ensure they are not overtaken by runners. Examples: creeping thyme (*Thymus serpyllum*), oregano (*Vulgare hirtum*), chives (*Allium* spp.), Roman chamomile (*Chamaemelum nobile*), self-heal (*Prunella vulgaris*).

See Washington State University's *Orchard Floor Management* publications[16] for additional information and research about weed management strategies.

Slow-Growing Grass Mix

The shallow, dense roots of conventional turfgrass robs young orchard crops of nutrients and water. A slow-growing, lower-competition native grass mix for pathways and mowed areas under tree crops will use:[17]

- Creeping red fescue (*Festuca rubra ssp. rubra*).
- Chewings fescue (*Festuca rubra ssp. commutata*) and/or hard fescue (*Festuca longifolia*).
- Dutch white clover (*Trifolium repens*).

Deter Voles

Eliminating vole habitat is important as these rodents can girdle and kill trees by eating bark. Voles take up residence in most tall ground covers and deep woodchip mulch. They prefer to eat white clover so this will not be planted under crop trees where vole activity is high.

Voles will also be deterred by mixing gravel with the soil at the base of trees, installing hardware cloth around trunks, encouraging predator activity, and establishing vole-repelling plants, such as sweet woodruff.[18] Providing habitat for predatory snakes and birds will also help manage rodent population.

Nectaries

Flowers blooming throughout the growing year provide support for beneficial insects and birds that in turn provide pollination and pest-management services. Native flowers are incorporated that bloom early or late in the season or have blooms for 2-4 months. This includes plants with short and long nectar tubes to encourage insect diversity.

Most flowers serve as food sources for "generalist" insects, but also select plants that attract "specialist" predatory insects to help control pests. All plant lists in this document designate nectary plants as generalists (G), specialists (S), or both (GS).

Long-blooming examples include anise hyssop (*Agastache foeniculum*), purple coneflower (*Echinacea purpurea*), blanket flower (*Gaillardia aristata*), fennel (*Foeniculum vulgare*), aster (*Aster* spp.), mint (*Mentha* spp.) and yarrow (*Achillea millefolium*).

Pest Confusers

Strong-scented plants can confuse pests and reduce their ability to find crops. Good aromatic plants include anise hyssop (*Agastache foeniculum*), yarrow (*Achillea* spp.), bee balm (*Monarda fistulosa*), broadleaf sage (*Salvia officinalis*), and mint (*Mentha* spp.).

	Crop Tree Size and Setting		
	• Standard-sized crop trees less than 4 years old. • Dwarf crop trees of any age.	• Standard-sized crop trees that are 4+ years old.	
		• High vole activity. • Large area.	• Low vole activity. • Medium to small area.
Pathway ground cover	• Slow-growing grass mix with alfalfa.	• Slow-growing grass mix with Dutch white clover.	
Crop ground cover	• Mulch of mowed grass and alfalfa blown from pathway. • Woodchip mulch.	• Chives, mint, sweet woodruff. • Slow-growing grass mix.	• Chives, dwarf yarrow, wild strawberry, Dutch white clover, creeping thyme, oregano, Roman chamomile, self-heal.
Notes	• Young trees grow faster in mulch with no competition from ground covers. • Due to weak root systems, crop yields from dwarf trees decrease when ground covers are present. • Successfully using mowed and blown grass as mulch requires narrow crop rows.	• For settings completely covered by grass, trees spaced evenly in a grid pattern will improve mowing efficiency. • Dropped fruit may be difficult to harvest in tall ground covers. • Rotating geese or other animals can keep grass low while cleaning up fallen fruit.	• Plants may be costly if they cannot be established through direct seeding.

Figure 15. Ground Cover Strategies

Use the tree size and setting to inform a mix of ground covers that will maximize crop yields while suppressing weeds.

5 CROP YIELDS AND HARVEST TIMES

Crop yields and harvest times are influenced by hardiness zone, sunlight and water availability, soil conditions, competition from other plants, pruning regimes, rootstock, variety, and plant age.

Figure 16. Black Cohosh
Black cohosh (*Actaea racemosa*) is a medicinal herb that can be grown under the shade of black walnut and other tree crops.
Photo by rockerBOO / CC BY

Approximate crop harvest times and yields for which data was available is shown in Figure 16. This information was used to inform decisions on which crops to grow. Harvest labor is reduced by grouping crops with similar harvest times.

Form	Common Name	Genus / Species	Hardiness Zones	Crops	Crop Yield Pounds / Plant	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Vine	Grape, Fox	Vitis labrusca	5-8	Fruit	12.5									
Tree	Apple, Dwarf	Malus spp.	4-8	Fruit	48.0									
Tree	Cherry, Sour Dwarf	Prunus cerasus	4-8	Fruit	22.0									
Tree	Cherry, Sweet Dwarf	Prunus avium	5-8	Fruit	22.0									
Tree	Chestnut, Chinese	Castanea mollissima	4-8	Nuts	30.0									
Tree	Crabapple, Siberian	Malus baccata	3	Fruit										
Tree	Mulberry	Morus spp.	5-9	Berries	17.5									
Tree	Pawpaw	Asimina triloba	4-8	Fruit	12.5									
Tree	Peach, Dwarf	Prunus persica	4-8	Fruit	57.0									
Tree	Pear, Asian	Pyrus pyrifolia	4-9	Fruit										
Tree	Pear, European Dwarf	Pyrus communis	4-9	Fruit										
Tree	Persimmon, American	Disospiros virginiana	5-9	Fruit	27.5									
Tree	Plum, American Standard	Prunus americana	3-8	Fruit	122.5									
Tree	Plum, European Dwarf	Prunus domestica	4-8	Fruit	8.8									
Tree	Plum, Japanese	Prunus salicina	6-10	Fruit										
Tree	Walnut, Black	Juglans nigra	4-7	Nuts	120.0									
Shrub	Aronia Berry, Black	Aronia melanocarpa	3-9	Berries										
Shrub	Beach Plum	Prunus maritima Ecos	3-6	Fruit										
Shrub	Blueberry, Half-High	Vaccinium spp.	3-7	Berries										
Shrub	Blueberry, Highbush	Vaccinium corymbosum	3-7	Berries	7.5									
Shrub	Blueberry, Lowbush	Vaccinium angustifolium	2-6	Berries	1.9									
Shrub	Cherry, Bush	Prunus japonica	4-8	Fruit										
Shrub	Currant, Black	Ribes nigrum	3-7	Berries	10.0									
Shrub	Currant, Red	Ribes silvestre	3-7	Berries	6.5									
Shrub	Elderberry	Sambucus canadensis	3-10	Berries	15.0									
Shrub	Gooseberry	Ribes uva-crispa	3-8	Berries	9.0									
Shrub	Hazelnut	Corylus americana	4-9	Nuts	22.5									
Shrub	Nanking Cherry	Prunus tomentosa	3-7	Fruit										
Shrub	Raspberry	Rubus idaeus	4-8	Berries										
Shrub	Saskatoon	Amelanchier alnifolia	2-7	Berries	5.7									
Herb	Asparagus	Asparagus officinalis	2-9	Shoots	0.4									
Herb	Blackberry, Thornless	Rubus fruticosus	5-8	Berries										
Herb	Rhubarb	Rheum x cultorum	1-9	Stalk	3.5									
Herb	Strawberry, Garden	Fragaria ananassa	4-9	Berries	1.0									

Figure 17. Approximate Crop Yields and Harvest Times

Yields and harvest times may vary greatly based upon site conditions. Estimates are provided from several sources.[19] [20] [21]

6 ESTABLISHMENT AND MANAGEMENT

Establishing an edible agroforestry system takes years or decades depending upon weather, soil conditions, the size of the site, and the amount of pressure from undesired weeds and animals. After the design was completed, a realistic establishment strategy was created that is within the available time, resources, and budget.

Figure 18. Woodland Medicinal Starter Beds
Raised beds can help keep weeds from intermixing with these newly planted medicinal herbs.
Photo by Katie Trozzo / CC AT ND

Weed Management

It is very important to create a weed management strategy before planting begins. The selected strategy influenced the site layout, plant selection, mowing regime, use of animals, and needed equipment. These designs demonstrate a “sandwich system” of grass pathways between wide strips of orchard crops with perennial ground covers.

Vigorous and persistent weeds exist on the site, so patiently taking multiple years to eliminate the weeds prior to planting will be necessary since it is more difficult to eliminate weeds around existing plants. Landscape fabrics that biodegrade in a year are also a good option for eliminating weeds.

See “Ground Cover Weed Suppressors” on page 15 for information about designing polycultures to manage weeds.

Soil Development

For all plants, the existing soil pH range, drainage, texture (sand, silt, clay), and organic matter were considered. Soil will not require remediation prior to planting because soil conditions already match plant needs.

Instant Succession

Succession is the observed process of change in the species structure of an ecological community over time.[22] A woodland normally takes a very long time to establish as it linearly goes from bare ground through successive stages of annual herbs, perennial forbs and grasses, pioneer shrubs and trees, to hardwood trees. By thoughtfully establishing high-functioning herbs, shrubs, and trees all at the same time, all layers of the woodland instantly begin growing. This strategy bypasses natural stages, greatly accelerating succession and yields while suppressing weeds.

Limiting factors may greatly influence resource needs and succession speed for each site. For example, a low-nutrient sandy site may require immense amounts of compost or an emphasis on temporary soil-development plants in early years. As nutrient levels increase, the soil-developers can be replaced with permanent plants.

Islands that Merge

Small islands of plantings that slowly expand and eventually merge will be utilized to minimize resources and labor where weed competition is high. These islands keep weeds at bay using wide, temporary barriers of landscape fabric and/or heavy mulch. The weed barrier will be expanded and plants propagated into the weed free area when weeds surrounding the islands are thoroughly suppressed by the barrier and ground covers within the islands are established.[23]

Over Planting

Trees and shrubs will be overplanted and then thinned as they reach maturity to allow several varieties or species to be evaluated for the most resilient, highest yielding plants in a specific area of the landscape. After several years, low-yielding plants will be removed and fragile plants may die. New plants may need to be planted if large gaps emerge where plants once stood.

Maintaining sunlight in lower layers may require removing perfectly good plants if preferred resilient species are planted too close. A staggered planting pattern will be used to help minimize this situation.

Animals

A Utah Department of Agriculture and Food licensed honeybee apiary has been operatd on the property since March 2021. Honeybees are artificially bred, domestic agricultural animals classified as livestock by the US Department of Agriculture (USDA) and the US Food and Drug Administration (FDA). USDA-accredited certifying agents may certify beekeeping operations under the existing organic regulations for livestock ([7 CFR] Sections 205.236 – 205.240). The entire property is managed in accordance with organic livestock pasture regulations but is not certified organic by the USDA. The USDA National Organic Standards Board (NOSB) Livestock Committee 2010 Apiculture Recommended Standards will be implemented on the site.

Additionally, domestic animals may be used seasonally (May - October) to prepare the land for permanent plantings, depending on the condition of the site and its vegetation. Drinking water source protection will be the top consideration when giving animals access to cropland. Where the land is lightly vegetated and prone to erosion, a movable poultry tractor may be used to quickly remove the tops of weeds and lay down a light coat of manure. Pigs, goats or cattle can initially prepare land crowded with weeds when the area is too rough for poultry.

Select areas far from sensitive soil or riperian zones can be partitioned with electric mesh or virtual fencing to contain animals that clear weed trees and brush before planting. For example, goats can initially graze tall, thick weeds, followed by poultry which spread manure and interrupt parasite life cycles. A pig tractor can be used to remove deeply rooted woody weeds. Pigs can also be rotated seasonally to clean up crop wastes or fallen fruit.[24]

Animal tractor systems are very effective for ground cover maintenance and work well with orchard or tree crops. In an orchard animal tractor system, the animals are rotated through the orchard, either in movable pens or in a series of fixed paddocks. The animals clean the area between and under the trees of grasses, weeds, and weed seeds, scavenge wastes and windfall fruits, and eat insects and their larvae. At the same time, animals add manure to help fertilize the crops. When the pen area has been cleared and fertilized by the animals, they are moved on to the next section of orchard. With the appropriate combination of animals and crop trees, this system has been effective with chickens, guinea fowl, turkey, pheasant, quail, sheep, and pigs in alley orchards.

On a healthy mixed diet from the orchard, animals tend to have less disease problems. Lighter animals such as chickens or other poultry can be rotated permanently through an orchard system. Geese can be employed to control grasses in orchards.[25]

Young saplings are susceptible to animal damage while the orchard is being established. Once perennial plantings, including ground covers, are established small breeds of chicken can be introduced to the orchard. The chickens will eat insects and the fruit that falls to the ground, stopping pests from gathering, and fertilize the soil. This can be done at a ratio of about 10 chickens per acre. When the orchard is 3-7 years pigs can be introduced, after 7 years, sheep. When the orchard is 15 years old cattle can be allowed to periodically graze in the orchard.[26]

When animal grazing is not possible, brush-hogs, tractors, winches, chainsaws, and hand tools will be used instead for manually removing undesired plants.

Pest Management

Crops will be periodically inspected to detect and manage pests. Fencing will be implemented around tree seedlings to protect from animal browsing. Non chemical corrective actions will be used, if any, to minimize negative impacts on beneficial insects.

AGROFORESTRY DESIGNS AND CONCEPTUAL SITE PLANS

Figure 19. Tour of Red Fern Farm
Red Fern Farm is family-owned nursery near Wapello, Iowa that grows a variety of tree crops.
Photo by Fred Meyer

7 ALLEY CROP ORCHARD

Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacings, creating alleys within which agricultural, horticultural, or forage crops are cultivated.[27]

Figure 20. Alley Crop Orchard
Walnut trees surround an alley of corn in this agroforestry planting.
Courtesy of USDA National Agroforestry Center

INVENTORY AND ASSESSMENT

The contours of the site were identified and used as a design foundation for long strips of plantings. The plantings will follow the contour of the land to maximize rainwater catchment and reduce erosion without needing irriation. Sunlight availability, soil types, frost pockets, and warm microclimates throughout the area were identified.

The direction of prevailing summer and winter winds are noted below.

The design considers required path width and turnaround space by light equipment for management and harvesting.

The travel routes of local wildlife are also considered where young plantings will need protection.

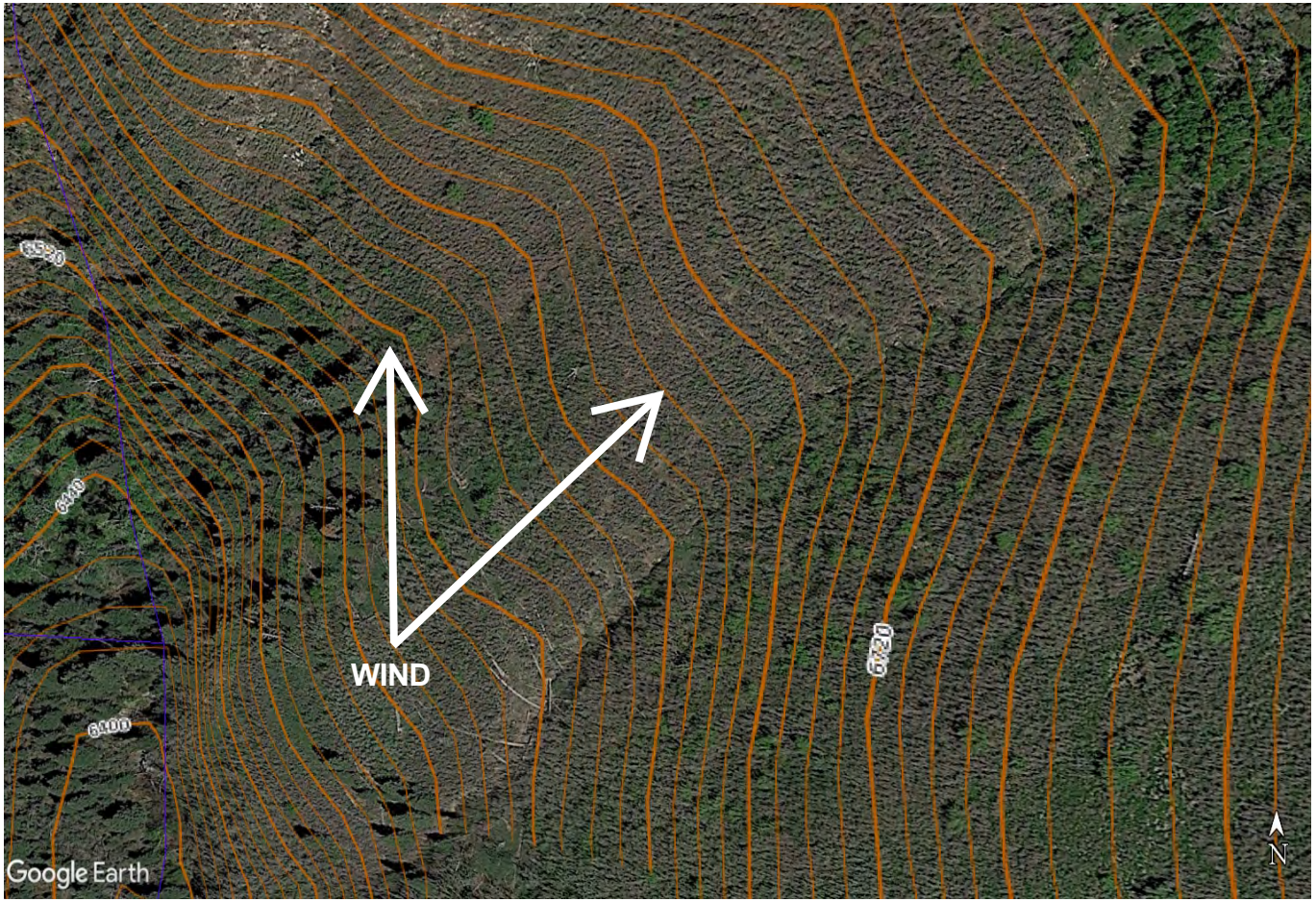

Figure 21. Alley Crop Orchard Base Map
Contour lines help form the foundation for the design.

CONCEPT DESIGN

Rows of woody perennials are placed at intervals of 60' - 100' on contour across the crop field. The width of the alleys between the rows of trees or shrubs were determined by considering slope length, field width, crop sunlight requirements, and equipment width. A north-south orientation of tree rows will maximize snowpack conserved in the alley crop.

Blocks of plants are organized strategically based on harvest times. These polycultures also help reduce pest pressure.

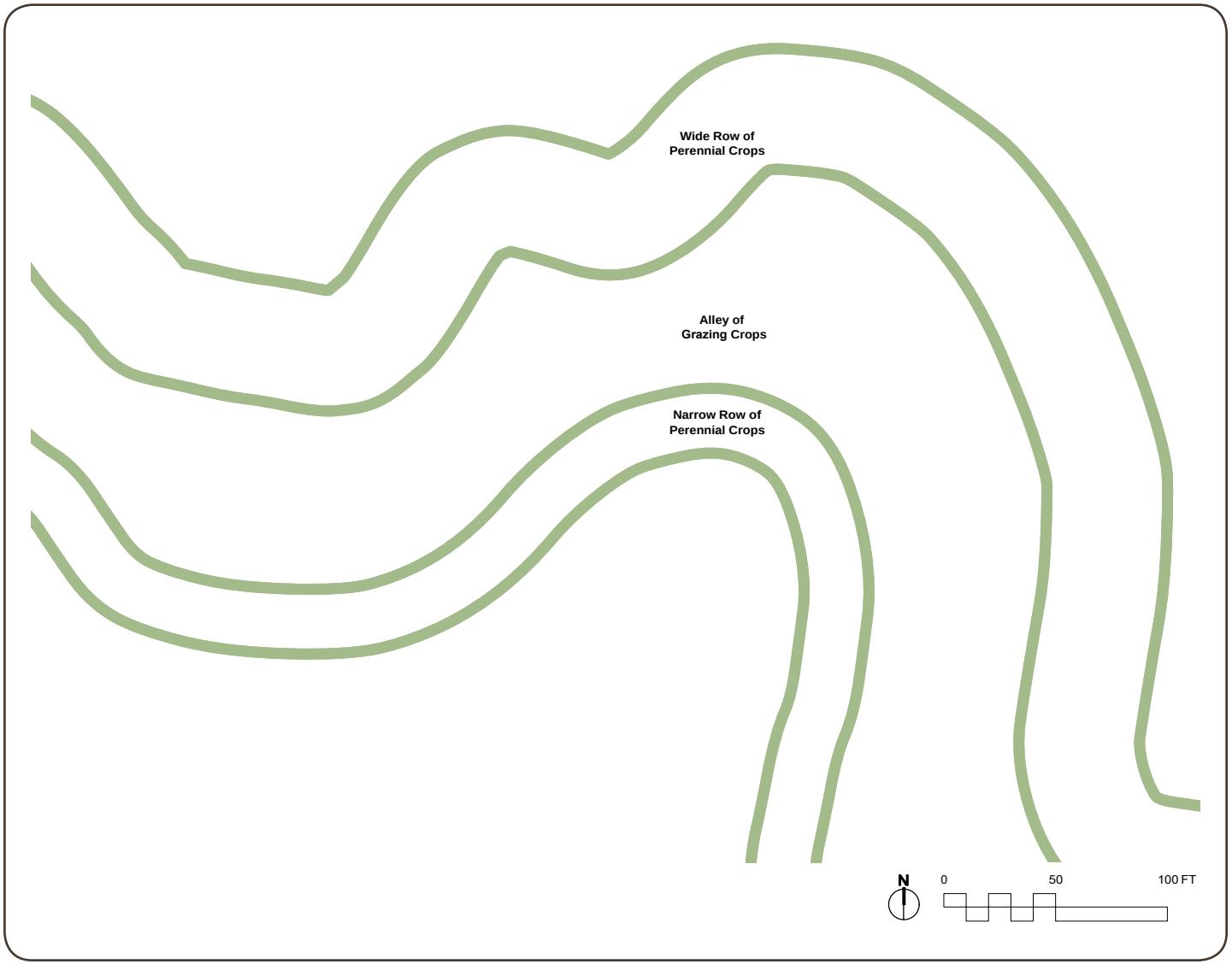

Figure 22. Alley Crop Orchard Concept Design
A wide row and narrow row of perennial crops surround a 60’ wide row of annual crops.

Competition and Cooperation

Trees compete with companion crops for sunlight, moisture, and nutrients. Attention was given to the root type and size of neighboring plants within the design to minimize competition. For example, root systems associated with warm season forages are typically deeper than cool season grasses. This makes them an excellent choice for controlling erosion and protecting subsurface water from leached nutrients. These warm season grasses will be less competitive in the early spring when many trees are beginning their annual growth. However, warm season forages grow vigorously in the hot summer months which may put them in competition with trees and other woody vegetation at a time of the year when water is possibly the most limited resource. Seasonal compatibility was considered when selecting the trees, shrubs, grasses, and crops for the alley cropping practice.

Perennial alley crops have positive influences on tree crops by suppressing weeds, providing nutrients, and creating microclimates. For example, many legumes fix nitrogen that can benefit nearby fruit trees while deterring weeds. Sunflowers can speed tree growth by creating a greenhouse effect for trees.[28] Chemical interactions can be controlled by choosing plant combinations that work together.

Multiple Rows

Multiple rows of trees and shrubs provide the same benefits as a single row of perennials, but allow structure and species diversity to be increased through vertical and horizontal vegetative layering. Water and nutrient loss is also improved by using multiple rows.

To enhance the growth of trees and shrubs in multiple-row plantings, plants are staggered between adjacent rows. This will permit maximum crown development by providing more room to grow. In addition, competition for sunlight between plants can be reduced through offset row configurations.[29]

Row Spacing

Wider row spacing is preferred for stock grazing. Closer spacing will provide better erosion control. Eighty to 120 foot spacing will allow production for up to 20 years or more. As the shade increases over the life of the trees, it may be necessary to change the companion crop being grown in the alleyway. As the alleyways become more shaded, shade tolerant species can be grown.[30]

Figure 23. Alley Crop Orchard.
Walnut trees surround an alley of soybeans.
Courtesy of USDA National Agroforestry Center

PLANT SELECTION

When selecting a tree species, the sunlight needs of the alley crop throughout its growth cycle were considered. Small tree leaves and light shade is preferable to heavy shade.

A thorny hedge of roses, such as dog rose (*Rosa canina*) or rugosa rose (*Rosa rugosa*), can be planted around the perimeter of an orchard to contain and shelter.

Dutch white clover (*Trifolium repens*) in preferred instead of red clover for areas where livestock may forage.

Hickories (*Carya* spp.), walnuts (*Juglans* spp.), oaks (*Quercus* spp.), persimmons (*Diospyros* spp.), and honeylocust (*Gleditsia triacanthos*) are recommended trees for North American systems.[31]

Form	Common Name	Genus / Species	Hardiness Zones	Height	Width	Light	Water	Crops	Materials	Nitrogen Fixer	Nutrient Accumulator	Ground Cover	Nectary	Medicine
Tree	Chestnut, Chinese	Castanea mollissima	4-8	40'	40'	Full Sun		Nuts						
Tree	Locust, Honey, Thornless	Gleditsia triacanthos	3-8	50-75'	50-75'	Full Sun	Xeric - Hydric	Seeds					G	x
Tree	Pawpaw	Asimina triloba	4-8	20-30'	20-30'	Full Sun - Part Shade	Mesic	Fruit						
Tree	Persimmon, American	Disospiros virginiana	5-9	15-75'	15-50'	Full Sun	Xeric - Mesic	Fruit					G	
Tree	Serviceberry, Downy	Amelanchier arborea	4-9	15-25'	15-25'	Full Sun - Part Shade	Mesic	Berries						
Tree	Walnut, Black	Juglans nigra	4-7	50-70'	30-50'	Full Sun	Xeric - Mesic	Nuts	Lumber		K, P, Ca			
Shrub	Aronia Berry, Black	Aronia melanocarpa	3-9	5-6'	5-6'	Full Sun - Part Shade	Mesic - Hydric	Berries						
Shrub	Elderberry	Sambucus canadensis	3-10	6-12'	6-12'	Full Sun - Part Shade	Xeric - Hydric	Berries					GS	
Shrub	Goumi	Elaeagnus multiflora	5-9	6-8'	6-8'	Full Sun - Part Shade	Xeric - Mesic	Berries		x				
Shrub	Hazelnut	Corylus americana	4-9	12-20'	12-15'	Full Sun	Mesic	Nuts						
Shrub	Saskatoon	Amelanchier alnifolia	2-7	5-15'	5-15'	Full Sun	Mesic	Berries						
Shrub	Sea Buckthorn	Hippophae rhamnoides	3-8	10-20'	10-20'	Full Sun - Part Shade	Xeric - Mesic	Fruit		x				
Herb	Clover, Dutch White	Trifolium repens	4-8	4-10"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Clover, Miniclover	Trifolium repens	4-8	4"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Comfrey	Symphytum x uplandicum	4-9	3-5'	3-5'	Full Sun - Full Shade	Xeric - Mesic				K, P, Ca, Cu, Fe, Mg			x

Figure 24. Alley Crop Orchard Plant List

Figure 25. Harvesting Pawpaws

Pawpaw trees (*Asimina triloba*) grown from seed begin yielding fruit in 4-8 years depending on seed quality, suitability of the location, the care the tree receives, and the species.

Photo by Fred Meyer

CONCEPTUAL SITE PLAN

This design depicts row crops of nuts and fruits with alleyways for annual crops. The top row, which is upslope, is comprised of a black walnut (*Juglans nigra*) polyculture of complementary plants. Plants were chosen that tolerate the juglone compound that is produced by black walnuts in seed husks, leaves, and roots. The polyculture was placed downslope to avoid complications with other rows containing crops that are sensitive to juglone.

Nitrogen Fixers

Nitrogen fixing plants include rows of alternating sea buckthorn (*Hippophae rhamnoides*) and goumi (*Elaeagnus multiflora*) with white clover (*Trifolium repens*) in the ground cover.

Pollinators

Plants that support pollinators and beneficial predatory insects include white clover, goumi, aronia berry (*Aronia melanocarpa*), American elderberry (*Sambucus canadensis*), saskatoon (*Amelanchier alnifolia*), and comfrey (*Symphytum x uplandicum*). The saskatoon alternates with aronia berry for pest interruption.

Harvest Strategy

Since walnuts, persimmons (*Disospiros virginiana*), and pawpaws (*Asimina triloba*) are har-vested by hand, the shrub understory will not interfere with harvesting. Trees are spaced to allow access to the shrubs for harvesting.

Competition Considerations

Sun-loving saskatoon and sea buckthorn shrubs were placed on southern rows while shade-tolerant goumi, elderberry, and aronia were placed north of trees. Wide spacing between shrubs reduces competition while easing harvesting and management.

Alleyway Crops

Crops chosen for the alleyways are determined by farm needs and the age of the perennial plantings. When trees are young, sun-loving perennial forage grasses for animal fodder are planned. As the trees mature, shade-tolerant perennials can be introduced into the alleys such as hazelnuts, elderberries, and aronia berries.

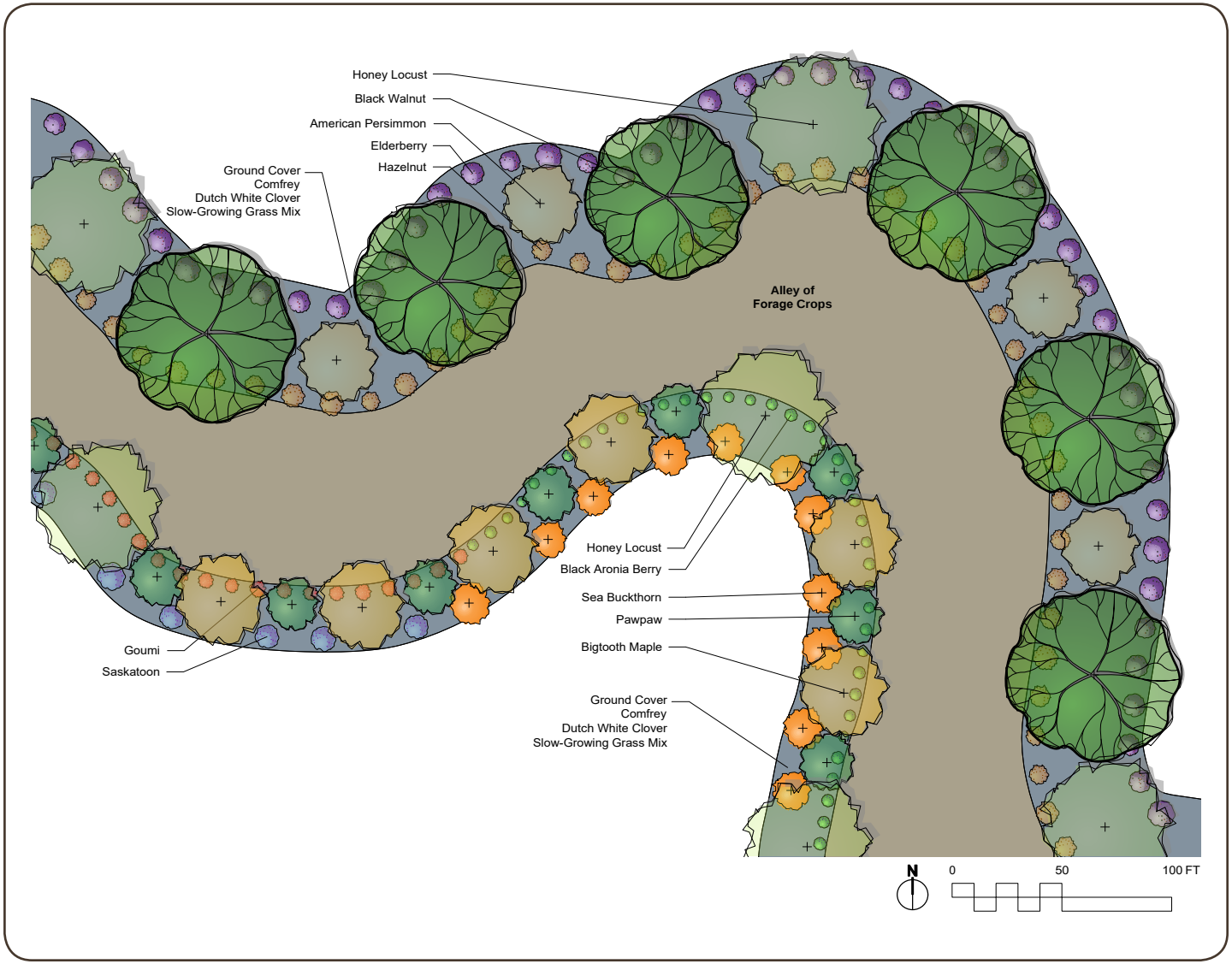

Figure 26. Alley Crop Orchard Conceptual Site Plan

ESTABLISHMENT AND MANAGEMENT

For tree rows, weeds must be minimized for the first 3-5 years in a band about 3 feet on each side of the trees. Nothing will improve the growth of trees and shrubs like the control of competing grasses.

Properly thinning trees within rows can maintain semi-open crowns. Maintained through regular thinning, these openings can help continue the vigorous growth of shade intolerant companion crops. Pruning basal branches before they reach 1” in diameter improves future wood quality and thins the depth of the canopy permitting more sunlight to reach understory crops.

If trees are shallow rooted, roots can be severed using a Ripper, Coulter, or Chisel Plow to decrease competition with annual crops. Begin when trees are young and annually or biennially rip lateral roots to decrease their presence in the plow zone. Remaining roots will be active deeper in the soil profile.[32]

As tree crops mature, less of the alley crop will thrive due to shading. Perennial alley crops could be replaced with shade-tolerant perennials.

As a system matures, it begins to propagate itself and expand. Consider allowing volunteer mulberries, raspberries, and grapes to thrive and provide yields provided they do not interfere with the rest of the system.

Figure 27. Tree Planting
A tractor-pulled tree planter can greatly increase planting efficiency and speed for large areas.
Photo by Fred Meyer

8 EDIBLE FOREST EDGE

Shady forests in the Mountain West often end abruptly when meeting steep, dry slopes. Orchard crops, beneficial insects, and wildlife can thrive in this sunny and partially protected environment while creating a beautiful and natural-looking transition of open woodland to dense forest.

Bees are important pollinators for many agriculture crops, but cultivated plants rarely provide their required nectar year round. Forest edges with large diversities of flowering plants can help support pollinators. In addition, the increased number of birds in forest edges help manage agricultural pests.[33]

Figure 28. Extending a Forest Edge
The edge of this forest is extended with newly planted fruit trees on the contour of the landscape.
Photo by Paul Trieu

INVENTORY AND ASSESSMENT

The forest edge design assessed existing tree canopy, sun exposure, soil type, and the slope of the land. Sun exposure is a major factor in determining species location in the forest edge habitat. The more deeply shaded forest areas share organic matter, shade, protective cover, and a fungal-driven soil. The sunnier grassland areas share sun, wind, openness, and bacterial-driven soil.[34]

Existing native species are desired for propagation.

The slope of the land does not require supplemental irrigation needs.

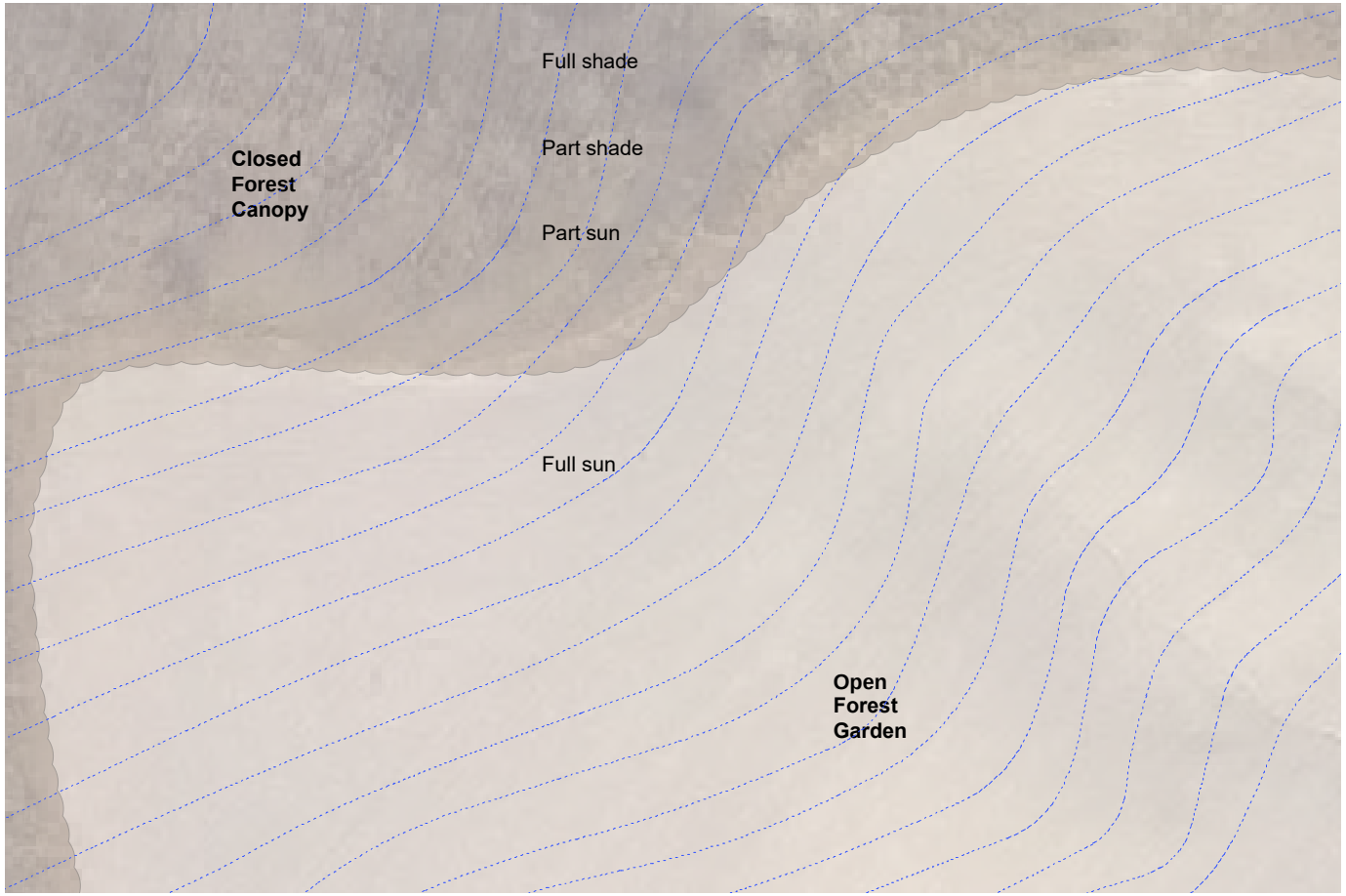

Figure 29. Edible Forest Edge Base Map
Contour lines help form the foundation for the design.

CONCEPT DESIGN

Carefully planning of paths to crops for ease of maintenance and harvesting was considered . using keyhole, sinuous, suntrap, crenellated, and gently curved designs.[35]

Livestock were also considered in placing and designing the forest edge planting. Enriching of the fodder base is incorporated with fruits, leaves, and branches by including forest edge planting near grazing areas.[36]

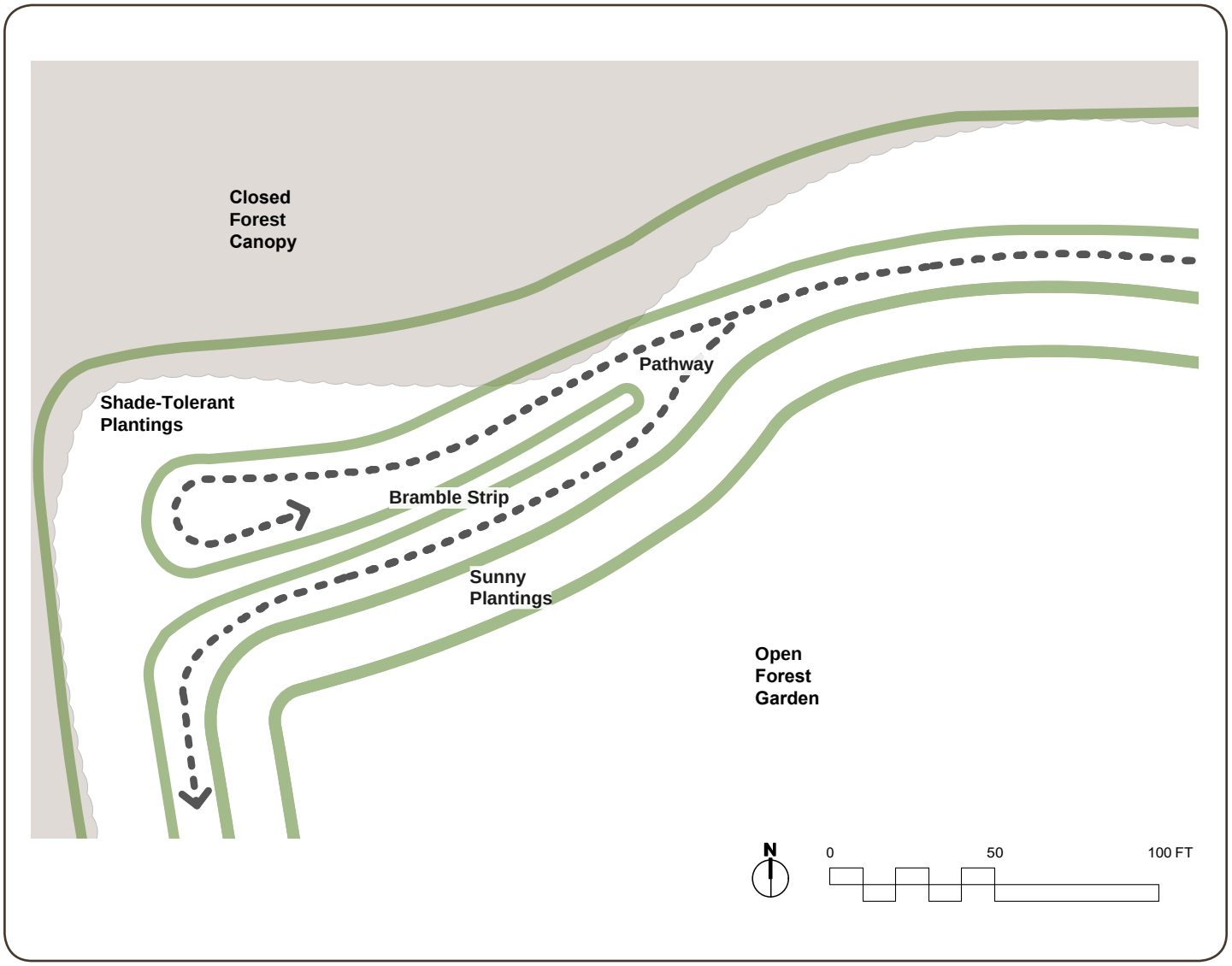

Figure 30. Edible Forest Edge Concept Design
Pathways extend through the forest edge to ease maintenance and harvesting.

PLANT SELECTION

Edible forest edge designs favor canes, shrubs, and small to mid-sized trees.[37]

Herbs also appreciate the fungal dominated soils of the forest edge. Marketable herbs such as thyme, lavender, and marjoram can be grown beneath the light shade of trees.[38]

Form	Common Name	Genus / Species	Hardiness Zones	Height	Width	Light	Water	Crops	Materials	Nitrogen Fixer	Nutrient Accumulator	Ground Cover	Nectary	Medicine
Tree	Crabapple, Siberian	Malus baccata	3	30'	25'	Full Sun	Mesic	Fruit			K			
Tree	Dogwood, Cornelian Cherry	Cornus mas	4-8	20'	20'	Full Sun - Part Shade	Mesic	Berries						
Tree	Pawpaw	Asimina triloba	4-8	20-30'	20-30'	Full Sun - Part Shade	Mesic	Fruit						
Tree	Pear, Asian	Pyrus pyrifolia	4-9	25-30'	25'	Full Sun	Mesic	Fruit					G	
Tree	Persimmon, American	Disospiros virginiana	5-9	15-75'	15-50'	Full Sun	Xeric - Mesic	Fruit					G	
Shrub	Elderberry	Sambucus canadensis	3-10	6-12'	6-12'	Full Sun - Part Shade	Xeric - Hydric	Berries					GS	
Shrub	Gooseberry	Ribes uva-crispa	3-8	3-5'	3-5'	Full Sun - Part Shade	Xeric - Mesic	Berries						
Shrub	Hazelnut	Corylus americana	4-9	12-20'	12-15'	Full Sun	Mesic	Nuts						
Shrub	Jostaberry	Ribes x culverwellii	4-7	4-8'	4-8'	Full Sun - Part Shade	Xeric - Mesic	Berries					x	
Shrub	Raspberry	Rubus idaeus	4-8	4-6'	Indef.	Full Sun	Mesic	Berries						
Herb	Blackberry, Thornless	Rubus fruticosus	5-8	4-5'	3-4'	Full Sun	Mesic	Berries						
Herb	Clover, Dutch White	Trifolium repens	4-8	4-10"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Clover, Miniclover	Trifolium repens	4-8	4"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Comfrey	Symphytum x uplandicum	4-9	3-5'	3-5'	Full Sun - Full Shade	Xeric - Mesic				K, P, Ca, Cu, Fe, Mg			x
Herb	Daffodil	Narcissus	4-8	3-5'	1-3'	Full Sun - Part Shade	Mesic						x	
Herb	Jerusalem Artichoke	Helianthus tuberosus	2-10	6-12'	Indef.	Full Sun - Part Shade	Mesic	Tubers						
Herb	Squash, Winter	Cucurbita moschata	2-11	18"	Indef.	Full Sun	Mesic	Vegetable						
Herb	Strawberry, Wild	Fragaria virginiana	3-8	4-12"	Indef.	Full Sun - Part Shade	Xeric - Mesic	Berries			Fe	x		
Herb	Yarrow, Dwarf Wolly	Achillea tomentosa	4-9	6-18"	Indef.	Full Sun - Part Shade	Xeric	Leaves (Tea)			K, P, Cu	x	GS	

Figure 31. Edible Forest Edge Plant List

Figure 32. Gooseberries
Many varieties of gooseberries produce high yields of sweet berries.
Photo by Fred Meyer

CONCEPTUAL SITE PLAN

This design depicts pawpaws (*Asimina triloba*) and persimmons (*Disospiros virginiana*) at the existing tree line with an understory planting organized by harvest times.

Design Strategy

In the southernmost row, berries tolerant of part-shade are planted on the north side of fruit trees. Daffodils (*Narcissus*) and chives (*Allium* spp.) planted around the trees confuse pests and provide a crop. Bulbs planted at the drip line of trees also help keep spreading grasses from competing with tree roots. Dutch white clover (*Trifolium repens*) and wild strawberries (*Fragaria virginiana*) complete the ground cover polyculture. The hedge of raspberries (*Rubus idaeus*) is surrounded by mowed pathways to contain their spread.

Harvest Strategy

Persimmons are harvested late in October into November. Pawpaws are harvested by hand in mid-September after elderberries (*Sambucus canadensis*) are harvested in late August.

ESTABLISHMENT AND MANAGEMENT IDEAS

Brush-hogs, tractors, winches, chainsaws, and other hand tools will be needed to initially clear trees and brush before planting the forest edge.

Animals contained within movable electric mesh fencing may also be incorporated to help prepare the forest edge. Goats can clear vegetation ahead of chickens, relying on the poultry to spread the manure and disrupt parasite cycles. The rooting behavior of pigs can remove deeply rooted woody weeds. Movable pig tractors can prepare a new area or can be rotated seasonally to clean up crop wastes or fallen fruit.

Elderberries grown for market are cut to the ground after the ground freezes to prevent mites from overwintering in the buds.[39]

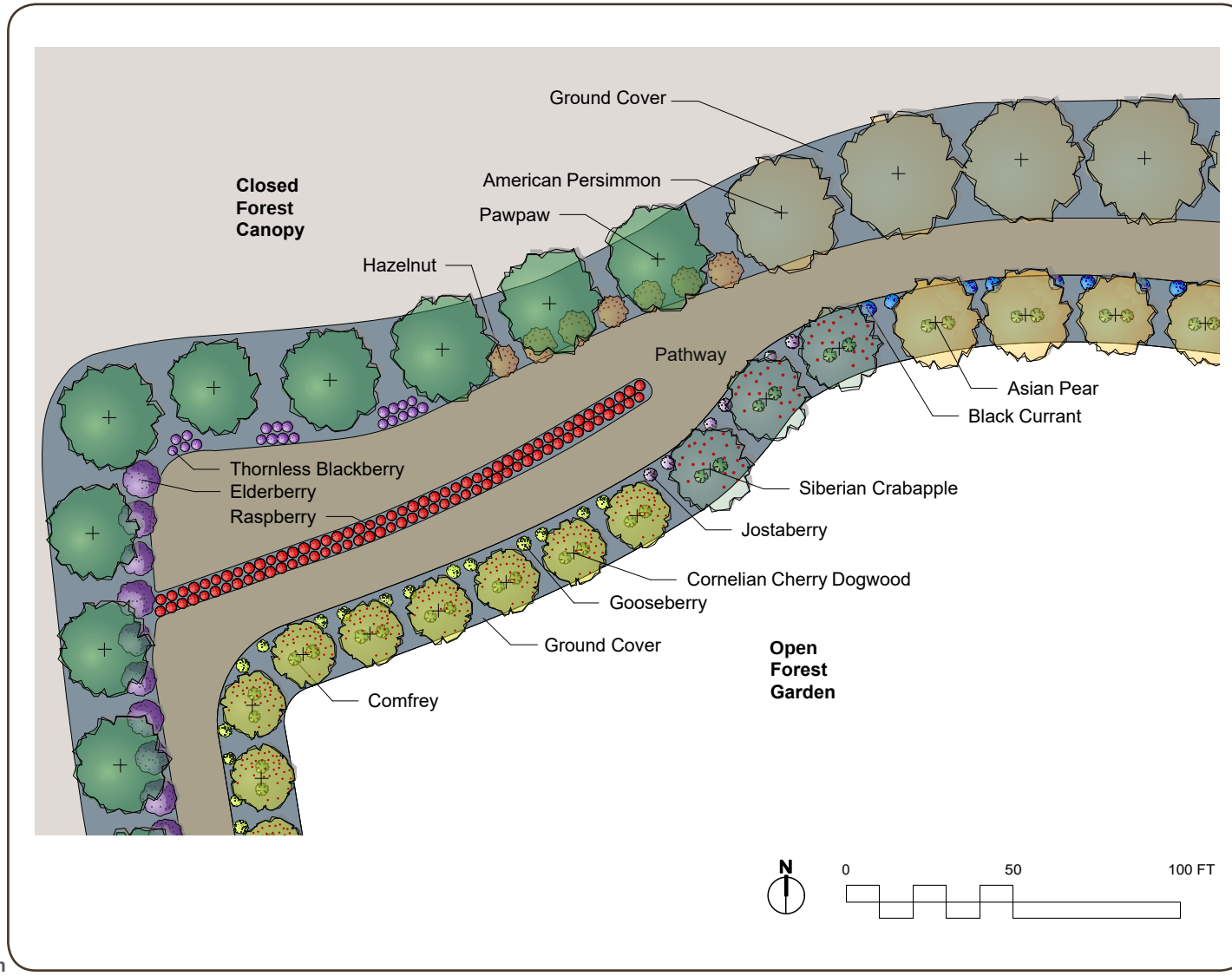

Figure 33. Edible Forest Edge Conceptual Site Plan

9 SHADY EDIBLE FOREST

Forest farming is the cultivation of high-value specialty crops under the protection of a forest canopy that has been modified to provide the correct shade level.[40]

Most shade-loving plants benefit from consistently moist soil and some direct or dappled sunlight. Thinning the upper canopy, removing underbrush, and removing entire trees may be required to provide the correct environment for forest crops to thrive.

Figure 34. Medicinal Herbs
Cultivated medicinal herbs can contribute to the health of a forest.
Photo by Forest Farming / CC BY ND

INVENTORY AND ASSESSMENT

This site was selected for ideal sunlight and soil moisture. Sunlight levels were carefully observed throughout the day: Most forest plants thrive only in part shade to full shade environments. These areas provide soil that is consistently moist, but well-drained.

Direct Sunlight Levels
Full Sun: 6 or more hours
Part Sun: 2-6 hours
Part Shade: 2-4 hours
Full Shade: Less than 2 hours

Vegetation Layers
Shrubs, ground covers, vines, or herbs can provide an opportunity for opportunistic weeds to gain a foothold. Saplings of desired canopy trees will be hand planted—these important young trees are the next generation in the stand awaiting a disturbance to fill in canopy gaps.

Mushrooms
Logs and woodchips inoculated with mushroom spawn are a popular medium because fungi requires almost no sunlight. A flat, protected area where logs could be stacked or leaned between trees has been identified for mushroom production.

When mushrooms are fruiting, daily misting and harvesting may be necessary to ensure freshness and prevent damage from insects. For this reason, growing mushrooms may only be practical when water rights are acquired and access allows the site to be visited frequently.

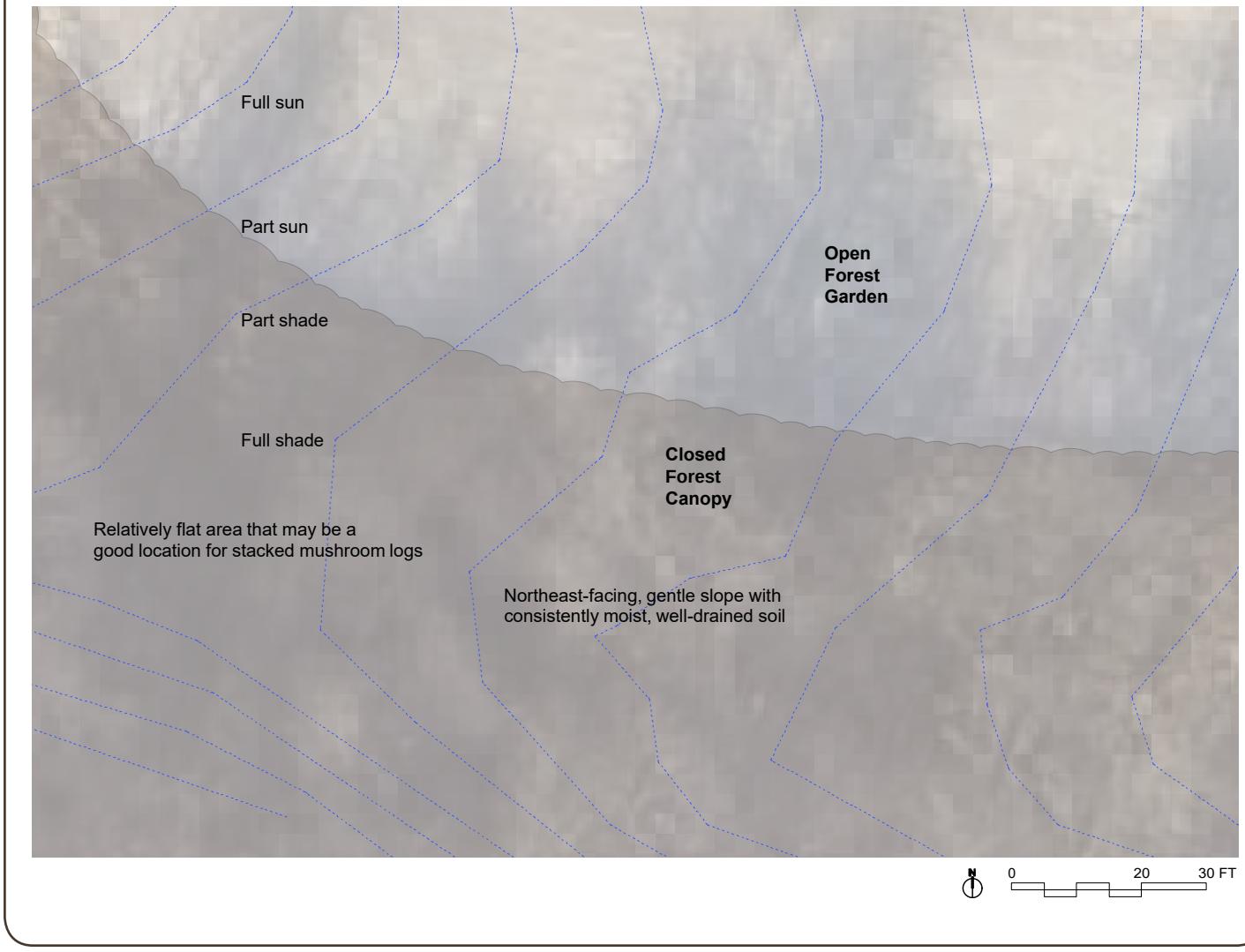

Figure 35. Shady Edible Forest Base Map
Contour lines help form the foundation for the design.

CONCEPT DESIGN

Sunlight is the greatest limiting factor in a forest design: too much or too little sun and plants will wither. Sunlight levels were used to identify planting areas then group plants based upon desired harvesting periods and growing conditions. For example, tall plants are used to fully shade mushroom logs and protect them from drying winds.

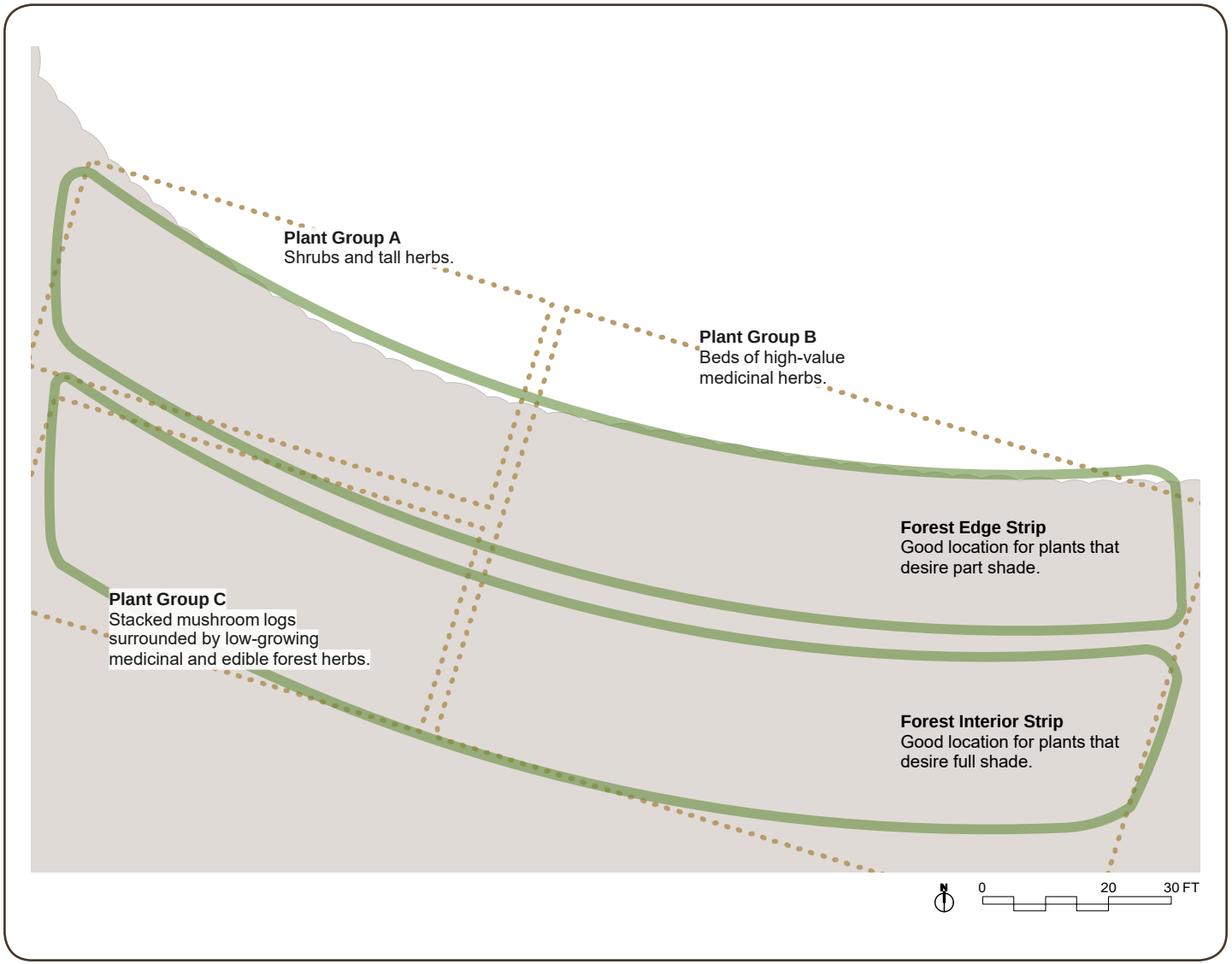

Figure 36. Shady Edible Forest Concept Design
Three plant groups are defined, each performing different functions.

PLANT SELECTION

Plants were selected and organized based upon their desired sunlight needs and moisture require-ments. Trees and stall shrubs help modify sunlight conditions and block wind.

Form	Common Name	Genus / Species	Hardiness	Height	Width	Light	Water	Crops	Materials	Nitrogen	Nutrient	Ground	Nectary	Medicine
Tree	Pawpaw	Asimina triloba	4-8	20-30'	20-30'	Full Sun - Part Shade	Mesic	Fruit						
Tree	Walnut, Black	Juglans nigra	4-7	50-70'	30-50'	Full Sun	Xeric - Mesic	Nuts	Lumber		K, P, Ca			
Shrub	Elderberry	Sambucus canadensis	3-10	6-12'	6-12'	Full Sun - Part Shade	Xeric - Hydric	Berries					GS	
Shrub	Gooseberry	Ribes uva-crispa	3-8	3-5'	3-5'	Full Sun - Part Shade	Xeric - Mesic	Berries						
Shrub	Oregon Grape Holly	Mahonia aquifolium	5	3-6'	3-6'	Full Sun - Full Shade	Xeric - Hydric	Berries					G	
Herb	Bloodroot	Sanguinaria canadensis	3-8	6"	Indef.	Part Shade	Mesic					x	G	
Herb	Cohosh, Black	Actaea racemosa	3-8	4-6'	2-4'	Part Shade - Full Shade	Mesic	Root						x
Herb	Cohosh, Blue	Caulophyllum thalictroides	3-8	1-2'	6-12"	Part Shade - Full Shade	Mesic	Root						x
Herb	Comfrey	Symphytum x uplandicum	4-9	3-5'	3-5'	Full Sun - Full Shade	Xeric - Mesic				K, P, Ca, Cu, Fe, Mg			x
Herb	Fern, Ostrich	Matteuccia struthiopteris	2-8	2-6'	Indef.	Part Shade - Full Shade	Mesic - Hydric	Shoots						
Herb	Ginseng	Panax quinquefolius	4-7	18"	18"	Full Shade	Mesic	Root						x
Herb	Goldenseal	Hydrastis canadensis	3-8	1'	1'	Part Shade	Mesic	Root						x
Herb	Mayapple	Podophyllum peltatum	3-8	12-18"	Indef.	Part Shade - Full Shade	Mesic	Fruit				x		
Herb	Ramps	Allium tricoccum	4-8	6-10"	Indef.	Part Shade - Full Shade	Mesic	Shoots, Root					G	
Herb	Solomon's Seal	Polygonatum biflorum	3-7	2-4'	2'	Part Shade - Full Shade	Xeric - Mesic	Shoots						
Herb	Trillium	Trillium grandiflorum	4-8	12-18"	Indef.	Part Shade - Full Shade	Mesic						G	x
Herb	Wild Ginger	Asarum canadense	3-8	4-8"	Indef.	Part Shade - Full Shade	Mesic	Root				x		
Fungi	Mushroom, Garden Giant	Stropharia rugoso annulata		6-18"	1-2'	Full Shade	Hydric	Fruiting body						
Fungi	Mushroom, Oyster	Pleurotus ostreatus		6"	4-10"	Full Shade	Hydric	Fruiting body						
Fungi	Mushroom, Shiitake	Lentinula edodes		6"	4-10"	Full Shade	Hydric	Fruiting body						

Figure 37. Shady Edible Forest Plant List

Figure 38. Stacked Mushroom Logs
The “log cabin” stacking style is a common method of managing logs inoculated with mushrooms.
Photo by Catherine Bukowski / CC BY ND

CONCEPTUAL SITE PLAN

This design depicts two rows of plantings: Plants in the row at the forest edge desire part shade while plants further inside the forest desire full shade. Pawpaws (*Asimina triloba*) provide fruit while shading beds of goldenseal (*Hydrastis canadensis*). Medicinal herb beds are aligned slightly off-contour to capture rain water, but stay well-drained.

A large amount of woodchip mulch inoculated with mushrooms will provide a harvest while suppressing weeds, retaining moisture, and enriching soil. Once fruiting begins, constant vigilance and daily harvests may be necessary to ensure freshness and prevent insect and rodent damage.

An edible forest ground cover grows through stacked logs that are inoculated with mushrooms. The plants help logs retain moisture and are short enough to not interfere with the mushroom harvest.

ESTABLISHMENT AND MANAGEMENT IDEAS

Several popular understory medicinal plants—ginseng (*Panax quinquefolius*), goldenseal (*Hydrastis canadensis*), black cohosh (*Actaea racemosa*), bloodroot (*Sanguinaria canadensis*)—require 3-6 years of growth before they are usable or marketable. Interplanting these areas with fast-yielding mushrooms, gooseberries (*Ribes uva-crispa*), and elderberries (*Sambucus canadensis*) will provide crops and build soil while the roots of these plants mature.

Oftentimes, thinning the canopy improves the health of the forest by allowing dappled sunlight to reach the forest floor. The resulting woody debris will be used to outline beds, cultivate mushrooms, and create woodchips for use around plants and for pathways. For more information about canopy thinning, see the Iowa State University Extension publication *Woodland Improvement and Crop Trees in Iowa*.[41]

Once mushroom fruiting begins, constant vigilance and daily harvests may be necessary to ensure freshness and prevent insect and rodent damage. Logs can be moved to a location that is frequently visited with ideal conditions, such a protected and shady area near access trails. Woodchip pathways inoculated with mushrooms will likely need to be remulched every year to remain productive. Visit the Cornell University *Forest Mushroom Cultivation* website[42] for research and best-practices for mushroom cultivation.

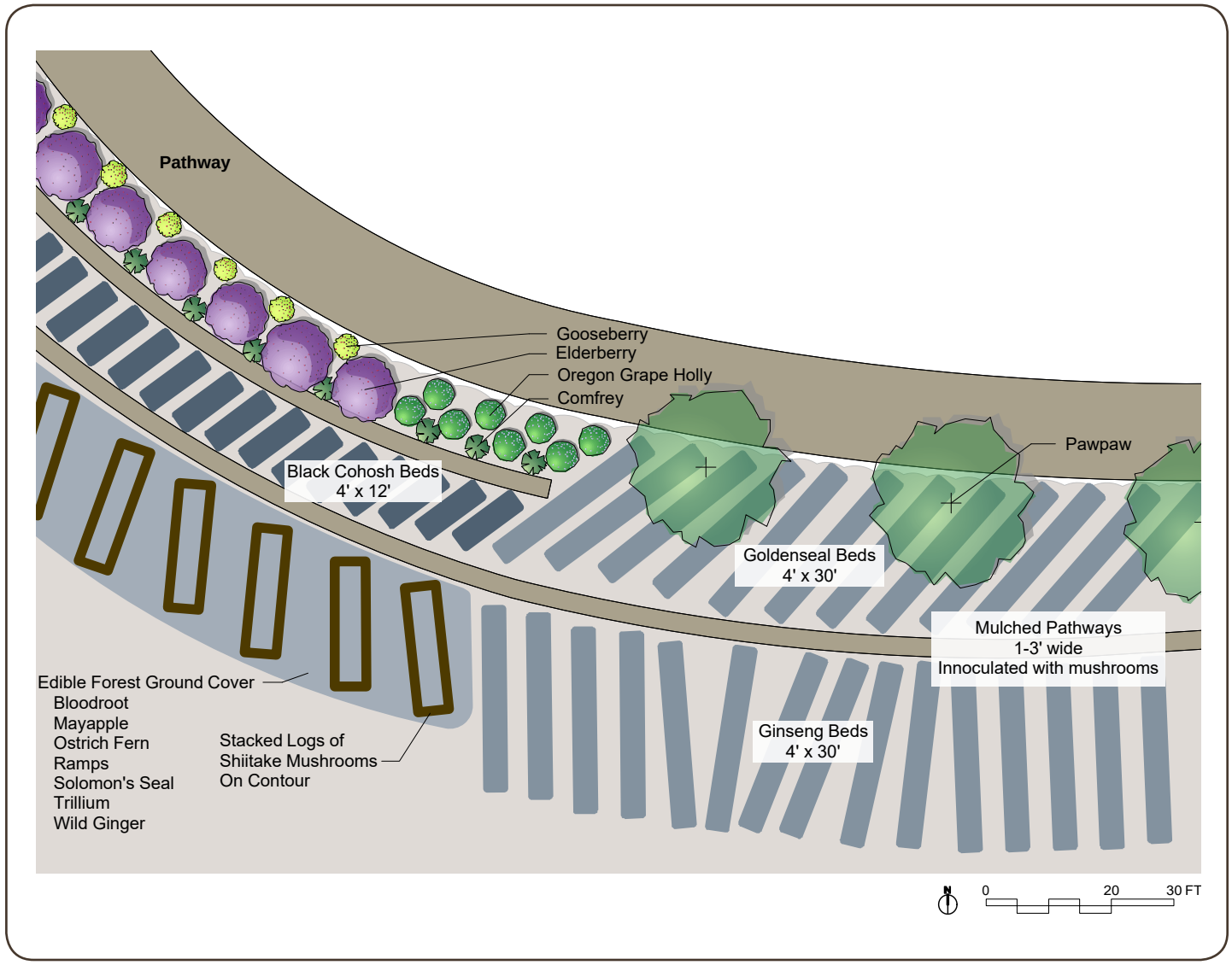

Figure 39. Shady Edible Forest Conceptual Site Plan

10 EDIBLE RIPARIAN BUFFER

Riparian forest buffers are ecosystems made up of tree, shrub, and grass plantings adjacent to watercourses and within floodplains. They buffer watercourses from pollution, stabilize stream banks against erosion, protect sensitive aquatic environments, enhance wildlife habitat, trap sediments, recharge groundwater, reduce flooding, and increase biodiversity.[43]

Few food crops tolerate the wet conditions along watercourses and in floodplains, but many ornamental and biomass plants thrive in this lowland environment.

Figure 40. Bear Creek
Multiple rows of trees and shrubs, as well as a native grass strip, combine in a riparian buffer to protect Bear Creek in Story County, Iowa. Few (if any) plants are edible at Bear Creek, but it still serves as an excellent example of a properly designed buffer.
Photo by Lynn Betts, USDA NRCS

INVENTORY AND ASSESSMENT

The conditions of watercourses and flood-plains are heavily influenced by weather and climate fluctuations. Rigorous observation over many years will continue to be required to thoroughly understand an area.

General flow patterns for the entire watershed have been observed to understand sources of water flowing through the landscape. Identifying sources of pollution that may need to be mitigated is a top priority.

The landscapes and stream has evolved to rapidly move water off property. This often causes further erosion and degrades the health of watercourses.

Contours and detailed water flow patterns for the area have been mapped.

Surface runoff, and stream flow during light showers, heavy rains, and spring-time snow melt were observed to identify areas of erosion, scouring, deep sediment, flooding, stream blockages, and bank undercutting.

Areas where soil is frequently scoured by fast-moving water and/or covered by sediment will be mitigated by soil and water erosion projects. The USDA Natural Resources Conservation Service (NRCS) funded EQIP 2018 748D43220U0 and CSP 2018 818D43220XG contracts in September 2022 to implement and/or maintain specific conservation practices, as set forth in the Conservation Plan Schedule of Operations attached in the appendix on the full 40-acre property (USDA Farm ID 1179, Tract ID 10780) through December 31, 2028.

Holes were dug in several areas to carefully document water table depths throughout the seasons. Areas of steep slopes are very dry during summer months which have informed plant selections.

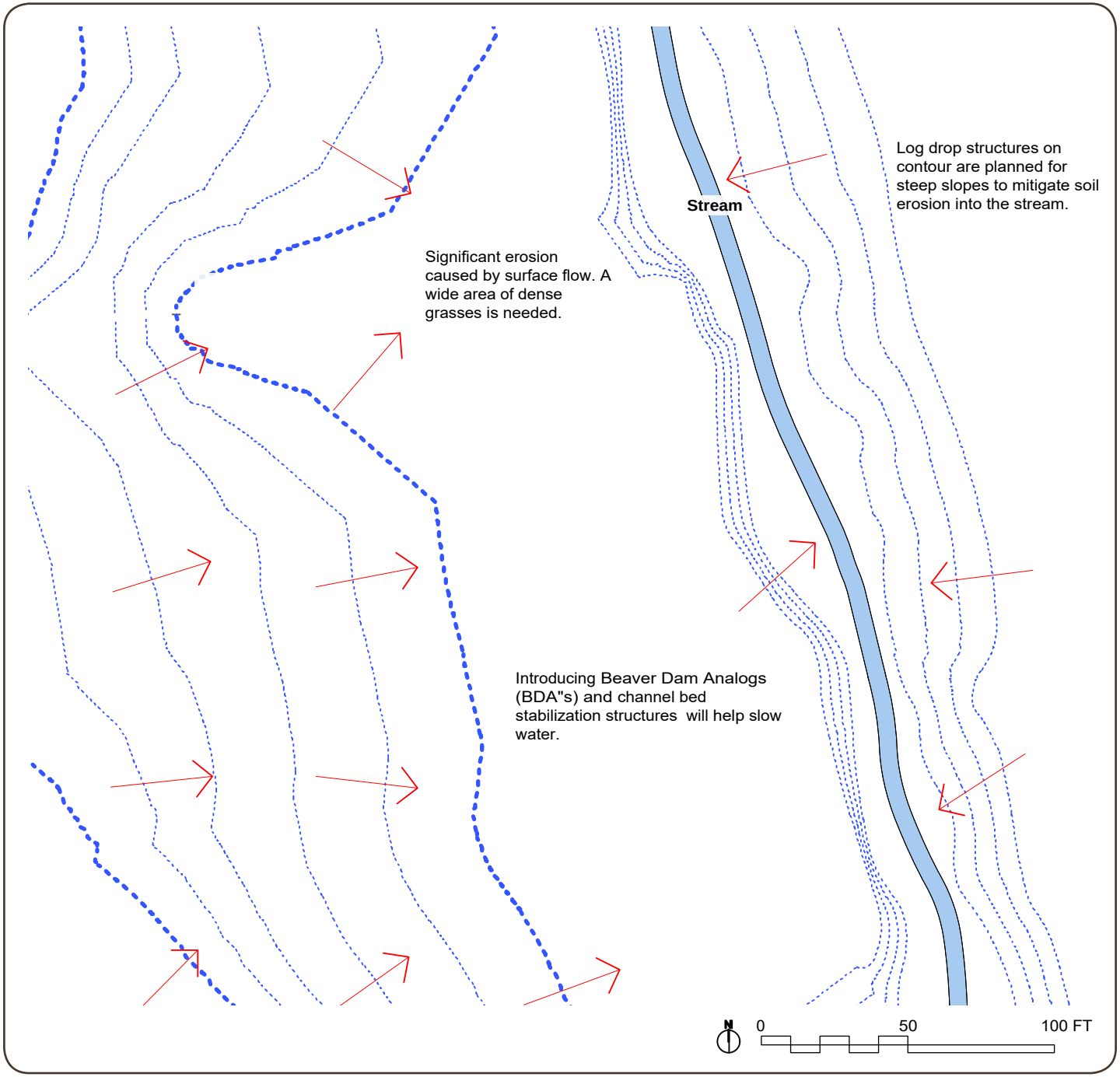

Figure 41. Edible Riparian Buffer Base Map
Contour lines help form the foundation for the design.

CONCEPT DESIGN

Three zones are typically defined in a riparian buffer, each with a specific width, function and design.[44] A total buffer width of 50 to 100 feet is recommended for the topographical features and goals. Width guidelines are provided here from the USDA *Conservation Buffers* publication based on detailed specifications for determining buffer widths.[45]

Riparian Buffer Zone Functions

Functions	Plant Characteristics	Management and Crops
Zone 1: Bank Stabilization - 20' strip along stream bank edge		
• Bank stabilization • Shade to moderate water temperature • Enhance aquatic habitat with organic matter • Reduce velocity of flood waters	• Fast-growing • Full sun to full shade • Water loving • Resprout when cut • Along the bank, herbaceous rushes and sedges have flexible stems and creeping roots[48] • Trees and shrubs have deep and wide roots	• Relatively unmanaged • Biomass and woodworking crops
Zone 2: Infiltration - 30' strip next to Zone 1		
• Maximize infiltration • Uptake, storage, and breakdown of nutrients and pollution • Reduce velocity of flood waters • Trap flood debris to keep it out of nearby crops	• Mixed growth rates • Full sun to part shade • Water loving or flood tolerant	• Actively managed • Avoid soil compaction • Cut flowers, fruits, nuts, herbs
Zone 3: Flow Control - 20' strip next to Zone 2		
• Slow surface runoff • Trap sediment and debris from surface runoff • Uptake of nutrients and pollution	• Fast-growing • Full sun • Warm season grasses and forbs • Tolerate wet soil	• Actively managed for vigorous growth by removing biomass through mowing or grazing • Avoid soil compaction • Cut flowers, forage

A buffer strip of undulating widths along the length of the stream will be required, with wider areas mitigating concentrated surface runoff due to high slopes.[46]

Zones have been widened beyond recommended minimums to mitigate higher flow rates in specific areas. Pathways and zones were identified to ensure convenient harvesting of crop plants located where their edible parts will not be submerged.

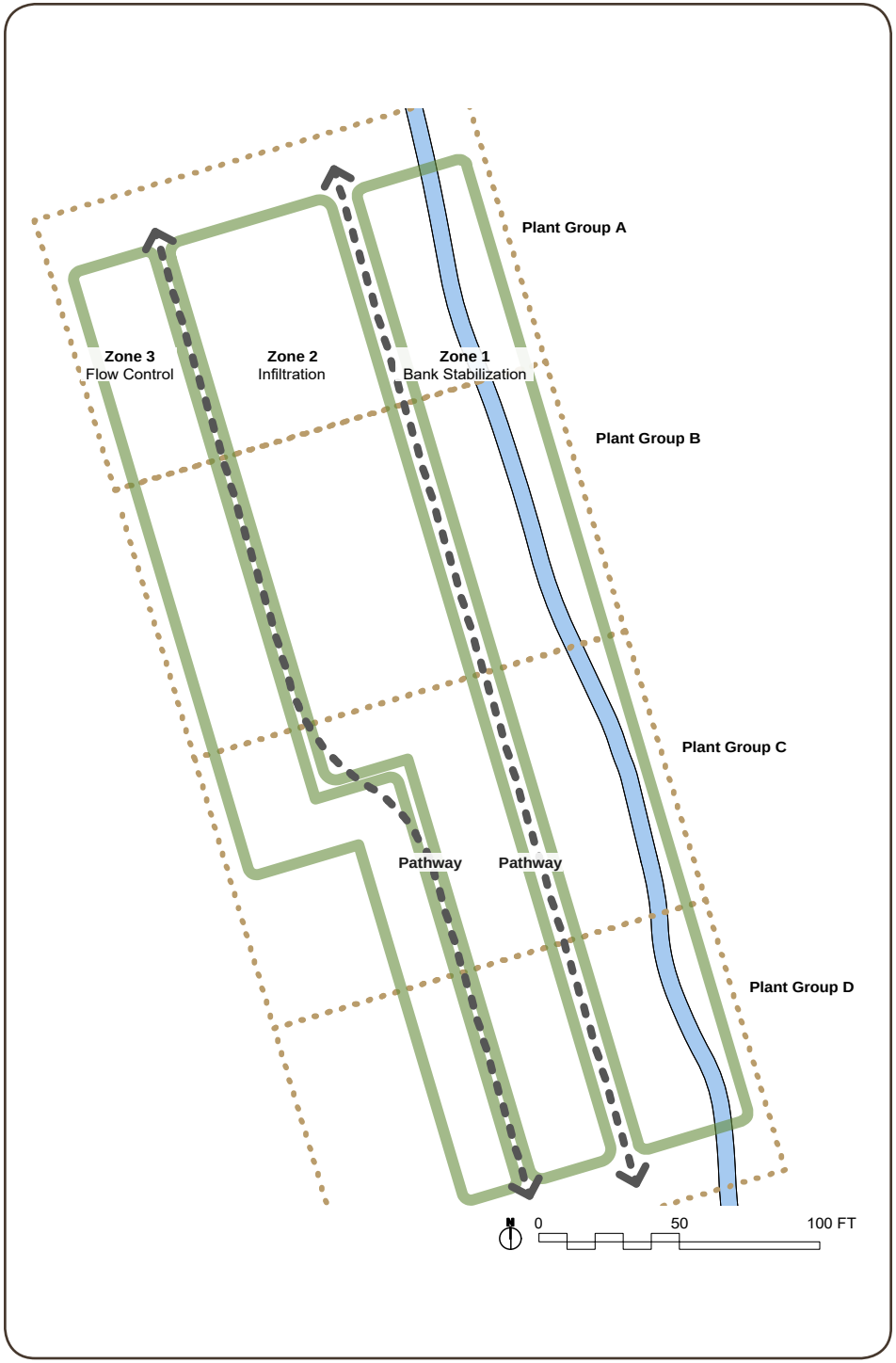

Figure 42. Edible Riparian Buffer Concept Design
Four plant groups and three riparian zones create a matrix of plant blocks with different harvesting times.

PLANT SELECTION

Buffers on both sides of the stream are composed of diverse woody and herbaceous plants that have stiff stems, are tolerant of wet soils and high nutrient levels, and have high root biomass to maximize effectiveness.[47] [48] Plants were identified for the desired zones and then grouped based upon harvesting strategies.

Tips

- To maximize sunlight in zone 2, select medium-sized or short trees and shrubs for planting next to watercourses. Large bottomland trees such as bigtooth maple, cottonwood, and box elder are typically recommended for streamside riparian plantings. Once established, debris from these fast-growing trees can contribute to aquatic habitat, but without significant and frequent pruning, their deep shade will greatly reduce food and ornamental crop yields.
- Some willow species may rapidly expand from zone 1 into crops located in zone 2. Carefully research willows and their growth habits. A wide, mowed pathway between zone 1 and 2 may help contain expansive willow growth.
- Seed mixes can be purchased that accommodate specific soil and sunlight conditions in each zone. Additional seed for desired cut flower species can augment mixes.
- Avoid nitrogen-fixing plants, such as clovers and legumes, which could contribute to water nitrification.
- Watercourses can quickly distribute plants and seeds. Use native plants and avoid plants with highly dispersive or expansive characteristics.
- If soil is dry during summer months or droughts, ensure plants can tolerate these conditions; do not simply select water-loving plants.
- Avoid cool-season grasses (brome and fescue): their flexible stems will not trap sediment.
- To decrease the amount of bare soil exposed between plants, consider overseeding a rhizomatous native perennial herb in zone 2 and 3, such as slender mountain mint (*Pycnanthemum tenuifolium*).
- Always include 3 or more grasses in zone 3 to utilize their soil-stabilizing, fibrous roots and to increase diversity. Switchgrass (*Panicum virgatum*) is an exception: it is an excellent choice for highly erodible soil, but mixing it with other grasses is not recommended as it will eventually out compete them.
- Kernza wheatgrass (*Thinopyrum intermedium*) is an edible, perennial grain under development at The Land Institute.[49] By 2022, the wheat may be suitable for planting in zone 3 in areas without pollution.

Figure 43. Native Prairie

Native prairie plants in zone 3 of a riparian buffer can help slow surface runoff and trap sediment. Emphasize plants with deep, fibrous root systems. Selecting beautiful flowers that can be used for cuttings may provide additional income.

Photo by Fred Meyer

Riparian Zone	Form	Common Name	Genus / Species	Hardiness Zones	Height	Width	Light	Water	Crops	Materials	Nitrogen Fixer	Nutrient Accumulator	Ground Cover	Nectary	Medicine
Stream Bank	Herb	Baltic rush	Juncus balticus	3-7	1-3'	Indef.	Full Sun	Hydric							
Stream Bank	Herb	Bottlebrush sedge	Carex comosa	3-9	1-2'	6"	Full Sun	Hydric							
Stream Bank	Herb	Dark green bulrush	Scirpus atrovirens	3-9	3-5'	3-4'	Full Sun	Hydric							
Stream Bank	Herb	Fringed sedge	Carex crinita	3-8	2-5'	Indef.	Full Sun - Full Shade	Hydric							
Stream Bank	Herb	Hop sedge	Carex lupulina	3-8	1-4'	1-2'	Full Sun - Part Shade	Hydric							
Stream Bank	Herb	Lurid sedge	Carex lurida	3-8	1-3'	1-2'	Full Sun	Hydric							
Stream Bank	Herb	Prairie cordgrass	Spartina pectinata	4-9	3-8'	Indef.	Full Sun	Hydric							
Stream Bank	Herb	Wild Rye, Riverbank	Elymus riparius	3-8	3-4'	1-2'	Part Shade	Hydric							
Stream Bank	Herb	Wool grass	Scirpus cyperinus	4-8	3-5'	Indef.	Full Sun	Hydric							
Stream Bank, Zone 1-2	Herb	Wild Rye, Virginia	Elymus virginicus	3-8	2-4'	2'	Full Sun - Part Shade	Xeric - Hydric							
Zone 1	Shrub	Dogwood, Red-Osier	Cornus sericea	3-8	9'	9'	Full Sun - Part Shade	Mesic - Hydric		Woody Florals					
Zone 1	Shrub	Dogwood, Yellow Twig	Cornus sericea	3-8	6'	6'	Full Sun - Part Shade	Mesic - Hydric		Woody Florals					
Zone 1	Shrub	Willow, Basket	Salix viminalis	4-8	8-10'	4-6'	Full Sun - Full Shade	Mesic - Hydric		Woody Florals					
Zone 1	Shrub	Willow, Bebb	Salix bebbiana	3-7	25'	20'	Full Sun - Part Shade	Mesic - Hydric		Biomass					
Zone 1	Shrub	Willow, Black	Salix nigra	4-9	50'		Full Sun - Part Shade	Mesic - Hydric		Biomass					
Zone 1	Shrub	Willow, Corkscrew	Salix matsudana	5-8	25'	20'	Full Sun - Part Shade	Mesic - Hydric		Woody Florals					
Zone 1	Shrub	Willow, Pussy	Salix discolor	4-8	15'	12'	Full Sun - Part Shade	Mesic - Hydric		Woody Florals					
Zone 1	Shrub	Willow, Sandbar	Salix interior	2-8	30'	20'	Full Sun - Part Shade	Mesic - Hydric		Biomass					
Zone 1	Shrub	Willow, Shining	Salix lucida	5-9	25'	20'	Full Sun - Part Shade	Mesic - Hydric		Biomass					
Zone 1-2	Herb	Aster, New England	Aster novae-angliae	4-8	5'	3'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Culver's Root	Veronicastrum virginicum	3-8	4-7'	2-4'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Golden Alexanders	Zizia aurea	3-8	3'	2'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Goldenrod, Grass-Leaved	Solidago graminifolia	3-8	2'	2'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Goldenrod, Riddell's	Solidago riddellii	3-7	3'	2'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Goldenrod, Zig Zag	Solidago flexicaulis	3-8	1-3'	1-3'	Full Sun - Full Shade	Mesic - Hydric							
Zone 1-2	Herb	Hyssop, Purple Giant	Agastache scrophulariaefolia	4-6	6'	3'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Ironweed	Vernonia fasciculata	4-9	6'	4'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Prairie Blazing Star	Liatris pycnostachya	3-9	4'	3'	Full Sun	Mesic - Hydric							
Zone 1-2	Herb	Slender Mountain Mint	Pycnanthemum tenuifolium	4-8	2'	Indef.	Full Sun	Mesic - Hydric						G	
Zone 1-2	Herb	Vervain, Blue	Verbena hastata	3-8	2-5'	2'	Full Sun - Part Shade	Xeric - Hydric						G	
Zone 1-2	Herb	Wild Rye, Canada	Elymus canadensis	3-8	5'	2'	Full Sun	Xeric - Hydric							
Zone 2	Herb	Blackberry, Thornless	Rubus fruticosus	5-8	4-5'	3-4'	Full Sun	Mesic	Berries						
Zone 2	Herb	St. John's Wort	Hypericum perforatum	3-8	1-3'	Indef.	Full Sun - Part Shade	Mesic - Xeric					x	G	x
Zone 2	Shrub	Aronia Berry, Black	Aronia melanocarpa	3-9	5-6'	5-6'	Full Sun - Part Shade	Mesic - Hydric	Berries						
Zone 2	Shrub	Elderberry	Sambucus canadensis	3-10	6-12'	6-12'	Full Sun - Part Shade	Xeric - Hydric	Berries					GS	
Zone 2	Shrub	Gooseberry	Ribes uva-crispa	3-8	3-5'	3-5'	Full Sun - Part Shade	Xeric - Mesic	Berries						
Zone 2	Shrub	Hazelnut	Corylus americana	4-9	12-20'	12-15'	Full Sun	Mesic	Nuts						
Zone 2	Shrub	Saskatoon	Amelanchier alnifolia	2-7	5-15'	5-15'	Full Sun	Mesic	Berries						
Zone 2	Tree	Serviceberry, Downy	Amelanchier arborea	4-9	15-25'	15-25'	Full Sun - Part Shade	Mesic	Berries						
Zone 2	Tree	Walnut, Black	Juglans nigra	4-7	50-70'	30-50'	Full Sun	Xeric - Mesic	Nuts	Lumber		K, P, Ca			
Zone 3	Herb	Bee Balm	Monarda fistulosa	3-10	3-4'	2-6'	Full Sun - Part Shade	Xeric - Mesic	Leaves (Tea)					G	
Zone 3	Herb	Big Bluestem	Andropogon gerardii	4-9	7'	4'	Full Sun	Xeric - Hydric							
Zone 3	Herb	Black-Eyed Susan	Rudbeckia hirta	3-7	2'	2'	Full Sun	Xeric - Hydric							
Zone 3	Herb	Blanket Flower	Gaillardia aristata	3-10	8-12"	1'	Full Sun	Mesic							
Zone 3	Herb	Boneset	Eupatorium perfoliatum	3-8	4-6'	3-4'	Full Sun	Mesic - Hydric							x
Zone 3	Herb	Hyssop, Anise	Agastache foeniculum	4-9	2-4'	1-2'	Full Sun - Part Shade	Xeric - Mesic							
Zone 3	Herb	Indian Grass	Sorghastrum nutans	4-9	6'	3'	Full Sun	Xeric - Mesic							
Zone 3	Herb	Joe Pye Weed	Eupatorium maculatum	4-9	5'	3'	Full Sun	Mesic - Hydric							
Zone 3	Herb	Joe Pyeweed, Sweet	Eupatorium purpureum	4-9	4-7'	3'	Full Sun	Mesic - Hydric							
Zone 3	Herb	Little Bluestem	Schizachyrium scoparium	3-9	3'	3'	Full Sun	Xeric - Mesic							
Zone 3	Herb	Prairie Wild Rose	Rosa arkansana	4-8	2'	Indef.	Full Sun	Xeric - Hydric	Hips						x
Zone 3	Herb	Purple Coneflower	Echinacea purpurea	3-8	3-4'	1-2'	Full Sun - Part Shade	Xeric - Mesic						G	x
Zone 3	Herb	Side-Oats Grama	Bouteloua curtipendula	4-9	2'	1-2'	Full Sun	Xeric - Mesic						S	
Zone 3	Herb	Switchgrass	Panicum virgatum	5-9	4'	3-4'	Full Sun	Mesic - Hydric							
Zone 3	Herb	Yarrow	Achillea millefolium	3-9	2-3'	Indef.	Full Sun - Part Shade	Xeric	Leaves (Tea)			K, P, Cu	x	GS	
Zone 3	Tree	Plum, European Semi-Dwarf	Prunus domestica	4-8	12-15'	10-15'	Full Sun	Mesic	Fruit					G	

Figure 44. Edible Riparian Buffer Plant List

Plants are grouped by riparian zone and form.

CONCEPTUAL SITE PLAN

This design accommodates the fast-moving stream and areas with high surface runoff. These conditions require an open, woodland canopy so sunlight can stimulate low-growing herbaceous plants that will stabilize soil. The open canopy can be created by thinly planting trees and shrubs or through frequent cutting of dense plantings. If the area had slower moving water, such as floodplain, the canopy could have 100% cover.

Elderberries (*Sambucus canadensis*) are interplanted with walnuts due to their ability to thrive in part shade and tolerate juglone.

In zone 1, next to the stream, willows and dogwoods with beautiful branches are planted near the pathway to ease harvesting access. Less ornamental species that will not be harvested are planted near the stream. The pathway will help contain the expansive growth of willows.

In zone 2, plant groups A and B are shown with and without blackberries to demonstrate two different planting patterns.

ESTABLISHMENT AND MANAGEMENT IDEAS

For streambank bioengineering and extensive planting details, see *Developing Water Trails in Iowa, Chapter 4: Land and Stream Management* by the Iowa Department of Natural Resources.[50]

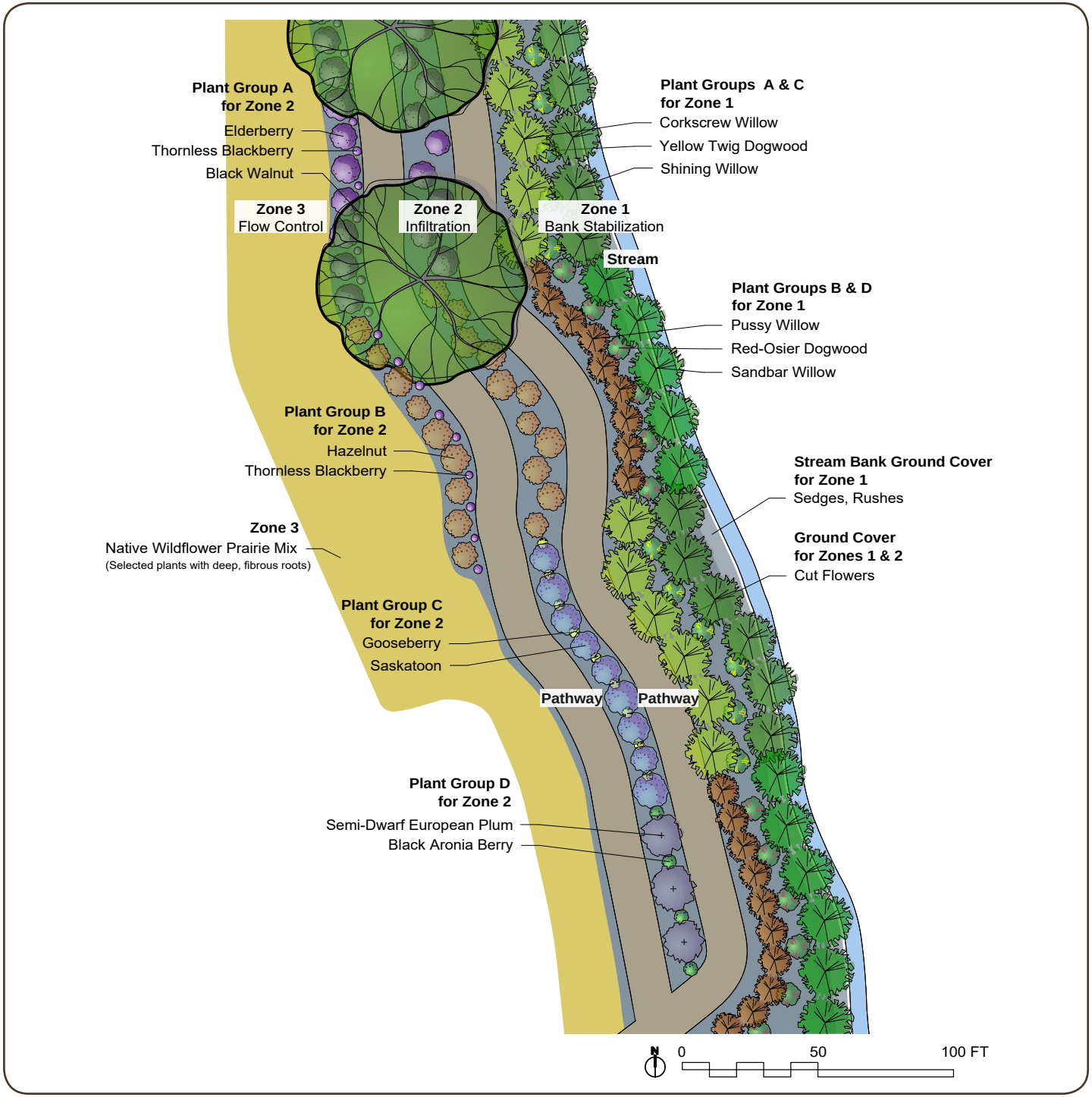

Figure 45. Edible Riparian Buffer Conceptual Site Plan

11 EDIBLE WINDBREAK

Windbreaks are planned and managed as part of a crop and/or livestock operation to enhance production, shelter livestock, protect buildings, provide wildlife habitat, and control soil erosion.[51] A thoughtfully designed windbreak that incorporates crop-bearing plants can provide a primary or secondary income while increasing property value.

Field windbreaks protect a variety of wind-sensitive row, forage, orchard and vine crops, control wind erosion, and increase bee pollination.[52]

Livestock windbreaks help reduce animal stress and mortality, reduce feed consumption, and help reduce visual impacts and odors.[53] Livestock protected by a windbreak will use more feed for weight gain and less to maintain body heat. Windbreaks also can provide protection for feedlots, pastures, calving areas, and confinement buildings. An outdoor “living barn” strategically located in open pasture can be helpful during calving and lambing season.[54] Primary windbreaks around farmsteads with secondary windbreaks around livestock facilities may provide optimum benefits.[55]

Living snowfences keep trails clean of drifting snow and increase driving safety. They can also shade snow across alleys, preserving snowpack and increasing spring soil moisture.[56]

Building windbreaks can reduce heating and cooling bills by decreasing the speed of summer and winter winds.[57]

Figure 46. Windbreak
This multi-row farmstead windbreak in Pocahontas County, Iowa, includes shrubs, conifers, and deciduous trees. Few (if any) plants are edible, but it still serves as an excellent example of a properly designed windbreak.
Photo by Lynn Betts, USDA NRCS

INVENTORY AND ASSESSMENT

These properties were assessed on the site:

- Area of desired protection, the desired wind speed in the area, and its distance from the future windbreak
- Prevailing wind direction and speed throughout all seasons
- Existing and future locations of plantings, roads, livestock grazing areas, and all buildings
- Soil types and drainage
- Sunlight
- Topography
- Property lines
- Existing wildlife habitat
- Beneficial insects, birds, native pollinators that need support
- Alternate host plants for diseases, such as cedar-apple rust

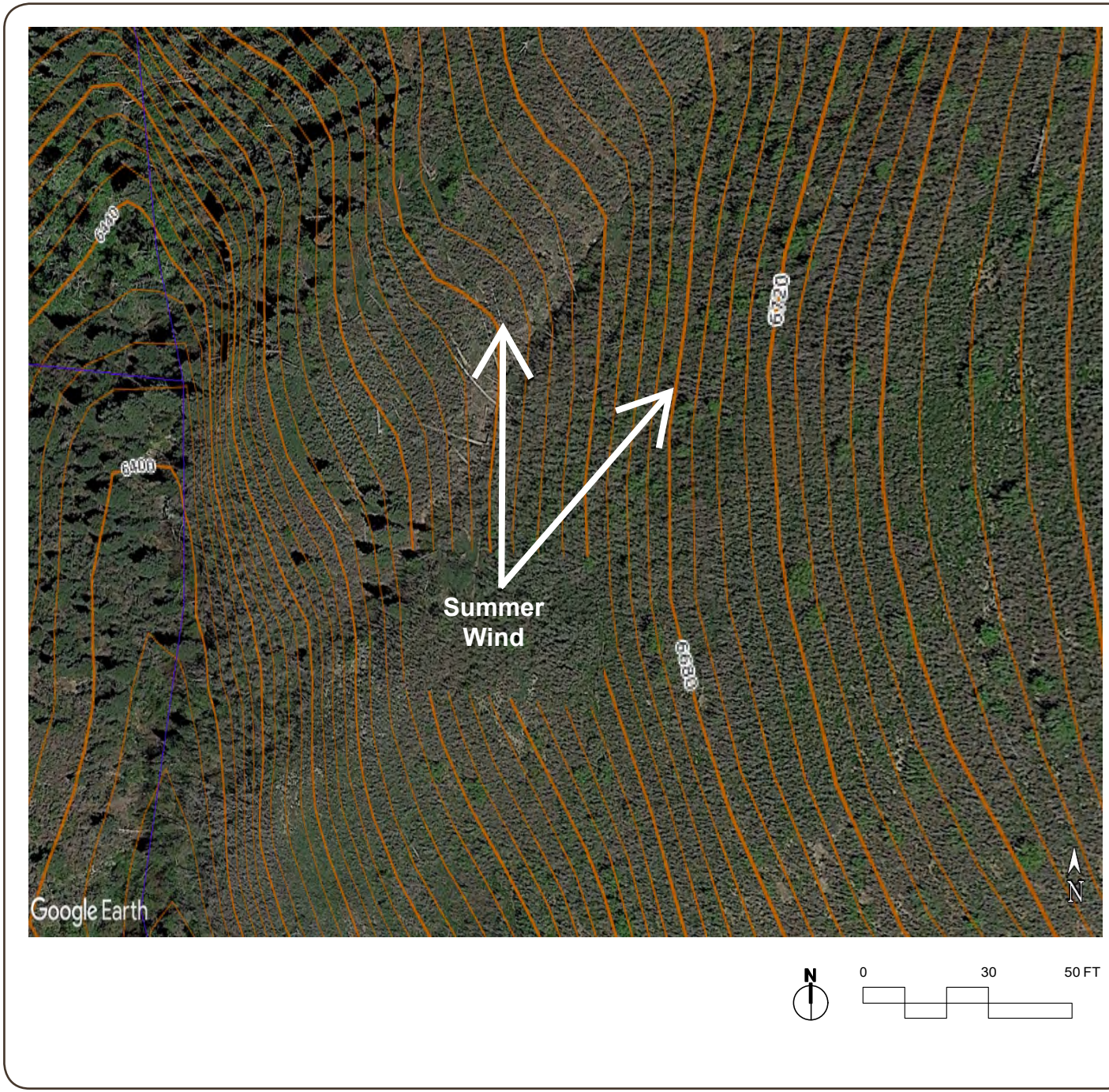

Figure 47. Edible Windbreak Base Map
Wind direction and the desired area of protection help form a foundation for the design.

CONCEPT DESIGN

Several factors must be simultaneously considered to design an effective windbreak.

Height

The windbreak height primarily determines the amount of protection received downwind; the taller the windbreak the greater zone of protection. Use the distance between the middle of the windbreak and the end of the area of protection to determine the windbreak height. Also consider the reduction of wind speed desired. For example, wind speed is reduced by 78% at a distance of 5 times the windbreak height. In this design, the distance between the middle of the windbreak and the end of the protected area is 200 feet. To achieve an 78% reduction in wind speed, the tallest trees must reach at least 40 feet (40 feet tall x 5 = 200 feet). See the Iowa State University Extension publication *Farmstead Windbreaks: Planning* for additional calculations for wind speed reductions.[58]

Length

Extend the planting beyond the protected area by at least 10 times the height of the windbreak to reduce turbulence at the ends. In this example, the 40 foot tall windbreak must extend at least 400 feet north and east.

Density

Allowing some air to pass through a windbreak reduces wind speed over the greatest distance. The most effective windbreaks are 50% permeable. With a permeable windbreak, some wind slips through to form layers of air. This blanket of layered air helps to keep blustery winds aloft after passing over the top of the windbreak. Very little protection from wind is provided with windbreaks below 30% density.

Windbreak Density[59]

60-80%	Winter protection of structures, livestock, farmsteads, and roads as well as noise and visual screens.
40-60%	Crop and soil protection.
25-30%	Snow distribution.

To achieve a density of 60% or more, plant at least three rows of trees and shrubs with at least one row being conifers. The standard arrangement is a row of shrubs with two rows of conifers. The function, durability, and longevity of a windbreak improves with each additional row up to 10 rows.[60]

Tips

- Windbreaks are most effective when oriented at right angles to prevailing or troublesome winds.
- Eliminate all gaps. Breaks in a windbreak become funnels that concentrate and accelerate wind velocity.
- Establish crop plants on the downwind side of a windbreak to increase yields.

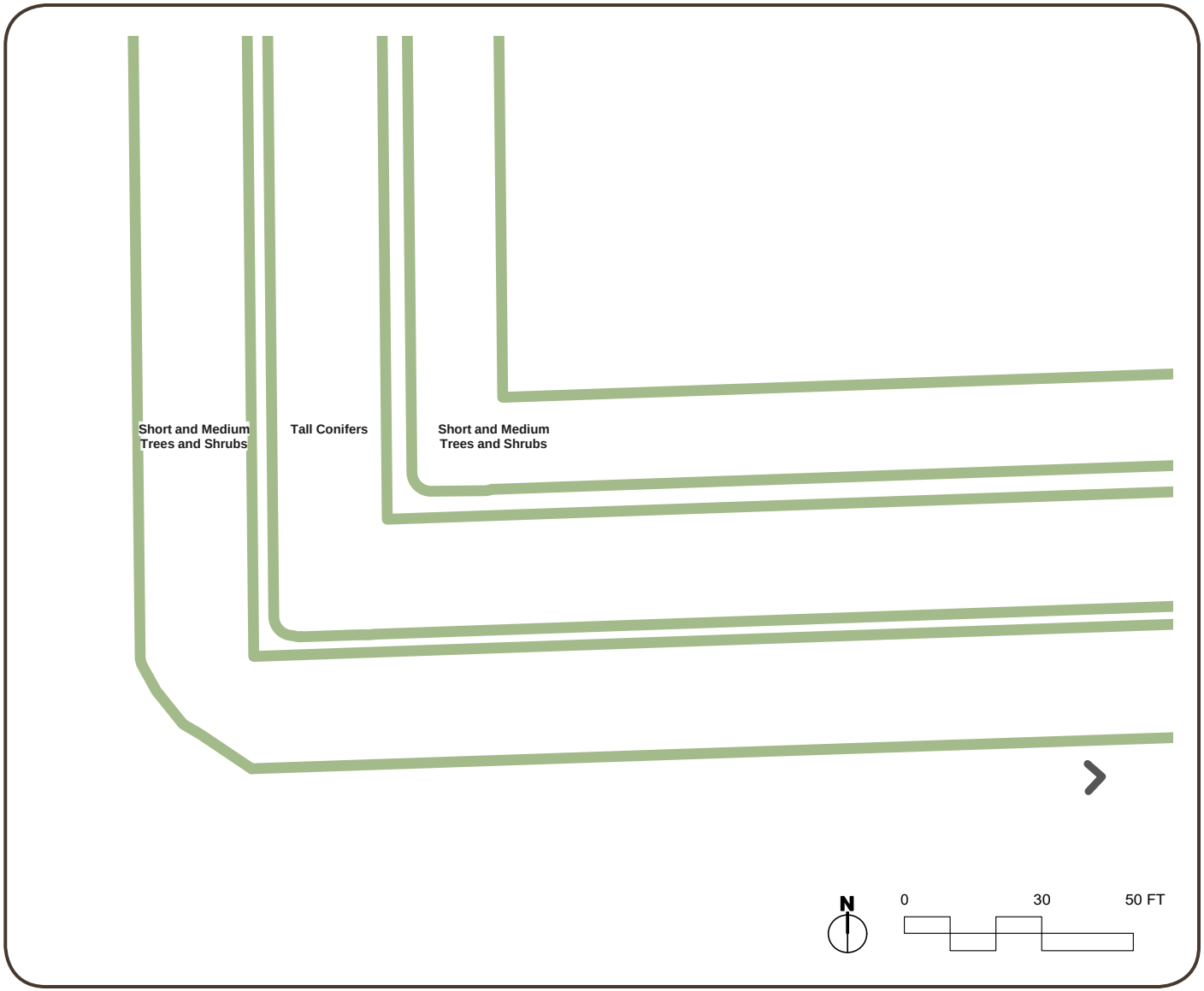

Figure 48. Edible Windbreak Concept Design
Each windbreak row contains specific plant types.

PLANT SELECTION

Windbreaks can increase the biological control of crop insect pests by incorporating specific plants that provide habitat for beneficial wildlife. Identify desired insects and birds and then choose plant species that support that wildlife. Larger windbreaks will support more wildlife.

Forage tree legumes can be planted as “fodder banks” along tree lines. Foliage from these trees is usually harvested under a cut-and-carry system and can be a principal source of high quality fodder to supplement lower quality crop residue fodder.[61]

Avoid alternate plant hosts of diseases, such as cedar-apple rust.

Evergreen trees and shrubs are valuable in the windbreak for their winter function. Consider species of conifers that yield crops, other than their value as lumber trees, such as pine nuts and medicinal oils.

Form	Common Name	Genus / Species	Hardiness Zones	Height	Width	Light	Water	Crops	Materials	Nitrogen Fixer	Nutrient Accumulator	Ground Cover	Nectary	Medicine
Tree	Crabapple, Siberian	Malus baccata	3	30'	25'	Full Sun	Mesic	Fruit			K			
Tree	Dogwood, Cornelian Cherry	Cornus mas	4-8	20'	20'	Full Sun - Part Shade	Mesic	Berries						
Tree	Fir, White	Abies concolor	3-7	40-70'	20-30'	Full Sun - Part Shade	Mesic							
Tree	Serviceberry, Downy	Amelanchier arborea	4-9	15-25'	15-25'	Full Sun - Part Shade	Mesic	Berries						
Tree	Spruce, Black Hills	Picea glauca	2-6	20-40'	10-15'	Full Sun	Mesic							
Shrub	Aronia Berry, Black	Aronia melanocarpa	3-9	5-6’	5-6’	Full Sun - Part Shade	Mesic - Hydric	Berries						
Shrub	Juniper, Common	Juniperus communis	2-7	2-4'	3-5'	Full Sun	Xeric - Mesic							
Shrub	Nanking Cherry	Prunus tomentosa	3-7	6-10'	6-8'	Full Sun	Xeric - Mesic	Fruit						
Shrub	Peashrub, Siberian	Caragana arborescens	2-7	8-20'	12-18'	Full Sun	Xeric - Mesic			x				
Shrub	Saskatoon	Amelanchier alnifolia	2-7	5-15'	5-15'	Full Sun	Mesic	Berries						
Herb	Clover, Dutch White	Trifolium repens	4-8	4-10"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Clover, Miniclover	Trifolium repens	4-8	4"	6-36"	Full Sun - Part Shade	Xeric - Mesic			x		x		
Herb	Comfrey	Symphytum x uplandicum	4-9	3-5’	3-5’	Full Sun - Full Shade	Xeric - Mesic				K, P, Ca, Cu, Fe, Mg			x
Herb	Goldenseal	Hydrastis canadensis	3-8	1'	1'	Part Shade	Mesic	Root						x
Herb	Purple Coneflower	Echinacea purpurea	3-8	3-4'	1-2'	Full Sun - Part Shade	Xeric - Mesic						G	x
Herb	Strawberry, Wild	Fragaria virginiana	3-8	4-12"	Indef.	Full Sun - Part Shade	Xeric - Mesic	Berries			Fe	x		

Figure 49. Edible Windbreak Plant List

Figure 50. Purple Coneflower
The stiff, upright stems of purple coneflower (*Echinacea purpurea*) can decrease wind speed and accumulate snow in a windbreak. The flowers, leaves and roots can be sold as medicinals.
Photo by Fred Meyer

CONCEPTUAL SITE PLAN

This design depicts 3 offset rows of conifer and fruit trees with an understory of shrubs and herbs that can provide marketable products.[62]

- Douglas fir (*Pseudotsuga menziesii*) provides needles that can be sold for medicine and brewing.
- White fir (*Abies concolor*) yields lumber and medicinal essential oil.
- Juniper (*Juniperus communis*) berries are used to flavor gin.
- Siberian peashrub (*Caragana arborescens*) fixes nitrogen and has edible seeds.
- Siberian crabapple (*Malus baccata*), saskatoon (*Amelanchier alnifolia*), Nanking cherry (*Prunus tomentosa*), cornelian cherry (*Cornus mas*) and aronia berry (*Aronia melanocarpa*) can be used for fruit preserves and juice in addition to being a nectar source for beneficial insects.
- Purple coneflower (*Echinacea purpurea*) can be harvested for seed, mulch, floral arrangements, and medicine while also providing nectar and building soil with its deep roots.
- Goldenseal (*Hydrastis canadensis*) is harvested for medicine, serves as a ground cover, and thrives under the shade of trees.
- Comfrey (*Symphytum x uplandicum*) serves many ecological functions: nectar source, ground cover, mulch, nutrient accumulator, and invertebrate shelter.

ESTABLISHMENT AND MANAGEMENT IDEAS

The first 1-3 years of growth are very important to the long-term vitality of the windbreak. Plants will require weed and grass control, replanting, animal protection, pest and disease control, pruning, and fertilization.

Planting conifers too closely is a common mistake which causes their lifespan to be reduced as they grow into on one another. Trees will be over-planting and then thinning as plants mature. White fir are a Christmas tree species, providing a holiday income for a few years in the large windbreaks.

See the *Producing Marketable Products from Living Snow Fences* publication from the University of Minnesota Extension Service for detailed lists of per-acre establishment costs and revenue for selected windbreak plants.[63]

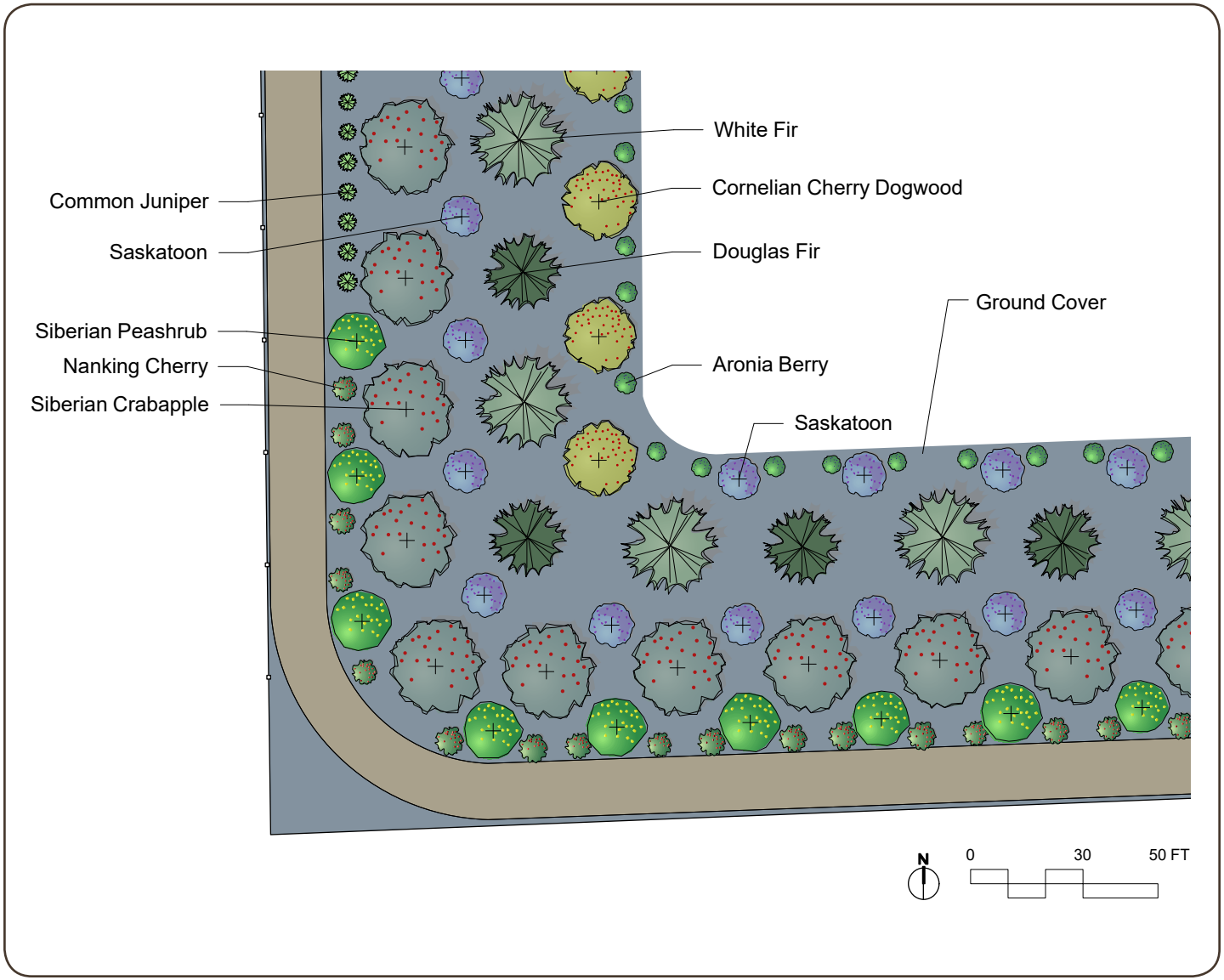

Figure 51. Edible Windbreak Conceptual Site Plan
The middle row of conifers will eventually grow up to 40 feet high which will decrease wind speed 200 feet away by 78% .

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The high-yielding heartnut tree (*Juglans ailantifolia var. cordiformis*) yields nuts that are easy to crack.
Photo by Fred Meyer

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