UNIVERSITY OF MINNESOTA | EXTENSION

Silvopasture

ESTABLISHMENT AND MANAGEMENT PRINCIPLES FOR MINNESOTA

University of Minnesota Extension

Hardwood Silvopasture in Fort Ripley, Minnesota

Silvopasture

ESTABLISHMENT AND MANAGEMENT PRINCIPLES FOR MINNESOTA

This guidebook was created to increase awareness of silvopasture in Minnesota.

Authors
Diomy Zamora, Extension Educator/Professor, University of Minnesota Extension, zamor015@umn.edu
Gary Wyatt, Extension Educator/Professor, University of Minnesota Extension, wyatt@umn.edu
Megan Buttler, Research Assistant, University of Minnesota, butle553@umn.edu
Maddie Ford, Research Assistant, University of Minnesota, fordx210@umn.edu
Joe Magner, Research Professor, University of Minnesota, magne027@umn.edu
Mike Reichenbach, Extension Educator/Professor, University of Minnesota, reich027@umn.edu
Eleanor Burkett, Extension Educator, University of Minnesota Extension burket044@umn.edu
Dean Current, Program Director, Center for Integrated and Natural Resource Agricultural Management, University of Minnesota, curre002@umn.edu
Dusty Walter, Director, Wurdack Research Center, University of Missouri Center for Agroforestry, walterw@missouri.edu

Special thanks to:
Ginger Kopp, Forester, NRCS Minnesota
Jeff Duchene, Grazing Specialist, NRCS Minnesota
Tyler Carlson, Farmer, Early Boots Farm
Jim Chamberlin, Food and Water Security Program Manager, Happy Dancing Turtle
Diane Mayerfeld, SARE Coordinator, WI
Tom Gervais, Regional Grazing Specialist, NRCS
Katherine MacFarland, Assistant Agroforester, National Agroforestry Center

Acknowledgements
This guidebook was developed as a component of the Legislative-Citizen Commission on Minnesota Resources (LCCMR) funded project “Enhancing Environmental and Economic Benefits of Woodland Grazing” Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 03j.. Funding was also provided by the Central Region Sustainable Development Partnership (CRSDP) – University of Minnesota Extension.

Table of Contents

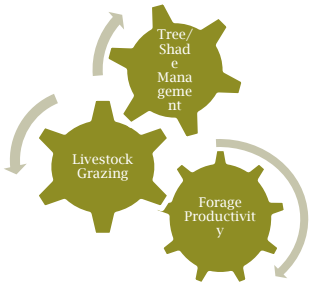
INTRODUCTION **4**
Potential of Silvopasture in Minnesota 5
Is Silvopasture Right For You? 6
Key Considerations 7
ESTABLISHING SILVOPASTURE **9**
From Grazed Woodland to Silvopasture
Site Preparation 9
Forage Establishment 10
Natural Regeneration 10
From Pasture to Silvopasture 11
Site Preparation 11
Tree Planting 12
Seedling Protection 12
Herbicides 13
Species Selection 13
TREE ARANGEMENT AND DESIGN **14**
Tree Pattern 14
Common Planting Arrangements 14
Spacing and Stand Density 16
Long-Term Tree Management 16
Canopy Management 16
Thinning 17
Pruning 17
LIVESTOCK **18**
Rotational Grazing Systems 19
Paddocks 20
Fencing 21
Gates and Access 22
Watering 22
FORAGE **23**
Forage Species Selection 23
Forage Establishment 25
Forage Management 25
Additional Considerations 26
Invasive Species 26
Plants Poisonous to Livestock 27
RESOURCES **28**
Online Resources 28
References 30
Glossary 31

INTRODUCTION

As an agroforestry practice, Silvopasture intentionally integrates livestock, forage production, and trees into an intensively managed system. The forage, trees, and livestock in silvopasture complement one another to increase productivity. The practice of silvopasture provides annual income from livestock (e.g., meat, dairy products) while fostering long-term economic benefits from trees including timber, fence posts, firewood, fruit, and nuts.

Components of Silvopasture:

In silvopasture , management of trees through thinning and pruning helps provide high value timber and ensures that sufficient light is available for forage while grazing animals control competition for moisture, nutrients and sunlight enhancing tree growth. Trees also provide shade for livestock and create a microclimate that improves forage quality. Livestock promote nutrient cycling and nitrogen fixing forage crops benefit trees.

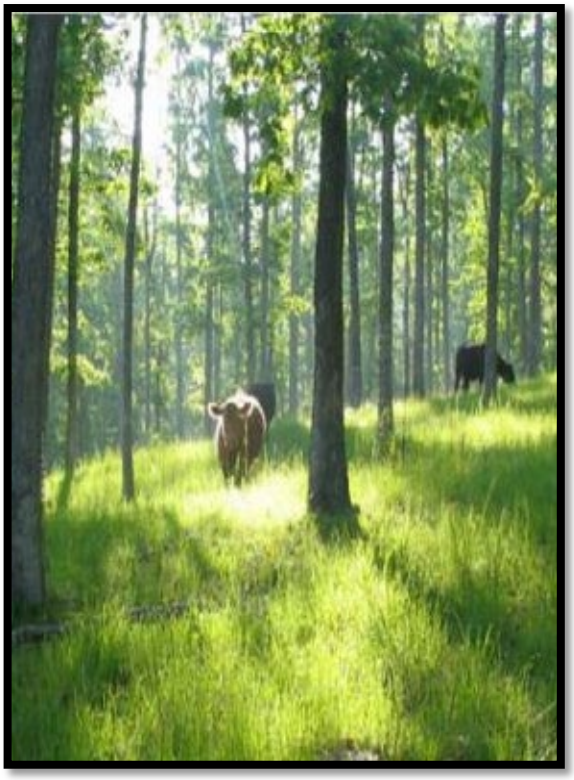


In addition to the potential gain from product diversification and improved timber and livestock production, well-managed silvopasture systems can:

- Reduce economic risk through product diversification
- Reduce harvest costs because of better access to trees
- Provide Erosion control
- Improve nutrient cycling
- Provide wildlife habitat
- Provide recreation opportunities
- Improve aesthetics and property values
- Sequester carbon
- Reduce fire hazard
- Control weeds
- Reduce habitat for rodents
- Improve pollinator forage

Due to these benefits, silvopasture can improve influence productivity and financial gain.

POTENTIAL OF SILVOPASTURE IN MINNESOTA



Silvopasture has great potential in Minnesota. Success has been demonstrated in Minnesota with rotationally grazed cool season forages grown in intensively managed upland oak hardwood forests.

In 2014, Minnesota had over 650,000 acres unmanaged farm woodlands being grazed by livestock. Allowing livestock to graze a natural woodland area without active livestock grazing, forage and tree management is detrimental to the forest and produces very limited forage for cattle, which do not gain weight as quickly as they might be in a managed system. Unmanaged woodland grazing can result in soil compaction, erosion, loss of biodiversity, water contamination, tree damage leading to reduced timber and livestock yields. Converting unmanaged grazed woodlands to silvopasture systems can generate ecological and financial benefits.

Shelter provided by trees decreases livestock stress, improves animal health, increases feeding efficiency and promotes uniform grazing within a pasture. Forage growing in a shady, low wind environment near trees is protein rich, lower in fiber and more digestible for livestock compared to forage growing in open pasture.

IS SILVOPASTURE RIGHT FOR YOU?

Silvopasture is a management option requiring a high level of management. It is possible to establish Silvopasture on any land that can support trees and forage systems. The conversion to a silvopasture system requires a well thought-out transition and active engagement in the management of the trees, livestock and forage components. When considering whether silvopasture is right for you, note the following:

- The transition to silvopasture requires a significant investment in fencing, water distribution, tree establishment or removal, forage establishment and even temporary pastures.
- Silvopasture systems typically require a large land base in order to sustain both tree and livestock production.
- The rotational grazing systems used in silvopasture system require more labor and regular monitoring compared to continuous stocking.
- Conversion to silvopasture may require changes to established cattle production cycles.
- Grazing unmanaged woodlands is not a silvopasture practice.
- If you love your natural forest or if you have a good stand of high quality trees, introducing livestock may not be the right choice.

If you are unable to contribute the time and infrastructure necessary to actively and intensively manage the system, then silvopasture may not be the right practice for you.

Silvopasture is not a plant it and leave it system. *Silvopasture does not involve allowing livestock to graze unmanaged woodlands and requires more than one or two trees in a pasture.*

Key Considerations

When is Silvopasture NOT appropriate?

- If your woods cast a deep shade (and you don't want to thin) – if grass won't grow there
- If your soils are too wet or your slopes are too steep
- If your woods have spring ephemerals or other sensitive flora
- If you have young trees that you want to keep
- If you are not sure the grazing will be well-managed

Cost-share program considerations:

- Financial assistance may be available for practices associated with establishing and managing silvopasture through the USDA – Natural Resources Conservation Service. Visit your county's USDA Service Center or www.mn.usda.nrcs.gov

Environmental considerations:

- Trees and forages in silvopasture must be well adapted to the site and compatible with the planned livestock management system.
- Adequate soil fertility, pH, and structure provide the foundation for the silvopasture system. Monitor the system for soil compaction, conduct regular soil testing to assess whether additional soil amendments is necessary.
- Protect any streams or water resources on the land. Unmanaged livestock grazing can alter a stream's morphology by causing the deterioration of stream banks. Unmanaged grazing may also be a nonpoint source of pollution by contributing excess phosphorous, nitrogen, and sediment loads to the water body.

Economic considerations:

Integrating trees, forage and livestock creates a land management system that may produce marketable products annually while maintaining long-term productivity of the trees. This system reduces economic risk by producing multiple products with established markets. Production costs are reduced and marketing flexibility is improved because management costs are distributed between timber and livestock. Due to these benefits, silvopasture often has a higher internal rate of return

compared to other management options. Landowners practicing silvopasture may also be able to generate additional income by:

- Offering recreational activities such as bird watching, wildlife viewing, or hunting on their property.
- Producing fruits, nuts, and materials for crafts, ornamental plants, maple syrup, mushrooms, organic mulch, and other secondary products.

Silvopasture establishment and management involves significant costs.

Costs Involved in Silvopasture

Prior to deciding to implement a silvopasture on your land, consider the following costs related to establishment, long-term management, and planning.

Initial Establishment Costs	*Long Term Management*

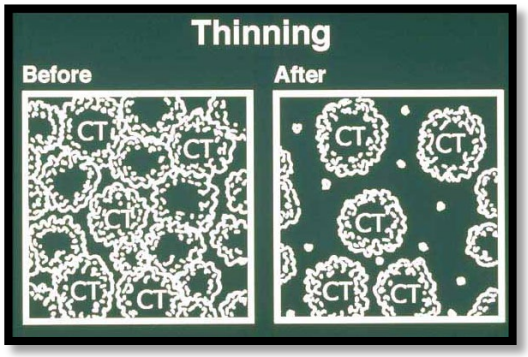
• Site Preparation
  ○ Costs involved in marking and thinning trees or clearing the area for seedlings (either mechanically or with herbicide) on a pasture (including cost of equipment, labor and cost of herbicide)
  ○ Tilling or plowing rows for tree planting
  ○ Soil sampling & fertilizer amendments (as needed)
• Seedling/forage seed costs
• Labor costs associated with planting Fencing costs (permanent or temporary, electric or portable
• Polywire, (solar or traditional)
• Watering facilities/structures for livestock
	• Tax value classification of the system (do you qualify for tax breaks?)
	• Yearly cost for annual crop/forage establishment (seeds, herbicide, labor, equipment etc.)
	• Fence maintenance
	• Livestock management expenses
	• Fertilizer amendments (for forage and/or trees)
	• Labor costs for pruning and thinning, and other forest management activities.

ESTABLISHING SILVOPASTURE

Silvopasture systems can be established in one of two ways by: 1) thinning existing woodland, or 2) planting trees on existing pasture. The former requires thinning of trees to a level that supports forages, and requires removing trees to create corridors. The latter involves planting of single or double rows of trees with forage corridors between them or in groups or blocks (non-linear plantings).

From Woodland to Silvopasture

Site Preparation:



- Thin the stand to reduce its canopy density to establish forage. Tree density must vary based on existing woodland. The goal is to increase the light levels to 30-50% that of open pasture. Light penetration required depends upon the shade tolerance of the forage species selected.
- Work with a Forester to select the highest quality trees to maintain as crop trees.
- Remove slash. Use a herbicide or goats to remove unwanted weedy vegetation from the area.
- Prepare the site for seeding as soon as possible after thinning or harvesting so undesirable herbaceous vegetation does not have a chance to invade the site.

Forage Establishment:

- Seed immediately to give forage seed an advantage over unwanted weeds A fall or dormant seeding before ground freezes is advisable. Consult your Agronomist or Grazing Specialist for appropriate forage to use.
- Using standard grass establishment techniques may not be appropriate for silvopasture. Instead, use alternative grass establishment approaches such as hand broadcast seeding using an ATV or hand, and have cattle work in the seed to allow seeds to contact on the soil.
- Manage understory vegetation to facilitate the establishment of the desired forage crop through browsing, mechanical treatment or herbicide application.
- Control noxious weeds or invasive species if present in the area.
- Seed annual or Italian ryegrass, oats, or other small grain, if necessary, to provide cover and to act as a nurse crop for desirable grasses.

Natural Regeneration

Natural regeneration is the re-establishment of a forest from seed and sprouts. The young scattered seedlings require protection from livestock.

- Plan in advance where natural regeneration is desired and redesign the silvopasture grazing plan accordingly to allow the seedlings to mature without livestock threats.
- When converting forest to pasture, protect seedlings from browsing and trampling by the livestock using fence, seedling tubes, block cages, or removing livestock from the forested paddock until the new trees are at a size and height that can withstand livestock pressure.

Key Messages

On converting woodland into silvopasture, thinning is necessary to:

1) Improve timber quality of remaining crop trees
2) Allow sufficient amount of light to penetrate into the ground for forage growth
3) Protect selected seedlings from animal browsing using seedling tubes or fence to ensure generation
4) Employ long rotational grazing (fallow period) to allow seedlings to grow to ensure regeneration
5) Additional efforts must be taken to ensure recruitment of the next generation of trees.

From Pasture to Silvopasture

Site Preparation

- Prepare the site by tilling, mowing or using herbicides to remove competition and establish rows for planting tree seedlings.
- Spray a strip or circle to provide a 4 to 6 foot diameter "competition free" zone around each tree seedling to avoid competition between forage and trees. Apply prescribed burning or herbicide treatment if necessary in other areas. Do this in fall to control rodents prior to planting.
- Sub-soiling is highly recommended when planting into pasture due to the potential compaction caused by grazing. Sub-soiling must be done along the contour to prevent erosion.
- Disk the soil if necessary to help break up the sod and incorporate herbicides.

Degraded pasture land (Photo: NAC)

Key Message

Establishing a silvopasture in existing pasture will require intensive seedling management. Seedlings will need protection from grazing and vegetative competition. Weeds and forages will need to be controlled near the trees. Suppression and competition control can be accomplished with through subsoiling, herbicides, tillage and/or mulch.

Tree Planting

- Purchase seedlings through state-operated or commercial nurseries[1]. Often, purchased must be made six month or a year in advance. When selecting seedlings:
    - Use improved tree seedlings when possible.
    - Plant large seedlings to help guarantee establishment and early fast growth.
    - Select seedlings with well-established root systems. Planting bare root trees in the spring offers the good success and economic value.
- Some Soil and Water Conservation Districts (SWCD) sell bare root trees. Call the local office for more information. They may also plant your trees with a tree planter, which is much faster than by hand.
- Planting rates are typically from 200 to 400 trees per acre. When planting trees, refer to the following guidelines: http://www.dnr.state.mn.us/treecare/index.html

Seedling Protection

- Maintain a "competition free" zone around the seedlings for several years until the trees are established.
- Protect new plantings from livestock to prevent browse and trampling. Livestock browsing can damage or kill the tree seedlings. Trampling damage can also cause deformation and weakening of the stem and can provide an entry point for pests and diseases.
- Protect seedlings with either electric or wire fencing.
- Seedlings should be protected from livestock until they grow several feet above the browse line.

Newly established oak silvopasture (Photo: UMCA)

- Protect seedlings by rotating cattle frequently and try to keep cattle far from trees when they are transitioning from their winter to summer coat and rubbing is most frequent.

[1] Refer to the following list of nurseries in Minnesota: http://www.nurserytrees.com/States/state%20Minnesota.htm

- During the years while the trees are establishing, the area between the rows can be hayed, grazed,or cropped. Make sure that row spacing is planned to fit the equipment that will be used.

Herbicides

- Use herbicide, if necessary, to establish or maintain the silvopasture system
- Pay attention to all environmental hazards and site-specific application criteria listed on herbicide labels. Always read and follow label directions.
- Consult with your Extension Agent for appropriate herbicide application.

Species Selection

The right choice of tree crop allows you to carry on a profitable livestock operation while creating a long-term investment in timber and/or forest products. Tree species selection should be done based upon local soil types, site characteristics and limitations, landowner objectives, projected or existing canopy characteristics, and forage, sunlight, marketable value of trees, and moisture requirements.

Trees suitable for silvopasture in Minnesota:

- Black Walnut (*Juglans nigra)* (Concern: Thousand Cancer Disease)
- Bitternut Hickory (*Carya cordiformis)*
- Northern Red Oak (*Quercus rubra*)
- White Oak (*Quercus alba*)
- Bur Oak (*Quercus macrocarpa*)
- Black maple *(Acer nigrum)*
- Silver maple (*Acer* saccharinum)
- Sugar maple (*Acer saccharum*)
- Paper Birch (*Betula papyrifera*)
- Green Ash (*Fraxinus pennsylvanica*) (Concern: Emerald Ash Borer)

DESIRABLE SILVOPASTURE TREE CHARACTERISTICS

- Marketability of the wood as well as secondary products such as fruits or nuts
- Compatibility with the chosen forage crop and livestock
- High quality
- Fast growing or of such high value that a species of medium growth rate is acceptable
- Deep roots so that trees do not compete with forage for moisture and nutrients
- Rapidly decomposing foliage
- Compatible with local climate, soil type, and moisture
- Canopy produces light enough shade so that forage can be established
- Capable of producing the products you desire

- Aspen (*Populus* spp)
- Red Pine (*Pinus resinosa*)
- White Pine (*Pinus strobus*)

Consult a forester for appropriate tree species to plant in your site.

TREE ARRANGEMENT AND DESIGN

Tree Pattern

Trees should be planted or thinned so that they are spaced to optimize growing space and light penetration for high-quality timber and forage. Key factors to keep in mind when establishing a silvopasture design include:

Bur Oak Silvopasture in the North Central United States

- **Equipment size:** The alley between tree rows should be wide enough to allow the passage of equipment.
- **Forage:** Most forages need a minimum of 50% light. Plan to manage canopy density to produce adequate light for forage growth.
- **Changes through time:** Increased shading occurs as trees mature increasing the need for pruning/thinning.
- **Thinning and pruning:** Timely thinning and proper pruning can increase log value and maintain sufficient sunlight for forage.

Common Planting Arrangements

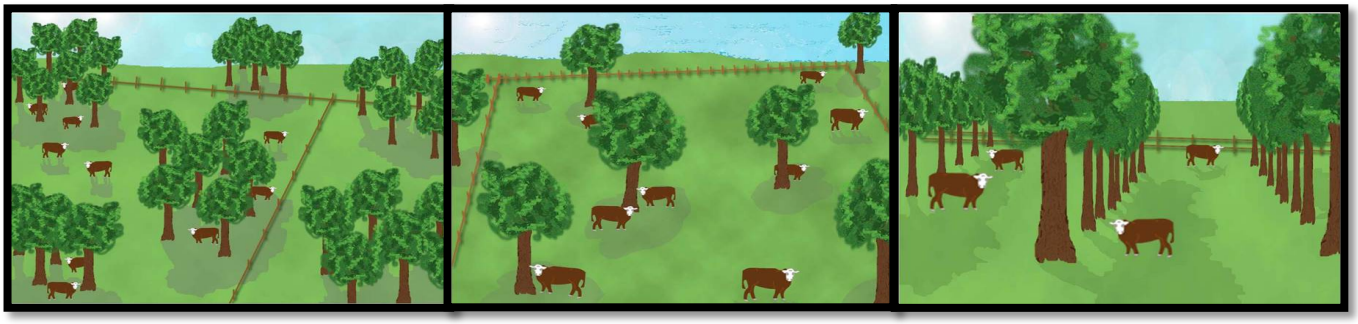
Single Row Plantings: Trees are spaced at a minimum of 8 up to 12 feet within the row and at least 50 feet between rows, depending on the landowner's objectives, spacing needs of the species and the equipment to manage the forage. Single row configuration depends on your objectives such as better crown space for nut production (if it is the primary objective), simplified maintenance (such as mowing), a diversified landscape, and enhanced farm production.

Double-Row plantings: Staggered tree rows with 8 to 10 feet or more as appropriate, between trees and rows. Once established, both forage and trees co-exist and can contribute to a highly productive silvopasture system.

Multiple-Row Plantings: Rows of trees at close spacing (for example: 8 x 10 feet or 10 x 10 feet with an alleyway at least 50 feet between sets of tree rows for forage production) may work well depending of the objectives of the landowner. Multiple

row plantings provide enhanced erosion control, better growth of trees for timber, improved wildlife value, and greater diversification of farm products. Closer spacings will need a higher level of forest management due to more periodic thinnings.

Block Plantings: Evenly distributed tress in block plantings optimize growing space and light for trees and forage. Trees grouped in rows or clusters concentrate shade and root effects, and provide open spaces for pasture production. Thin the plantings routinely to maintain forage production.



Common Planting Formations: Group plantings, single plantings, and row plantings

Protecting Young Trees from Livestock

Protect young trees from livestock using fence. Install block cages around individual trees or use strips of portable fencing along rows of trees.

A black walnut sapling protected from animal browsing and trampling (Photo: UMCA)

Spacing and Stand Density

The number of trees per acre will affect the number of thinnings that will need to occur and the types of products that will be produced (i.e. poles, chip and saw lumber, saw timber, firewood). Lower density stands that are more open tend to favor forage production, accelerate tree diameter growth due to reduced competition, provide easy access for harvest and reduce harvesting costs. However, trees in lower density stands may require pruning to maintain straight limb free boles.

Other things to consider while planning tree spacing include:

Within a Row

- Federal/State subsidy program requirements
- Production vs. conservation benefits
- Wood production vs. other tree benefits
- Markets for low volume, small-diameter material

Between a Row

- Production vs. conservation objectives
- Wood production vs. other tree products
- Forage light requirements
- Width of farm equipment

South facing slopes could have a higher tree density because they have more sunlight.

Tree density also has an important effect on cattle distribution within a pasture. When shade is isolated in only a few areas of a paddock, cattle can begin to concentrate in shaded areas, which can damage trees and decrease the overall productivity of the paddock.

Long-Term Tree Management

Once the silvopasture system is established, careful management is necessary to ensure that the timber-forage-livestock system is well balanced. The goal of tree production in a silvopasture system is to produce high-quality timber or non-timber forest products.

Canopy Management

Manage the tree canopy to allow 40 and 60 percent light penetration. Once canopy cover begins to exceed 50-60%, the amount of light reaching the ground will decrease and the quality of the forage crop will deteriorate. Conduct regular thinning to keep the amount of light necessary for the forages and forbs. At some point a final harvest of the forest stand may be necessary followed by either planting or natural regeneration.

Thinning

Thin trees as needed. The timing of thinning will depend on initial stocking, tree growth and product type. Remove enough trees at each thinning to maintain sufficient sunlight for forage.

Pruning

Pruning helps ensure that sufficient light is available for forage crops and that the silvopasture system is producing high quality, knot-free wood. Factors to consider include:

- **Trunk diameter:** Once trees are large enough to shade forage, begin pruning to maintain canopy density at around 50%. . Maintain a live crown of no less than 1/3 of tree height.
- **Season of year:** The best time to prune living branches is in the dormant season or in late winter or early spring. This reduces insect and disease problems.
- **Refer to** http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/pruning-trees-shrubs/ for proper pruning of branches.

Hardwood trees can develop epicormic branches. Epicormic scars can result in lower log values. From most likely to least likely to produce epicormic branching: white oak, black cherry, red oak, hickory, red maple, and sugar maple. Image Source: www.agriculture.purdue.edu

LIVESTOCK

Livestock used silvopasture systems include cattle, sheep, goats, horses, turkeys, and chickens. Livestock in silvopasture can:

- Provide short term income
- Help manage weeds and tree-forage competition
- Reduce fertilizer needs by recycling soil nutrients.

Key Messages

1). Carefully monitor the timing and duration of grazing, stocking rates, and carrying capacity of the pasture in order to maintain the quality of the site and ensure tree survival. Insufficient attention to managing livestock by allowing them to roam the system freely without monitoring or managed rotational grazing can result in overgrazing, soil compaction, water contamination, damage to trees and declines in the overall productivity of the system.

2). Develop a comprehensive rotational grazing management plan that includes fencing, a rotational grazing schedule, fertilization, placement of watering and supplemental feeding areas.

3.) Monitor trees for browsing, trampling or rubbing. Protect trees if needed.

4.) Monitor soil for compaction. If the forage stand is thin and does not grow back following removal of livestock, then soil compaction may be a problem. This assumes that drought or lack of nutrients is not a factor limiting production.

5.) Remove livestock from the silvopasture during excessively wet periods to avoid soil compaction and tree damage

Rotational Grazing Systems

A rotational grazing system is a main requirement for livestock management in silvopasture. Continuous stocking (maintaining animals in a single pasture during the entire grazing season) is not recommended for silvopasture systems.

Levels of Management for Livestock

OPTIMAL: Timing livestock access to the area to maximize positive interactions with the forages and minimize negative interactions with tree seedlings. Frequent rotation is necessary to optimize forage health.

Improved: Moving livestock when forage supply is starting to decline and seedling trees have minimal damage.

Poor: "Dumping" livestock on an area and leaving for extended periods, causing overgrazing of forages and damage of trees.

A rotational grazing system will help encourage uniform distribution of cattle on the system. Strategically place shade, watering areas, and supplemental feeding areas to encourage uniform livestock distribution within cells, paddocks, or a pasture.

Rotational grazing uses a system of grazing and recovery periods by rotating animals among different cells, paddocks or pastures.

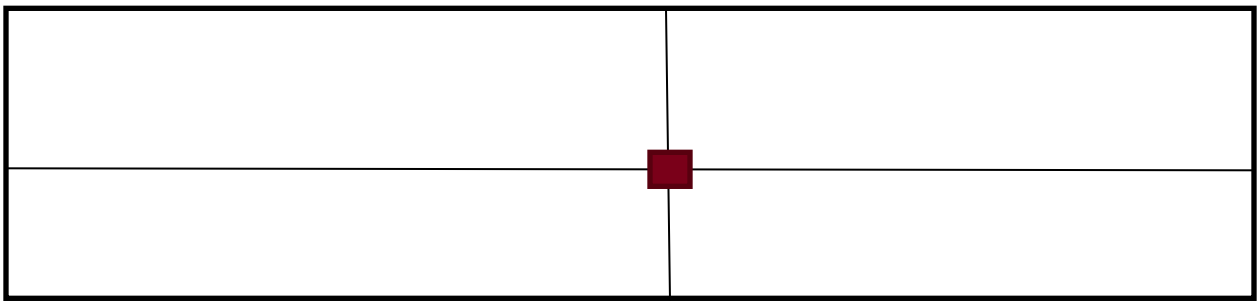
Rotational grazing:

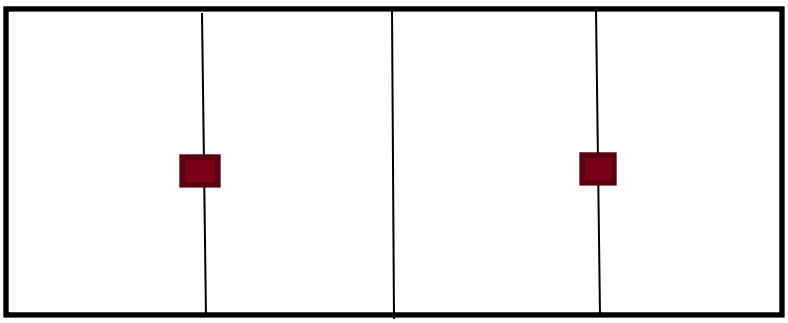
- Grazing periods could range in duration from 1 day to 6 days but should typically be less than 3 days. Establish grazing periods according to the rate of forage regrowth in the paddock rather than following a set calendar schedule.
- Use higher quality parts of forage plants for grazing (the top third of the leaf) and rotate out the pasture before the animals begin eating the lower quality parts of the plants.
- Move the grazing animals to a new paddock or grazing area once the forage is grazed to a minimum of 3-4 inches in height. This will allow the forage to regrow rapidly, and ultimately remain healthy and productive.
- The forage regrowth rate varies based upon several factors including forage species, climate, precipitation, shade, soil nutrients, and time of year. Recovery periods may last between 20-45 days or longer depending upon forage growth rates.
- Plan to manage rotation around forage growth to take full advantage of forage quality when it peaks.
- Adjust livestock numbers up and down based upon forage production to manage available forage.

Paddocks

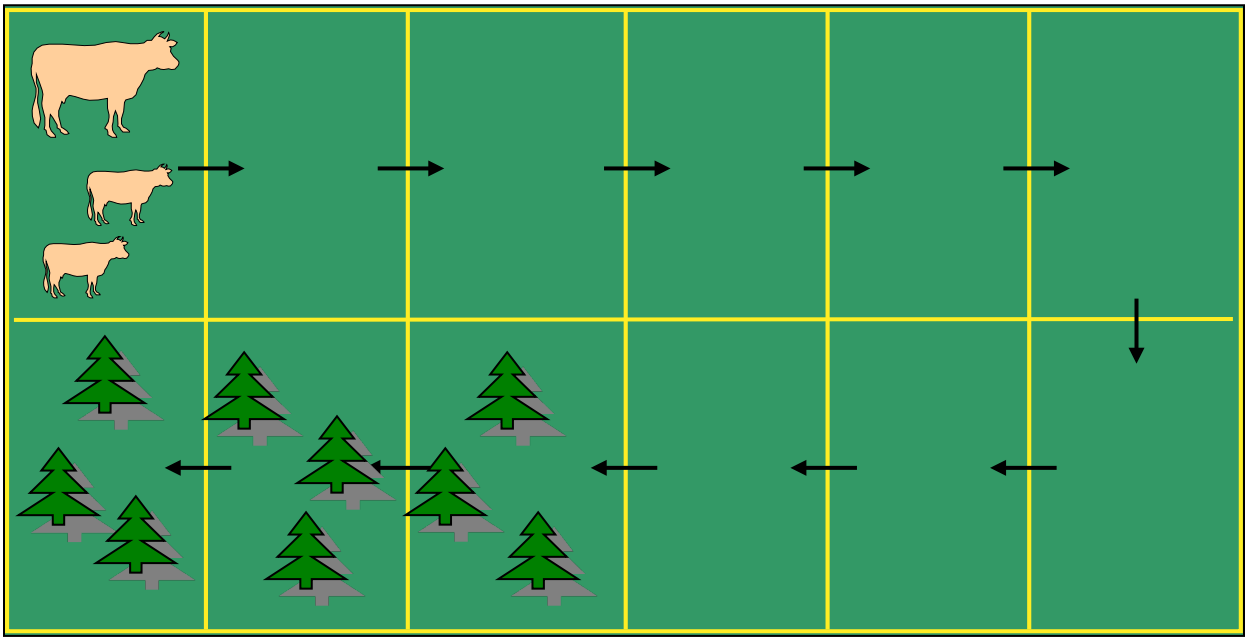
Once forage is established, lay out pastures and fencing for rotational grazing and ensure that each pasture has a sufficient water supply for livestock requirements. Do this before introducing livestock to the system. Proper pasture rotation using a paddock fencing system provides recovery periods for grazed forage, minimizes soil compaction and protects trees. The optimum number of paddocks in a silvopasture system will vary depending upon individual circumstances, resources, goals for the system, environmental conditions and the desired level of animal production.

Where land allows, uniform sized paddocks with parallel sides are desirable to facilitate better grazing distribution. The diagrams below show options for dividing grazing areas into paddocks. The red squares indicate water sources and lines indicate fencing.





For beef cattle, grazing 5-10 paddocks with each paddock grazed 3-6 days and rested 25-35 days may be enough. Provide adequate feeding management to increase the economic efficiency of the livestock production system. Silvopasture can be part of the whole rotational grazing plan, and can be used especially in hotter summer months.



Fencing

Fencing helps control and restrict animal movement within the rotational grazing system. Fence plans should be flexible and not limit grazing options. Common types of fencing include perimeter fences, permanent subdivisions, and temporary/portable fences. Electric fences using battery or solar power are commonly used to contain livestock in paddocks. High tensile wire is recommended when using energized fences.

Gates and Access

The location of gates in the rotational system is important to facilitate movement of livestock through the paddocks and the alignment of temporary lanes and alleyways. Consult your local NRCS grazing specialist for proper fencing and gate access.

Watering

All grazing animals need to drink water regularly. Water requirements vary for the type, size, age and breed of livestock (see table) and can vary considerably depending upon the animals' health, air temperature, water temperature, stage of lactation and other environmental factors.

Refer to the following guidelines:

- Each paddock should have access to an adequate water supply. A rule of thumb is one gallon of water per day per 100 pounds of body weight per animal.
- Water is especially critical as air temperatures exceed 77 F (or temperature-humidity index of 72 F).
- Ensure that water is accessible within 600 feet of the herd. If watering facilities are over 600 feet away, cattle will begin to congregate and form use lanes and alleyways to get to the water source. This can result in mud, trampling of the water source and a less uniform grazing pattern in the paddock.
- Place one water source in a way so that it serves more than one paddock by placing watering tanks in the fence lines toward the center of the paddocks. This allows a wider area of access and keeps compaction and animal concentrations to a minimum.

Water intake

Daily Needs in Gallons per Head

	50 F	90 F
Beef Animals		
400lb Calf	4	10
800lb Feeder	7	15
1000lb Feeder	8	17
Cows and Bulls	8	20
Dairy Animals		
Cows	15	30
Calves	2	12
Replacement Heifers	6	15
Bulls	8	20
Horses and Mules	8	12
Sheep or Goats	1.5	3.5

Source: D.M. Ball, C.S. Hoveland, and G.D. Lacefield. 2000. Southern Forages and the Foundation for Agronomic Research. Norcross, Georgia.

- When possible, use portable water facilities. These facilities allow the tank location to move as needed.

FORAGE

The level of forage production in a silvopasture depends upon:

- The established rotational grazing system
- The tree species, spacing and age
- Forage species and shade tolerance

The tree canopy density must allow sufficient light to reach the understory in order for forage crop to flourish. Reducing tree density, managing tree spacing and pruning adjust light.

Forage Species Selection

The forage crop in a silvopasture must:

- Be suitable for livestock grazing and be able to meet the nutritional needs of the chosen livestock.
- Be compatible with site.
- Be productive under partial shade. It is important to choose forage that will do well in the level of shade produced by the tree cover.
- Be resilient to moisture stress and responsive to intensive management.
- Be well adapted to local climate and site conditions.
- Have a high forage production.
- Use warm season grasses if site is appropriate for these species.

The following table lists cool season grasses, forbs and legumes recommended for Minnesota.[2]

Cool season grasses, forbs and legumes recommended for Minnesota

Native Grasses	**Native Forbs/Wildflowers**
Big bluestem (*Andropogon gerardi*)	Partridge Pea (*Cassia fasciculata*)
Fringed Brome (*Bromus ciliatus*)	Prairie Coreoposis (*Coreopsis palmata*)
Kalm's Brome (*Bromus kalmia*)	White Prairie Clover (*Dalea candida*)
Poverty Oat Grass (*Danthonia spicata*)	Purple Prairie Clover (*Dalea purpurea*)
Canada Wildrye (*Elymus canadensis*)	Illinois Bundleflower (*Desmanthus illinoensis*)
Bottlebrush Grass (*Elymus hystrix*)	Showy Tick Trefoil (*Desmodium canadense*)
Slender Wheat Grass (*Elymus trachycaulus*)	Narrow-leaved Coneflower (*Echinacea angustifolia*)
Virginia Wild Rye (*Elymus virginicus*)	Purple Coneflower (*Echinacea purpurea*)
Nodding Fescue (*Festuca subverticillata*)	Rattlesnake Master (*Eryngium yuccifolium*)
Fowl Bluegrass (*Poa palustris*)	Joe Pye Weed (*Eupatorium maculatum*)
Little Bluestem (*Schizachyrium scoparium*)	Boneset (*Eupatorium perfoliatum*)
Indiangrass (*Sorghastrum nutans* L)	Bottle Gentain (*Gentiana andrewsii*)
	Cream Gentain (*Gentiana flavida*)
Introduced Grasses	Prairie Smoke (*Geum triflorum*)
Crested Wheatgrass (*Agropyron desertorum*)	Sneezeweed (Helenium autumnale)
Smooth Bromegrass (*Bromus inermis*)	Tall Sunflower (*Helianthus giganteus*)
Orchardgrass (*Dactylis glomerata*)	Maximillian's Sunflower (*Helianthus maximilliani*)
Tall Fescue (*Festuca arundinacea*)	Early Sunflower (*Heliopsis helianthoides*)
Perennial Rye (*Lolium perenne*)	Round-Headed Bush Clover (*Lespedeza capitata*)
Timothy (*Phleum pretense*)	Button Blazing Star (*Liatris aspera*)
Kentucky Bluegrass (*Poa pratensis*)	Meadow Blazing Star (*Liatris ligulistylis*)
	Dotted Blazing Star (*Liatris punctata*)
Introduced Legumes	Prairie Blazing Star (*Liatris pycnostachya*)
Red Clover (*Trifolum pretense*)	Great Blue Lobelia (*Lobelia siphilitica*)
White Clover (*Trifolium repense*)	Wild Lupine (*Lupinus perennis*)
	Wild Bergamot (*Monarda fistulosa*)
Native Forbs/Wildflowers	Spotted Bee Balm (*Monarda punctata*)
Wingstem (*Actinomeris alternifolia*)	Common Evening Primrose (*Oenothera biennis*)
Anise Hyssop (*Agastache foeniculum*)	Foxglove Beardtongue (*Penstemon digitalis*)
Purple Giant Hyssop (*Agastache scropulariaefolia*)	Large-Flowered Beardtongue (*Penstemon grandiflorus*)
Thimbleweed (*Anemone cylindrica*)	Prairie Phlox (*Phlox pilosa*)
Swamp Milkweed (*Asclepias incarnata*)	Prairie Cinquefoil (*Potentilla arguta*)
Common Milkweed (*Asclepias syriaca*)	Mountain Mint (*Pycnanthemum virginianum*)
Butterfly Weed (*Asclepias tuberosa*)	Panicled Aster (*Aster simplex*)
Whorled Milkweed (*Asclepias verticillata*)	
Heath Aster (*Aster ericoides*)	

[2] Check NRCS website (http://plants.usda.gov/java/) for information of each of these species. Each forage species will have a different growth period. Check with your local forage specialist for the appropriate forage to plant.

Native Forbs/Wildflowers	
Silky Aster (*Aster sericeus*)	Long-headed Coneflower (*Ratibida columnifera*)
Canadian Milk Vetch (*Astragalus canadensis*)	Yellow Coneflower (*Ratibida pinnata*)
White Wild Indigo (*Baptisia leucantha*)	Black-eyed Susan (*Rudbeckia hirta*)
Showy Goldenrod (*Solidago speciosa*)	Compass Plant (*Silphium laciniatum*)
Blue Vervain (*Verbena hastate*)	Cup Plant (*Silphium perfoliatum*)
Hoary Vervain (*Verbena stricta*)	Stiff Goldenrod (*Solidago rigida*)
Common Ironweed (*Vernonia fasciculata*)	Culver's Root (*Veronicastrum virginicum*)
Smooth Blue Aster (*Aster laevis*)	Heart-leaf Golden Alexander (*Zizia aptera*)
New England Aster (*Aster novae-angliae*)	Golden Alexanders (*Zizia aurea*)

Forage Establishment

- Plant only viable, high quality and well-adapted planting stock and seeds in the silvopasture system. Follow the same procedure of establishing forages in silvopastoral system as that of the traditional pasture when converting an existing pasture to silvopasture. On the other hand, use alternative seeding approaches such as broadcast seeding using ATV or by hand to establish forage when converting woodlands into silvopasture.
- When using soil amendments and fertilizer, account for the requirements and limitations of both forage and tree components of the silvopasture systems.
- Control all perennial weeds that are not desirable or are noxious or invasives.

Forage Management

- Control animal movement within the silvopasture to prevent overgrazing.
- Rotate the livestock when the forage has been grazed to a height between 3 inches to 4 inches. Forages should be grazed no shorter than three inches and should be six inches in height at the end of the growing season.
- Time the fallow period to allow adequate regrowth and carbohydrate storage prior to a killing frost.
- The number of grazing units ultimately depends upon plant recovery time, the livestock species being allowed to graze, and the final goal of livestock production (milk vs. meat).

Additional Considerations

Low growing plants like Kentucky bluegrass, white clover, etc. can withstand close late-season grazing because they hold some leaf area close to the ground and have carbohydrate reserves in their stems and rhizomes. Other species such as orchardgrass and many native grasses have less leaf area after close grazing and contain most of their carbohydrate reserves in their stem bases

It is important to recognize that forage species respond differently to grazing pressure.

Recommended Grazing Height and Recovery Periods			
Forage Height	Target Height (Inches)		Usual Days Rest for Recovery of Leaf Area
	Begin Grazing	End Grazing	
Alfalfa	10-16	3-4	15-30
Clover, white and sub	6-8	3-4	7-15
Tall Fescue	4-8	3-4	15-30
Orchardgrass	8-12	3-4	15-30
Ryegrass	6-12	3-4	7-15
Small grains	8-12	3-4	7-15

Invasive Species and Noxious Weeds

Producers should be aware of the laws regarding invasive species and noxious weeds. Each state has agencies designated to monitor and provide educational information about management and control. Some laws mandate the landowner to control specific weeds. In Minnesota, the Minnesota Department of Natural Resources (DNR) is the lead agency for invasive species (both terrestrial and aquatic) and the Minnesota Department of Agriculture (MDA) is the lead agency for noxious weeds. To learn more about the laws and invasive noxious species you should be aware of, look on the following web sites.

Minnesota Invasive Species (MN DNR)
www.dnr.state.mn.us/invasives/index.html

Minnesota Noxious Weed Law (MDA)
www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist.asp

Plants Commonly Found in Established Minnesota Horse Pastures
www.extension.umn.edu/agriculture/horse/order/docs/DI8646.pdf

Plants Poisonous to Livestock

There are plants in the Midwest that can be toxic or poison to livestock. Producers should be aware of these plants in their pastures and control them when necessary. To learn more about these plants, look at the web sites below:

Plants Poisonous to Livestock
http://poisonousplants.ansci.cornell.edu/comlist.html

Poisonous Plants
www.extension.umn.edu/agriculture/horse/pasture/poisonous-plants/

Plants Poisonous or Harmful to Horses in the North Central United States
http://pss.uvm.edu/pdpforage/Materials/AnimalDisorders/PlantsPoisonousHorses_Un_Minn.pdf

RESOURCES

Online Resources

USDA National Agroforestry Center (NAC) http://www.unl.edu/nac/silvopasture.htm

Auburn University https://etd.auburn.edu/handle/10415/3347

The University of Missouri Center for Agroforestry
http://www.centerforagroforestry.org/practices/sp.asp

Association for Temperate Agroforestry (AFTA)
http://www.aftaweb.org/entserv1.php?page=2

TreeSearch http://www.treesearch.fs.fed.us/

Dale Bumpers Small Farm Research Center –USDA Agricultural Research Service
http://www.ars.usda.gov/research/projects/projects.htm?accn_no=412583

University of Minnesota "My Minnesota Woods"
http://www.myminnesotawoods.umn.edu/2009/01/silvopasture/

University of Minnesota Extension
http://www.extension.umn.edu/environment/agroforestry/silvopasture/silvopasture.html

Discovering profits in unlikely places: agroforestry opportunities for added income
http://www.extension.umn.edu/environment/agroforestry/discovering-profits-in-unlikely-places/

Pastures for Profit: A Guide to Rotational Grazing
www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1097378.pdf

Silvopasture Ning site. http://silvopasture.ning.com/

Plants Poisonous to Livestock
http://poisonousplants.ansci.cornell.edu/comlist.html

Poisonous Plants
www.extension.umn.edu/agriculture/horse/pasture/poisonous-plants/

Plants Poisonous or Harmful to Horses in the North Central United States

http://pss.uvm.edu/pdpforage/Materials/AnimalDisorders/PlantsPoisonousHorses_Un_Minn.pdf

Minnesota Invasive Species (MN DNR)
www.dnr.state.mn.us/invasives/index.html

Minnesota Noxious Weed Law (MDA)
www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist.aspx

Plants Commonly Found in Established Minnesota Horse Pastures
www.extension.umn.edu/agriculture/horse/order/docs/DI8646.pdf

References

Bambo, S.K.; Nowak, J; Blount, A.R; Long A.J; Osiecka, A. 2009. Soil Nitrate Leaching in Silvopastures Compared with Open Pasture and Pine Plantation. Journal of Environmental Quality. 38: 1870-1877

Brantly, S. 2005. Silvopasture Water and Fencing Systems for Cattle. USDA National Agroforestry Center.

Garrett, H.E.; Kerley, M.S.; Ladyman, K.P.; Walter, W.D.; Godsey, L.D.; Van Sambeeck, J.W.; Brauer D.K. 2004. Hardwood Silvopasture Management in North America. Agroforestry Systems. 61: 21-33.

NASS (2015) 2014 Census of Agriculture.

Raising Cattle and Timber for Profit: Making Informed Decisions about Woodland Grazing. 2004. University of Minnesota Extension.

Silvopasture Establishment and Management Principles For Pine Forests In the Southeastern United States. 2008. USDA National Agroforestry Center.

Training Manual for Applied Agroforestry Practices. 2013. University of Missouri Center for Agroforestry.

Glossary

Agroforestry	The intentional combination of agriculture and forestry to create an integrated and sustainable land use system. Agroforestry takes advantage of the interactive benefits of combining trees and shrubs with crops and/or livestock.
Carrying capacity	The stocking rate that provides a target level of performance while maintaining the integrity of the resource base.
Epicormic branches	Shoots arising from adventitious or dormant buds on the stem or branch of a woody plant, often following exposure to increased light levels or fire
Forage	Vegetation browsed or grazed by livestock.
Forage Allocation	The process of dividing forage resources among livestock for different dietary needs. Forage allocation depends on the type of forage available, the carrying capacity of the site, and the seasonal needs of the type of livestock using the site. Forage allocation for calves will be different than for non-lactating cows.
Herd Effect	The impact of a concentrated herd of livestock on soil, water and vegetation resources on a site. Dense herds often lead to soil compaction, erosion and other undesirable effects on a site.
Joule	The actual quantity of energy that passes through an animal in an energized fencing system.
Paddock	A fenced area used to confine livestock to a particular area.

Pruning	The removal of branches from trees. Pruning is carried out to improve the market value of the final wood product by producing knot-free wood for the improvement of timber quality.
Stocking rate	The number of animals or animal live weight assigned to a grazing unit on a seasonal basis. Stocking rate has an effect on intake and availability.
Thinning	Selective removal of trees, primarily undertaken to improve the growth rate or health of the remaining trees.
Voltage	In considering the voltage necessary to deter livestock, a minimum level of voltage is required to overcome the resistance of the animal's skin, fence, wire and soil. Voltage delivered can be reduced by energy "leakage" through dew, grass etc. Thus, an animal's nose is more sensitive than its hide, as there is less resistance. It is important to consult an energized fencing supplier or livestock specialist in designing and implementing an energized fencing system.