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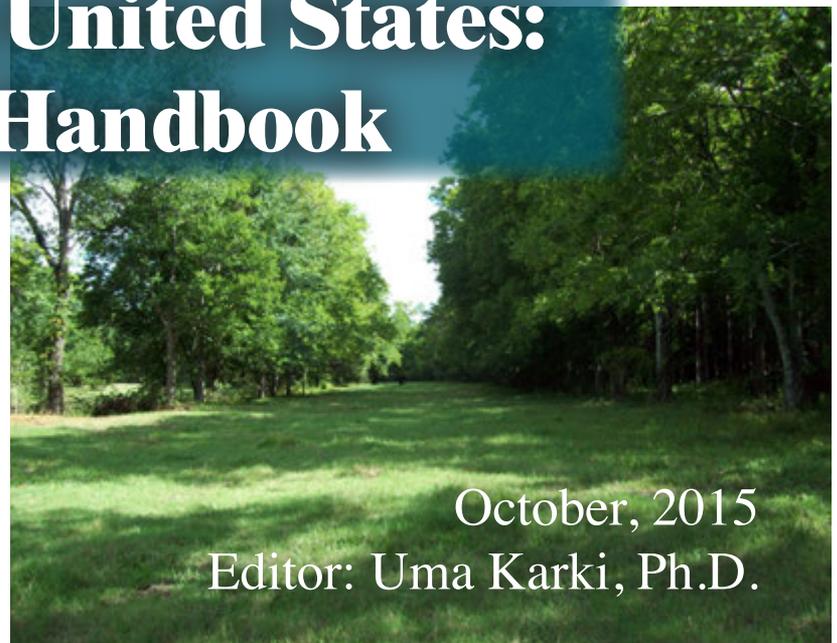


# Handbook for Training Field Extension and Technical Assistance Personnel



**Sustainable Agroforestry  
Practices in the**

**Southeastern United States:  
Training Handbook**



October, 2015  
Editor: Uma Karki, Ph.D.





A silvopasture plot prepared for planting forages, September 2014, Atkins Agroforestry Research and Demonstration Site, Tuskegee University, Tuskegee, AL.



A silvopasture with cool-season forages, January 2015, Atkins Agroforestry Research and Demonstration Site, Tuskegee University, Tuskegee, AL.



Alleys prepared for planting forage seeds in a silvopasture demonstration site, September 2015, Plantersville, AL.



Forage seeds are being planted in a silvopasture demonstration site, October 2015, Plantersville, AL.

## Sustainable Agroforestry Practices in the Southeastern United States



Goats grazing cool-season forages in the Atkins Agroforestry Research and Demonstration Site, April 2015, Tuskegee University, Tuskegee, AL.



Goats grazing warm-season forages in the Atkins Agroforestry Research and Demonstration Site, July 2015, Tuskegee University, Tuskegee, AL.

## PREFACE

### **About the Handbook**

This handbook has been developed to train field-level Extension and technical assistance personnel (hereafter field personnel), who are involved in educating and helping farmers and landowners in the southeastern United States understand and adopt sustainable agroforestry practices. The purpose of developing this handbook is to extensively increase the training and educational opportunities for farmers and landowners in the southeastern United States on sustainable agroforestry practices, and eventually enhance their income opportunities, sustainable land management practices, and ecosystem services.

This handbook contains 11 chapters. **Chapters 1 to 5** are on **Silvopasture Systems**. **Chapter 1** introduces silvopasture introduction, **Chapter 2** presents the establishment and management of trees in silvopasture systems, and **Chapter 3** discusses forage selection and establishment in silvopasture. **Chapter 4** focuses on suitable animal species and facility requirements for grazing animals in silvopasture, and sustainable grazing management in silvopasture systems is presented in **Chapter 5**. **Chapter 6** presents different types, aspects, and methods of **Forest Farming**. Information on different aspects of **Alley Cropping** is presented in **Chapter 7**. **Chapter 8** on **Riparian Buffers** discusses basic information and economics of these buffers, and possible assistance available to develop these buffers. **Chapter 9** is about **Windbreaks**, and includes the basic information, usage, and designs of windbreaks. This module also presents the tentative costs involved and possible sources of assistance to develop this system. **Ecosystem Services** that can be obtained from different agroforestry practices is presented in **Chapter 10**. **Chapter 11** discusses economic aspects of agroforestry practices in comparison to various monocultures, such as forestry, crop farming, and pastures. All chapters include hands-on activities to be incorporated during the training sessions. When field personnel are trained by subject matter specialists on the content of this handbook, including the hands-on activities, these field personnel are expected to be able to conduct similar training sessions for farmers and landowners in their working areas by using this handbook as a guide. Field personnel can also use this handbook as reference material to develop various fact sheets and articles to fulfill the needs of their clientele.

### **Acknowledgements**

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Uma Karki, Ph.D.  
Editor



Trainees learning about medicinal plants, July 2015, Alabama A&M University Winfred Thomas Agricultural Research Station, Hazelgreen, AL.



Trainees are taking a silvopasture site tour and engaged in group discussion, November 2014, USDA NRCS East National Technology Support Center, Greensboro, NC.

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# Chapter 1 SILVOPASTURE INTRODUCTION

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## Introduction

Silvopasture is a sustainable agroforestry system where trees, forages, and grazing animals are intentionally integrated and managed for economic, environmental, and social benefits. It is different from animal grazing on the voluntary understory vegetation present in forests without proper management of trees or understory vegetation. Silvopasture involves management of all three components in such a way that optimizes the benefits of the whole system and minimizes the negative effects of one component over others. The concept behind adopting a silvopasture is to obtain higher total benefits than from an individual component practiced alone. As the production of quality saw logs takes several years (25 to 30 years for loblolly pine and more for other timber species), there would be no regular income from the sole tree plantation until the trees are ready for timber harvest. Nevertheless, landowners have to spend money on the land for annual tax payments and periodic woodland management such as thinning, pruning, and burning (for pine plantation).

Regular short-term income is possible by adopting agroforestry practices including the silvopasture system, in which trees are grown for different tree products, such as high quality saw logs, fruit, nuts, or Christmas trees, and forages for animal feed. Animals utilize the forages, converting them into high quality animal protein, which the farmers can consume or sell for regular incomes while the trees are maturing. Silvopastures are practiced most successfully in regions with mild, moist climates suited for commercial timber and grazing animal production, such as that found in the southeastern US (Rietveld and Francis, 2000). There are tremendous opportunities for developing silvopastures and other agroforestry practices in the Southeastern Region as most of the landowners have woodland. USDA-ERS (2011) data shows that forest-use land consists of 58.5 percent of the total land area in this region, and 60 percent of the timberland in the eastern US is owned by private non-corporate individuals. This situation reveals the opportunities for private landowners to develop their forestland into silvopastures and other agroforestry practices, and get higher benefits than from traditional forestry operations.

Silvopastures can be established by introducing a low density of trees into the existing pastures (Figure 1.1A), thinning down the existing tree stands and establishing pastures in the available space between tree rows (Figure 1.1B), or by planting forages and tree saplings at the same time in a new field: trees in rows (double row is the most common) and forages in the alleys (wide space between the tree rows). Pine silvopastures are very common in the Southeast. However, silvopasture development is also possible in fruit and nut orchards and other types of tree production systems (Christmas trees and ornamental trees) for multiple income options.



Figure 1.1. Three-year-old longleaf pine-bahiagrass silvopasture established in an existing pasture, Americus, Georgia (A); 20-year-old loblolly pine-bahiagrass silvopasture, Chipley, Florida (B).

Picture courtesy: M. S. Goodman (A), U. Karki (B).

### Importance of Silvopasture Systems

Silvopastures are practiced to obtain more economic, environmental, and social benefits than from a pasture or forest monoculture. As trees require several years to be ready for marketable products, one has to wait for a long time to get incomes from the forest monoculture. However, a silvopasture system offers both long-term and short-term income opportunities. Livestock and forage components serve as regular short-term income sources while waiting for the tree component to be ready for sale. Moreover, there are prospects for an alternative income from hunting and wildlife tourism as the silvopasture system attracts wildlife for food and shelter. Higher tree growth and development can occur in silvopastures as there will be lower tree density than in sole-tree plantations. Faster growth of trees in silvopastures is also facilitated by the removal of understory vegetation through grazing, which minimizes or eliminates the need for mechanical or chemical methods of weed control. Moreover, nutrient recycling by the grazing animals in the form of urine and feces, and the supply of nutrients from liming and fertilization of forage crops present in the system enhance faster tree growth. Similarly, when legume forages are introduced into the system, more nitrogen is available for trees and supports faster growth. All these save money, promote environmental quality, and make the whole system sustainable.



Figure 1.2. Cattle grazing in a pine silvopasture system, Chipley, Florida.

Picture courtesy: U. Karki.

The economic benefits of a silvopasture system have been highlighted by several authors. Onokpise and Hamilton (no date) have cited two cases of silvopastures that showed greater economic benefits than the sole tree plantation: 1) George Owens in Chipley, Florida getting 10 percent more in annual revenue from pine silvopasture combined

## Silvopasture Introduction

with beef cattle production; 2) Allen Edwards showing the possibility of earning up to \$500 per acre per year from a silvopasture system with sheep and/or goats versus only \$150 per acre annually from traditional saw-log production. Clason (1995) reported greater net revenue for loblolly pine silvopasture than for pure pasture or pure timber systems in Louisiana. Stainback et al. (2004) stated that when the environmental benefits of a silvopasture in south Florida were considered, it could be substantially more profitable than traditional ranching.

The environmental benefits of a silvopasture system include, but are not limited to, the creation of milder microclimatic conditions, minimization of nutrient loss and erosion, higher carbon sequestration, and biodiversity as compared to pasture or forest monoculture. Trees work as wind break and provide natural shade, thereby protecting grazing animals from inclement weather conditions such as when it is raining, very hot, cold, or windy. From a Southern SARE-funded research project, Karki and Goodman (2010) found lower diurnal dew point (1–29%), wind speed (29–58%), gust speed (23–58%), solar radiation (14–58%), and photosynthetically active radiation (10–72%) in a 20-year-old loblolly pine (*Pinus taeda* L.)-bahiagrass (*Paspalum notatum* Flugge) silvopasture compared to a bahiagrass open-pasture (pasture without trees) landscape in Chipley, Florida, indicating milder microclimatic conditions in silvopastures. Because of milder climate, cattle in silvopastures spent 50 to 63 percent diurnal time grazing (6.4 h in September and 9.4 h in June) (Figure 1.2) compared to 26 to 40 percent in open-pasture (3.1 h in September and 6.0 h in June), where cattle spent most of their time lying or standing in the nearby tree shade. From another SSARE-funded study conducted in a young longleaf pine silvopasture (5-8 yrs old) in Americus, Georgia, these authors also found lower wind speed (12–73%) and gust speed (5–64%), but higher water retention in a five- to eight-year old long-leaf-pine- (*P. palustris* Mill.)-bahiagrass silvopasture than in an adjacent bahiagrass open-pasture in Americus, Georgia (Karki and Goodman 2013). Silvopasture had higher soil moisture content (15–173%) and a lower evapotranspiration rate (11–32%) compared to open-pasture. Milder microclimatic conditions and higher water retention promote the growth and productivity of understory vegetation.



Figure 1.3. Goats (A) and cattle (B) congregated under the tree shade, July, 2013, Alabama. Picture courtesy: U. Karki.

In the extreme environmental conditions such as during very hot summer days in the Southeast, grazing animals seek shelters, such as tree shade, to avoid the environmental stress (Figure 1.3A&B). Studies have suggested that the provision of shade in the grazing land facilitates

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higher performances of grazing animals. When shade is present, livestock spare energy and use it for growth and production. Fike et al. (2004), by reviewing different research results, highlighted an increase in milk yield, weight gain, and conception rate of sheep and cattle that grazed in silvopasture with abundant forages. Godsey (no date) reported a 20 percent increase in average daily gain for cattle with shade versus those without any shade; shaded cows produced 10 to 19 percent more milk than unshaded cows, and the provision of shade increased the pregnancy rate of cattle by nearly 40 percent.

Nutrient loss and erosion is minimized in silvopasture as the ground is kept covered with trees and understory vegetation. Well-covered ground protects the surface soil and nutrients from run off and wind erosion. Nutrient loss through leaching in silvopasture is reduced because forage roots are basically spread in the higher soil profile and tree roots are present in the deeper soil profile. Thus, nutrients available near the ground surface are absorbed and utilized by forage plants, while those available in the deeper profile are taken up by tree roots and prevented from leaching to the underground water bodies. Nair et al. (2007) compared three production systems in coarse-textured soil in Florida: bahiagrass open-pasture, bahiagrass-slash pine silvopasture, and native forages under pine trees for nutrient retention in the system. They found the highest concentration of phosphorus and nitrogen in soil profiles under open-pasture, indicating the risk of nutrient loss from the treeless system. Less nutrient loss and soil erosion means more resource conservation and higher water quality. Moreover, root distribution of forages and trees into different soil profiles also facilitates efficient use of water available in the system in the same manner as that of nutrient utilization.

Another environmental benefit of the silvopasture system is the higher amount of carbon storage as compared to forest or pasture monoculture. Sharrow and Ismail (2004) found from an 11-year study conducted in western Oregon that 11-year-old Douglas-fir-perennial ryegrass-subclover silvopasture stored 740 kg per hectare per year more carbon than Douglas-fir sole plantation, and 520 kg per hectare per year more carbon than perennial ryegrass-subclover pasture. Studies have demonstrated that an “average tree” sequesters about six kilograms of carbon and carbon dioxide per year. If in agroforestry, trees were planted using a 3m x 12m spacing, a spacing that could be used in establishing trees in a pasture, these 267 trees per ha could potentially tie up 1575 kg of carbon dioxide per hectare per year (Garrett et al. 1994). By storing a huge amount of atmospheric carbon, the silvopasture system helps reduce the global warming process.

The social benefits of a silvopasture system are its scenic beauty and public acceptance (Garrett et al. 2004). Agroforestry systems including silvopastures are often park-like in appearance (Figure 1.4), and social acceptability is higher than for traditional forest plantations. Social acceptability is becoming a significant issue because many hill lands are near urban centers, so land use must be especially sensitive to environmental quality issues including environmental contamination, the destruction of native plants or animal habitats, and visual appeal (Sharrow and Fletcher 2004). Clason and Sharrow (2000) also noted intangible social benefits, such as aesthetics, social responsibility (being a good neighbor), and intergenerational responsibility (stewardship for future generations) that help determine the success of a silvopasture practice.

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Figure 1.4. Young pine silvopasture, Americus, Georgia (A); older pine silvopasture with cattle grazing in it (B).

Picture courtesy: M. S. Goodman (A).

Source for (B): <http://www.aces.edu/pubs/docs/A/ANR-1399/index2.tmpl>.

### **Consideration While Developing a Silvopasture System**

As a silvopasture system involves three components: trees, forages, and grazing animals, it requires careful selection, establishment, and management of all components to get the benefits of this system. Tree selection should be based on the soil type, climatic condition, production goal, suitable growth pattern with minimum canopy to allow enough light to the ground vegetation, and a deep root system to utilize nutrients and moisture available in the deeper soil profile, and market demand. Forages should be selected depending on shade tolerance capacity along with their adaptation to the given soil type and climatic condition, productive capacity, nutrient contents, palatability to the target grazing animals, and grazing tolerance. Various grazing animals such as beef cattle, goats, sheep, horses, emu, elk, bison, rhea, or other animals can be integrated to utilize the forages in a silvopasture system. Animals which inflict minimum damage to the trees, have high market value and demand, and are well-adapted to the local environment should be selected. Grazing should not begin until forages are well-established and trees become resistant to grazing damage. Rotational grazing is recommended for a sustainable management of the silvopasture system. More information on each component has been presented in separate sections of this handbook.

### **Advantages and Challenges Associated with Silvopasture Systems**

Like other systems, a silvopasture system also has some advantages and challenges as listed below. However, if properly established and managed, the advantages outweigh the challenges.

#### **Advantages**

- Minimizes economic risk by producing multiple products – tree products, livestock and livestock products, or hay if not grazed.

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- Provides annual cash flows from the sale of livestock and/or livestock products, which would be lacking from sole tree plantation.
- Trees protect grazing animals from inclement weather conditions such as wind chill, blowing snow, and heat stress.
- Animal distribution becomes more even and grazing time increases in silvopasture because of a less stressful environment as compared to open-pasture (Karki and Goodman 2010). Even distribution of animals is desirable for sustainable land use, pasture persistence, and uniform nutrient recycling.
- Longer grazing period occurs as tree shade lengthens maturation of fall forages and promotes early growth of spring forages (Nowak et al. 2009).
- Because of slow maturation of forages under shaded conditions, they remain less fibrous and high quality with greater digestibility than those grown in open-pastures.
- Grazing animals harvest the ground vegetation and minimize the vegetation competition with trees, and thus provide better growing conditions for trees.
- Feces and urine from grazing animals provide nutrients for plant growth.
- Because of utilization of understory vegetation by grazing animals, there is no or minimum need for chemical or mechanical procedures to control ground vegetation, and fire hazards are minimized.
- Efficient use of nutrients and water occurs as the root systems of trees and understory forage crops reach different levels of soil profiles.
- Better water quality exists as nutrient loss and soil erosion is prevented in this system. Less nutrient and soil loss means higher environmental quality.
- More pleasing scenery than either solid forest or open-pasture, so increases land value.
- Low or no need for nitrogen fertilizer application if legumes are introduced into the system. Legumes fix atmospheric nitrogen into soil. This nitrogen is available for plant growth.
- No need for separate tree fertilization if the pasture is fertilized (Nowak et al. 2009).
- Better cover and forage for wildlife. Additional incomes can be generated from hunting and/or wildlife tourism.

### **Challenges**

- Need skills, knowledge, and time to manage trees, forages, and livestock.
- Establishment cost may be higher than any component monoculture.
- Trees require a long time to be ready for sale.
- Need to have certain acreage of trees to satisfy the requirement of loggers for harvesting.
- Too much pine needle accumulation (if pine trees are used) may hinder forage production and grazing.

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- Young trees can be damaged if grazing is not managed properly, and/or if available forage and supplements are not enough for grazing animals.
- Interruption of grazing when trees are not grazing resistant (very young) and mechanical/manual harvest of forages is necessary during this time.

### Who Should Consider Having Silvopasture

- Landowners who want to diversify their products.
- Forest landowners who want to have regular short-term incomes.
- Livestock producers who want to minimize the environmental stress to the animals, and also diversify their products.
- Pine-plantation owners who want to utilize the available ground space after the first thinning and diversify their products.
- Producers and landowners who would like to continue the business and want to make a long-term investment.

### Key Points

1. Silvopasture is an agroforestry system that involves intentional integration and intensive management of trees, forages, and grazing animals in a single management unit.
2. A silvopasture system is practiced for better economic, environmental, and social benefits by optimizing the performance of all three components.
3. To be successful in silvopasture operations, one must have enough knowledge and skills in selection, establishment, and management of all three components.

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## **Chapter 2 ESTABLISHMENT AND MANAGEMENT OF TREES IN SILVOPASTURE SYSTEMS**

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### **Introduction**

Silvopasture, an agroforestry practice, is an intentional integration of trees, forages, and livestock on the same piece of land. This system is intensively managed and there is an interaction of components. Silvopastures can be developed in planted pines, fruit and nut orchards, pastures and/or woodlands depending on the objectives and circumstances of the landowner. The goal of silvopasture management is to produce high-value timber products and related crops in the long term while obtaining short-term economic benefits from the fruits/nuts, livestock, and forage components (Clason 1995). Livestock may be large ruminants such as bison and cattle, or small ruminants, for example goats and sheep, and domestic geese or pasture poultry used in fruit tree orchards and related trees. All these farming systems are common in the southeastern United States.

Successful silvopasture establishment and operation depend on the selection of suitable sites, forages, and livestock that match the sites. These silvopasture systems require a lot of economic and management considerations to ensure the success in the long run (Garrett et al. 2004). Realization of the potential benefits of silvopastures requires combined expertise in timber, forage, and livestock management. A variety of farmers could favorably consider silvopasture establishment on their property. These include: pine-plantation owners who are interested in diversifying income sources after first commercial thinning, livestock producers who want to improve their grazing conditions or diversify their enterprise, and non-industrial private forest landowners who are interested in annual forest-derived incomes. Suitable tree species include all southern pines, hardwoods, nuts and fruit trees, and Christmas trees (Onokpise and Hamilton 2012). Diverse tree patterns and designs are available.

Tree management is essential for the effective functioning of the system components and system as a whole. Some benefits that the tree component provides to the silvopasture system involve improved air quality and nutrient cycling, nitrogen fixation by leguminous trees, improved forage and animal performance because of shade, erosion control, and aesthetics (Nowak et al. 2011; Onokpise 2005). Successful silvopasture establishment and productivity also involve the application of appropriate silvicultural practices or tree management in a timely manner. Such silvicultural practices include and are not limited to tree planting, thinning or harvesting, pruning, prescribed burn, and fertilization. In all these options, financial assistance programs are available with agencies such as the USDA-NRCS, Farm Service Agency, and the USDA Forest Service to assist with the establishment and management of silvopasture by providing specialized funding.

## **Suitable Tree Species**

Tree consideration in silvopasture includes both coniferous and broadleaved species (Garrett and Kurtz 1983; Hamilton 2008). Choice of suitable tree species is determined by soil, climate of the location, and potential market for the products. Conifers are more suitable in silvopasture than hardwoods. Selected trees need to be able to share the existing site resources without much reduction in each other's growth. In general, in silvopasture systems, the most suitable criteria or check list for tree species include compatibility with the site, open-crowned to allow sunlight penetration for sufficient forage production, potential for high-value products, pest and disease resistance, and deep-rooted to avoid competition with forages for nutrients and water. Silvopasture systems provide environmental benefits such as potential for limiting nitrogen and phosphorus runoff, sequestering atmospheric carbon dioxide, improving habitat for wildlife, and capable of enhancing landowner's objectives (Bambo et al. 2009; Nowak et al. 2011; Onokpise and Hamilton 2012).

In the Southeast, common commercially grown pines (loblolly, slash, and longleaf) are suitable for silvopasture systems. Among these, slash is the most suitable due to its open crowns, good self-pruning capability, and ease of regeneration. Slash pine is adaptable to a variety of site and topographic conditions, but it grows best on pond margins and in drainages where soil moisture is ample but not excessive and the soil is well aerated. Longleaf has similar characteristics as slash pine; however, it is more difficult to establish. Longleaf does have additional advantages in that its needles are valuable pine straw mulch and it has the greatest potential for high value timber products among the southern-pine species (Demers et al. 2013). Loblolly pine has the greatest growth potential and is suitable for upland and clay soils. However, it is less desirable due to its branching and branch retention nature; it occasionally produces high-value timber (poles or veneer) if the lower branches are pruned from time to time. In addition, loblolly pine needles are hardly used for pine straw mulch. Generally, conifers are better suited than hardwoods to silvopasture systems, but grazing is successful in pecan orchards. Pecans are locally suitable and mainly managed for nut production. Pecan tree spacing allows for grazing and/or haying.

## **Suitable Acreage and Sites for Developing a Silvopasture System**

Silvopasture systems can be established in any land and climatic conditions capable of simultaneously supporting trees, forage, and livestock. The key to the successful establishment of silvopasture systems and operations highly depends on picking a suitable site and well-matched trees, forages, and livestock (NAC 2008; Onokpise et al. 2004). Suitable acreage varies from one acre to more than 100 acres and this depends on the expectations the landowner places on the components to be considered in the system and the productivity of the land-use. To sustain timber and large livestock production, a relatively large land base is required. On the other hand, if growing space is limited, there are attractive alternatives for small ruminants or other livestock, such as goats, sheep, hogs, and poultry. These small livestock require less acreage. For instance, if the choice of livestock is chicken or related birds, an acre of land can be suitable; again, it depends on the landowner's objectives and management plans. Acreage involved and the establishment phase may limit some larger species, and the landowner must consider effects of some larger animals on crops, trees, and other plant species during the establishment phase. If silvopasture is managed mainly for wood products, then large acreage

(50 acres or more) would be needed to be profitable. On the other hand, the acreage for fruit and nut trees varies greatly, depending on choice of livestock to be included and the objectives of the landowner.

Landowners must take into consideration which type of logging company will provide thinning, pruning, and harvesting. Companies operating on a lower scale require a minimum of 20 acres when clear-cutting, and a minimum of 50 acres when thinning. The number of trees per acre constitutes one of the key elements for the logging company to provide service to the landowner. Fewer trees per acre will demand more acreage for the logging company to provide the necessary service of thinning, pruning, and harvesting of timber. The proposed site must be accessible to livestock and support tree and forage production. Environmental considerations such as land use, zoning, and land use regulations are important factors to consider. Some environmental considerations include stream-side protection and wildlife habitat maintenance. The site for developing a silvopasture system must also allow for site preparation activities and equipment use (Sharrow 1999). The soil type must be suitable for the tree, forages, and livestock species in order to deploy the silvopasture system. A site with a steep slope may be productive for trees and forages, but not compatible with the animal component.

### **Different Designs of Silvopasture Systems**

The tree component is the most important in a silvopasture system. Different designs depend on the arrangement of the trees or tree spacing. Possible tree spacing or arrangements in silvopasture include trees in single rows with wide-spaced alleys, clusters, random spacing, and sets of 2 rows with wide alleys between the set of rows. Generally, silvopasture requires tree spacing that allows adequate timber and forage production. Different designs or tree spacings are capable of producing different benefits. For example, double-row 4x8x40 feet tree spacing yields more timber and forage than a single-row 8x12 feet tree design in the same location (Lewis et al. 1985). Designs with wide forage alleys are more compatible with machinery or equipment use than other designs. A healthy tree stand stocking rate ranges from 150 to 400 trees per acre, though the target should be about 100 trees per acre at the final harvest. The number of trees per acre determines the number of thinnings needed and the potential products (pulp, poles, chip-and-saw timber, or sawtimber) in the rotation. Livestock (large or small) and forage (winter, summer, mixed species of grass, legumes, and shrubs) are also considerations in designing a silvopasture. Examples of some designs are presented in Figure 2.1 to Figure 2.3

Random spacing of trees as shown in Figure 2.1 may not follow any specific distribution of trees across the landscape. The number of trees per acre typically ranges from 100 to 300 trees. This pattern of tree distribution limits the use of equipment or machinery, but it allows a uniform distribution of sunlight in the pasture.



Figure 2.1. A silvopasture system with random spacing of trees.

Picture courtesy: S. K. Bambo.

In silvopastures with a single row configuration, distance between trees within a row ranges from eight to fifteen feet, and 24 to 40 feet wide alley (Figure 2.2). The wide alley spacing supports more forage production than closer tree spacing. In silvopastures with double-row designs, tree spacing within a row ranges from four to ten feet, distance between adjacent rows of trees ranges from eight to twelve feet, and the width of alley ranges from 24 to 88 feet (Figure 2.3). This design has more trees than the single-row design. This design can consist of up to 400 trees per acre. In general, wide alley spacing between tree rows, single or multiple, supports greater levels of forage production than closely-spaced tree rows. There is usually a trade-off between timber and forage production due to tree spacing design. Tree spacings are set out with consideration to the size and use of equipment for forage management. Tree patterns are established to increase growing space and available light for high quality logs and forages.



Figure 2.2. A silvopasture system with a single row of trees and wide alleys (10' x 40').

Picture courtesy: S. K. Bambo.

### Silvopasture Development Methods

Silvopasture establishment requires different management processes, which depend on the nature of the land or its previous use. Ways to establish a silvopasture include converting a pasture to a silvopasture (planting trees in an improved pasture) and converting a forest plantation into a silvopasture (thinning a tree stand and planting improved forages) (Sharrow 1999). The following are different possible scenarios applicable to the establishment of silvopasture systems.

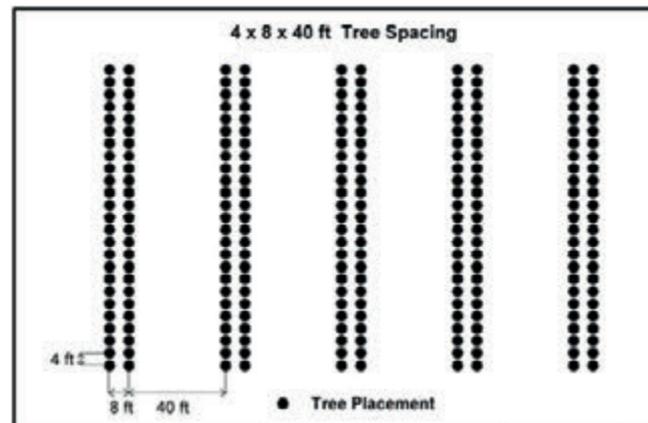


Figure 2.3. A silvopasture system with a double-row configuration.

### Silvopasture Development in an Existing Pasture

Often times, silvopastures are established by planting trees in existing pastures. Prior to tree planting, site preparation is essential. Site preparation before seedlings are planted improves seedling survival, early growth, water availability, and the access of nutrients and light to newly-planted seedlings. Well-established and managed pastures of bahiagrass, bermudagrass, and other comparable forages are suitable for this purpose. Tree planting density varies from 150 to 450 trees per acre, depending on the tree species, landowners' objectives, and management intensity. Planting fewer trees with a wide spacing requires pruning for quality timber products. On the other hand, denser planting allows for thinning of pulp-wood sized trees during the tree rotation. The target number of trees per acre should be 100 trees at the final harvest.

Necessary site preparation before planting trees can be achieved by chemical (herbicides), mechanical, and/or prescribed fire management. The method choice depends on site conditions, location, treatment costs, and the compatibility of the treatment method to the site and location. Preparing the tree bed includes opening up rows where trees will be planted by scalping or spraying the area with herbicide in bands along planting rows or around planted spots. This kills the existing grass in order to minimize competition when trees are planted and keeps the trees free from having to compete with the grass. A fire may be set to temporarily reduce competition before trees are planted. Although it is a cheaper method of controlling understory vegetation, pasture grass re-sprouts fast after a fire. Subsoiling is recommended, if there is a subsurface hard pan, after site preparation in order to plant seedlings or saplings into the pasture (Hamilton 2008; Nowak et al. 2013). This process eliminates the compact layer from previous pastureland use and improves water infiltration. Normally a shank is sunk to rip the soil to a depth of about 18 to 24 inches. The ripping of the soil determines the tree row planting direction. Most often, planting is done in the East-West direction, but in an area with slopes, trees are planted along the contour of the site.

General guidelines for planting trees in silvopastures are the same as for tree plantations in traditional forestry. Seedlings should be kept in a shady or cool place and roots kept moist until planted. The preferred planting period is November to mid March while seedlings are dormant. Planting options are either a mechanical planter or hand planting. Hand planting is possible, especially on small or irregular tracts of land. Machine planting is desirable because it produces straight rows and uniform spacings, which is essential in a silvopasture system. Bare root seedlings are planted with the root collar (the section between the seedling roots and the stem) even with ground level and the soil firmly packed around the base of the root collar. Seedlings planted too deep, too shallow, j-rooted, with air pockets, or turned up roots may not survive. To

maintain tree growth, mowing or hay cutting between the tree rows to reduce the competition from understory forages is necessary.

Livestock should be excluded from areas where trees planted during

vulnerable periods when livestock can destroy the trees by trampling, browsing, or rubbing on them. When trees are young and vulnerable to the damage by grazing animals, forages should be harvested for hay (Figure 2.4). When trees reach sufficient height, livestock can be introduced to the system. Trees take about three to four years, depending on the site index, to reach the sufficient height for livestock introduction.

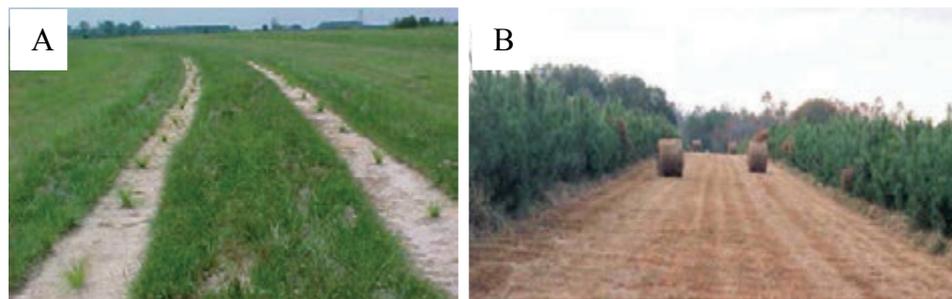


Figure 2.4. Existing pastures (A) converted to silvopasture systems (B) and hay production prior to livestock introduction.

Picture courtesy: USDA/NRCS & O.U. Onokpise.

### Converting a Forest Plantation into Silvopasture

Converting a forest plantation into a silvopasture system is an option for forest landowners who want a short-term income from forestland. This method of establishment requires commercial thinning of the plantation to reduce the tree density to a desirable number of trees per acre. Thinning to create silvopasture systems requires harvesting trees to allow enough sunlight to penetrate the forest floor for forage growth. Thinning is mostly conducted in plantations aged 15 to 20 years, when the harvestable products are pulpwood or poles (Bambo et al. 2009; Onokpise et al. 2004). The desired number of residual trees per acre depends on the silvopasture system design, which allows the growth of trees and forages. Subsequent thinning can be carried out over a period of time depending on the age of the stand, thinning intervals, and intensity. It is important to make sure thinning limits wind-throw and top breakage of the residual trees. Generally, the underlying concept of stand density, crown position, and forest health determine if, when, and how to thin a forest stand. Thinning also depends on the site and weather conditions, whether there is a market for the thinned wood, and the market value of the harvested products. The residual trees left on the site usually range from 150 to 400 trees per acre. The number of trees per acre and the design determine the number of times trees can be thinned before the end of the rotation. Nut and fruit trees are usually planted with wide spacing that can accommodate forage growth and animal grazing. For example, pecans are planted at 30 x 30 feet to 40 x 40 feet. Such spacing gives a maximum of 50 trees per acre. In such cases thinning is not necessary.

After thinning the forest plantation according to objectives and designs, site preparation is required to aid forage plantation and establishment. Site preparation methods include mechanical, chemical, and prescribed burning to remove the understory brush and unwanted vegetation. Chemical treatment is applicable where there is a requirement to kill the unwanted green vegetation present on the site, mechanical treatment involves cleaning the site of debris and disking to prepare the seedbed, and prescribed burning removes slash or debris from the land. These treatment methods can be used in combination to achieve the desired site preparation for the establishment of forages and the introduction of livestock (Figure 2.5).



Figure 2.5. Solid pine stand (A), light disking between trees to plant forages (B), and goats grazing in an established silvopasture system (C).

Picture courtesy: O.U. Onokpise.

### Converting an Existing Woodland or a Natural Forest into Silvopasture

Most natural forests or woodlands grazed by livestock are termed passive forest grazing (Figure 2.6). This type of grazing is disadvantageous to the forest and contributes little forage towards sustaining the livestock component. In contrast, silvopasturing has the potential to increase the forested land that is under management for wood production and available forages for livestock production. Silvopasturing has benefits of increasing grazing area available for livestock and also serves as an incentive for landowners to place currently unmanaged forestland under management. For



Figure 2.6. Goats browsing underbrush in woodland (A) and in naturally regenerated loblolly pine stand (B).

Picture courtesy: A. Makenzie-Jakes (A) and S. K. Bambo (B).

example, the USDA-Natural Resources Conservation Service has a financial assistance program in this regard for limited resources and underserved landowners, ranchers, and farmers. Woodland grazing is inferior due to forage insufficiency and low nutritive quality of understory brushes and browses; such lands would negatively impact timber stands by damaging young trees.

It is possible to manipulate tree, forage, and livestock interactions to enhance forage production and animal growth without negative effects on tree performance. The expected outcome is that silvopastoral practices will be employable because they improve the productivity of the grazing animal and the quality and diversity of forage available to the grazing animal and wildlife, and effectively interpolate timber stand improvement across a wide array of forested land. This situation involves choosing applicable activities from the previous two approaches. The nature of land and the amount of forages and trees available will determine which of the activities will be necessary and what portion of land will be needed for these activities. Portions of land may require planting trees and/or forages. Small ruminants such as goats can be used for the initial vegetation management and land preparation of woodlands for a silvopasture system after fencing the designated area for silvopasture. Remove poisonous herbage and foliage. Identify valuable softwoods (pines) and hardwoods (such as oaks, hickories, and magnolias) (Garrett et al. 2004). Some of the existing trees, depending on age, species, and quality can also be left for aesthetics, and later harvest and environmental sustainability before introducing new pastures and conventional tree species.

### Tree Management in a Silvopasture System

Management objectives are based on climate, site conditions, nature of land, and existing or previous land use. The following are some management options to consider.

### Fertilizer and Lime Application

Silvopasture systems require fewer inputs of fertilizers and other inputs than standard agriculture production systems. Liming and fertilizer application requirements are mainly based on forage species production and not on trees after thinning or planting. This is because typically, nutrient availability is rather high following harvesting or thinning and site preparation (for planting) as these disturbances provide suitable conditions for rapid decomposition and release of nutrients from the accumulated forest floor and slash material. Nutrient use by newly-planted trees is minimal due to their small size, but as trees grow, nutrient demand and use increase quickly in typical plantation forestry. Pine often requires phosphorus and nitrogen nutrients. Fertilization for tree consideration requires soil and foliar tests and a correct interpretation of the results. At an intermediate age, southern pine plantations may need fertilization if available nutrients are low. In plantation forestry, up to two applications of fertilizers may be needed during the entire rotation; but in silvopasture systems, frequent fertilizer application to meet the need of the forages usually takes care of trees and the soil volume exploitation by the tree roots is not limited due to fewer number of trees per acre. Most often, trees, particularly conifer species, prefer acid soil conditions and can tolerate very low soil pH (pH<4.0). Hence, there is no obligation to apply lime to improve tree growth. It is important to perform continuous soil tests mostly because of the forage species, especially grasses in the silvopasture system.

### Pest Control

Pests in silvopasture include unwanted woody and herbaceous plants, diseases, and insects. These tree pests can be managed similar to how unwanted plant pests are managed. Different pest control strategies available include prevention, prescribed fire, and biological, chemical (herbicides), and mechanical methods. Prescribed fire is an effective control method to deal with some insects and diseases when used in a timely manner. Chemical and mechanical methods can be very costly to manage pests, but these costs can be greatly reduced if combined with fire. Some insect and disease pests of pines include fusiform rust (*Cronartium quercuum*), southern pine beetle (*Dendroctonus frontalis*), brownspot, and annosum root rot (*Heterobasidion annosum*) (Demers et al. 2013). Infected trees with fusiform rust can be thinned out or clear-cut and then improved rust-resistant pines can be planted. When southern-pine beetles infect a tree, it never survives (Figure 2.7).



Figure 2.7. A pine stand infected by Southern pine beetles.  
Source: University of Georgia.

Fusiform rust (*Cronartium quercuum f. sp. fusiforme*), annosum root rot, and Pitch canker (*Fusarium moniliforme var subglutinans*) are the most serious pests of slash pines (Demers et al. 2013). Fusiform rust is an obligate parasite that requires two living hosts, pine trees and oak leaves to complete its life cycle. The fungus cannot spread from pine to pine, but must return to the oak leaves to produce the spores, which in turn infect pine. The disease develops at or near the point of infection which results in tapered, spindle-shaped swells, called galls, on branches

and stems of pines. Annosum root rot is a fungal disease that infects freshly cut stumps of slash pine, and spreads to other trees by root contact. Diseased or dead and dying trees are usually found in groups. Insect pests such as pales weevil (*Hylobius pales*) can also damage slash pines, by invading logging areas and feeding on the bark of young seedlings, girdling the stem and causing wilting and death. Blockheaded pine sawfly (*Tetralopha rosburstella*) and several different needle feeders may defoliate young trees. Other pests include the black turpentine beetle (*Dendroctonus terebrans*) and engraver beetles, which can become major problems, especially in naval store plantations. The southern-pine beetle is not a major pest of slash pine except in areas where the growing environment has placed the trees under stress.

### Pruning

Pruning is a key element in creating valuable timber in a silvopasture. It involves the removal of the lower tree branches of standing trees to produce a clear bolt or logs (Figure 2.8). The goal of pruning is to reduce opened crown trees from developing a greater taper and larger side branches, and hence, produce high quality sawtimber (Hamilton 2008; Hubbard 1999). It is important to prune trees in order to confine the knots produced by the limbs to either a small diameter or knot-free wood on the outer diameter of the tree stem (Adams and Clason 2002). Pruning also reduces the tree canopy, allowing more sunlight to reach the understory vegetation for sufficient forage production. Pruning is applicable in silvopasture when fewer trees are planted with wide spacing.



Figure 2.8. Pruning trees in a silvopasture system after establishment. Picture courtesy: O.U. Onokpise.

Pruning guidelines in silvopasture systems:

- The first pruning should occur when trees are 10 to 20 feet tall.
- Prune trees when they are 4, 7, and 10 years.
- Prune branches where the trunk diameter is greater than four inches. Only a third to a half of the total crown should be removed. Also, a live crown equal to a third of the tree height should be maintained.
- Prune trees up to 22 feet.
- Pruning should be on the branch side of a stem-branch node.
- All pruning cuts should be made on the branch side of this stem collar.
- Prune trees during the late winter or early spring before trees break their dormancy.
- Pruning equipment includes hand pruning saws, loppers, and lopping shears. Machetes and axes are not good options.

## Thinning

Thinning is an important silvicultural practice that partially harvests trees in an immature forest plantation. The purpose is to maintain or accelerate diameter growth of residual trees. Silvicultural approaches for thinning trees (e.g. southern pines) include method, intensity, and timing (Harrington 2001). Thinning results in a particular stand-density target or number of trees per acre. Thinning also removes poorly-performing trees, leaving healthy and vigorous trees for more productivity. In the southeastern US, thinning is mostly carried out in planted pine plantations. Pine trees respond to thinning best if they are thinned before 16 years. In silvopastures, thinning is carried out depending on the silvopasture design. For example, two or more tree rows may be removed to create wide alleys between single or multiple rows of trees to allow for forage production underneath the tree canopy.

Thinning is a necessity for landowners who want to harvest high-value timber-, plywood-, or pole-sized products at the end of the tree rotation. Thinning can be a combination of row and selection thinning (Figure 2.9). The desired number of residual trees per acre depends on the silvopasture system design, which allows tree and forage growth. Subsequent thinning can be carried out every five to seven years over a period of time depending on the age of the stand, thinning intervals, and intensity. Benefits of thinning include increased return on the initial investment from the sale of high-value forest products; improved access for equipment, people and wildlife; short-term incomes from the land; and the possibility of silvopasture establishment by utilizing the available space from thinning to grow forage crops.



Figure 2.9. Commercial thinning of a mid-rotation loblolly pine plantation.

Picture courtesy: S. K. Bambo.

## Prescribed Fire or Burning

Prescribed fire is a tool used to achieve various forest management objectives. In silvopasture, it is used in a similar manner. Prescribed burning is a desirable and economically sound practice on most southern pine sites due to its low cost and effectiveness. Chemical applications generally cost more than 10 times as much per acre as prescribed fire. Mechanical treatments such as disking, chopping, or raking are at least 20 times more expensive. A prescribed fire can be applied in a skillful manner, under specific weather conditions, and in a defined place to achieve specific results. Prescribed fire is a complex tool, and should be used only by those trained to use it. The advantages of burning include preparing the site for seeding and planting, reducing hazardous fuel, destroying logging debris, improving wildlife habitats, managing competitive vegetation, recycling nutrients, increasing forage palatability, and controlling pests.

## Determining the Yield and Quality of Tree Products

The yield and quality of any tree product depend on management objectives and intensity. Tree products include both timber and non-timber products such as lumber, plywood, mouldings, poles, fence posts, firewood, pulpwood, saw timber, pine straw, fruits, nuts, Christmas trees, and

turpentine. The number of trees per acre, basal area, and the age of the trees determine the quantity of the tree products. In silvopasture systems, tree-age class, tree pattern or arrangement, pruning and thinning intervals, and land management will highly determine how much tree product can be obtained from the land and the quality.

A tree pattern with much open space leads to less wood production. For example, a 4x8x40 feet tree spacing produces twice as much wood as a 4x8x88 feet tree spacing. The quality of the tree products depends on the tree species and the management applied to the stand. For instance, longleaf pine produces higher quality pine straw than any other pine species. Knot-free stem (pruned trees) and healthy (disease free) trees produce high quality wood. Wood quality is determined by the strength, density, and value of the wood. Factors such as tree species, percent of summerwood, and age affect wood quality more than growth rate. Appropriate tree pattern results in larger logs. For stumpage, size is more meaningful than wood density and strength. On the other hand, high quality nuts and fruits need to be free of diseases.

### **Price Determination of Tree Products**

It is important for landowners to know their marketing options for tree products and the market value of each product (Demers and Long 2013). The demand, season, and use of tree products determine its prices. Products with multiple uses will yield more money than single use products. The land acreage, quality, and quantity of tree products are important factors when considering selling or buying tree logs. Sawmills pay a price for tree products depending on the log sizes and variety of the logs. It is important to know that sawmills are interested in different log sizes. Sometimes it is not a simple matter to market large diameter, high quality silvopasture wood for a higher price. Some sawmills do not purchase younger, plantation-grown pines with the specific gravity of less than 0.48. Tree products such as pine straw can obtain higher prices if mulch is clean and free of cones and debris.

It is important to exercise caution when pricing tree products to avoid running into prices that are too low. During poor marketing conditions, timber should be stored on the stump until the market improves. The following factors can be used to determine product price: the demand for and type of product, the tree species to sell, the quality of timber, the volume for sale, the distance of products from the market, and the size of tree products. Also, landowners may consider payment methods (lump sum or pay-as-cut), selling methods (negotiation or sealed bid), and timber sales tax situation (Demers and Long 2013; Wang and Greene 2012). However, it takes specialized knowledge to price wood. Thus, it is never recommended that a landowner sell timber without professional aid. Consultant foresters provide technical assistance for a fee. Technical assistance services include surveying, planting, timber sales, thinning, prescribed burns, herbicide and fertilizer applications, and forestry inventory. A rough estimate of tree volume can be calculated using the following formulae.

$$BA (m^2) = \pi * \{DBH (cm)\}^2 / 40000$$

Where, BA is basal area, pi is 22/7, and DBH is diameter at breast height (4.5 feet).

Total volume = main stem from ground to tip,

Merchantable volume = main stem excluding stump and tip defined to a minimum diameter. The volume equation enables the calculation of volume from tree diameter and height as follows:

Tree volume =  $0.42 * BA * H$ ; where V= volume, BA = basal area, H = tree height.

Based on the shape of trees, the volume formula can be complicated. Sometimes tables are composed that list volume by DBH and height. This volume table allows you to look up tree volume from diameter and height.

### **Tree Harvest and Sale**

Many landowners and tree growers sell timber only two or three times in the life of the plantation. After decades, it is easier to lose much of the timber value because of one or more mistakes at the time of sale. Mistakes in selling timber can be costly. Inadequate preparation and a poor marketing strategy can guarantee less than adequate compensation and can lead to difficulties during and after the sale. The most important step in tree production is the sale of timber. Timber is harvested and sold in various units, such as cords, tons, board feet, and cubic feet. Selling timber requires expert advice as to what trees to harvest, how to harvest, and what the trees are worth (Demers and Long 2013). It is important to have a forester review the sale proposal. One option is to contact a private consulting forester. Although consultant foresters charge a fee, this expense can be offset by the higher selling price a consultant often secures for timber sale. It is important to get professional advice in this process. Future property management such as for recreation, wildlife, and aesthetics should be considered before the sale. It is the most appropriate to harvest wood when the land is dry rather than during wet conditions. It is important to know information on how timber sale and harvest may be handled (Brinker 1998).

### **Some Estimated Costs Associated with Establishing a Silvopasture System**

There are no flat fees or costs for these activities. The cost estimates below include supplies and labor. The values are in a range because costs vary from region to region and by land (physical conditions and the number of acres to be considered). It should be noted that labor requiring a specialized skill may substantially exceed the range stated below (Table 2.1 to Table 2.3).

Establishment and Management of Trees in Silvopasture Systems

Table 2.1. Cost estimate for converting pastures with satisfactory forages to silvopastures.

Component	Component description	Unit	Price/acre (\$)
Medium mechanical	Four of the five (Sub-soiling, mowing, disking, chemical, scalping)	Acre	270 - 330
Light mechanical	Two of the five (Sub-soiling, mowing, disking, chemical, scalping)	Acre	76 - 95
Fire	Prescribed burning	Acre	31 - 39
Tree planting	Pine seedlings, planting, & fertilization	Acre	101 - 127
Fencing	Barbed wire	Foot	2.5 - 3.13
	Woven		3.2 - 3.9
	Electric		1.5 - 1.9
Watering facilities	Pipe	Foot	2.0 - 2.5
Soil amendment	Liming / fertilization		
Tree pruning	Equipment and labor	Tree	0.55 - 1.00

Table 2.2. Cost estimates for converting pine plantations to silvopasture.

Component	Component description	Unit	Price (\$)
Site preparation*	Shear, rake, pile, and burn	Acre	450 – 595
Fire	Prescribed burning	Acre	31 – 39
	Fire breaks	Foot	0.36 – 0.45
Soil	Soil test analysis and shipping	Box	7 + shipping
Forages	Liming & fertilization, grass/legume seeds and planting (drilling or broadcasting)	Acre	320 - 400
Fencing	Barbed wire	Foot	2.5 – 3.13
	Woven		3.2 – 3.9
	Electric		1.5 – 1.9
Watering facilities	Pipe	Foot	2.0 – 2.5

\* It is recommended to include this as a part of tree thinning activities. This cost is only applicable if it was not the part of the thinning arrangement.

Table 2.3. Cost estimates for converting woodlands to silvopastures.

Component	Component description	Unit	Price (\$)
Site preparation	Initial vegetation management using goats for example. Remove poisonous herbage and foliage. Identify valuable softwoods (pines) and hardwoods (such as oaks, hickories, and magnolias)	Acre	250 - 300
Fire	Prescribed burning	Acre	31 - 39
	Fire breaks	Foot	0.36 - 0.45
Soil	Soil test analysis and shipping	Box	7 + shipping
Forages	Grass/legume seeds and planting (drilling), slight disking.	Acre	320 - 400
Fencing	Barbed wire	Foot	2.5 - 3.13
	Electric		1.5 - 1.9
Watering facilities*	Pipe and water basins	Foot	2.0 - 2.5

\* Some woodlands may already have a water source either as a small stream, creek, pond, or water hole.

## Hands-On Activities and Demonstrations

### Silvopasture site tour

Participants will be taken on a tour to view a forest plantation that has potential to be thinned into different tree patterns and a stand that needs pruning. Participants will figure out the tree spacing and possible thinning options for the forest plantation.

### Pruning

Participants will familiarize themselves with the different pruning equipment and demonstrate the pruning exercise on trees that require initial pruning. The instructor will give guidelines on how to carry out pruning on pine trees.

### DBH and height measurement

With guidelines and demonstrations from the instructor, each participant will receive diameter tape and a clinometer to take the following measurements:

- The diameter of five trees at breast height (4.5 feet)
- The total height of five trees on which the diameter was measured
- The merchantable height of the fifth tree on which previous measurements were carried out
  - Calculate the differences between merchantable height and total tree height
  - Find out the relationship between the diameters and the total height of the trees

### **Tree productivity calculation**

- The instructor will demonstrate how to calculate tree productivity.
- Each participant will be given a formula and tree data to calculate stand basal area, individual tree volume, and stand volume as demonstrated by the instructor.

### **Key Points**

1. A silvopasture system is an intentional combination of trees, forages, and livestock on the same piece of land. The establishment and management of trees are significant for successful system functioning.
2. The most important thing is the landowners' objectives and management intensity.
3. Suitable trees for the Southeast silvopasture include:
  - a. Conifer, e.g., slash pine, loblolly pine, longleaf pine. The number of trees per acre ranges from 150 to 400 trees.
  - b. Hardwood species are hardly considered, but will consist of 75 to 250 trees per acre.
  - c. Fruit and nut trees. These are planted with a wide spacing ranging from 20 x 20 feet to 40 x 40 feet.
4. Suitable acreage ranges from 50 to 100 acres. Acreage consideration depends on the major component of interest to the landowner.
5. Commercial timber logging companies require a minimum of 40 acres to render pruning, thinning, and harvest services.
6. Site development is determined by topography, soil type, and the types of components to be integrated into the silvopasture system.
7. A silvopasture system can be developed in one of the following ways:
  - a. Converting an existing pasture into silvopasture
  - b. Developing an existing plantation into silvopasture
  - c. Developing an existing woodland into silvopasture
8. Tree design and arrangement in a silvopasture system include:
  - a. Single-row spacing
  - b. Double-row spacing
  - c. Multiple-row spacing
  - d. Cluster or block planting
9. Managing trees for high-quality products involves the following:
  - a. Thinning
  - b. Pruning
  - c. Pest and disease control

10. Timber and non-timber products include poles, fence posts, firewood, pulpwood, saw timber, pine straw, fruits, nuts, and Christmas tree. The number of trees per acre, basal area, and the age of the trees determine the quantity of tree products.
11. For the landowner to receive an appropriate return on their tree products, proper product pricing must be determined by contacting a forester or a forest consultant prior to selling the products to the logging company.

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### **Useful Resources**

- USDA National Agroforestry Center: <http://www.unl.edu/nac/silvopasture.htm>
- 1890 Agroforestry Consortium: [http://www.powershow.com/view/19b639-MDQ2Z/AGROFORESTRY\\_AT\\_THE\\_1890\\_LAND\\_GRANT\\_UNIVERSITIES\\_power\\_point\\_ppt\\_presentation](http://www.powershow.com/view/19b639-MDQ2Z/AGROFORESTRY_AT_THE_1890_LAND_GRANT_UNIVERSITIES_power_point_ppt_presentation)
- Auburn University: <http://www.ag.auburn.edu/agrn/silvopasture/silvopastureindex.htm>
- Alabama Cooperative Extension Systems: <http://www.aces.edu/natural-resources/forestry/agroforestry.php>
- Southern Federation of Cooperatives: [www.federation.coop](http://www.federation.coop)
- 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>
- University of Florida: <https://edis.ifas.ufl.edu/>
- Appalachian Farming Systems Research Center-USDA Agricultural Research Service: <http://www.ars.usda.gov/pandp/people/publications.htm?personid=1685>
- Dale Bumpers Small Farm Research Center – USDA Agricultural Research Service: [http://www.ars.usda.gov/research/projects/projects.htm?accn\\_no=412583](http://www.ars.usda.gov/research/projects/projects.htm?accn_no=412583)
- Silvopasture in the Southeast Blog: <http://silvopasture.blogspot.com/>
- Online short-course in silvopasture. <http://www.silvopasture.org>

## Chapter 3 SUITABLE FORAGES AND THEIR ESTABLISHMENT IN SILVOPASTURE SYSTEMS

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### Introduction

Any herbaceous plant that is eaten by grazing animals to fulfill their nutritional requirements is forage. Forages can be grasses, legumes, or forbs. Grasses are monocots – they produce a single seed leaf and have parallel leaf venation. Examples are corn (*Zea mays* L.), bahiagrass, bermudagrass (*Cynodon dactylon* Pers.), rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.), and ryegrass (*Lolium multiflorum* Lam) (Figure 3.1B). Legumes are dicots – they produce two seed leaves, have reticulate leaf venation, and bear seeds in pods. Examples are clovers, peas, beans, sericea lespedeza (*Lepedeza cuneata* (Dum. Cours.) G. Don), and kudzu (*Pueraria montana* (Lour.) Merr.) (Figure 3.1A). Grasses are good sources of energy while legumes are good sources of protein. Legumes' roots are colonized by *Rhizobium* bacteria, which form root nodules (Figure 3.2) and fix atmospheric nitrogen into soil. Different legumes have specific *Rhizobium* bacteria. So, while introducing legumes into a new field, legume seeds must be inoculated properly to establish the stand successfully and get good production.

Because of the nitrogen-fixing ability of legumes, sole legume stands or grass-legume mixed stands containing 33 percent or higher legume forages do not require the application of commercial nitrogen fertilizer – which saves money (Ball et al. 2007). Also, the addition of legumes in pastures improves forage quality, productivity, and production duration. From a previous SSARE-funded research project, Karki et al. (2009) found a 40 percent increase in productivity and a 27 percent increase in the nitrogen content (quality) of available spring forage when crimson clover (*Trifolium incarnatum*) was overseeded into bahiagrass pasture, as compared to the same pasture managed with commercial nitrogen fertilizer in Americus, Georgia. Cuomo et al. (2005) found higher biomass production from smooth brome grass (*Bromus inermis* Leyss)-legume mixtures without N fertilizer versus smooth brome grass monocultures with N fertilizer applications up to 336 kg ha<sup>-1</sup> in an experiment conducted at the University of Minnesota's West Central Research and Outreach Center near Morris, MN. Malhi et al. (2002) reported from research conducted at Lacombe and Eckville, Alberta, Canada that brome grass-legume mixtures without N fertilizer produced more forage versus brome grass monocultures with N fertilizer applied at 50 kg N ha<sup>-1</sup>; forage biomass from brome grass-legume mixtures without N fertilizer and brome grass monocultures with N fertilizer applied at 100 to 150 kg N ha<sup>-1</sup> was equivalent.

## Suitable Forages and their Establishment in the Silvopasture System

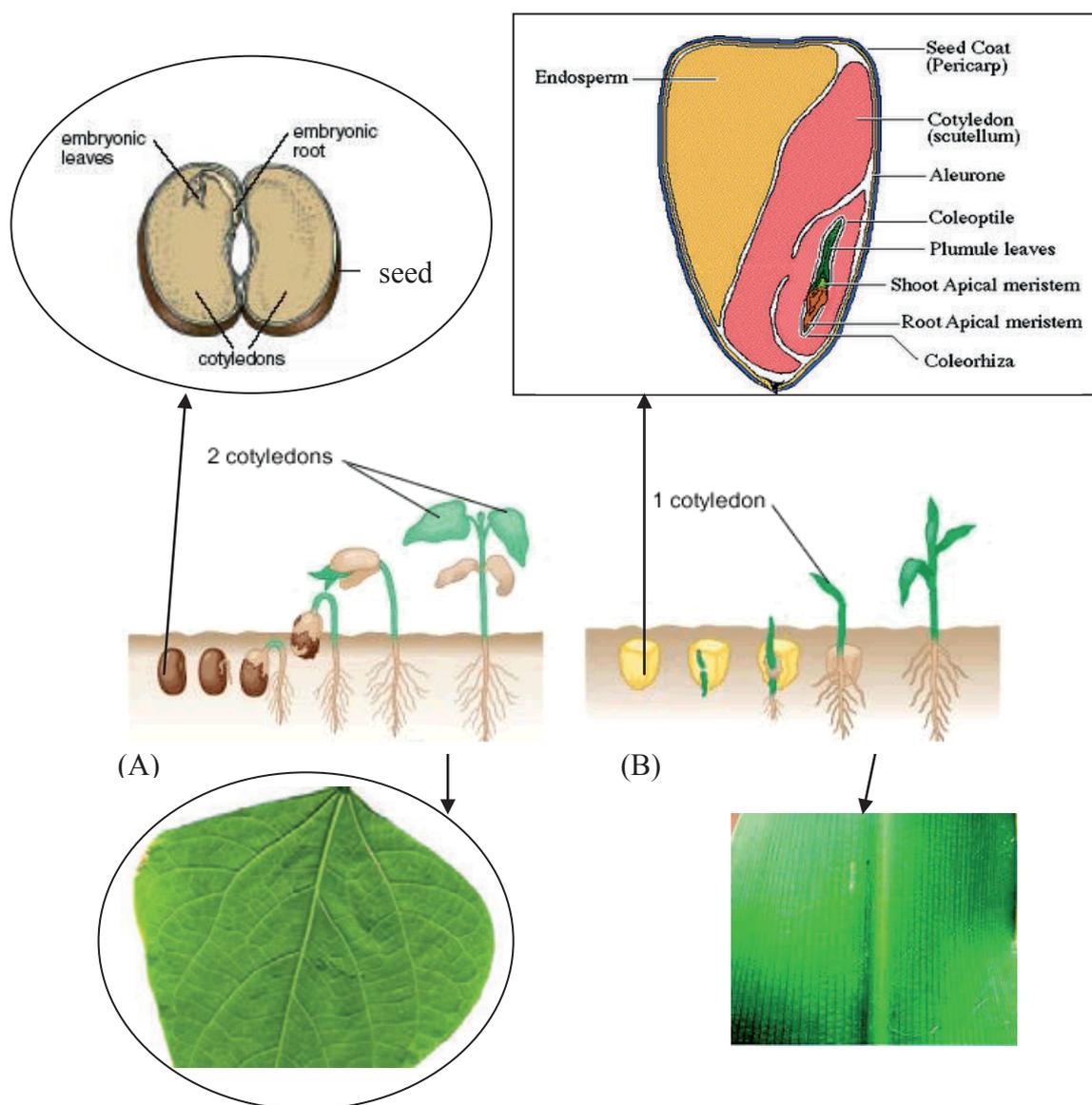


Figure 3.1. Examples of dicot and monocot seeds, seedlings, and leaf venation: (A) Bean and (B) Corn.

Source: Karki and Gurung 2009.

Forages can be classified into annuals and perennials based on how long they survive and produce once planted. Annual forages grow and mature during favorable seasons and die at the end of the season within a year; examples are annual ryegrass, wheat, oats, cowpea, soybean, and crimson clover. Some annuals, if managed properly, can reseed, so they may not need to be planted every year. However, if harvested before seeds are matured and dropped into the soil, annuals need to be planted each year. Perennial forages survive for several years – they grow and mature in favorable seasons and become dormant during off-seasons; examples are bahiagrass, bermudagrass, dallisgrass (*Paspalum dilatatum* Poir), johnsongrass (*Sorghum halepense* (L.) Pers.), switchgrass (*Panicum virgatum* L.), white clover (*Trifolium repens* L.), and sericea

lespedeza. When managed properly, perennials, once established successfully, produce during favorable seasons for several years.

Forages can also be categorized as prostrate, semi-erect, and upright growers based on their growth pattern. Prostrate species crawl on the ground surface such as bahiagrass, common bermudagrass, and subterranean clover (*Trifolium subterraneum* L.). These species tolerate close and continuous grazing. Semi-erect species like tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort., nom. cons.), orchardgrass (*Dactylis glomerata* L.), and arrowleaf clover (*Trifolium vesiculosum* Savi) are fairly tolerant to close grazing except under stressful conditions, when forages become more vulnerable to grazing pressures. Forages like switchgrass, sericea lespedeza, and alfalfa (*Medicago sativa* L.) are upright growers. These forages cannot tolerate continuous close grazing, so rotational stocking with a suitable rest period or continuous stocking at a rate low enough to leave enough leaf area for re-growth is required for these species.



Figure 3.2. Root nodules on inoculated winter peas (look at the arrow).

Picture courtesy: U. Karki.

Forages are also classified as cool season or warm season based on when they grow. Cool-season forages like oats, rye, ryegrass, tall fescue, clovers, and vetches grow during the cool season and die or remain dormant during the warm season. Warm-season forages like bahiagrass, bermudagrass, dallisgrass, johnsongrass, switchgrass, perennial peanut (*Arachis glabrata* Benth), and sericea lespedeza grow during the warm season, and remain dormant in the cool season.

### **Suitable Forages for Silvopasture Systems**

The shade tolerance is one of the major criteria while selecting forages for a silvopasture system. Other forage selection criteria involve their suitability to soil types and climatic conditions, palatable to grazing animals, tolerance to grazing, desirable productivity and quality, adaptation to the local environment, and the forage production goals of the producer. Warm-season perennial grasses like bahiagrass (both Pensacola and Tifton-9) and bermudagrass can do well in the silvopasture system in the South if other growing conditions (soil type, pH) are met and trees are managed properly to allow 55 to 75 percent of sunlight to reach the ground. Cool-season grasses like tall fescue, orchardgrass, ryegrass, rye, wheat, and oats will grow well when around 35 to 65 percent sunlight reaches the ground (Garrett et al. 2004). Similarly, cool-season legumes like subterranean clover, white clover, crimson clover, and vetches are suitable to grow in silvopastures along with the cool-season grasses if enough sunlight (35 to 65%) reaches the ground and other growing conditions (soil type, pH, and climate) are suitable. Selected grasses

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with suitable soil type, seed rate, planting depth, and companion forages have been presented in Table 3.1 and selected legumes and forbs are presented in Table 3.2.

Table 3.1. Selected grasses with suitable soil type, production region, planting time, seed rate, planting depth, and suitable companions.

Forage species	Soil type	Region	Planting time	Seed rate (lb/acre)	Planting depth (in.)	Suitable companion
<b>Warm-season perennial grasses</b>						
Bahiagrass	Sandy	Coastal plain	Spring	10-15	1/4-1/2	Clovers (arrowleaf, berseem, crimson, rose, subterranean) hairy vetch, small grains, annual ryegrass
Bermudagrass	Wide range, but sandy is the best	Warm climate with mild winter	Spring	5-10	0-1/4	
Dallisgrass	Loam and clay	Southern coastal plain	Spring	10-15	1/4-1/2	Clovers (red, white, berseem)
Johnsongrass	Clay	Most of the Southeast	Spring	20-30	1/2-1.0	Clovers (red, berseem)
<b>Warm-season annual grasses</b>						
Crabgrass	Wide range	Most of the Southeast	Spring	4-6	1/4-1/2	
<b>Cool-season perennial grasses</b>						
Tall fescue (MaxQ)	Clay and loam	Humid temperate areas (mid to upper Southeast)	Aug.- Oct.; Early spring in the northern part	20-25	1/4-1/2	Alfalfa, birdsfoot trefoil, clovers (red, white)
Orchard grass			Aug.- Sept.	15-20	1/4-1/2	
<b>Cool-season annual grasses</b>						
Annual ryegrass	Wide range	Most of the Southeast	Sept.- early Oct.	20-30	1/4-1/2	Annual legumes
Small grains (Oats, rye, triticale, wheat)	Wide range	All states	Late summer or fall	90-120	1-1.5	Annual legumes

Source: Adapted from Ball et al. 2007.

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Table 3.2. Selected legumes and forbs with suitable soil type, production region, planting time, seed rate, planting depth, and suitable companion forages.

Forage species	Soil type	Region	Planting time	Seed rate (lb/acre)	Planting depth (in.)	Suitable companion
<b>Warm-season perennial legume</b>						
Sericea lespedeza	Clay and loam	Humid region (most of the Southeast)	Spring	20-30	1/4-1/2	Small grains, ryegrass
<b>Cool-season perennial legumes</b>						
White clover	Clay and loam	Humid temperate areas (most of the Southeast)	Early spring or late summer	2-3	1/4-1/2	
Alfalfa	Well-drained clay and loam	All states	Early spring or late summer	15-20	1/4-1/2	
Red clover <sup>1</sup>	Well-drained clay and loam	Humid region (all Southeast States)	Spring or late summer	8-12	1/4-1/2	
<b>Cool-season annual legumes</b>						
Arrowleaf clover	Well drained	Humid areas with mild winter	Sept.-early Nov.	10-15	1/4-1/2	
Crimson clover	Well drained	Humid areas with mild winter	Late summer to early fall	20-30	1/4-1/2	
Hairy vetch	Wide range; sandy is the best	Most of the Southeast	Sept.-Oct.	20-25	1-2	
<b>Forbs</b>						
Chicory	Wide range, but moderately to well-drained soil is the best	All states	Sept.-Oct., or Apr.-May (upper Southeast)	3-4	1/4-1/2	Bermudagrass, tall fescue
Brassicas (Kale, rape, turnip)	Moderately to well-drained soils	All states	Spring or Summer	Rape, Kale: 3.5-4.5 Turnip: 1.5-2.5	1/4-1/2	

<sup>1</sup>Biennial or annual in the South

Source: Adapted from Ball et al. 2007.

## Important Steps to Establish Forages

The establishment of forages in a silvopasture system is not much different than in an open-pasture (Hamilton 2008). Planting depth, seed rate, planting method, soil test, liming, and/or fertilization are similar in silvopasture to that in open-pasture. In preparation for forage plantation, any unwanted plants and debris should be removed from the alleys (wide space between tree rows) by suitable means (manually, heavy grazing/browsing, mechanically, burning, or chemically – which is less desired, and one should be careful because the chemical may be harmful to the trees). Important steps for forage establishment are presented below:

1. Soil test: forage plants get all the necessary nutrients and water as well as the support required for their survival and growth from the soil. Therefore, it is very important to check the nutrient status and acidity of pasture soil regularly and add lime and/or fertilizers based on the soil test results to maintain forage productivity.

Materials required for collecting soil samples: a soil core sampler or shovel, a clean bucket for collecting and mixing all the subsamples, a soil sample bag, pens, and a field map with sampling points.

- a. Collect 15-20 representative, random sub-samples in a zigzag manner from a plot (20 acres maximum area for one composite sample) with uniform soil type, vegetation, and topography (Figure 3.3).
- b. Collect samples from 0-4 inches depth for perennial pastures and 0-6 inches or to the depth of tillage for annual pastures. Discard the top level of the soil core containing organic matter (fallen leaves, plant debris) before putting the core into the bucket.
- c. Avoid collecting samples from within a 150 ft radius of areas with high nutrient concentration such as shade, watering and feeding facilities, and manure piles (Figure 3.3).
- d. Collect all the sub-samples into a clean bucket and mix thoroughly. Remove any pebbles, roots, and other organic matter from the soil sample.
- e. Take a pint of composite soil sample and put in a sample bag, close it, label it with your name, address, sample name or field name (you need to know which sample is from which field when you receive the soil test results from the laboratory), and forage species that are growing or to be planted in the field.
- f. Mail the sample with required payments to a nearby soil testing laboratory.

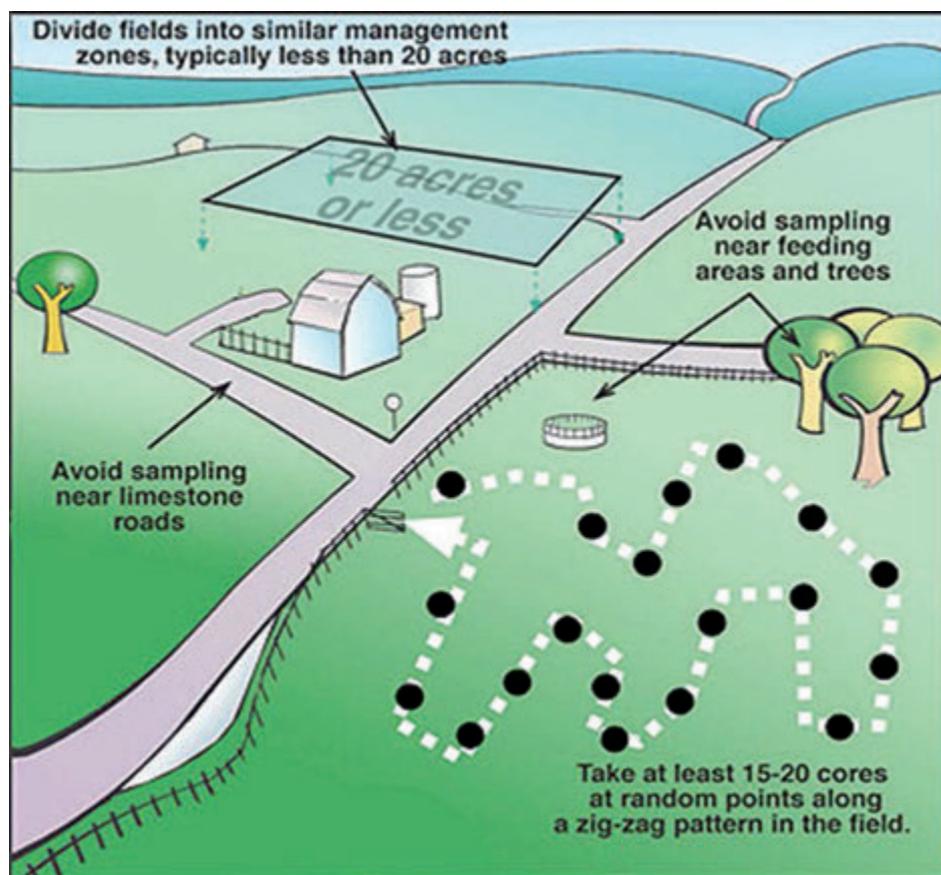


Figure 3.3. A schematic diagram for collecting a representative soil sample.  
Source: <http://extension.missouri.edu/p/G9215>

2. Weed control: Weeds are any plant growing out of space. Pasture weeds are those plants that are left unutilized by the grazing animals. Weeds may not have much nutrient value for livestock, and some may also be poisonous. They compete with forages for nutrients, space, sunlight, and moisture, and reduce the productivity and quality of forages. There is no reason to lime and fertilize weeds and support their growth. Weeds must be controlled before applying any lime or fertilizer. Weeds can be controlled by performing the following steps:
  - a. Walk your pastures regularly and identify if there are any weeds.
  - b. If there are just a few weed plants here and there, these can be manually uprooted and removed before they flower and produce viable seeds. Mowing will be helpful if weed infestation is widespread. However, if the weed plant is capable of vegetative propagation (such as cactus), then mowing will make the situation worse.
  - c. Cultural practices: Fixing the soil pH and adding required nutrients for desirable forage growth will minimize the weed problem. If there are any empty spots in the pastures, overseeding with the desirable forage species will occupy the space and diminish the chance for weed growth.

## Suitable Forages and their Establishment in the Silvopasture System

- d. Mob close grazing may be helpful as it forces the animals to eat whatever vegetation is available at the given spot.
- e. Herbicide: If methods mentioned above are not effective for weed control, then an appropriate herbicide should be selected and applied at the suitable stage of weed growth. For proper herbicide selection and application, one needs to consult a weed specialist working in the local area.

Whichever control method is used, weeds need to be controlled before they flower and produce viable seeds. For further information about the pasture weed management, please visit the link given below:

<http://www.tuskegee.edu/sites/www/Uploads/files/About%20US/TUCEP/Livestock%20Program/WeedProceedings.pdf>

3. Soil pH amendment: The pH indicates how acidic or alkaline the soil is. The pH scale ranges from 0 to 14; 7 is neutral, below 7 is acidic, and above 7 is alkaline. Certain soil pH range is necessary for nutrient availability to forage plants. The recommended target pH range for most forage grasses is 5.5 to 6.5, for most grass-legume mixture is 6.0 to 7.0, and for alfalfa is 6.5 to 7.0 (Snyder and Leep 2007). Generally, grasses can grow well in lower pH compared to most legumes. To correct the acidic pH, lime should be added three to six months before planting. If there will be no tillage operation involved and lime is applied on the soil surface, it requires even up to a year to correct the soil pH. Similarly, to correct the alkaline pH, any of these products – sphagnum peat, elemental sulfur, aluminum sulfate, iron sulfate, acidifying nitrogen, or organic mulches – can be used. The application of any of these products to correct the soil pH must be based on the recent soil-test recommendation.
4. Fertilizer application: Phosphorus, potassium, and nitrogen are major nutrients required for forage development, growth, disease resistance, and persistence. Generally, the soil testing laboratory, based on the soil test results, will recommend the required amount of these fertilizers for growing specific forages. The stability, role in plant growth, development, disease resistance, and application frequency of these fertilizers are briefly presented below.
  - a. Phosphorus: This nutrient is necessary for root growth and development, the growth and survival of seedlings, and fruit and seed formation. It stays in soil for a long time, so frequent application of this fertilizer is not required. When recommended, apply the fertilizer a few weeks before planting (or at the time of planting if prior application is not possible). Single, annual application will be enough for annual/cultivated forages and hay fields; one application in two to three years will be enough for permanent pastures. However, application should be based on soil-test results.
  - b. Potassium: This nutrient is necessary for maintaining cold hardiness, disease resistance, and root growth and development. It is intermediate between phosphorus and nitrogen in terms of stability in soil. When recommended, apply it few weeks before planting (or at the time of planting if not possible to apply before planting); a second application may be required to meet the crop demand.

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- c. Nitrogen is required for photosynthesis and green leafy growth. It remains in soil for a short time because of leaching, surface runoff, and gaseous loss. So, it must be applied when actually needed; that is, when the plants are actively growing. Apply the recommended amount in divided doses:
  - i. First application – Apply 50 percent of the recommended dose after seeds are germinated well and the pasture looks green; if applied at the time of planting, weeds will use it and shadow the newly growing forage seedlings.
  - ii. Second application – Apply in the mid-growing season, or after every harvest if used for hay.
- d. Secondary nutrients (calcium, magnesium, and sulfur) and micro-nutrients (boron, manganese, copper, iron, molybdenum, chloride, zinc, and nickel) may be deficient in some pastures. If forages are not performing well after fixing pH and adding major nutrients based on soil test results, then further tests may be necessary to determine and correct other deficient nutrients.
- e. Fertilizers should be applied when there is enough moisture in the soil so that these are dissolved and be available for plants. Avoid drought conditions to apply fertilizers.

Fertilizer calculation: Generally, the soil testing laboratories recommend the actual amount of nutrients based on the soil test results, but do not state the amount of fertilizers available in the market to apply per acre pasture. For example, if 60 pounds of nitrogen per acre is recommended, it means the amount of actual nitrogen. So, if a producer would like to buy urea fertilizer, which contains 46 percent nitrogen, he or she has to calculate the amount of this fertilizer that would supply 60 pounds nitrogen as given in the following example.

Given situations and fertilizer calculation:

The recommended amount of nitrogen = 60 lb/acre

Urea fertilizer contains 46% nitrogen (remaining is the filler material)

The amount of urea fertilizer required to supply 60 lb nitrogen =  $60 \div (46 \div 100) = 130.43$  lb

So, the amount of urea fertilizer required to supply 60 pounds nitrogen per acre is 130.43 pounds. Once the amount of fertilizer required for one acre is found, this amount can be multiplied with the number of acres that need fertilization.

Similarly, the amount of other fertilizers (phosphorus, potassium, and others) can be calculated following the above example. As an alternative, one can use the online calculator at this link - <http://www.aces.edu/anr/soillab/chemfertilizercalc.php> to calculate the required amounts of fertilizers using the recommended amounts of nutrients based on the soil test.

5. Add organic matter and build your soil: Compost, plant residues (shoots and roots), and animal wastes are sources of organic matter. The addition of organic matter into the soil is beneficial to maintain soil health because of the following reasons:

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- a. In association with plant roots and soil microorganisms, organic matter holds the soil particles together by forming aggregates, thereby reducing the risk of soil erosion.
- b. It maintains soil porosity and facilitates air and water movement through the soil as well as nutrient uptake by plant roots.
- c. It increases the nutrient retention and water holding capacity of soil, and makes them available to plant roots for a long time.
- d. It facilitates the survival and growth of various floras and faunas (earthworms, microbes) and enhances the microbial activity and overall soil health.
- e. Organic matter itself serves as a source of various nutrients required for plants.

Besides adding or promoting the gains of organic matter in the soil, minimizing its loss from soil is essential to maintain soil organic matter. Table 3.3 shows different factors that promote gains and losses of soil organic matter.

Table 3.3. Factors influencing the gains and losses of soil organic matter.

Factors that promote gains of soil organic matter	Factors that promote losses of soil organic matter
Green manures or cover crops	Erosion
Conservation tillage	Intensive tillage
Return of plant residues into the soil	Whole plant removal
Low temperatures and shading	High temperatures and exposure to sun
Controlled grazing	Overgrazing
High soil moisture	Low soil moisture
Surface mulches	Fire
Application of compost and manures	Application of only inorganic fertilizers
Appropriate nitrogen levels	Excessive mineral nitrogen
High plant productivity	Low plant productivity
High plant root:shoot ratio	Low plant root:shoot ratio

Source: Brady and Weil 2002.

6. Land preparation: Pastureland can be prepared in various ways depending on the availability of equipment, type of forage to be established, and topography.
  - a. The use of no-till drill: It drills seeds into the soil without opening much of the ground surface; so, there is very little or no soil erosion risk. A no-till drill can be rented or borrowed from most soil conservation districts or private companies. The use of a no-till drill is suitable to overseed annual or perennial forages in the existing pastures, and to establish pastures in sloppy land that is not suitable for conventional tillage because of the risk of soil erosion.
  - b. Light harrowing: If a no-till drill is not available, then existing pastures can be slightly opened up with light harrowing so that seeds can be in close contact with fresh soil for germination and growth.

## Suitable Forages and their Establishment in the Silvopasture System

- c. Prepared seedbeds are necessary for establishing new pastures, especially with forages that have poorly competitive seedlings and take a long time to be established, such as sericea lespedeza, bahiagrass, and bermudagrass. Seedbeds are prepared by disking, leveling, and cultipacking the soil, which should be left for about a month to develop firmness. The step depth of one-fourth ( $\frac{1}{4}$ ) of an inch is a good indication of required firmness for a prepared seedbed.
7. Planting forage seeds
- a. Forage species selection, seeding rate, and seed calculation: Forage species that are shade tolerant and suitable for the local climatic conditions, soil type, and grazing animal species should be selected and procured on time. One needs to know the pasture area for planting and seeding rates for the selected forages. Then calculate the required seed amount, taking into account the germination percentage and seed purity. Seed rate for different forages is given in Tables 3.1 and 3.2. An example of calculating the required seed amount is shown below.

### Seed calculation formula

Assume the following values for this calculation:

Pasture area to be planted (A) = 1 acre

Recommended seed rate for selected forage species (B) = 25 lb/acre

Seed purity = 98%

Germination rate = 90%

The actual amount of seed required per acre = recommended seed rate  $\div$  (Purity% x germination%)

When the assumed values are put in the formula, the following value is obtained:

Required seed amount (lb/acre) =  $25 \div (0.98 \times 0.90) = 28.34$  lb/acre

- b. Inoculation of legume seeds: Inoculation is mixing inoculums with legume (all types of clovers, vetches, peas, beans, sericea lespedeza, alfalfa, sunn hemp (*Crotalaria juncea* L.), and other legumes) seeds before planting. Inoculums contain certain *Rhizobium* bacteria that colonize legume roots, form root nodules, and fix atmospheric nitrogen into the soil. This nitrogen is available to the plant. Legume seeds must be inoculated before planting to a new field; otherwise, legumes cannot perform well. Inoculums must be fresh and stored refrigerated until used. The inoculation process has to be completed in a cool, dry, and shaded place just before planting. Before starting the



Figure 3.4. Inoculation of legume seeds.

Picture courtesy: U. Karki.

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inoculation process, use protective gloves, goggles, and a dust mask (Figure 3.4). To inoculate, i) put the legume seeds into a clean container that is big enough to mix the given amount of seeds comfortably, ii) moisten seeds with water (about 8.5 ounces of water will be enough to moisten around 50 lb of seeds), iii) mix thoroughly such that seeds in every corner of the container become moist, iv) add enough quantity of specific inoculum that is suitable for the selected legume seed (follow instructions on the inoculum packet), and v) mix thoroughly. Plant the inoculated seeds. Some legume seeds may be pre-inoculated, which do not require inoculation. Inquire with the seed supplier whether they are pre-inoculated while buying them.

- c. Hulling or scarification of hard-coated seeds is necessary for successful germination. Inquire with the vendor whether the supplied seeds require any scarification at your level, and do so if needed.
- d. Planting depth and seed size: planting depth depends on seed size. Small seeds must be planted to a very shallow depth and larger seeds should be planted comparatively to a deeper level (Table 3.1 and Table 3.2). A few examples of planting depth are given below:
  - i. Planting depth for small seeds: Bahiagrass, sericea lespedeza, tall fescue, crimson clover, and berseem clover –  $\frac{1}{4}$  to  $\frac{1}{2}$  inch.
  - ii. Planting depth for larger seeds: hairy vetch, rye, wheat, and cowpea – 1-2 inches.

Planting too deep is the number one cause of stand failure. Materials available in the following two links will be helpful to determine the planting depth and other details for selected grasses and legumes in Alabama and other states in the South with similar climatic conditions:

- i. Alabama planting guide for forage legumes:  
<http://www.aces.edu/pubs/docs/A/ANR-0150/ANR-0150.pdf>
  - ii. Alabama planting guide for forage grasses:  
<http://www.aces.edu/pubs/docs/A/ANR-0149/ANR-0149.pdf>
- e. Make sure the planted seeds are in good contact with soil, which is necessary for getting moisture, germination, and good growth. The poor soil contact of seeds is the number two cause of stand failure.
  - f. Plant forages at the right time. Late planting will reduce competitiveness as weeds and other seasonal plants will be favored by the weather conditions. As a result, the growth of target forage will be dominated by the weeds at an early growth stage and forage establishment will be affected.
8. Avoid shadowing the short growing forages with taller forages in the mixed pastures. A few forage species grow faster than the others, and create shadow over the short and slow-growing species. Shadowing prevents seedling growth and establishment. Shadowing can be prevented by either selecting all species with similar growth patterns

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and rate, or lightly grazing the tall and fast growing species when they start shadowing the short and slow growing species.

9. Irrigate the pasture in case of drought. Avoid grazing/harvesting until the forages are well-established and have reached the recommended grazing height.
10. Repeat soil tests annually for cultivated or annual pastures and hay fields, and once in two to three years for permanent pastures. Apply lime and fertilizers as recommended based on the soil test results.
11. Overseed the pastures next season if the land cover with forages is between 40 to 75 percent.
12. Develop year-round pastures: Once the originally planted perennial species are well-established, suitable cool-season and warm-season annuals and/or perennials can be overseeded on the same plot for year-round pasture production and extending the grazing season. Soil test, liming, and fertilization may be required before planting the additional forages.

### **Hands-On Activities and Demonstrations**

Participants will see demonstrations and will be involved in the following activities:

1. Collection and preparation of soil samples for lab tests.
2. Interpretation of a soil test report and calculation of the required amount of recommended nutrients using a fertilizer calculation sheet.
3. Demonstrations of different forage seeds and discussion on seed size and planting depth.
4. Calculation of required seed amount for selected forage.
5. Inoculation of legume seeds.

### **Key Points**

1. Forages can be classified in different ways based on
  - a. How long they survive: Annual, biennial, and perennial
  - b. Forage structure: Grass, legume, and forb
  - c. When they grow: Warm season and cool season
  - d. Growth pattern: Prostrate, semi-erect, and erect
2. Forage should be selected based on
  - a. Shade tolerance
  - b. Adaptation to the local environment
  - c. Soil type
  - d. Productivity, quality, and palatability
  - e. Grazing tolerance

## Suitable Forages and their Establishment in the Silvopasture System

- f. Grazing animal species
3. Forages in silvopastures can be established following similar steps as those in open-pastures once the ground is cleared of the unwanted vegetation and debris. The major steps for establishing forages are:
    - a. Soil test
    - b. Weed control
    - c. Lime application
    - d. Land preparation
    - e. Addition of organic matter
    - f. Fertilizers application
    - g. Hard-seed treatment: hulling or scarification if required
    - h. Legume-seed inoculation if required
    - i. Planting
    - j. Irrigation
    - k. Overseeding in the subsequent years if required

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## **Chapter 4 SUITABLE ANIMAL SPECIES AND FACILITY REQUIREMENTS FOR GRAZING IN A SILVOPASTURE SYSTEM**

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### **Introduction**

When animals are integrated into silvopasture systems, landowners or producers need certain facilities to manage animals, forages, and trees. Facilities are needed for low-stress handling of animals such as corralling, sheltering, and providing water, fencing to keep animals in and predators out, for forage management, and protecting trees. The design and use of good handling facilities are positively correlated with enhanced animal productivity due to minimizing stress.

### **Selection of Livestock Species**

Silvopasture systems can integrate cattle, sheep, goats, horses and other livestock species. Cattle and sheep are the preferred species for landowners although other species (goats, horses, and deer) offer great potential. The use of cattle has proven successful, whereas, there is a lack of information on guidelines for integrating other animals like goats. Differences between livestock species need to be taken into consideration while integrating them into silvopasture systems. For example, cattle are more likely to trample young trees or compact wet soils while sheep and goats are more likely to browse trees if trees are not tall enough. Monogastric species and other herbivores can also be integrated into silvopastoral systems such as hogs, llamas, and horses, or domestic birds such as chickens, geese, and ostriches. Chickens and turkeys, considered as scratch birds, can be integrated into silvopasture systems if land owners are interested to aerate soils or organic matter into forest soils. Chickens should be egg laying and mixed breeds because they are considered better foragers. Compared to chickens and turkeys, ducks and geese are more resistant to diseases and cold. Wildlife such as deer and elk can benefit from a silvopasture system and provide additional income to tree growers through hunting and wildlife tourism. The main considerations on the choice of livestock species are whether they are compatible with the understory forages and tree species, and whether animals integrated into the system have marketable value to provide supplemental income to producers. While trees are still growing and not tall enough, browsers such as goats and elk are more likely to damage young trees from the top while grazers such as cattle are likely to step on young trees. Young and less experienced animals are more likely to damage trees. Broadleaf trees are more vulnerable to livestock than conifers (Klopfenstein et al. 2008). Mudge and Gabriel (2014) have published simple guidelines on using different species of livestock, except cattle, in the forest farm (Table 4.1).

Table 4.1. Considerations for selecting animals to be used in the forest farm.

Animal	When and where appropriate	Advantages	Disadvantages	Cautionary Tales
Goats	Young and middle stages of marginal forests; clearing undesirable brush; can tether or fence in hedgerows and for “cleanup”	Will eat almost anything, including thorny invasive species	Fencing needs to be robust; will eat everything, including valuable crops!	Goats cannot survive on brush alone; need supplement
Chickens and Turkeys	All stages; marginal forests or on quicker rotations so that scratching does not do damage	Easy to move and house; can forage much of their own food	Susceptible to diseases; scratching could damage tree roots; turkeys have high rate of mortality	Predator food! Extra caution and care to secure and protect birds is a must
Ducks and Geese	All stages; better for more mature, choice forests, still need to rotate, but less frequently than scratch birds	Heavy down feathers mean they benefit from shade in hot summer; disease free; will not damage tree roots	Need lots of water for drinking and bathing	While geese can help as guard animals, still vulnerable to predators
Pigs	Best for clearing and reclaiming of marginal lands; may be hard to sustain forest land every year	Root dig, aerate, fertilize, and rapidly convert marginal lands	Too much time in one place can be devastating	Pigs are smart! Keep the fence hot, or they will get out.

Source: Mudge and Gabriel 2014.

## Fencing Designs

Fencing is a very important component of silvopastoral systems. Fencing keeps grazing animals inside the system, keeps predators out, and also helps manage the grazing system. This is one of the most significant investments in silvopasture systems; however, there is no single fencing system that fits all situations. The fencing system has to be designed based on budget, the degree of security needed, managerial skills, and the degree of predator protection needed. There are differences in fencing designs among livestock species because of the differences in their behavior. For example, a one-wire cross will contain dairy or trained beef cattle but a five-wire boundary is necessary for stocker/yearlings. Similarly, animals respond to or cope with electric fencing differently. Goats are not as grounded as cattle due to their smaller hoof size and therefore require higher voltage (Brann 2005). There are three types of fencing systems according to the function of the fence: perimeter, permanent subdivision fences and temporary or portable fences, which may also be used for cross-fencing (NRCS 2008).

Under silvopasture conditions, many forest managers prefer net wires rather than electric fencing. Power is often unavailable on site. Electric fences require regular inspection to make sure the power is on, and may be insufficient as a physiological barrier; if the animals become habituated to the power being off they lose respect for the fence and go through it constantly. Net wire may be a better choice for the perimeter where containment is essential, but electrical fences that will have to be moved for tree harvest may be better for internal fences. Net wires should be 4-inch squares not 6-inch squares so animals cannot get their heads stuck in the wire. Electric fencing is the most appropriate, if properly managed, because of ease of moving, cost, and also it is more resilient to falling limbs or trees. Electric fences should have 4,500 to 9,000 volts continuously and must be checked on a regular basis. Fence designs should also conform to institutional, local, state and federal requirements. They vary from state to state. Laws governing livestock including fencing are available at [http://asci.uvm.edu/equine/law/fences/fnc\\_menu.htm](http://asci.uvm.edu/equine/law/fences/fnc_menu.htm). The following sections will discuss different kinds of fences for different species with special focus on meat goats. (For an excellent reference see Electric Fencing for Serious Grazers, Tennessee Grazing Coalition).

### Fencing for Goats

Goats are the most unique animals and are very difficult to contain. Unlike sheep, goats do not flock, as a result, they are at risk all the time. Goats can stick their head in the fence, but goats with short horns can get out. The electric fences are more suitable for goats in silvopasture systems over conventional fencing systems, because they are often cheaper to install, but goats need to be trained to electric fencing and electric fencing also needs a higher degree of maintenance. Hart (2001) published information on different types of fencing that were used by goat producers successfully with cost estimates for 2001 (see Langston University website). The following costs are revised estimates per 2014 prices and some designs are also revised Table 4.2 to Table 4.9). The information was gathered from local hardware stores and the local Tractor Supply Company in Auburn, Alabama. The costs reflect material costs for one-fourth (1/4) mile of fencing and do not include labor costs. For additional reference, there is an excellent Fencing Budgets Calculator program developed by David Bilderback, Extension area specialist, The University of Tennessee, Eastern Regional Extension Office, as a decision aid tool to help Tennessee landowners estimate the cost of fencing their land for barbed wire, woven wire, HT fixed knot, HT electric, and poly fence (<http://economics.ag.utk.edu/fencingcalculator.html>). The shapes of paddocks also determine the amount of fencing needed (Figure 4.1). Research has shown that square paddocks are economical to construct and allow animals to obtain their daily forage intake with minimum grazing time, effort, and trampling damage (Lacefield 2011 adapted by Smith et al. 2011).

Table 4.2. Cost estimate for a one-fourth-mile of 10-47-12 sheep and goat net-wire fence with one strand of barbed wire.

Items	Quantity	Price/Unit	Total
End braces	2	\$92.00	\$184.00
Sheep and goat wire	4	\$149.00	\$596.00
Barbed wire	1	\$75.00	\$75.00
T-posts	110	\$4.88	\$536.80
<b>Total</b>			<b>\$1,391.80</b>

The net wire fence is very reliable but expensive for permanent fencing. The net wires must be placed on the inside of posts because goats tend to walk beside the wire, tend to rub along the wire, and stretch and lower the integrity of the fence. The mesh size should be smaller than 6 inches for goats because goats with long horns can become trapped in the fence. Sheep and goat wires allow greater spacing between line posts than the conventional barbed wires; usually 50 feet as a minimum (Table 4.4). Make sure to keep wires more flexible to allow for wildlife impacts, snow loading, and falling tree branches.

Figure 4.1. The effect of pasture shape on the amount of fencing needed for one acre.  
Source: Lacefield 2011 adapted by Smith et al. 2011.

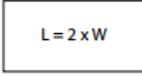
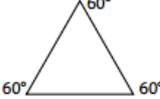
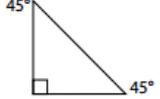
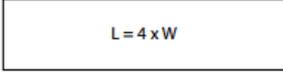
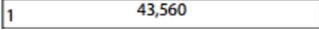
Shapes	Length
	744'
	836'
	888'
	951'
	1,007'
	1,040'
	87,122'

Table 4.3. Cost estimate for a one-fourth-mile net wire fence: 10-47-12 sheep and goat net wire fence with one strand of barbed wire.

Items	Quantity	Price/Unit	Total
End braces	2	\$92.00	\$184.00
Sheep and goat wire	4	\$149.00	\$596.00
Barbed wire	1	\$75.00	\$75.00
T-posts	65	\$4.88	\$317.20
Total			\$1,172.20

Table 4.4. Cost estimate for a one-fourth-mile fence with nine strands of barbed wire.

Items	Quantity	Price/Unit	Total
End braces	2	\$92.00	\$184.00
Barbed wire	9	\$75.00	\$675.00
Fence stays	110	\$0.60	\$66.00
T-posts	110	\$4.88	\$536.80
Total			\$1,461.80

Note: The nine-strand barbed-wire fence is very strong and secure to keep predators out.

Table 4.5. Cost estimate for a one-fourth-mile fence with the addition of three strands of barbed wire to existing five-strand fence.

Items	Quantity	Price/Unit	Total
Barbed wire	3	\$75.00	\$225.00
Fence stays	110	\$0.60	\$66.00
Staples	6	\$2.00	\$12.00
Total			\$303.00

Table 4.6. Cost estimate for a one-fourth-mile fence with the addition of two strands of electric wire to existing five-strand fence.

Items	Quantity	Price/Unit	Total
¼ energizer	1	\$125.00	\$125.00
12 gauge ht wire	2640	\$0.06	\$158.40
36" fence posts	65	\$3.40	\$221.00
Spring grip clip	130	\$0.20	\$26.00
Corner insulator	4	\$3.00	\$12.00
Total			\$542.40

Table 4.7. Cost estimate for a one-fourth-mile fence with five strands electric fence.

Items	Quantity	Price/Unit	Total (\$)
End brace	2	\$92.00	\$184.00
14 gauge wire	6,600	\$0.08	\$528.00
Corner insulator	10	\$3.00	\$30.00
Fiberglass t-post	65	\$8.05	\$523.25
¼ Energizer	1	\$125.00	\$125.00
Total			\$1,390.25

The main advantages of electric fencing are that there is less animal hide and pelt damage, and it is easily available. Electric fences are effective to keep goats in and keep predators out. Major disadvantage are that poor quality materials are difficult to distinguish from high quality materials and chargers.

Table 4.8. Cost estimate for a one-fourth-mile of high-tensile electrified fencing with six strands.

Items	Quantity	Price/Unit	Total
End brace	2	\$140.00	\$280.00
12 gauge ht wire	8000	\$0.05	\$400.00
Insulators	390	\$0.30	\$117.00
T-posts	65	\$4.88	\$317.20
Insulator misc.	1	\$25.00	\$25.00
¼ energizer	1	\$125.00	\$125.00
Total			\$1,264.20

Note: This fence is very effective for predator control compared to temporary electric fencing.

Table 4.9. The recommended wire spacing for the high-tensile electrified fencing.

Wires	Animal type	Wire spacing from the ground (inches)
3	Cattle, sheep, goats	8, 16, 28
4	Cattle, sheep, goats	8, 16, 24, 32
5	Cattle, horses, sheep, goats	8, 14, 22, 32, 42
6-8	Predator control	6, 12, 18, 26, 34, 44, 56, 68

Source: Brann 2005.

Note: The recommended height of the fencing is 47 or 48 inches to prevent jumping. For reducing shocks, all wires should be electrified. However, in drier conditions, every other wire should be grounded to improve shock (Brann 2005).

Table 4.10. Cost estimate for one-fourth-mile of electrified net-wire fencing.

Items	Quantity	Price/Unit	Total
Net fence	8	\$149.00	\$1,192.00
End posts	4	\$6.50	\$26.00
¼ Fence charge	1	\$125.00	\$125.00
Total			\$1,343.00

Electric netting combines traits of net-wire and electric fencing, providing a formidable mental and physical barrier in a portable format suitable for temporary or semi-permanent fencing of pastures. It is constructed of polywires and plastic twines. Netting is lightweight and easy to install. Compared to other temporary fences, electric netting provides greater protection from predators. However, with electric netting, there is some risk of animal entanglement, especially of young lambs and animals with horns.

Table 4.11. Cost estimate for a one-fourth-mile of temporary polywire fencing with four strands.

Items	Quantity	Price/Unit	Total
Polywire	4	\$68.00	\$272.00
Step-in posts	45	\$3.40	\$153.00
End posts	2	\$6.50	\$13.00
¼ Fence charge	1	\$125.00	\$125.00
Total			\$563.00

The main points to remember while using electric fencing are: 1) it requires a higher level of management, 2) animals need to be trained, 3) voltage should be checked every day and must be maintained at least 4,500 volts, 4) appropriately sized energizer should be used, 5) energizers should be properly grounded (Hart 2001) because inadequate grounding of the electric system causes over two-third of all power problems. With solar chargers, there is a serious theft problem in areas that are less remote. In more remote areas, people do not see chargers, so they are often safer than those closer to where people live or travel often. Solar chargers often cannot develop the really high voltages needed for goats and sheep. They also need a high quality, back-up, Marine battery for nighttime and under very cloudy conditions.

### Fencing for Sheep

Sheep enterprises also consider fencing as the biggest investment. Because this is the biggest capital investment, existing fencing can be modified. A 32” high-tensile net wire with HT upper wires and offset “hot” wires is the excellent fence for sheep and goats and reliable in all seasons. This is a maintenance-free fencing system and is a very effective way to keep out most coyotes and dogs. For sheep an approximately 4,000 volt charger is adequate. Electrified fencing is the least expensive method of fencing sheep (Table 4.12).

Table 4.12. Estimates for one-fourth of a mile of different types of fencing for sheep.

Fencing type	Total cost	Cost per foot
Net wire, 1 barbed strand	\$1,987.09	\$1.51
Barbed wire, 5 strands	\$1,613.65	\$1.22
High tensile, non-electric, 8 strands	\$1,483.75	\$1.12
High tensile, electric, 5 strands	\$927.13	\$0.70
Electrified polywire, 3 strands	\$309.69	\$0.24

Source: <http://www.sheep101.info/201/fencing.html>.

### Fencing for Cattle

Electric fencing works best for cattle because cattle are very sensitive to electric shock. The reasons for effective electric fencing for cattle are their short hair coat, heavy body, and large hooves. Cattle are a low resistance animals compared to other animals like sheep and goats. Cattle also walk slower rather than run so they can see fences more clearly. Cows are very effectively controlled by live wire about two feet above the ground; as a result, grass to wire

contact is much reduced. Unlike horses, cattle can see low-visibility fences more clearly. Predators are also less common in cattle compared to sheep and goats.

### **Fencing for Horses**

Horses do not see smaller objects as clearly in front of them and have a poor depth perception when they are running or on the move because their eyes are located on the side of their heads. This makes it easy for them to run into a fence. Horses also react more swiftly to alarming situations by fleeing. This can be dangerous to horses and horse owners. An escaped horse on the road is a dangerous threat to vehicles and their occupants. The equine barriers should be taller, stronger, and more visible with contrasting colors. High tensile smooth wire fences are not advised for horses to avoid potential injuries. The types of fences commonly used for horses are trailer paddock, rope or tape, and semi-permanent fences like horse quick fence or rope. Trailer paddocks are useful for fencing horses for short periods. The temporary rope or tape fences are very affordable and easy to install. The choice of any fencing designs or types depends on the need of the producers. Some consider barbed wires to be less desirable for horses as they will cause serious damage to horses with even minimal contacts, but some others have used barbed wires for horses without any problems. Horses often scratch themselves or cast their winter coats along barbed wire fences, damaging the fence. They also reach over or through it to get to feed on the other side, stretching or breaking the fence. The height for mares and foals should be at least 4.5 feet tall to discourage jumping and reaching over. The best recommendation for perimeter fences for horses are net wires with a barbed or electric top wire to prevent reaching over. There are many private companies that sell excellent fencing materials for horses. Make sure to do a thorough research before making a decision on fencing designs.

### **Fencing for Birds, Ducks, and Geese**

The most practical and affordable solutions for fencing birds are electrified netting that works for birds with clipped wings or for non-flying birds. One can have temporary or semi-permanent nets. The goal of using nets is to create a physical and visual barrier to birds and predators. The semi-permanent nets need stronger posts to avoid sagging. One can purchase complete net and energizers or plug-in kits from many private companies. Points to remember: 1) birds have higher total body resistance to electricity than cows, horses, pigs, or dogs and 2) fences being low in heights are prone to frequent weed contacts; so, make sure to purchase energizers. Grasses around the fence must be mowed or trimmed regularly to avoid contact. One can also spray herbicides, such as Roundup, to control weed growth along the fence line.

### **Fencing for Pigs**

Pigs can be easily trained to a single- or double-wire fence that can be strung up posts (Mudge and Gabriel 2014). These fences are also easily movable. Alternatively, pigs can be fenced by using a cattle panel bent and secured to a frame and covered with roofing.

### **Fencing to Exclude Predators and Wildlife**

The greatest predator problem for grazing livestock in the United States is the coyote due to their wide distribution followed by domestic dogs in areas with high human population (Ferrell and Huskey 2005). Coyote predation is more frequent during the early spring and summer months

than the winter months. This is because coyotes produce litters in the spring so the nutritional needs of the females are increased. Livestock are also more intensely managed during winter months. Sheep and goat enterprises suffer the most from predators when expressed as a function of the value of the industry (Ferrell and Huskey 2005). Other important predators include bear (grizzly or black), mountain lions, wolf, domestic dog, wild or feral swine, bobcat, lynx, fox, and raptors such as the golden eagle or black vulture.

The control options to prevent losses from predators and wildlife include fencing (discussed in this chapter in detail), the use of livestock guardian dogs (also discussed in details in this chapter), traps and snares, and frightening devices. The use of any of the suggested control measures depends on the location of the farm, the prevalence and type of the predators, and the size of the herd. Some producers pen or stable their vulnerable livestock at night time. The federal Animal and Plant Health Inspection Service (APHIS) office in each state can provide a trapper whom producers can consult on predator problems.

## Facilities for Grazing Animals

### Shelters

Grazing animals need shelters to protect themselves from extreme temperature, wind, and precipitation. Trees can provide shelter depending on the size of the trees, distance between trees, and rows, but trees alone may not be adequate during cold and windy weather conditions. Trees and brush can reduce wind velocity by as much as 70 percent and prevent the direct cold effect by 50 percent or more (Klopfenstein et al. 2008). Cattle prefer shade from trees rather than constructed structures. Portable low-cost shade structures can be built from 2.5 inch pipe welded into a frame sturdy enough to withstand cattle (Figure 4.2; Higgins et al. 2011). They can also be moved easily to avoid manure buildup or soil compaction. Shelters, whether purchased or locally made, should provide enough space for animals to avoid overcrowding which can injure pregnant, young and submissive animals (Figure 4.3 and Figure 4.4). For example, adult goats need 20 to 30 square feet per goat. Ducks and geese are nesting animals. The housing can be constricted to be shorter - the roof can be just above standing height. The space requirements are 1.5 to 3 square feet per animal (Mudge and Gabriel 2014). Chickens and turkeys roost at night and are vulnerable to predators. They can be provided shelters with movable coops. Shelter designs and types depend on the management of the silvopasture system. The main point is that the shelters should be cost effective, practical to use, and easily portable, especially when rotational grazing is practiced. Cornell University has plans of portable windbreak, which is easily built and easily



Figure 4.2. Portable shade structure for cattle with a shade cloth roof.

Source: Higgins et al. 2011.

moved from pasture to pasture (Thonney 2013). There are many private companies that sell prefabricated shelters in different sizes and shapes.

Limited resource landowners are advised to build their own shelters from available materials that can be easily moved from paddock to paddock. The most important thing is that the open side should be against the wind to protect goats from draft (Porter 2006; McKinney 2000). For goats, the eave height should be six to eight feet while the rear height should be from four to six feet tall. The higher roof heights are useful for summer months. Shelters built on skids can be easily transferred from one paddock to the other (Correa et al. 2010). Permanent shelters can be cost-prohibitive, especially to limited resource landowners. The shelters should be placed on firm ground where water accumulation or water logging is not likely to happen. However, if reasonable stocking rates are followed, earthen floors will be adequate. In high rainfall areas, elevated portable shelters can be built to protect animals from mud and standing water because these conditions make goats susceptible to foot problems, pneumonia, internal parasites and other diseases. The height of the floor should be raised to 3 to 4 feet above the ground and floors should be slatted or made of expanded metal for fecal pellets to fall through and not get legs caught. The raised floor height facilitates easy removal of manure from the ground. The slatted floor surface should be smooth and free of rough edges to prevent injuries to legs. The illustrations given Figures 4.3 and 4.4 are mainly used for goats.



Figure 4.3. Shelter made by covering a tarp over a car port frame for winter for disbudded goats.

Picture courtesy: A. Peischel.



Figure 4.4. Portable shelter used at the Tuskegee University Agroforestry demonstration site.

Source: Port-A-Hut shelters at [www.port-a-hut.com](http://www.port-a-hut.com)

### Watering Facilities

Water is the most important nutrient for animals. Water supplies can be from different sources but water quality must be tested on a regular basis. Ideally water facilities should be designed for implementing rotational grazing and uniform grazing management. The facility should be designed in such a way that it will not create over-grazing. The consumption of water is greater when water is made available in every paddock and the travel distance is kept below 800 feet.

The location of waterers can be heavily trafficked so crushed stone or stone dust should be installed to prevent muddy areas. Generally, a water trough system supplied by well water or a rural water system is preferable. During the hot summer months, goats can drink three to four times the amount of dry matter they consume daily which can amount to as much as four gallons a day for a lactating doe. Clean water can enhance rumen function thereby increasing forage digestibility. The waterer can be made of different materials with various shapes and sizes depending on one's need and topography of the systems (Figure 4.5, Figure 4.6, and Figure 4.7). The example in Figure 4.5 is of an automatic float valve attached to a running hose or pipe fastened to the edge of a cut-off that barrel will



Figure 4.5. Automatic waterer with fresh and clean water.

Picture courtesy: A. Peischel.

be able to provide water at all times. The waterers should be cleaned on a regular basis to maintain proper sanitary conditions. Plastic and metal waterers are commonly used because they are easier to keep clean. The cost of an automatic watering system is within reason and fresh water can be supplied continuously.

During the winter months, the water pipes or valves can freeze unless they are insulated or drained during freezing weather (Solaiman 2010). The non-automatic watering system requires more labor for hauling, piping or simply carrying water from elsewhere (Figure 4.6 and Figure 4.7). Concrete tanks can be installed if the producer wants a permanent installation. Permanent tanks should be made of concrete with covers. It is desirable to have the waterer in the shade during the summer so that the water is cool for drinking. It is important that the location and distribution of water, minerals, or supplemental feed when needed is adequate to avoid the over-utilization of the silvopasture areas.



Figure 4.6. Water can be hauled and delivered daily in small troughs.

Picture courtesy: N. Gurung.

### Corrals and Working Facilities

Corrals or catch pens are necessary to work animals irrespective of the size of the herd. The size of the working facilities depends on the size of the herd. The pens or corrals must be made up of strong materials because working animals are overcrowded and corrals or pens are under pressure (Shurley 2007). Corrals or pens should be on the property on a well-drained site to avoid mud problems leading to foot and parasite problems (Figure 4.8 and Figure 4.9). Working facilities are designed to make it easy to work animals from different paddocks when animals need to be physically restrained, treated, vaccinated, hoof trimmed, dewormed and loaded for transportation (Solaiman 2010). There are



Figure 4.7. Small to medium-sized tanks can easily be moved from paddock to paddock for cattle.

Source: Smith et al. 2011.

many prefabricated commercial goat handling facilities available which are very well-designed and sophisticated but may take time to put together or disassemble and may be very expensive. Producers/landowners can build their own handling facilities by using cattle panels. Small producers can use this facility to catch goats, treat them, and load them. Solaiman (2010) has recommended a working facility with the following dimensions for a working chute, 8-12 ft. long, 4 ft. high, 14-16 inches wide for Spanish and Kiko goats, and 16-20 inches for Boer goats (they turn their heads sideways). The chutes longer than 10 feet need to be divided into sections with a gate if the goats are wild, as they will crowd at the end, walk over one another, and escape (Solaiman 2010). But an elaborate working facility may not be needed for silvopastoral systems. Tuskegee University has purchased the facility illustrated below for demonstration and training purposes (Figure 4.8; D-S Livestock Sheep and Goat Handling Facility). Stegall Fabrication and Engineering LLC., located in Missouri ([www.stegallfab.com](http://www.stegallfab.com)) also makes a totally portable working facility.



Figure 4.8. Goat Handling Facility at the Tuskegee University Caprine Research and Education Unit (CREU). Picture courtesy: N. Gurung.



Figure 4.9. Quick corral setup to unload goats.

Picture courtesy: A. Peischel.

## Feeders

Cows, sheep, or goats should be provided with supplementary feeds if understory forages in silvopasture are not adequate to provide nutritional needs. Normally hay is supplemented to meet energy needs first and protein needs second. Hay can be fed in racks and other feeding structures to minimize hay wastage (Figure 4.12 to Figure 4.14). Feeder shown in Figure 4.13 has a wheel attachment and can be hooked to an ATV to move around as needed. Hay waste is minimized. Grain or mineral feeders should be made up of plastic or metals because they are easier to clean (Figure 4.10 and Figure 4.11). A mineral supplement should always be available. Wooden structures are cheaper but they are more difficult to keep clean. Feeders should be constructed in such a way as to keep animals from defecating in them and spreading disease such as coccidiosis or Johne's. The feeding space should be about 12 inches per adult goat and 28 to 36 inches per cow.



Figure 4.10. Mineral feeder purchased from a supplier.  
Picture Courtesy: N. Gurung.



Figure 4.11. Another example of mineral feeder.  
Picture courtesy: A. Peischel.



Figure 4.12. Hay feeder with 4"x4" metal squares.  
Picture courtesy: A. Peischel.



Figure 4.13. Hay feeder movable with an ATV.  
Picture courtesy: A. Peischel.



Figure 4.14. Hay feeder on skids which is movable with an ATV and also with roof for inclement weather conditions.

Picture courtesy: A. Peischel.



Figure 4.15. Collapsible round-bale feeder for goats and feeder lambs.

Source:

<http://www.sydel.com/product/collapsible-round-bale-feeder-for-goatsfeeder-lambs/>

## Use of Livestock Guardian Animals

The safety of animals in a silvopasture system is one of the key components of the production system. When sheep and goats are raised in areas where they are prone to predators, the use of livestock guardian animals is necessary (Peischel 2010). Common predators are mountain lions, bobcats, coyotes, packs of dogs, buzzards, snakes, and fire ants. Domestic dogs are the main predators for goats in the rural and suburban areas in the US followed by coyotes. There are many livestock guardian animals producers have used successfully. They include guardian dogs, llamas, donkeys, mules, and ostriches. Producers have used these species successfully under different situations. The main advantage with llamas, donkeys, and mules is that they can live off the land. However, llamas are vulnerable to wolves and large wildcats.

The choice of livestock guardian dogs is difficult because each breed has its own loyal supporters. However, the most common breeds used in the US are Great Pyrenees, Anatolian Shepherd, Akbash, and Maremma (Lane and Lane 2007). The main considerations for selecting a suitable breed for your operations should include adaptability to the climatic conditions, the physical setup, location, type of the animal (long- or short-haired), and temperament. The final deciding factor should be based on the ability to protect the herd and not based on cost. Do thorough research before making a choice for a particular breed. You may also want to visit producers who are using livestock guardian dogs and see how they work. Also, ask for references about any breeder you may want to purchase from and guarantees from the breeders. Peischel (2005) recommends that Great Pyrenees are less aggressive to humans and Akbash are more suitable for forest/brush and rangeland operations. Anatolians tend to be more aggressive; however, there is often much difference between individuals as between breeds. If pups are purchased, they should be given a safe place to protect them from aggressive goats. A safe pen similar to a creep feeder which allows pups in and out while denying access to the larger goats is

recommended (Lane and Lane 2007). The fences should be able to stop dogs from getting out. When dogs get out, there may be a problem with neighbors and law enforcement, or dogs may get injured or thieves may steal dogs. Crossbreeding between Great Pyrenees and Akbash brings the best out of both breeds. Akbash dogs are very hard-working dogs. There are many useful websites that offer advice on livestock guardian dogs. The crossbreeds will have short coats with the athletic ability of the Akbash and the bone structure of the Pyrenees (Peischel 2005).

The breed of guardian dogs depends upon the class of livestock to be protected, topography, and type of predators (Peischel 2010). Shade is also important for dogs. General health maintenance, mainly the prevention or treatment of internal parasites (especially heartworms and tapeworms) and external parasites, are of utmost importance. Animals with long hair-coats such as the Great Pyrenees need to be brushed occasionally to remove shed hair. They may also get areas of fly irritation on their nose that may need to be treated. Rabies vaccines are a must, and some states require the vaccine to be administered by a licensed veterinarian although in some states, producers can vaccinate. Pinkerton (2010) recommends two dogs for 100-400 goats in one pasture although the number of dogs depends more on the size of the pastures rather than the number of goats. Dogs dig under the fence if fences are not energized. Placing a strand of electrified wire along the bottom and one at the top will prevent both dogs and goats from digging under and climbing over the fence. Dogs can be fed once a day and must be fed individually. Some producers use self-feeders without any problems. Problems of keeping guardian dogs are the amount of food they eat and the need for goat-proof enclosures to feed dogs (Figure 4.16).



Figure 4.16. Special feeding structures designed to prevent goats from sharing dog food. Picture courtesy: S. Hart.

## Parasite Management

Internal parasites are major production impediments in small ruminant production systems, especially in the Southeast. Silvopasture systems are not immune to parasite problems. The indiscriminate use of chemical dewormers has created parasite resistance problems with most of the approved dewormers. Parasite control measures include smart drenching™, the use of alternative dewormers (non-chemical), grazing management, Faffa Malan Chart (FAMACHA), measuring packed cell volume, and rotational grazing. In silvopasture systems, the best grazing system is a rotational grazing which can help reduce parasite problems, allows proper pasture

growth, and enhances pasture persistence. The use of an appropriate fencing system, placement of shelters, and location of watering and mineral facilities are helpful to properly manage the grazing system. Producers should also prevent wet areas from developing around water troughs. These steps will help reduce internal parasites and other disease problems. When goats are browsing, internal parasite problems are minimal, but when animals graze closer to the ground, internal parasite problems become serious.

### **Animal Welfare Issues**

The issues are how to address the natural behavioral habits and basic physiological characteristics of animals when planning and designing handling and feeding facilities. Well-planned facilities reduce the time and labor required to handle the livestock while reducing the chances of injury to both animals and operators. Animals integrated into silvopasture systems are not the main components of the system, but they provide supplemental income to producers or landowners and should be cared for. The nutritional needs should be met, and a quality health management program should be in place. Body condition should be monitored on a regular basis. The main consideration for body condition score is stocking rates. Too many animals on a small area (overstocking) leads to reduced animal productivity and the deterioration of forage plants leading to poor stand persistence, reduced animal health and increased parasite problems. If guardian dogs are used to protect animals, they should be properly and individually fed with high energy and protein diets. Make sure there are no ruminant proteins in dog food, because goats can have access to it as goats are generally greedier than dogs.

### **Hand-On Activities and Demonstrations**

1. Participants will be shown how to install an automatic watering system.
2. The Tuskegee University Goat Handling facility will be used for hands-on activities involving live goats.
3. Participants will be shown different types of shelters used at the Caprine Research and Education Unit and at the Tuskegee University Agroforestry Demonstration site.
4. Electric fencing demonstrations will be conducted.
5. Guardian dogs will be observed at work at the Tuskegee University Caprine Research and Education Unit.

### **Key Points**

1. The selection of proper facilities is a key to enhancing animal productivity, forage productivity and persistence, and tree growth, thereby ultimately promoting the profitability of the silvopasture systems.
2. Energized fencing is preferable for silvopasture systems.
3. Goats are the most difficult domestic species to contain.
4. Proper waterers, shelters, and feeders are essential for the well-being of animals in silvopasture systems.

5. Barbed wire is not recommended for horses because it may cause serious injury.
6. Materials and labor required for building power fences are significantly less than for barbed wire.
7. A rotational grazing system is preferable for silvopasture systems.
8. High tensile power fence is as permanent as barbed wire.

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## **Chapter 5 SUSTAINABLE GRAZING MANAGEMENT IN A SILVOPASTURE SYSTEM**

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### **Introduction**

Sustainable grazing management is one of the major aspects of becoming successful in a silvopasture operation. Farmers or managers managing grazing must consider minimizing the untoward effects of grazers on trees, forages, and soil, while obtaining the desirable performance of the grazers. Except for minimizing the possible damage to trees, the basic principles of grazing management in silvopasture systems remain similar to those in open-pastures. Grazing should be avoided when tree crowns are still within the reach of the grazing animals, and forages should be harvested manually until trees achieve the suitable height for the target grazing animals. Once trees are tall enough, just as in open-pastures, grazing should begin when forages are well-established and reach the grazing height, and end grazing at the suitable stubble height. To minimize tree damage, the rotational or other forms of a controlled grazing system should be followed in silvopastures. Stocking rate should be based on the available forages.

### **Possible Tree Damage by Grazing Animals and Mitigating Such Damage**

When animals are introduced in a young silvopasture, where terminal leaders and top lateral branches are still within the reach of grazing animals, animals may damage the young trees by browsing on them and rubbing on the tree saplings. Animals may break the terminal leaders and branches while browsing and rubbing on them. Sharrow (1998) mentions that 3-6-ft trees are preferred by deer as rubbing posts. Conifer trees and saplings appear attractive to grazing animals, especially during spring bud break until the leaves appear light green, so possible damage may remain high during this time (NRCS 2005). Therefore, grazing on the Christmas tree silvopasture should be avoided for 60 days once the spring buds break, or until the new growth has hardened off (Sharrow 1998). Animals may browse a small amount of leaves every day as they want variety in their diet. Little browsing may not inflict an untoward effect on tree growth and development. Hamilton (2008) states that limited browsing by livestock would not kill the trees; nevertheless, the removal of terminal buds of the conifer trees or 50 percent of the current year's foliage would reduce tree growth in that year. Another potential damage to young seedlings is through trampling, especially by large animals such as cattle (Hamilton 2008). Goats may browse on different trees, shrubs, and vines when allowed to graze woodlands and create a browse line at a certain height. When goats are allowed to stay in one spot for a long time (several days or weeks), they develop favorite spots, chew the bark of the trees, and rub on the trees causing significant tree damage. A recent grazing study conducted in mixed-pine (longleaf and loblolly, 10-year-old) silvopasture systems showed a significant debarking behavior of Kiko wethers, especially on the longleaf pines (Figure 5.1) (Karki et al. Unpublished). There is not much publication on tree damage by other grazing animals in a silvopasture system. Therefore, it

is necessary to watch the grazing animals closely while they are in silvopastures and know their patterns of utilizing ground vegetation and tree foliage at different spots and causing damage on trees, and make adjustments to minimize the untoward effects.



Figure 5.1. Kiko wethers debarking the longleaf pine tree (A), and a significantly debarked longleaf pine tree (B) from grazing in a longleaf-loblolly-mixed-pine silvopasture system, Atkins Silvopasture Research and Demonstration Site, Tuskegee University, Tuskegee, AL.

Picture courtesy: U. Karki.

To avoid tree damage, animals must not be introduced to a silvopasture unless trees become strong enough to resist the breakage by animals' rubbing on them or bending them. Under a compelling situation when animals need to be introduced into a young silvopasture, the young trees must be protected by using an appropriate barricade, such as fencing, caging, tubing, or a chemical repellent (Figure 5.2 A&B). Once the terminal leaders and top branches grow beyond the reach of grazing animals, and the stem is covered with a thick layer of bark, tree damage by livestock remains low (Hamilton 2008; Garrett et al. 2004). From this point, silvopastures can be managed somewhat similarly to open-pastures with the rotational or other forms of controlled grazing. Rotational grazing involves a shorter grazing period and longer resting period that help avoid the chances of grazing animals' congregation in one location or certain locations and their developing a spot grazing or an animal trail. Garrett et al. (2004) state that when cattle are allowed to remain on a paddock beyond three days, spot grazing and pronounced cattle trails will begin to develop. When the cattle return to this paddock they will again begin to follow the previously established grazing patterns. The rotational grazing along with the removal of animals from silvopastures during the wet period minimizes soil compaction and physical damage to roots near the surface (Garrett et al. 2004).

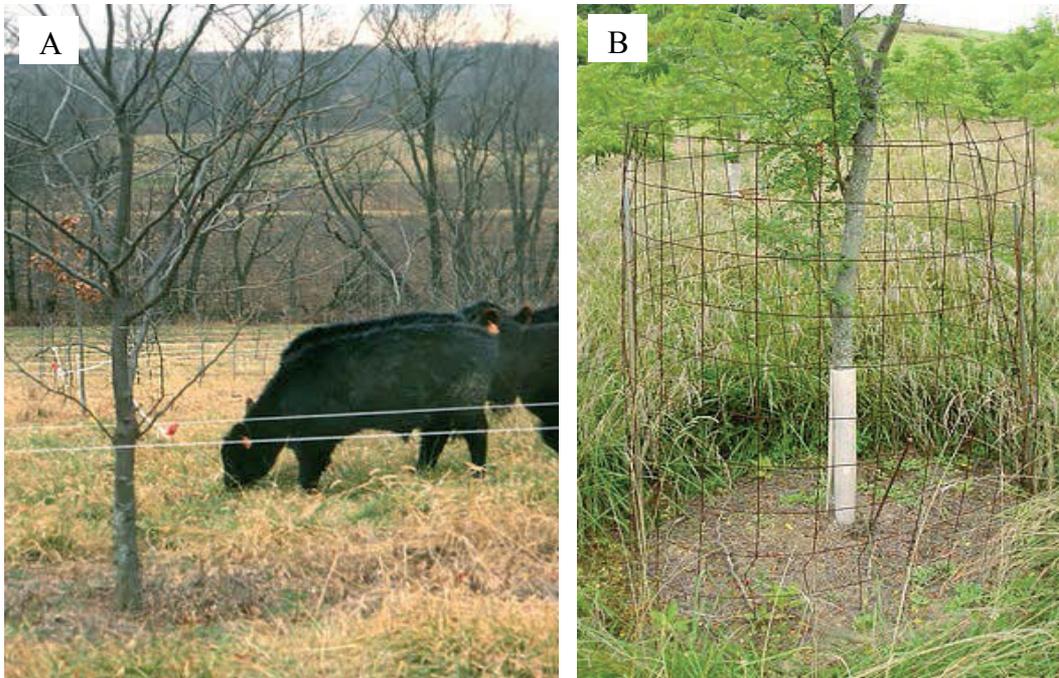


Figure 5.2. Trees protected by electric fence (A) and both cage and tree tube (B).  
Source: Fike et al. 2004.

### **Suitable Grazing Systems in a Silvopasture System**

Grazing management in a silvopasture system must take care of trees, forages, and soil at the same time achieving the desired livestock performance. All available literature in silvopasture systems recommends a rotational grazing system to avoid tree damage by the grazing animals (Fike et al. 2004; Garrett et al. 2004; Hamilton 2008; Sharrow 1998). A continuous grazing system, where animals are allowed to stay in the whole area throughout the grazing season, is not suitable for a silvopasture system because animals will have choices on where to go, what to eat, where to camp, and where to develop trails. This means that they may congregate in a selected area and rub on trees, trample on superficial tree roots, and browse on tree foliage there repeatedly throughout the grazing season. Such repeated action may damage trees significantly. Therefore, the rotational or other forms of controlled grazing, as appropriate to the resources available and goal of the producers, should be applied. The rotational and other forms of controlled grazing system can be developed and used as is done in open pastures, which has been discussed well by Karki (2013) and presented below.

#### **Rotational Grazing**

A rotational grazing system requires several subdivisions (paddocks) through appropriate fencing, and animals are allowed to graze one paddock at a time and are moved to another paddock in a sequence or rotation based on forage availability. Rotational grazing is based on the principle that pasture is benefited from a shorter grazing period and longer resting period. When animals are moved off a paddock, plants and soil in that paddock have a chance to recover from the grazing pressure that grazing animals inflict through defoliation (removal of foliage) and trampling. The duration of recovery or resting period required varies for different forages. For

example, bermudagrass, dallisgrass, small grains, and annual ryegrass may recover within seven to 15 days; however, some tall growing forages such as switchgrass and eastern gamagrass (*Tripsacum dactyloides* (L.) L.) need 30 to 45 days of recovery period (Table 5.1). Moreover, the grazing period should be adjusted such that animals would not have a chance to remove more than 50 percent of the forage leaf volume, damage trees, and develop a camp site, spot grazing, or trail.

Table 5.1. Guidelines for beginning and ending heights for grazing and recovery period for selected forages under rotational grazing.

Forage crop	Target height (inches)		Usual recovery period (days)
	Begin grazing	End grazing	
Alfalfa (grazing type)	10-16	2-3*	15-30
Bahiagrass	6-10	1-2	10-20
Bermudagrass	4-8	1-2	7-15
Big bluestem	15-20	10-12	30-45
Clovers, white and sub	6-8	1-3	7-15
Clovers, all others	8-10	3-5	10-20
Dallisgrass	6-8	3-4	7-15
Eastern gamagrass	18-22	10-12	30-45
Fescue, tall	4-8	2-3	15-30
Indiangrass	12-16	6-10	30-40
Johnsongrass	16-20	8-12	30-40
Orchardgrass	8-12	3-6	15-30
Ryegrass, annual	6-12	3-4	7-15
Sericea lespedeza	8-15	4-6	20-30
Small grains	8-12	3-4	7-15
Switchgrass	18-22	8-12	30-45

Source: Ball et al., 2007.

\*Ending grazing height must be four inches or higher for small ruminants to minimize the internal parasite infection.

### *Pasture Subdivision*

Usually, four to five paddocks, but not more than eight paddocks, will be enough for managing the forages sustainably. With four paddocks, there will be around a one-week grazing period and a three-week resting period for each paddock. Similarly, for eight paddocks, grazing period and resting period will be, respectively, of around four days and 28 days. In Figure 5.3, we can see that the recovery period increases dramatically from zero to 15 days when the pasture is divided into two paddocks. Then the increment in the recovery period goes on decreasing with the additional paddocks, and becomes negligible after eight paddocks. Therefore, there is no need to have more than eight paddocks from the standpoint of forage management. However, while grazing occurs in a silvopasture system, close observation must be made on whether animals are damaging trees, and one must move them off the paddock faster if damaging activity increases with a longer grazing period.

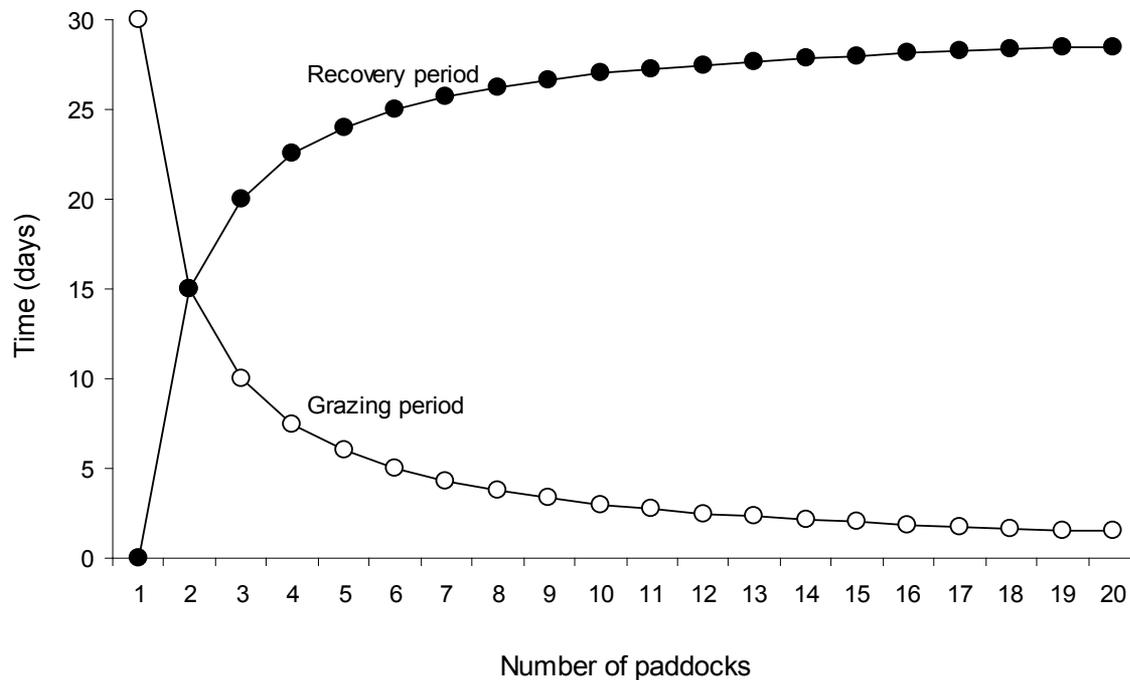


Figure 5.3. Grazing and recovery periods for different numbers of paddocks in a rotational grazing system with 30-day grazing.  
Source: Karki and Gurung 2009.

Based on resting and grazing periods suitable for forage species, the number of paddocks required can be calculated as follows.

$$\text{No. of paddocks required} = (\text{No. of days required for resting} \div \text{no. of days grazed}) + 1$$

Suppose the resting period required is 28 days and grazing period is 4 days for each paddock at a time, then the number of paddocks required would be  $28 \div 4 + 1 = 8$  paddocks.

While dividing the pasture into paddocks, the following points should be considered.

- Each paddock should be uniform in terms of natural variation (quantity, quality, and the composition of forages, shade, topography, access to water source, and soil quality) so that the selection of forage species and space is minimized.
- Gates should be placed in such a way to facilitate easy movement of animals while transferring them from one paddock to another.
- Water tank should be placed towards the center of the pasture so that animals from any portion of the paddock do not have to travel a long way to drink. It is a good idea to keep animals within 600 to 800 feet of the water source.
- Each paddock should be of similar size and production capacity and square shaped as much as possible.

#### *Forage Plantation and Grazing Schedule*

Forages can be planted once or at different times to adjust with the animal movement in different paddocks. If planted once, animals should be allowed to graze the first paddock earlier than the

optimum growth stage of the forage is reached, and move the animals faster to other paddocks so that the forage would not be overgrown and lower in quality in any of the paddocks. If animal grazing cannot catch up with the forage growth in all paddocks, a few paddocks should be mowed to make hay or burnt (if appropriate for the tree species) and rotate animals in the remaining paddocks to maximize the forage utilization. If forage growth is faster, animals should be moved faster, and vice versa. One has to be flexible with animal movement frequency and sequence for the maximum utilization of forages. If forages in different paddocks are sown at different times, manage the movement of animals to harvest the forages at optimum time, when the lowest leaves appear yellowing. Table 5.1 presents general guidelines on when to begin and end grazing various forage crops for proper pasture management. However, the resting period may vary depending on the stubble height – a longer resting period is required for shorter stubble height and vice versa for the same forage.

### **Strip grazing**

A strip of a pasture is fenced temporarily with a movable fence and animals are allowed to graze the strip for a short time, which may vary from a few hours to a couple of days depending on the strip size and forage availability. When the strip is grazed to a desirable level, the fence is moved to allow animals to move to another fresh strip.

### **Limit Grazing**

Animals are allowed to graze a high-quality pasture such as legumes or winter annuals for a limited time, e.g., for a few hours every day. Growing high quality forage on a separate piece of pasture and allowing animals on this pasture for a few hours every day is useful to fulfill the nutrient requirements of animals grazing low-quality pastures during the rest of the day. It may work well for producers, who would like to grow leguminous forages in the silvopasture and grasses that require more sunlight exposure than legumes in the open-pasture, and manage the legumes with limit grazing.

### **Mixed-Species Grazing**

Mixed-species grazing involves two or more animal species, for example, cattle and goats grazing together. Mixing cattle and goats for grazing can be more beneficial than grazing either species alone because goats eat many plant species that would not be eaten by cattle, and cattle lower parasitic infestation in goats as the goat-worm larvae ingested with forages grazed by cattle are destroyed when they are in the stomach. The inclusion of goats with cattle would also be useful to manage unwanted shrub and hard-wood species new growth or regrowth.

### **Forward-Creep Grazing**

Young animals are allowed to creep through a creep gate to a fresh pasture first and then mature animals are allowed to graze the same paddock. This way, the young, growing animals will have a chance to fulfill their nutritional requirements and minimize the chances of being exposed to parasite larvae.

### First and Last Grazer

When there are different classes of animals in terms of nutrition requirements, those requiring a high plane of nutrition are allowed to graze the fresh pasture first. Then other classes of livestock in sequence of nutritional requirements are allowed to graze. For example, the grazing sequence can be 1) does in their early lactation, 2) young growing kids, and 3) dry does.

### Available Forage, Animals' Requirements, and Stocking Rate

Stocking rate is the number of animals stocked per unit pasture/silvopasture for a grazing season. It should be determined based on available forages or the carrying capacity of the given silvopasture. The carrying capacity indicates the number of animals the silvopasture can support to achieve a targeted performance for a specified period, which can be a grazing season or year after year, without detrimental effects on the silvopasture. Carrying capacity depends on the standing forage available for the grazing animals. When the growing condition is the most favorable, forage production remains high and adequate dry matter may be available to support more animals. But under unfavorable conditions like limited moisture availability and other stressful conditions, production decreases and would not support the same number of animals as under favorable production conditions. Therefore, the manager or producer should adjust the stocking rate depending on the available forages. Understocking would lead to the wastage of resources while overstocking is detrimental to silvopasture health and future production (Figure 5.4). For determining a proper stocking rate, managers also need to know the dry matter requirements of grazing animals.

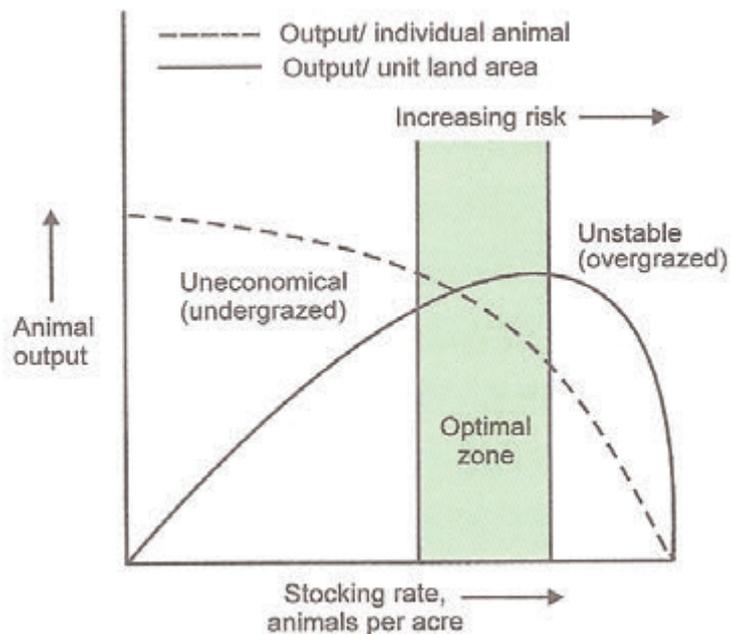


Figure 5.4. Relationship between stocking rate and animal output (per animal and per acre).

Source: Ball et al. 2007.

Generally, goats require dry matter at the rate of two to six percent of their body weight depending on the physiological stage, productivity, live weight, and animal type (such as dairy, angora, and meat) (NRC 2007). For example, a mature, dry (maintenance only) meat doe

weighing 110 lb requires dry matter two percent of her body weight; whereas, a mature lactating dairy doe with the same live weight and producing 15 to 21 lb milk requires more dry matter (6.07% of her body weight). From the pasture yield estimation and animals' dry matter requirement data, the carrying capacity of a pasture can be estimated. Let's assume that a dry meat doe with 100 lb body weight requires dry matter 2.0 percent of her body weight, then she needs 2 lb ( $100 \times 0.02 = 2.0$ ) dry matter per day, which is equivalent to 13.33 lb green forage assuming that the dry matter content of the available forage is 15 percent ( $0.15 \times X = 2.0$ ,  $X = 2/0.15 = 13.33$  lb). One acre pasture with 1000 lb of available forage dry matter will support this doe for 75 days ( $1000/13.33 = 75.02$ ). For grazing purposes, one should use the target stubble height while estimating the available forage mass (forages available above the target stubble should be accounted for). Supplying forages higher than animals' requirement is wasteful. Animals might eat more than their requirement if they have access, but the utilization of the ingested forage decreases as the intake increases (Figure 5.5).

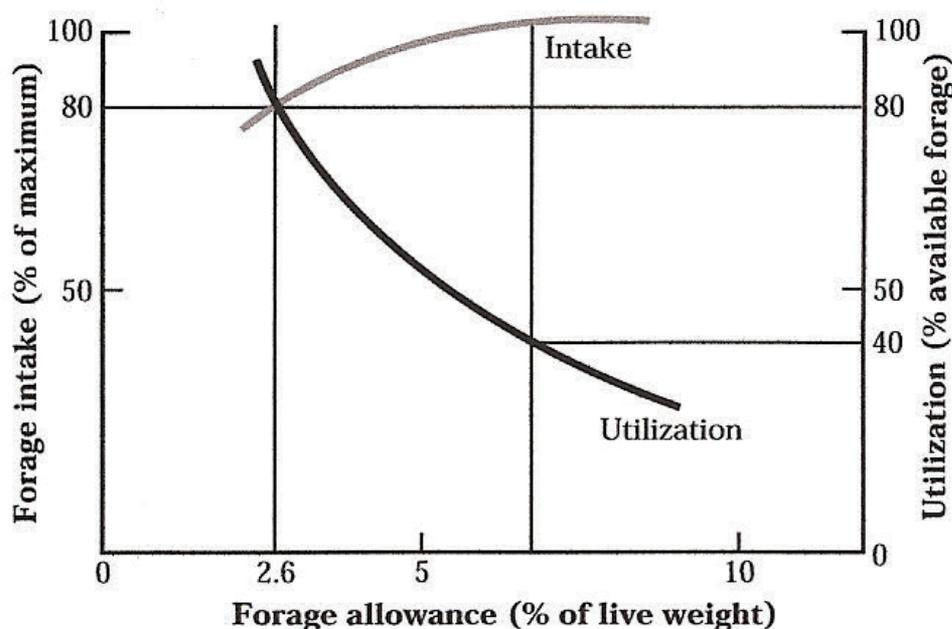


Figure 5.5. Forage utilization decreases with the increase in intake; allowing more forage than required is wastage.

Source: Hodgson 1990; NRCS 1997.

### Forage Type and Time to Begin and End Grazing

Forages differ in grazing tolerance depending on their growth patterns. Erect species such as johnsongrass, switchgrass, and alfalfa are the least tolerant to grazing pressure. The prostrate species such as bahiagrass, common bermudagrass, and white clover are the most tolerant to grazing. Semi-erect species such as tall fescue and orchardgrass are intermediate between the previous two categories of forages in grazing tolerance (Figure 5.6 A-C). Prostrate species crawl on the ground by means of rhizomes and stolons, which have nodes and internodes. Shoots and roots are developed from each node. Also, with their being so close to the ground animals will not remove all leaves from the plant. So, these species are capable of regrowing and recovering from the grazing pressure quickly, resulting in greater tolerance to grazing than semi-erect and

erect species. Semi-erect species have most of the leaves close to the ground, so they are fairly tolerant to close grazing. Erect species have most of their leaves above the ground level, so most of the leaves are removed through grazing if controlled grazing is not practiced. Because of these different growth patterns, the beginning- and ending-grazing heights for erect species are higher compared to the other two species categories (Table 5.1). Similarly, erect species require longer periods for recovering from the previous grazing compared to the other two categories; semi-erect species need longer recovery/resting periods than prostrate species (Table 5.1).

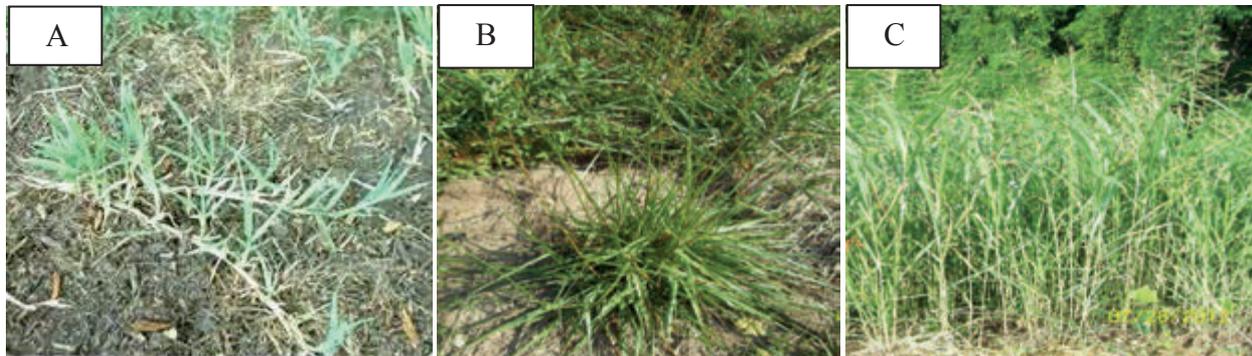


Figure 5.6. Example of prostrate species (common bermudagrass) (A), semi-erect species (tall fescue) (B), and erect species (johnsongrass) (C).

Picture courtesy: U. Karki.

In Figure 5.7, we can see why stubble height needs to be different for forages with different growth patterns. Bluegrass (*Poa* L.) and bermudagrass can withstand close grazing because most leaves that are close to the ground are left ungrazed, which can continuously be involved in photosynthesis and manufacture food for plant regrowth. Additionally, stored food present in rhizomes and stolons of these forages supply nutrients for vigorous regrowth. Unlike these forage species, grazing should end at higher stubble height for orchardgrass and tall fescue to leave enough leaf volume for photosynthesis after grazing.

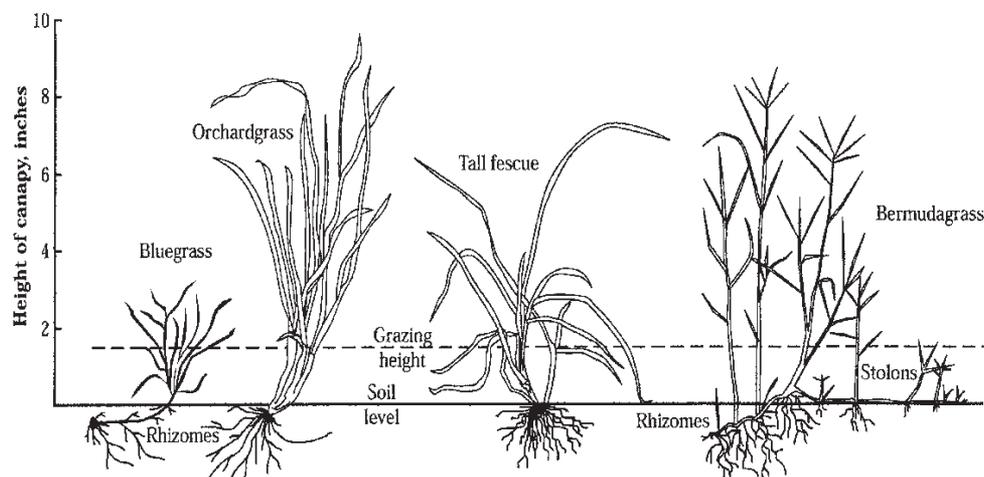


Figure 5.7. The nature of forage growth patterns influences grazing height. Source: Blaser 1986.

## Harmful Effects of an Inappropriate Grazing/Harvesting

### Grazing When Plants Are Too Young

Grazing should begin only when forages are established very well with enough leaf volume and stored food available for plant regrowth after defoliation. Depending on the forage species, excess food (spared from that required for plant growth and development) from photosynthesis is stored in roots, stems and stem bases, crown, rhizomes, and/or stolons. The grazing manager should monitor the forage plant very well for available leaf volume and well-developed food storage structures before grazing. If grazed when plants are too young (Figure 5.8A), they will not be able to cope with the grazing pressure. As a result, plants may die, or show very poor regrowth. After a couple of grazing cycles, the stand will be very poor with several patches without any forage. This situation requires replanting the pasture and providing enough recovery period before the next grazing can begin. On the other hand, if grazing begins when forages are ready for grazing (Figure 5.8B) and ends when the desired stubble height is reached, forages will regrow and maintain a good stand provided enough recovery period (Karki 2013).

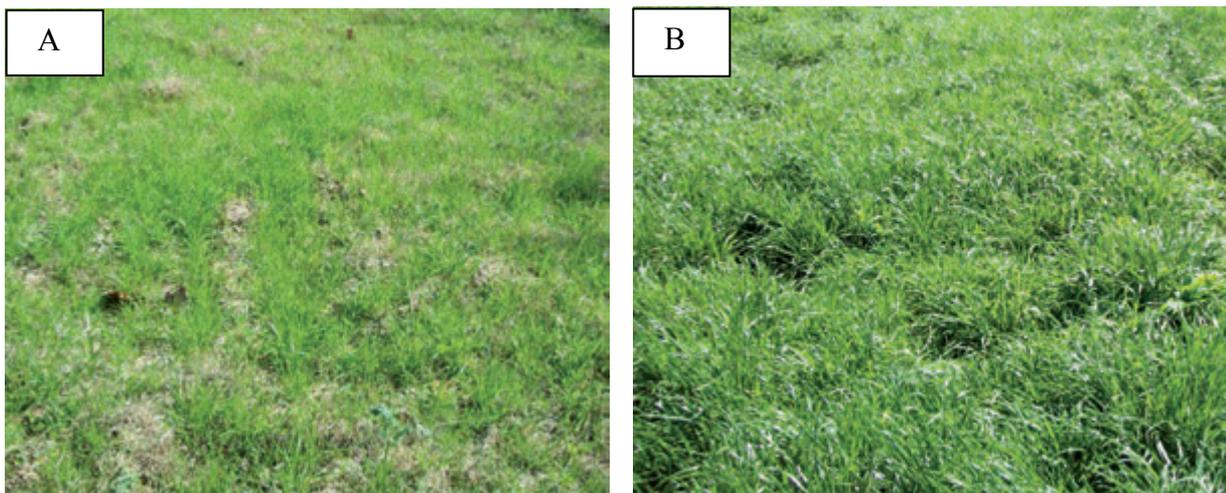


Figure 5.8. Portions of Marshall Ryegrass pasture (A) too early to begin grazing, and (B) right time to begin grazing.

Picture courtesy: U. Karki.

### Grazing When Plants Are Too Mature

Forages become more fibrous and less nutritious as they mature. Grazing animals select young shoots and leaves over mature stem when allowed to graze mature plants (Figure 5.9A). As a result, most leaves and young shoot tips are removed and mature fibrous stems are left, especially when grazing with goats (Figure 5.9B). This prevents vigorous regrowth and results in low productivity and quality (Karki 2013).

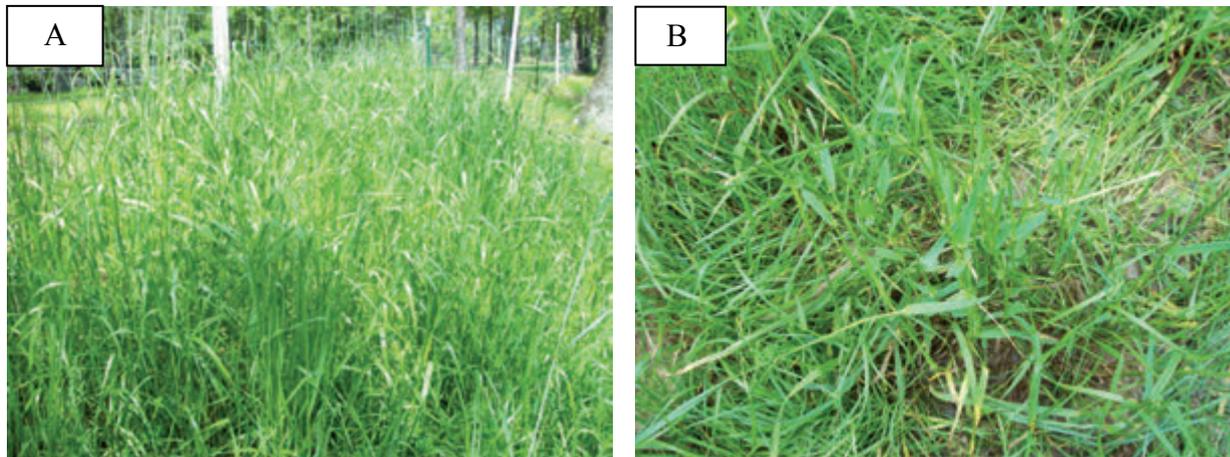


Figure 5.9. Marshall ryegrass pasture (A) became mature when not grazed on time, (B) goats selected leaves and young shoots and left fibrous stem when allowed to graze the mature ryegrass pasture, spring 2012, Phenix City, AL, USA.

Picture courtesy: U. Karki.

### **Grazing Perennial Forages Before They Go Dormant**

Perennial forages produce biomass during their suitable growing seasons and remain dormant when the growing season ends. For example, tall fescue grows during spring and fall, and remains dormant during the hot summer months. Similarly, warm season, perennial forages such as bahiagrass, dallisgrass, bermudagrass, and sericea lespedeza grow during warm-season (April to September/October), and become dormant during cool season (October/November to March). Forages need to have enough stored food before they go to dormancy for surviving while they are dormant and growing back vigorously in the next growing season. Therefore, grazing on these forages must stop four to six weeks before they become dormant. Otherwise, there will be limited or no stored food available for their survival during dormancy and vigorous regrowth in the next growing season. As a result, some of the forage plants may die and surviving forages may have poor stand in the next growing season. Additionally, grazing animals must be taken off the pasture while forages are dormant unless there are other forages growing vigorously in the same pasture, such as in the case of mixed-species pastures.

### **Grazing During a Drought or Adverse Weather Conditions**

Young, growing plant tissues constitute 80 percent or more water. So, forage plants require enough moisture for vigorous growth. During drought condition, forage plants are stressed; they reduce or stop growing depending on the severity of the drought. Based on the condition of available forages during drought, grazing must be reduced or stopped completely and animals should be supplied with hay or other supplementary feedstuffs. When the drought condition is over and plants receive enough moisture for normal growth and development, the usual grazing schedule can resume. Similarly, in other adverse weather conditions such as flooding, stagnant water conditions, and extreme cold, forages stop growing or may die depending on the severity and duration of the adverse conditions. Under such situations, stocking rate and periods for

resting and grazing should be adjusted so as not to hurt the forages and damage pasture (Karki 2013).

### **Undergrazing**

Undergrazing of pastures results from not putting enough animals in the pasture to achieve the desired level of forage defoliation at the given time. When pastures are understocked, animals will have too much to select from. Consequently, animals will select what they like the most and leave the less desirable ungrazed. This situation will favor less desirable forages to take over the pastures, while preferred species become scant or extinct. Additionally, much of the available forages are left unutilized, which results in low animal productivity per acre of pastures (Karki 2013).

### **Overgrazing**

Overgrazing is severe and repeated defoliation of forages accompanied with associated trampling. It results from stocking too many animals, exceeding the carrying capacity of the given pastures. Overgrazing results in various untoward effects on pasture plants and soils. Continued overgrazing of erect and semi-erect forage species generally weakens plants resulting in reduced root systems, lower forage yield, higher soil erosion and water run-off, and increased weed invasion. Also, there can be significant negative impacts of overgrazing on soil by contributing to soil compaction and creating smaller macroporosity, loss of pore continuity, greater bulk density, and pugging and puddling of soil when water content is high (Chen and Cui 2001; Southorn and Cattle 2004). Damaging effects of overgrazing on roots are discussed further in the following paragraph (Karki 2013).

Root is very important for plant production as it absorbs water and mineral nutrients necessary for photosynthesis. Additionally, it serves as food storage for several plant species. Maintaining root mass and volume is important for maximum forage production. Defoliation hinders root growth and with severe defoliation, root mass and volume decrease. This occurs because when there is not enough leaf volume for photosynthesis and only little or no stored food is available to meet the plant demand, whatever food available from photosynthesis or storage has priority for shoot development. As a result, roots die back and only a limited amount of root volume is present in the shallow area. A deep and extended root system makes the plant able to access moisture and nutrients from deep and wide areas. So, a producer or a grazing manager needs to manage grazing (defoliation) so that root growth and development would not be hurt (Karki 2013). Table 5.2 shows that 40 percent of the forage can be harvested without any detrimental effect on roots. When defoliation is increased from 40 to 50 percent, two to four percent root will stop growing; defoliation beyond 50 percent is very detrimental to root growth.

Table 5.2. The effect of defoliation on root growth.

Leaf volume removed (%)	Root growth stoppage (%)
≤ 40	0
50	2-4
60	50
70	78
≥ 80	100

Source: Dietz 1989.

### Preservation and Utilization of Extra Forages

If there is extra forage remaining from grazing, it can be conserved in different forms: hay, silage, stockpiled forage depending on the type of forage, available facility and equipment, and the producer's preference. Conserved forages can be used during the time when there is not much forage available for grazing, such as during wintertime and late spring or early summer when cool-season forages are dead or dormant and the warm-season forages are still to grow. Each conservation method is briefly explained below.

#### Hay Making

Forages with thin stem, and not much succulent such as bermudagrass, bahiagrass, and sericea lespedeza can be used for hay making because these would not take much time for drying. Weather conditions and forage maturity determine the harvesting time. Dry and sunny days will allow forage drying in a short time and avoid loss due to rain and preserve quality. The aim of selecting the proper harvesting time is to maintain the highest quality in hay without compromising too much on quantity. Forage maturity suitable for hay cutting is shown in Table 5.3. If harvested earlier, there will be less dry matter and if delayed, the quality will deteriorate as forages mature. At harvest, green forage may contain 70 to 90 percent moisture, which has to be reduced to 15 to 20 percent for baling. Rapid drying is necessary since there will be a greater loss as drying time increases. If baled and stored without drying properly, hay can be moldy. After proper drying and baling, hay should be stored in a covered area with enough airflow so that it does not get wet, become moldy and rotten, and get heated to produce fire. The storage floor should be raised to about six inches or above with slatted wood, metal, or similar other materials to minimize hay damage, which results from the direct contact of hay with moist ground or soil (Karki and Gurung 2009).

Table 5.3. Recommended maturity stage for harvesting hay crops.

Forage species	Time of harvest
Alfalfa	Bud stage for first cutting, one-tenth bloom for second and later cuttings. For spring seedlings, allow the first cutting to reach mid-bloom
Orchardgrass, timothy, or tall fescue	Boot to early head stage for first cut, then at 4 to 6 weeks intervals
Red, arrowleaf, or crimson clovers	Early bloom
Sericea lespedeza	Height of 15 to 18 inches
Oats, barley, or wheat	Boot to early head stage
Soybean	When pods are about half-filled and before bottom leaves begin to fall
Annual lespedeza	Early bloom and before bottom leaves begin to fall
White (or ladino) clover	Cut at the correct stage of companion grasses
Hybrid bermudagrass	15 to 18-inch height for first cutting, then every four to five weeks or when 15 inches high
Birdsfoot trefoil	Bud to early bloom or at correct stage for companion grass
Sudangrass, sorghum-sudan hybrids, pearl millet	Height of 30-40 inches

Source: Ball et al. 2007.

### Silage Making

Silage is prepared by fermenting green forage in a silo – pit in ground, trench, tower, bunker, or plastic bag suitable for creating anaerobic condition (suitable to make airtight so that there would not be oxygen supply; by doing so acid forming bacteria can grow and function for fermentation). Succulent forages and forages with big stem like corn and sorghum can be preserved by making silage. High energy crops like corn, grain sorghum, and small grains are extensively used for silage making. Forages having low energy like legumes may require energy addition for proper fermentation. Or, high energy crops can be mixed with legumes to obtain high quality silage (Karki and Gurung 2009).

Silage crops are harvested and wilted, if necessary, to obtain the moisture content of around 65 to 70 percent. They are chopped to 3/8 to 1/2 inch and packed tightly so that minimum air is left in the silo. Silage crop is put into silo one layer at a time, compact this layer, and put and compact another layer until the silo is full. Fill the silo rapidly, do not leave any time interval between filling layers, and complete it continuously once it is started. Then quickly seal the silo so that no further air would enter the silo. If chopped fine and packed well, aerobic bacteria present there will use up remaining oxygen and release carbon dioxide (within four to six hours under a favorable condition), which will raise silo temperature. When the silo temperature becomes 80 to 100°F, anaerobic bacteria develop and produce acetic acid. After the second or third day, lactic acid producing bacteria become active and produce lactic acid for 16 to 18 days until the pH drops to 3.6 to 4.2; when this pH is reached, all bacterial activity is stopped and fermentation is complete. Under favorable conditions, silage should be ready in three weeks. Well-fermented silage must have pleasant smell and bright yellowish color. Foul smelling and brown or blackish

color indicates low quality or spoiled silage. The quality of silage should remain intact as long as there is no oxygen or water entering the silo (Karki and Gurung 2009).

The quality of well-fermented and preserved silage depends on the stage of forage maturity at harvest. Also, forage should be harvested high enough not to contaminate with soil, as this hinders fermentation. Usual guideline of harvesting forages for silage making is presented in Table 5.4. Silage should be fed as soon as possible after taken out from the silo to avoid possible degradation.

Table 5.4. Usual recommended stage of maturity for harvesting forage for silage making.

Crop	Maturity stage
Corn	Kernels will be dented and black layer visible
Grain sorghum	Late milk to late dough
Forage sorghum	40 inches or late boot stage
Sorghum, sudangrass, johnsongrass, millet	40 inches or boot stage, whichever comes first
Small grains, ryegrass	Boot to early head
Soybeans	Late bloom, seed forming in pods and before lower leaves fall
Alfalfa	Bud to early bloom
Cool-season grasses	Boot to early head, first cutting; thereafter at four to six week intervals.
Hybrid bermudagrass	15 inches at first harvest, thereafter at four to five week interval.

Source: Ball et al. 2007.

### Stockpiling

Cool-season forages such as tall fescue and warm-season forages such as bahiagrass and bermudagrass can be stockpiled for 70-80 days before they go dormant or before the killing frost. Tall fescue is more suitable for stockpiling as compared to orchardgrass and warm-season grasses. Stockpiled tall fescue contains around 14 percent crude protein and over 60 percent digestible dry matter. Orchardgrass makes less growth in fall and deteriorates more quickly in winter compared to tall fescue. Quality of stockpiled bahiagrass and bermudagrass is lower than tall fescue and their leaves deteriorate quicker. To begin stockpiling, the forages in the plots must be closely grazed or harvested for hay, and grazing animals must be taken off these plots for 70 to 80 days before the killing frost or before they go dormant. Fertilizers should be applied to the plots as required based on the soil test recommendation for the desirable quality and quantity of the stockpiled forages. When the stockpiled forage is ready and no other forage available for grazing, it can be utilized with strip grazing. A strip of the stockpiled forage should be made available to the grazing animals using a temporary fence. When that strip is utilized well, the fence should be repositioned making the new strip available for the grazing animals. This way grazing season can be extended, and the requirement of hay and supplementary feeding can be reduced.

## Hands-On Activities and Demonstrations

1. Calculation of the number of paddocks for developing rotational grazing system taking examples of forage species
2. Forage height measurement and calculation of available forages

## Key Points

1. Only rotational or other forms of controlled grazing suitable to manage forages in silvopasture should be practiced. These systems provide a rest period, when pasture plants and soil get a chance to recover from the previous grazing pressures.
2. Grazing should begin only when trees are resistant to possible damage by grazing animals, and forages are well-established and have achieved the grazing height.
3. Grazing should stop when the recommended stubble height for the given forage is reached.
4. At least 50 percent of the leaf volume of forages must be remaining intact with forage plants at the end of each grazing rotation.
5. Stocking rate must be adjusted based on the available forage biomass and animals' requirement.
6. Overgrazing and undergrazing must be avoided.
7. Animals' behavior must be closely monitored and animals moved out of the paddock before they cause any untoward damage to the trees.

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## Chapter 6 NON-TIMBER FOREST PRODUCTS: FOREST FARMING

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### Introduction

Agroforestry is defined as the intentional integration of agriculture with forestry to multiply benefits of both forests and agriculture, resulting in efficient land use and sustainable farming systems. In agroforestry systems, trees or shrubs and their products are intentionally used within agricultural systems, with livestock, or in forests and are cultured with forest trees and plants. Symbiotic relationships between and within species are an important determinant of forest ecosystems and therefore, knowledge, careful selection of species, and good management of trees and crops are needed to optimize the production and positive effects within the system and to minimize negative competitive effects. Agroforestry systems can be advantageous over conventional agricultural and forest production methods through increased productivity, improved economic benefits and social outcomes, and the enhanced ecological goods and services provided. Forest farming is in use worldwide today.

While forest farming, a key agroforestry practice, has been defined as “the intentional manipulation, integration, and intensive management of woodlands that capitalize on specific plant interactions to produce non-timber products,” non-timber forest products are defined as “all biological materials other than timber which are extracted from forest for human use” (De Beer and McDermott 1989). Thus, non-timber forest products include forest produce such as pine leaves, cones, mushrooms, bee products, fruits and nuts, Christmas trees, materials for crafts, fence posts, fuelwood, and medicinal plants. Forest farming allows one to benefit from multiple harvests and multiple products in the short term while waiting for returns from timber in the long run. Many high-value specialty crops are cultivated under the protection of a forest canopy that has been modified to create conducive microclimates and appropriate light conditions. To support this practice, timber-stand improvement activities are carried out to develop the appropriate understory conditions. Shade-tolerant medicinal plants such as American ginseng (*Panax quinquefolius*), black cohosh (*Actaea racemosa*), and goldenseal (*Hydrastis canadensis*), shiitake mushrooms (*Lentinula edodes*), and decorative ferns are grown and sold for medicinal, culinary, or ornamental uses. Other specialty crops include coffee and maple syrup. Forest farming activities modify the forest ecosystem but do not significantly interfere with its crucial contributions of water capture and filtering, soil erosion control, microclimate moderation, and wildlife habitat. Managing the forest to produce non-timber forest products, particularly medicinal plants, is a guaranteed way of generating cash flow faster and in the short term while the landowner waits for years to harvest timber for sale. These forest-farming options need attention in different seasons: bee products, fruits and nuts, mushrooms, and medicinal plants are usually managed during warmer months. Maple syrup is collected and processed in mid to late winter. Firewood, fence posts, and craft materials can be collected year round. Management of these options may compete with time, money, and energy needed by other farm crops. However,

developing several of these options will improve the quality of the remaining timber on the forested land and at the same time provide annual or short-term extra incomes for the landowner (Hill and Mentreddy 2012).

## Beekeeping

Honey, with a total consumption of 410 million pounds in 2010 and valued at \$317.1 million (NASS 2014), is a valuable commodity in the United States (US). The US per capita consumption of honey is around 1.3 pounds per year. The demand for honey in the US far exceeds domestic production, requiring importation of honey mainly from Argentina, India, Vietnam, and Canada. Honey production in the US has steadily declined from 220 million pounds in 2000 to about 178 million pounds in 2014, whereas honey imports increased from 198 million pounds to 365 million pounds during the same period (USDA-NASS 2015). Bees are an important component of forest ecosystems, and forests provide excellent resources for bees and beekeeping (Figure 6.1). Indigenous bee species are natural forest resources, and beekeeping enables their exploitation for valuable products, without necessarily damaging the honeybee populations, or extracting anything except the products, honey and beeswax. While beekeeping is often seen as a hobby in urban areas, it is an important occupation and contributes significantly to livelihoods in rural communities around the world (Adjare 1990). Raising honeybees in hives can produce honey, beeswax, pollen, propolis (beehive glue) and royal jelly. These products can be harvested every year (honey possibly can be harvested more than once a year) and can provide good cash flow. From these basic products, several other value-added products can be developed for more income; for example, Burt's Bees products. Beehives in boxes in woods or along the borders help with pollination of cultivated crops on the farm.

### Bee Basics

Honeybees are highly organized and diligent social insects. Bees are vegetarians; pollen is their source of protein, and honey is their source of carbohydrates derived from nectar. Bees live together in groups, cooperate in foraging tasks and the care of young, and have different types, or “castes,” of individuals (Delaplane 1993). There are three castes of honey bees. Reproductively underdeveloped females are called **Workers** and they do all the work of the colony. A colony may have 2,000 to 6,000 workers. As they age, workers do the following tasks, in this sequence: clean cells, circulate air with their wings, feed larvae, practice flying, and receive pollen and nectar from foragers, guard hive entrance and forage. A **Queen** is a fertile female specialized for producing eggs. When a queen dies or is lost, workers select a few young worker larvae and feed them a special food called “royal jelly.” These special larvae develop into queens. There is only one queen per colony. The queen secretes certain chemicals called “pheromones” in order to regulate the behavior of other bees. Male bees are called **Drones**. A colony may have up to 500 drones during spring and summer. Drones fly from the hive and mate in the air with queens from other colonies. The queen lays all her eggs in beeswax cells built by workers. Developing young



Figure 6.1. A natural beehive on a tree branch in a forest.

Source:

[http://beneficialbugs.org/bugs/Honeybee/honey\\_bee.htm](http://beneficialbugs.org/bugs/Honeybee/honey_bee.htm)

honeybees (called a “**brood**”) go through four stages of development from egg to a young adult. Honeybee colonies live year round. The queen starts laying eggs in January and much of stored honey and pollen is fed to larvae. The colony could fall short of supplies and endanger the bee colony in late winter when plants are not yet producing nectar or pollen. Bee populations grow rapidly as the spring weather and nectar-bearing flowers become more abundant. The colonies become very crowded in April-May when they may split and form new colonies by a process called “swarming.” A crowded colony rears several daughter queens, and then the original mother queen flies away from the colony, accompanied by up to 60 percent of the workers. These bees cluster on some object such as a tree branch while scout bees search for a more permanent nest site - usually a hollow tree. Within 24 hours, the swarm relocates to the new nest. In the original colony from which a swarm left, one of the daughter queens kills the weaker queens and becomes the only queen of the colony. Throughout summer and autumn, bees concentrate on storing honey and pollen for winter. During winter they huddle together into a ball and survive the winter by eating the honey and pollen mix (Delaplane 1993).

### **Getting Started**

In forests, beehives are found on tree branches, in tree hollows, and crevices. Swarms on tree branches can be moved to artificial beehives. This will be easier if the swarm is on a low-lying tree branch or under wooden roof. Spray the swarm with sugar syrup, place a bucket underneath it and then dislodge the swarm by shaking the branch sharply. The swarm will fall into the bucket. Quickly cover the bucket with a screen, for example, a window screen. Install the swarm in a hive. Place the hive in a part of the forest where there is an abundance of flowering plants and it is safe from predators. You can seek the help of a county Extension agent or US forest service agent. Beekeeping in forests is cheap and affordable because there is little or no investment and provides sustained benefits if properly managed. All you need is proper equipment for harvesting honey (Delaplane 1993). Thus, your investment may not exceed \$100.

Whether the beehive is a natural one in a forest or in artificial hives, it must be frequently inspected. An experienced beekeeper usually has a fair idea of how the colonies are progressing by observing them from outside. However to know if honey is being properly made and capped, the artificial hives must be opened and inspected occasionally. Such inspections also help monitor health and loss of honey and bees to predators. Bee colonies must be inspected for a good laying queen; every colony should be protected from extremes of weather. For inspection and harvesting of honey from hives, smoking is practiced rather than fire or live torch. Collecting honey by fire or by live torches is an unsustainable method of harvesting. Beehive management and profiting from beekeeping in forests has been described in detail by Adjare (2009). Though the description is in the African context, most of the information is useful to beekeepers worldwide.

### **Using Beehives in Boxes**

Bees can be reared in artificial boxes, a popular method of beekeeping, in and around the forested area on your farm (Figure 6.2). Buy your bees, equipment and materials and put your hives in a place protected from wind and near either crops or orchards. Get advice from neighbors or your extension office on how many hives to start with and what kinds of bees have been most successful in your area. Check your hives at least once a week for disease or loss of

bees. During dry weather, place sources of water with pieces of wood or styrofoam floating so that bees do not drown in water. Keeping sugar water can help when not many nectar-bearing flowers are around, particularly in winter. Always leave enough honey in the hive for the bees to feed on during the winter – other beekeepers can help you with this. Delaplane (1993) has provided an illustrated guide to beekeeping in the southern US. A detailed description of how to get started and costs involved is provided in Hill and Mentreddy (2012).



Figure 6.2. A beehive in an artificial box hung on a tree branch in a forest.

Source:

<http://www.mbeya.go.tz/investments/investment-in-natural-resources>

### Equipment Required For Beekeeping in Forests or Outside in the Open

A **smoker** is the second most important equipment after the beehive itself. The smoker has two main parts: the container, which is a metallic can, big enough to carry enough dry material to last at least 40 minutes; and the bellows section, which puffs air into the container to drive the smoke out of the can. The container is loaded with wood shavings, smouldering cow-dung, or any dry fuel which provides white smoke. (No oil or kerosene should ever be used in a smoker.) The smoke renders bees docile, so that the beekeeper can work undisturbed (Adjare 1990).

- A **hive tool** in case of artificial hives or simple **knife** for beehives on tree branches in forests. This tool is required to pry up and remove the frames from the beehive.
- The **brush or quill**: A strong, large quill like an ostrich or turkey feather or a brush made of soft hairs is often used to gently brush the bees into a container or another hive.
- The **feeder**, useful to feed bees with water or sugar water on hot dry days. This can be a glass jar or a special container turned upside down and arranged in a way that water trickles slowly from it for the bees to drink.

**Protective clothing (bee suit, veil, gloves, and boots):** A beekeeper is advised to wear suitable protective clothes to keep the bees from reaching his/her flesh. Thus a bee suit, gloves, veil, and a pair of boots should be worn before the honey is harvested or before any work involving the opening of the hive is undertaken. When working with bees during the daylight hours, light-colored clothing (preferably white, yellow, or green) should be worn; for night work, dark colors are better. The cost may vary between \$50 and \$75.

### Crafts

Forests offer tremendous resource materials for making handicrafts ranging from simple wood toys and ornamentals to decorative cloth and furniture. Crafts are an important source of income from forests and are much part of social traditions in almost all states of the US. Crafts from forests are limited by your own imagination! A few examples of crafts that can be made and

sold for profit include but are not limited to: Christmas tree ornaments, wreaths, sweetgum balls, and locust pods painted in various colors, sculptures made of wood, and crafts options created from wood or other materials (seeds, branches, twigs, roots, burls) found in woodlots. Moreover, leaves, pine cones, and nuts can be used as ornaments on wreaths and other arrangements. Baskets and wreaths made of grapevine are quite popular. Typical markets for crafts are floral shops, festivals, county fairs, craft supply stores, and tourist gift shops. Online sales are a major marketing strategy for crafts. Crafts need minimal investment, but marketing is non-traditional and often inconsistent.

Prices for various crafts, for example, wreaths and baskets vary with size, amount of decoration, and location of sale. Retail prices for undecorated wreaths range from \$8 to \$20 and baskets from \$10 to \$25, depending on the size. Decorated wreaths range from \$25 to \$35 and decorated baskets from \$35 to \$45. Large wreaths four to five feet in diameter may be sold for \$100. Prices may be higher or lower depending on product quality and sale location. Prices are higher in the urban locations (Greene et al. 2000). Musical instruments fetch higher prices but need appropriate skills, suitable wood and a few non-forest inputs. Musical instruments have more organized markets and may be easier to sell.

### Floral, Fruits, and Nuts

Most wooded lots or forests abound in various native flora, fruit, and nut-bearing plants that can be harvested and sold for profit. These are mostly seasonal and must be harvested on time. Some common florals that are at the ground level are star flower and club mosses. A few commonly found shrubs are: rhododendron, azaleas, mountain laurel, and huckleberries. The number of floral species found in a forest varies with forest type, elevation, rainfall, and environmental conditions. Investment may not be necessary if these are wild harvested and supplied to local florists. However, flower arrangements and decoratives made from native flowers and plants will need some investment.



Figure 6.3. Non-timber forest products: crafts (A), florals (B), and nuts (C).

Source: <http://www.fao.org/forestry/enterprises/60702/en/> (A)

[http://photos1.blogger.com/img/250/1358/1024/100\\_4219.jpg](http://photos1.blogger.com/img/250/1358/1024/100_4219.jpg) (B)

<http://conservationbiologyforall.blogspot.com> (C)

**Fruits and nuts** occur naturally in woodlots. These include persimmons and pawpaws, wild grapes and berries, black and white walnuts, hickory nuts, hazelnuts, and beech nuts. Because native fruits seem to ripen at the same time, it is hard to get a good price for them as fresh fruit. To avoid competition in the fresh fruit and nut market, consider making value-added products

such as jams, jellies, wines, fruit leathers, or other products. Value-added products have long shelf lives, and can be marketed year-round. The nuts can be gathered in the fall and marketed through farmer's markets and local grocery stores.

It is important to know what is already growing in your woods well. Walk through them and learn to identify the trees and shrubs that are there. If you have these types of native fruit and nut trees, and berries, clear some of the trees that are right next to them, so that the fruit and nut trees can grow bigger crowns, where the fruits and nuts are produced. Make sure you do not over-harvest and lose flowering plants, shrubs, and fruit trees. Ensure they get adequate growing conditions such as light, no or little competition from weeds, and enough nutrients and water. Also allowing some of them to go to fruiting and seeding will ensure sustained supply over the years. There are no special materials or equipment needed for growing and harvesting native fruits and nuts. If you have an established market fetching good prices, it will be worthwhile to buy collecting baskets or bags to make collection easier in the fall, but you can also use buckets and baskets that you may already own. If you decide to make value-added products, then you would need whatever materials and equipment that are necessary to make those (for example: large pots, canning jars and lids for jams and jellies, fermenting equipment, and bottles and caps for wines). Whatever containers (jars, bottles, lids, caps, labels) your value-added products are sold in are examples of materials that will need replacement on an annual basis. Labeling your products and if possible giving away free recipes will help attract buyers more consistently.

## Maple Syrup

(Adapted from Hill and Mentreddy 2012)

Maple syrup is one of our oldest forest products of North America. Native American tribes, particularly in the northeastern US, made it from the sap of maple trees (*Acer* spp.) (Figure 6.4). Maple syrup may be sold as is or converted to high-value products such as maple butter, maple sugar, and maple candies. All of these products have a long shelf-life and can be sold year round. The market for maple syrup and candies generally tends to be greater than the supply.



Figure 6.4. Tapping maple syrup from a maple tree (A), bottled maple syrup (B).

Source:

[https://en.wikipedia.org/wiki/Acer\\_saccharum](https://en.wikipedia.org/wiki/Acer_saccharum) (A), [www.mymnnesotawoods.umn.edu/2011/04/minnesota-maple-blog-series-our-final-post/](http://www.mymnnesotawoods.umn.edu/2011/04/minnesota-maple-blog-series-our-final-post/)

Potential producers of maple syrup must carefully check their woodlots to see what kinds of maple trees are present before starting on this labor intensive enterprise. Maple species such as sugar maple, black maple, silver maple or boxelder at least ten inches in diameter are necessary to begin harvesting the sap. The investment amount varies with the size of the operation size. A small home-use production may require an investment of about \$50 to \$100 whereas a large commercial operation may need investment of several thousand dollars and must be mechanized and automatic (Randall 2015). The number of trees may vary from 20 to more than 100 depending on the size of the operation. Tree health and proper care will ensure sustained

production of good quality syrup. For more information on maple syrup production refer to *North American Maple Syrup Producers Manual* (Bulletin 856) from The Ohio State University.

Maple syrup production is probably the most expensive among non-timber forest products. You need stainless steel equipment (pans, piping, baffles or flanges in the boiling pans) to boil down the sap and should have a special “sugar shack” for exclusive use for making the syrup. The expensive equipment is probably a one-time cost, but it still means the money is going out before the product is bringing in any profits. Buying second-hand equipment may be cost-effective or getting into partnership with others who might be interested in making maple syrup can bring down initial costs. Recurring costs include buckets or tubing, *spiles* (the spigots that go into the trees to collect the sap) for collecting the sap and containers for selling the syrup. Maple syrup and other products may be sold at local grocery stores, craft stores, and farmer’s markets.

## **Medicinal Plants**

Forest medicinal plants grow mostly near the ground under shade, and, like most plants, need special soil and environmental conditions. It is important for the grower to understand the special plant-soil relations for the target plant. Many medicinal plants are most valuable for their roots. Many are also perennials, so that once you have started them growing in an area, they will continue to grow year after year. Some can be harvested every year; some, like ginseng (*Panax quinquefolius*), take many years to grow big enough for a marketable harvest. Before you decide on what crop to grow, walk through your woods and find out what type of trees you have, what your soil type and pH are (see your County Cooperative Extension office for help with this), and what kinds of plants are growing under trees and shrubs. Most of the forest medicinal plants grow in mixed communities. For example, if you have mayapple (*Podophyllum peltatum*), you may also have ginseng, black cohosh (*Actaea racemosa*), goldenseal (*Hydrastis canadensis*) and/or bloodroot (*Sanguinaria racemosa*) growing in your forestland. One very important thing is to find out what the market is for the plant or plants you want to grow by consulting relevant magazines; for example, HerbalGram and internet sources. If raw materials are being sold directly to a consumer, encourage your customers to consult with their doctor when using medicinal plants to help treat health conditions or illnesses.

Most of the well-known forest medicinal plants need 60 to 80 percent shade during their growing season (spring and summer) and deep, moist, well-drained forest soils with pH measurements between 6 and 7. They also will grow best if they have special fungi growing on their roots called *mycorrhizae*. Ginseng, for example, grows well under dense shade from tree species such as sugar maple, tulip-poplar, or black walnut. Ginseng also needs a lot of calcium and does well under maple trees, which supply calcium. There are other forest medicinal plant species such as vanillaleaf (*Carphephorus odoratissimus*), roundleaf sundew (*Drosera rotundifolia* L.), true unicorn (*Aletris farenosa* L.), and trilliums (*Trillium* spp.) commonly found in Southern forests.

## **Forest Farming With Medicinal Plants**

Among non-timber forest products, medicinal plants are probably the most lucrative and perhaps the least understood forest resources. Forest farming is a holistic land-use approach that can enable woodland owners to diversify income opportunities, improve management of forest resources, and increase biological diversity. Forest farming with medicinal plants offers much

potential for woodland owners to generate forest-based incomes in the short term from forest farming with a wide variety of medicinal plant species while waiting for returns from timber in the long term. The forests in the southeastern US are considered to be the most diverse in the country. Yet, there have been limited studies on the potential for growing shade-tolerant plants as understory crops in southeastern forests. There is a renewed interest in forest farming as an enterprise either via wild simulation (growing ginseng using seed stock of wild ginseng without the use of fungicides or expensive equipment). The plants compete with local trees and other wild plants for nutrients and water) or woods cultivation (cultivated using artificial shade and all inputs are provided to avoid competition for nutrients and water) of native forest botanicals in the woods. The USDA listed nearly 50 forest medicinal plant species with potential for commercial use for treating common colds to complex chronic illnesses such as cancers and diabetes. While American ginseng (*Panax quinquefolius*), goldenseal (*Hydrastis canadensis*), and black cohosh (*Actaea racemosa* L.), among a few others, are well-known and perhaps well-exploited, the following medicinal plant species have potential for commercial production in Alabama in particular and the southeastern US in general: vanillaleaf (*Carphephorus odoratissimus*), fringe tree (*Chionanthus virginicus*), roundleaf sundew (*Drosera rotundifolia*), evening trumpet flower (*Gelsemium sempervirens*), Canadian licorice root (*Ligusticum canadense*), queen's delight (*Stillingia sylvatica*), yellowroot (*Xanthorhiza simplicissima*), true unicorn root (*Aletris farinosa*) and Hercules' club (*Zanthoxylum clava-herculis*). Scouting your woodland will help you find out what is already growing in your woodlot and also helps decide what grows best among the forest trees. Forest farming can be growing adapted species as wild-simulated or woods-cultivated.

#### *Wild-Simulated Method*

The wild-simulated method is easier and cheaper, and can make money on a large or small scale. Planting seed or propagules in the fall is preferable. After identifying what grows best in your wood lot, select suitable spots which allow for limited manipulation of the site without much disturbance to the ecosystem. Take soil samples representative of the site and have it tested for pH and other soil nutrients. Soil pH may be adjusted using gypsum to correct acidic soil or rock phosphate or elemental sulphur if the soil pH is too alkaline. This is usually done the previous fall. Using a rake or a garden hoe, rake the leaves aside, make furrows one inch deep and about three inches wide, about 18 inches apart in beds or five feet wide and about 50 feet long under trees that make about 70 percent shade. Plant stratified seed (seed that has gone through a cold period – either over winter or in a refrigerator) three inches apart in the furrow, cover the seeds with a three-fourth ( $\frac{3}{4}$ ) inch of soil and lightly press down the soil. Rake the leaf litter back over the seedbed. Water well if the soil is dry and rainfall is inadequate. The seed will germinate the next spring. In the wild-simulated method for ginseng, no more work is required after planting until the roots are dug six to ten years later. The valuable part of the plant in most forest medicinal plants is the root. Since many of the medicinal plants need more than one year to mature for market, new beds should be planted every fall, for future harvests. The quality of harvest depends on whether or not you have chosen a site that is good for your target plants.

#### *Woods-Cultivated Method*

Preparing cultivated beds (woods-cultivated) under the forest canopy requires more labor, so it is more difficult to develop an acre of product using this method. You need small machinery for

disking and preparing seed beds. This has a higher cost because it needs more materials, equipment, and/or labor. In this method, prepare a fine seed bed under the shade of the trees using farming equipment. Soil sampling and adding amendments are the same as those described for the wild-simulated method. Plant seeds or 1- to 2-inch long root pieces the same way as in the wild-simulated method. However, with woods-cultivation, you may need to apply organic chemicals to protect the plants from weeds, insects, and diseases more than wild-simulated. In terms of both labor and chemicals, this increases the cost of production. The more intensive management for woods-cultivation may give you higher yields than you would get with the wild-simulated method.

#### *Insect and Disease Management*

Generally, insects and diseases may not be a major problem if locally adapted species are cultivated in their habitats. However, organic pesticides such as neem extract, dipel, and pyganic may be used to control insect pests, and elemental copper, sulfur, and biosafe fungicides listed by Organic Materials Review Institute may be used to control diseases. Encouraging birds and bats helps control insect pests. Select disease-free seed and propagules when planting.

#### *Yields and Production Economics*

Medicinal plants can be grown for raw products such as the roots, stems, bark, leaves, or combinations of these from the same kind of plant. Some can be marketed fresh, but most are sold dried. They are bulky materials and need proper storage and packaging. They will involve shipping costs which may reduce the amount of your profit. Adding value or product packaging, such as making tinctures, lotions, steam-distilled aromatic oils, and soaps could bring higher prices and greater profits. Organic production of medicinal plants is preferable to the conventional production system.

#### *Goldenseal Production*

**Goldenseal** production (Based on information provided by goldenseal producer, Mr. Randy Beaver, Dalton, GA):

Land preparation and planting system:

- Clear six to eight-foot wide alleys between the larger trees of scrub and undergrowth using a small backhoe
- Prepare four-foot wide fine seedbeds by tilling within the alleys.
- Adjust soil pH to native conditions, 6.0 to 6.5 with dolomitic lime or elemental sulfur.
- Divide each goldenseal rhizome into 4.5 to 5.0 gram pieces each with a bud and at least one root, and use as planting stock. (Based on grower's experience, the rhizome is expected to double in size every two years, resulting in a harvest size of 18 to 20 grams after four years.)
- Plant pieces of goldenseal rhizomes in a 6" x 6" spacing pattern, yielding 400 plants per 100 square feet. (Because of tree placement, topography, and the need to retain sufficient space for bed maintenance, about 25 percent or 10,000 square feet of bed space is usable per acre, providing room for roughly 40,000 plants per acre.)

A summary of the production and yield assumptions underlying the 5-year financial projections for goldenseal are presented in the tables below (Table 6.1 and Table 6.2).

Table 6.1. Estimated yield and return from one-fourth of an acre of goldenseal cultivation.

Yield or return	Amount
Yield per ¼ acre	400 lbs (10,000 plants per ¼ acre @ 18 grams = 180,000 grams)
Yield allocation	133 lbs replanted, 277 lbs net fresh harvest, 89 lbs net dry harvest
Return per ¼ acre	\$6,372 (89 lbs dry harvest x \$71.59/lb)

Income potential for farmer from raw goldenseal production

An annual net income potential of \$5,600/acre for a small farmer with one acre of forestland suitable for goldenseal production is possible when planted according to the following sustainable production system:

- The farmer would plant ¼ acre of goldenseal per year for four years.
- In the fifth year the farmer would harvest the goldenseal planted in the first year.
- Approximately one-third of that harvest would be replanted and harvested in another four years.

The potential profit from a production cycle of goldenseal is presented in Table 6.2.

Table 6.2. Net profit or loss from one complete 8-year goldenseal production cycle.

Item	Year							
	1	2	3	4	5	6	7	8
Planting stock & seed	\$1,250	\$1,250	\$1,250	\$1,250	\$0	\$0	\$0	\$0
Equipment costs	\$250	\$250	\$250	\$250	\$125	\$125	\$125	\$125
Soil amendments	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
Property taxes	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50
Organic certification					\$500	\$500	\$500	\$500
Out-of-pocket expense	\$1,650	\$1,650	\$1,650	\$1,650	\$775	\$775	\$775	\$775
Income	0	0	0	0	\$6,372	\$6,372	\$6,372	\$6,372
Profit or (Loss)	(\$1,650)	(\$1,650)	(\$1,650)	(\$1,650)	\$5,597	\$5,597	\$5,597	\$5,597

- No income is received in Years 1 through 4. In Year 5 (the first harvest year), the farmer recovers 85 percent of the out-of-pocket expenses incurred in Years 1 through 4.
- The system is sustainable, with the planting stock cost of the first four years becoming a capital investment which doesn't have to be repeated.
- This system gives individuals contemplating entering agriculture an opportunity to develop a reliable income stream on a part-time basis before going full time.

- It also allows existing farmers to diversify their operations without taking away from acreage used for other crops.

### Selected Forest Medicinal Plants and Their Uses

Many of the following species have been described in Davis and Persons (2014).

**American ginseng**, grown for its rhizomes, is used as an adaptogen, stimulant and a tonic (Figure 6.5). According to Ehrlich (2013), American and Asian ginsengs have been shown to have antidiabetic and anticancer properties in laboratory research. American ginseng in combination with ginkgo (*Ginkgo biloba*) has been suggested to help treat attention deficit hyperactivity disorder. American ginseng is also known to reduce the duration of flu symptoms.



Figure 6.5. American ginseng.

Source:

[http://www.hobbyfarms.com/images/blog/dawn/american-ginseng\\_800.jpg](http://www.hobbyfarms.com/images/blog/dawn/american-ginseng_800.jpg)

**Goldenseal:** Rhizomes of this plant are used as an antimicrobial, anti-inflammatory and as an astringent (Figure 6.6). It soothes irritated mucus membranes aiding the eyes, ears, nose and throat. Taken at the first signs of respiratory problems, colds and flu, goldenseal may help prevent further symptoms from developing. It may be used to help reduce fevers and relieve congestion. Goldenseal is known to cleanse and promote healthy glandular functions by increasing bile flow and digestive enzymes, and to regulate healthy liver and spleen functions. It eases inflamed peptic ulcers, aids digestion and relieves constipation. It may be used to treat infections of the bladder and intestines as well (Ehrlich 2013).



Figure 6.6. Goldenseal.

Source:

<http://www.alchemyifa.org/herbs/goldenseal.html>

**Black cohosh:** Rhizomes of black cohosh are known to alleviate menopausal symptoms and the plant is generally used as an alternative to hormonal replacement therapy (Figure 6.7). Some of the traditional uses of black cohosh include: malaise, gynecological disorders, kidney disorders, malaria, rheumatism, and sore throat (Foster 1999). Upton (2002) reported that it was also used to treat colds, cough, constipation, hives, and backache.

**Bethroot (*Trillium erectum*)** rhizomes are known for their antiseptic, poultice, tonic, expectorant, birthing aid, aphrodisiac and astringent properties (Plants for future 2015) (Figure 6.8). Davis and Greenfield (2002) reported the use of **Ramps or Wild leeks (*Allium tricoccum*)**

as an integral part of a vitamin and mineral tonic (Figure 6.9). They have also been used as a preventative measure against colds and the flu, and for part of a cure for scurvy (Legault 2003; Feiring 2006). The plant is also used as a blood and digestive system cleanser and as an anticholesterolemic and antilipidemic agent (Cavender 2006). Selenium-enriched ramps have been shown to reduce effects of cancer in a rat-model study (Davis and Greenfield 2002).

**Bloodroot** rhizomes are used as an expectorant, alterative, stimulant, diuretic, febrifuge, sedative, antibacterial, emmenagogue, tonic, and as an emetic in larger doses (Figure 6.10) (Medicinal herb information 2015).



Figure 6.8. Bethroot.

Source:

<https://upload.wikimedia.org/wikipedia/commons/d/df/TrilliumErectum.jpg>



Figure 6.7. Black cohosh.

Source:

<https://belfirebotanicals.wordpress.com/2011/03/07/black-cohosh-and-the-latest-%E2%80%9Cstudy%E2%80%9D/>



Figure 6.9. Wild leeks.

Source:

<http://kuse.medford.k12.wi.us/Plants/FlowersWild/LilyFamily/LeekWild.htm>

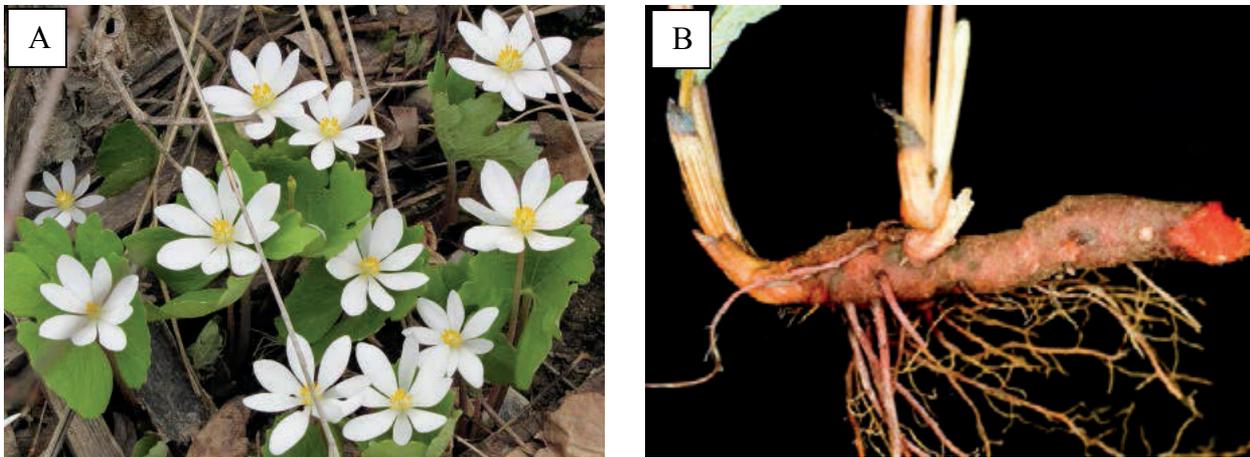


Figure 6.10. Bloodroot flower (A), root (B).

Source: [https://playoaklandcounty.files.wordpress.com/2014/12/img\\_0217.jpg](https://playoaklandcounty.files.wordpress.com/2014/12/img_0217.jpg) (A), [http://23.253.106.247/plant-talk/wp-content/uploads/2013/04/CG-1-Sanguinaria\\_canadensis\\_02\\_rhiz\\_GWD.jpg.jpeg](http://23.253.106.247/plant-talk/wp-content/uploads/2013/04/CG-1-Sanguinaria_canadensis_02_rhiz_GWD.jpg.jpeg) (B)

**False Unicorn (*Chamaelirium luteum*):** The rhizome and root are used for treating ovarian cysts, menstrual problems, menopausal symptoms, vomiting from pregnancy and infertility in women (Figure 6.11). Some women take it to normalize hormones after discontinuing birth control pills. False unicorn is also used to treat digestive problems and to relieve water retention by increasing urine flow. Some people also use it to rid the intestines of worms (WebMD 2015).



Figure 6.11. False unicorn.

Source:

[http://www.wildcrafted.com.au/Botanicals/False\\_Unicorn.html](http://www.wildcrafted.com.au/Botanicals/False_Unicorn.html)



Figure 6.12. Mayapple.

Source:

[http://plants.usda.gov/java/largeImage?imageID=pope\\_003\\_avp.tif](http://plants.usda.gov/java/largeImage?imageID=pope_003_avp.tif)

**Mayapple:** This plant is known for its action on liver and bowels, and is used as purgative in mild doses (Figure 6.12). At large doses, it can damage the intestines and could prove to be fatal. Mayapple can influence every system of the body as it stimulates the glands. It is used to treat skin diseases at small doses (Greaves 2015). Traditionally mayapple rhizomes were used to treat typhoid, hepatitis, fever, and cholera (Davis and Persons 2014).



Figure 6.13. Spikenard.

Source:

[https://upload.wikimedia.org/wikipedia/commons/2/20/Aralia\\_racemosa1.jpg](https://upload.wikimedia.org/wikipedia/commons/2/20/Aralia_racemosa1.jpg)



Figure 6.14. Wild ginger.

Source:

[http://plants.usda.gov/java/largeImage?imageID=asca\\_002\\_ahp.tif](http://plants.usda.gov/java/largeImage?imageID=asca_002_ahp.tif)

**Spikenard (*Aralia racemosa*)** root is used for treating colds, coughs, asthma, arthritis, and skin diseases (Figure 6.13). It is also used to loosen chest congestion, boost tissue growth and promote sweating (WebMD, 2015). **Wild Ginger (*Asarum canadense*)** rhizomes have been used as a stimulant, diuretic, and carminative (Figure 6.14). Native Americans and then early settlers used the plant as a poultice to treat wounds as it was known for its antibiotic properties (Stritch 2015).



Figure 6.15. White fringetree.

Source:

[http://plants.gertens.com/12070009/Plant/89/White\\_Fringetree](http://plants.gertens.com/12070009/Plant/89/White_Fringetree)

#### **Suitable Medicinal Plants for the Southeast**

Some forest medicinal plant species with potential for production in the southeastern US, particularly Alabama are presented below.

**White fringetree** roots are used as a diuretic, tonic for treating disorders of abdominal glandular organs, external inflammations, and wounds (Figure 6.15). **Vanillaleaf** leaves are used for treating coughs, malaria, and neurosis (Figure 6.16). It could be toxic at high doses.

**Roundleaf sundew** plant is used as an antibacterial, antibiotic, antispasmodic, antitussive, expectorant, and hypoglycemic (Figure 6.17). It is also used in treatment of whooping cough, chronic bronchitis, and asthma. Externally, it has been used to treat corns, warts, and bunions. Use with caution. Internal use of this herb causes a harmless coloring of the urine. **Evening trumpet flower** is used for various ailments in different countries (Figure 6.18). It is used as an analgesic in Mexico. In many countries, it is used for treating asthma, cough, as a dermatologic aid, and depressant. It is also used for cephalgia, dysmenorrhea, fever, gonorrhea, hypertension, malaria, migraine, neuralgia, pertussis, pleurisy, and stomachache.



Figure 6.16. Vanellaleaf.

Source:

[http://goldsborodailynews.com/wp-content/uploads/Carphephorus\\_odoratissimus1.jpg](http://goldsborodailynews.com/wp-content/uploads/Carphephorus_odoratissimus1.jpg)



Figure 6.17. Roundleaf sundew.

Source:

[https://en.wikipedia.org/wiki/Drosera\\_rotundifolia](https://en.wikipedia.org/wiki/Drosera_rotundifolia)



Figure 6.18. Evening trumpet flower.

Source:

[https://commons.wikimedia.org/wiki/File:Gelsemium\\_sempervirens\\_002.JPG](https://commons.wikimedia.org/wiki/File:Gelsemium_sempervirens_002.JPG)



Figure 6.19. Canadian licorice-root

Source: <http://plants.usda.gov/core/profile?symbol=LICA16#>

**Canadian licorice-root** is chewed in the treatment of any stomach disorders (Figure 6.19). **Queen's Delight** root is antiemetic (Figure 6.20). A decoction has been used to treat bird sickness, diarrhea, vomiting, and appetite loss in children and in adults. It has also been used to treat menstruation sickness, yellow eyes, and skin weakness. A decoction or tincture of the root has been used to treat the worst forms of venereal disease.

**Slippery Elm (*Ulmus rubra* - Muhl.):** Slippery elm bark is a widely used herbal remedy and is considered to be one of the most valuable of remedies in herbal practice (Figure 6.21). It is an effective remedy for irritated mucus membranes of the chest, urinary tubules, stomach, and intestines. The inner bark contains large quantities of a sticky slime that can be dried to a powder or made into a liquid. The inner bark is harvested in the spring from the main trunk and from larger branches; it is then dried and powdered for use as required. Ten-year-old bark is said to be the best.



Figure 6.20. Queen's delight.  
Source: <https://whatfloridanativeplantsbloomingtoday.wordpress.com/category/red-blooms/>

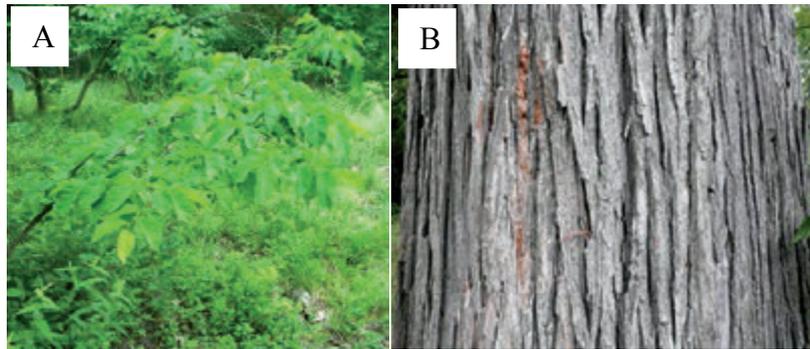


Figure 6.21. Slippery elm plant (A) and trunk (B).  
Source: <https://gobotany.newenglandwild.org/species/ulmus/rubra/> (A), <http://www.hydratationfactor.com/celldrate/> (B).

**Yellowroot:** A tea made from the roots of this forest medicinal species is used to treat mouth ulcers, stomach ulcers, colds, and jaundice (Figure 6.22). The alkaloid 'berberine' in its roots is used for its tonic properties and for digestive disorders. It is also used as an anti-inflammatory, haemostatic, antispasmodic, immuno-stimulant, and antimicrobial. It stimulates the secretion of bile and bilirubin, and may be helpful in correcting high tyramine levels in people with liver cirrhosis.

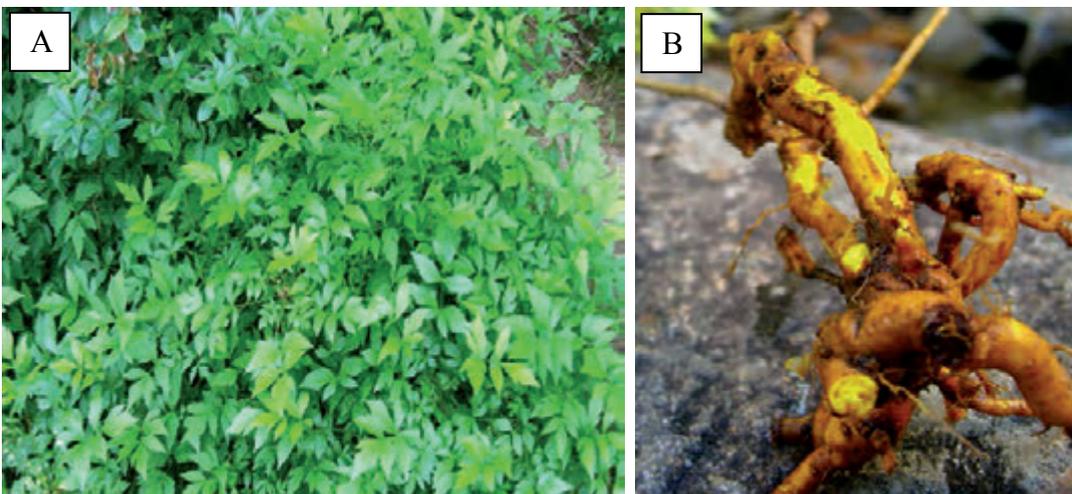


Figure 6.22. Yellowroot plant (A), root (B).  
Source: <http://www.naturallandscapesnursery.com/xanthorhiza.htm> (A)  
<https://woolgatheringwildcrafting.wordpress.com/tag/red-amaranth> (B)

**White colicroot (*Aletris farinose* L.):** The fresh roots of this plant are used for “female complaints”; tones the uterus, calms stomach, and may have narcotic and estrogenic properties (Figure 6.23). This plant is also called star grass, colicroot, true unicorn root, and ague root.

## Mushrooms

(Adapted from Hill and Mentreddy 2012)

Several kinds of mushrooms grow naturally in woodlots; some can be eaten and others may be poisonous. Fortunately, most of the ones you can eat look a lot different from the ones that can make you sick. In addition to the kinds of mushrooms that grow naturally in our woodlots, there are some that can be grown commercially. The major mushroom that is grown commercially is a Japanese mushroom called shiitake (*Lentinula edodes*). Most mushrooms grow either on the forest floor or on wood. Shiitake mushrooms are grown on native hardwood trees. Although they can be grown on pine and other conifer trees, the resins in those trees affect the way the mushrooms taste, so they are not recommended.

## Production

If you are interested in native mushrooms, the first step is to walk through your woods and see what kinds of mushrooms you find. Presented below are some of the mushrooms that can be grown commercially.

**Morels** mushrooms (*Morchella* spp.), often called dry land fish, are very valuable in the marketplace and are highly prized by restaurant chefs (Figure 6.24). They appear in the spring, grow on the forest floor, and have a cone-shaped cap with lots of pits or “holes” in them – they can be black, cream-colored, or yellowish. They often can be found where there has been a fire, or near apple or elm trees (there might be apple trees in the woods where an old homestead once was). **Chanterelles** mushrooms (*Cantharellus*

*cibarius*) are bright yellow mushrooms that also grow on the forest floor, often in groups, and their shape is like a vase rather than a rounded cap like many other mushrooms (Figure 6.25). These two mushrooms are most likely found on north- or east-facing hillsides



Figure 6.23. White colicroot.

Source:

<http://plants.usda.gov/core/profile?symbol=ALFA2#>



Figure 6.24. Morels mushroom.

Source:

<https://en.wikipedia.org/wiki/Morchella>



Figure 6.25. Chanterelles mushroom.

Source:

<http://tcpermaculture.com/site/2013/12/12/seventy-distinctive-mushrooms-part-six-51-60/>

where the soil is damp and cool. Both are worth a lot in the marketplace, but are very difficult to control in any way.

**Lion’s mane** mushrooms (*Hericeum erinaceus*), which is a white or cream-colored mushroom, either looks like large cotton balls or like a frozen waterfall of little teeth in summer or fall (Figure 6.26). These are single mushrooms that can grow quite large, and they often are found on hardwood trees that have been injured.



Figure 6.26. Lion’s mane mushrooms.  
Source:  
<http://www.vitalitymushrooms.com/category/lions-mane/>

**Hen-of-the-woods** mushrooms (*Grifola frondosa*), also called maitake, often grows at the base of trees and looks like turkey feathers, with many overlapping shell-like brown and cream-colored rosettes in the late summer or fall (Figure 6.27). **Wine-cap** or burgundy-cap mushrooms (*Stropharia rugoso-annulata*) can be found alone or in groups on the forest floor, but in areas that are more open, even in grassy areas in the spring and summer (Figure 6.28). These reddish-capped mushrooms (which give them their common names) can grow to be very large, and are best picked when they are small – the size of button mushrooms in the market. **Reishi** mushroom (*Ganoderma tsugae*) is not edible, but is used as a medicinal plant (Figure 6.29). When it forms a mushroom, usually growing on logs or stumps of conifer trees, it hardens quickly. When picked, it can be ground to a powder and put in capsules or made into tinctures. The Chinese call it “elixir of life” and, like many natural medicinal plants, it could improve the immune system. These can be found all year, but usually grow from spring to fall.



Figure 6.27. Hen-of-the-woods mushroom.  
Source:  
<http://effegua.myphotos.cc/Funghi/Pori/Grifola%20frondosa-2008%2010%2022-Lombardore.jpg>



Figure 6.28. Wine cap mushroom.  
Source:  
[https://commons.wikimedia.org/wiki/File:Kulturtr%C3%A4uschling\\_Stropharia\\_rugosoannulata.jpg](https://commons.wikimedia.org/wiki/File:Kulturtr%C3%A4uschling_Stropharia_rugosoannulata.jpg)

Lion's mane, hen-of-the-woods, and reishi mushrooms can be grown on logs (hardwoods for the first two, and conifers for reishi). Wine-cap can be grown on sawdust or wood chips. Growing these mushrooms intentionally is pretty much the same for all types. You need logs of a size that you can lift and move around (usually three to eight inches in diameter and three to four feet in length). The trees from which you get the logs **MUST** be alive and healthy at the time you cut them. Then you inoculate the logs with the spawn of the mushroom you want to grow. Spawn is a mixture of sawdust and spores of the mushrooms, with a little grain added for extra food for the growing mycelium, which is the main part of the organism – mushrooms are the fruits of the organism. For shiitake, sometimes the spawn comes in the form of small dowels which have been mixed with the spores so that the mycelium starts to grow. Inoculation is simply drilling holes in the logs, putting the spawn into the holes and sealing the holes with hot wax. Then the logs are left to incubate in damp, humid conditions under shade of trees or in a controlled environment in greenhouses for several months before it is time for the mushrooms to start growing.



Figure 6.29. Reishi mushroom.  
Source: <http://fungially.com/mushroom-species/>

#### *Materials and Equipment*

To start a mushroom production business, you will need logs, a high-speed drill with wood bits, spawn, an inoculating tool if you use sawdust spawn, cheese wax and something flameless to heat it in (a secondhand fry-daddy works well, or a hot plate), something to use to put the hot wax with on the logs (dauber, paintbrush), aluminum tags, hammer, and nails. It will protect your back if you have a high table or bench, or an X-shaped sawhorse to work on when you are drilling the logs. You will also need containers for selling the mushrooms, and a refrigerator to store them in. Most of the mushrooms you can grow will take several months to incubate in the logs. Mushrooms like moisture; so, you need to make sure the logs stay damp during their incubation period, and you will need either something like a stock watering trough or a sprinkler system to keep them damp. Check with your local Cooperative Extension Office to see if there are any inoculation workshops scheduled and go to one of those to get some hands-on experience. There also are materials on the internet that can walk you through the steps of inoculation (for example, FOR-77 *Growing Shiitake Mushrooms on Logs: Step-by-Step in Pictures* from the Department of Forestry at the University of Kentucky). Materials and tools are also available from several sources around the US. If you are collecting native mushrooms, all you need is containers to collect them into (bags, baskets) and the time to go mushroom hunting!

#### *Start-Up and Recurring Costs*

If you do not already own a high-speed drill (800-1000 rpm), that will be the most expensive start-up cost (\$250-300). Any kind of equipment that you need to buy for your mushroom operation (for example, an inoculation tool (\$30-40)), will be a start-up cost and will not need to be repeated. The cost of wax and spawn will be the next highest cost (approximately \$25 for 2

lbs of sawdust spawn or 1000 dowels – enough to inoculate 10-15 logs). If you do not have your own woodlot, then the logs themselves will be a cost (\$1-2/log). You may be able to work with an ongoing logging operation and get logs from the tops of trees or from large branches – this may reduce the cost of the logs. Once the logs have been inoculated, they can probably produce mushrooms for a few years (3-5 years, depending on the diameter of the logs). If you want a steady business for several years, you would be inoculating some new logs every year. Start small (maybe 50 or 100 logs) and find out how well the logs produce and whether or not you like working with logs and mushrooms. The mushroom season runs from early spring to late fall, and if you have a building in which you can control heat and humidity, it is possible to produce mushrooms all year long. Because the logs are usually stacked like cordwood several logs high, 50 or 100 logs do not take up much space. They DO need to be in an area where they will receive 80 percent or more shade year round, so if you have a little pine stand, that might be the best place to put the logs.

Marketing these unusual mushrooms is the hard part. You will need to contact local grocery stores, farmers' markets, and restaurant chefs to sell them. It would be good to check out the market possibilities BEFORE you inoculate logs, but if you start with a small number of logs, you have about six months to do your homework before the mushrooms start appearing. Throughout the South, shiitake mushrooms have sold from \$8 to \$16 a pound fresh weight, mainly in farmers' markets. Selling to restaurants is like selling wholesale, so you would get less from them, but they can be very reliable customers. There is no set market like those for corn and soybeans and other products for these mushrooms; so, you have to make your own markets. If you do not like working with the public and with small businesses like grocery stores, then this is not a good option for you.

## **Economics**

(Adapted from Hill and Mentreddy 2012)

The economics of developing non-timber forest products in a forest farming system can be very different from open field agriculture. Options like maple syrup or medicinal plants will probably need an investment of several hundred dollars to get all the necessary equipment. On the other hand, options like crafts materials and native fruits and nuts may not require any out-of-pocket costs other than containers to sell the products in. Products like maple syrup, some medicinal plants, mushrooms, and honey are high-value products and will bring a quick return on investment, while crafts, jams, and jellies may make money in volume rather than in per unit value. A variety of options have been provided to you here. References to help you look into further options have also been listed. Depending on what resources you have in your woodlots, you could choose to do one of these options, or do several, or all of them. Many have specific times of year when you need to work on them (maple syrup production is usually a four- to six-week period in late winter/early spring, and then you are done for the season), and others (for example, crafts) can be worked on all year. Choose things that interest you and that you know you will be able to market locally (or on the internet if you are computer savvy).

Thus, this multistoried farming with trees enhances economic diversification and improves value and diversity of existing woodlands. Forest farming increases cash flow in the short term while the owner waits for years for economic returns from harvesting timber. Production of forest

farming products, particularly handicrafts, medicinal plants, and mushrooms, has remarkable cultural and social implications besides economics and efficient land utilization.

### **Hands-On Activities and Demonstrations**

1. Honey production tools and supplies will be demonstrated and described, and honey harvesting and tasting opportunity offered.
2. Mushroom spawn inoculation will be demonstrated, and then participants will be offered with the chances of inoculation.
3. Medicinal plants will be demonstrated and described.

### **References**

Hill, D. R., and R. S. Mentreddy. 2012. "Forest Farming." In: J. O. Idassi (Compiler). *Profitable Farms and Woodlands: A Practical Guide in Agroforestry for Landowners, Farmers and Ranchers*. USDA National Agroforestry Center, Lincoln, NE.

### **Useful Resources**

#### **Apiculture**

Brushy Mountain Bee Farm, Inc., 610 Bethany Church Rd., Moravian Falls, NC 28654. [www.brushymountainbeefarm.com](http://www.brushymountainbeefarm.com)

Dadant & Sons, Inc., 2014, *The hive and the honey bee*, Hamilton, Illinois.

Delaplane, K.S., 1993, *Honey bees & beekeeping: A year in the life of an apiary*, The University of Georgia, Georgia Center for Continuing Education, Athens, GA.

Honey, National Agricultural Statistics Service, USDA, and Bureau of the Census, U.S. Dept. of Commerce. Retrieved May 9, 2015.

Morse, R.A. & T. Hooper (eds.), 1985, *The illustrated encyclopedia of beekeeping*, E. P. Dutton, Inc., New York, NY.

National Agricultural Statistics Service, Agricultural Statistics Board, USDA, 2014. Retrieved May 8, 2015.

Rossmann Apiaries, Inc., P. O. Box 909, Moultrie, GA 31776. [www.gabees.com](http://www.gabees.com)

Seeley, T.D., 1985, *Honeybee ecology*, Princeton University Press, Princeton, NJ.

Winston, M.L., 1987, *The biology of the honey bee*, Harvard University Press, Cambridge, MA.

State Beekeeping Associations

Beginning Beekeeping in Kentucky

Stephen O. Adjare. 1990. FAO Agricultural Services Bulletin 68/6; Food and Agriculture Organisation of the United Nations, Rome, 1990.

The A.I. Root Co., 1990, *ABC & XYZ of bee culture* (40<sup>th</sup> edition). Medina, Ohio.

The Walter T. Kelley Co., P.O. Box 240, Clarkson, Kentucky 42726. [www.kelleybees.com](http://www.kelleybees.com)

**Crafts**

Local or state crafts guilds or other organizations

Local or state floral distributors/wholesalers

Greene, M. Sarah, A. L. Hammett and Shashi Kant. 2000. Non-Timber Forest Products Marketing Systems and Market Players in Southwest Virginia: Crafts, Medicinal and Herbal, and Specialty Wood Products. *Journal of Sustainable Forestry*, Vol. 11(3):19-39.

Wood workers organizations

**Fruits & nuts**

Cooperative Extension county offices

Nut growers' associations

Orchard organizations

State Departments of Agriculture

**Maple syrup**

Dominion & Grimm Inc. dgusa@together.net

Leader Evaporator Co., Inc. LEADER@Together.net

*North American Maple Syrup Producers Manual* (Ohio State University)

North American Maple Syrup Council: [www.northamericanmaple.org/](http://www.northamericanmaple.org/)

Waterloo/Small, Waterloo USA Inc. [www.waterloo-small.com](http://www.waterloo-small.com)

**Medicinals/botanicals**

American Botanical Council -- <http://www.herbalgram.org/>

American Herbal Products Association (AHPA) -- <http://www.ahpa.org/>

Association for Temperate Agroforestry [http://www.aftaweb.org/forest\\_farming.php](http://www.aftaweb.org/forest_farming.php)

Aveda Corporation -- <http://www.aveda.com/>

Botanical Enterprises, Inc. -- <http://www.bei-botanicals.com/>

Botanical Liaisons -- <http://www.botanicalliaisons.com/>

De Beer, J.H. and McDermott, M.J. 1989. *Economic Value of Non-timber Forest Products in Southeast Asia*. Netherlands Committee for IUCN, Amsterdam.

Elk Mountain Herbs -- <http://www.elkmountainherbs.com/>

Frontier Herbs – <http://www.frontiercoop.com/>

Hardscrabble Associates – 1061 Mountainview Rd., Waterbury, Vermont 05676, USA

Foster S: Black cohosh: *Cimicifuga racemosa*: a literature review. *HerbalGram* 45: 35-49, 1999.

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<http://www.pfaf.org/user/Plant.aspx?LatinName=Trillium+erectum>. Retrieved May 8, 2015. <http://medicinalherbinfo.org/herbs/Bloodroot.html>
- <http://www.webmd.com/vitamins-supplements/ingredientmono-193-false%20unicorn.aspx?activeingredientid=193&activeingredientname=false%20unicorn>
- Jeanine M. Davis and W. Scott Persons. 2014. *Growing & Marketing Ginseng, Goldenseal & Other Woodland Medicinals*. New Society Publishers. ISBN: 978-0-86571-766-4
- Non-Timber Forest Products <http://www.sfp.forprod.vt.edu/>
- Non-Timber Forest Products Information Exchange - <http://www.ifcae.org/ntfp/>
- Pfizer - <http://www.pfizer.com/pfizer/main.jsp>
- Scott Persons, W. *Green Gold* (ginseng)
- Steven D. Ehrlich. 2013. Solutions Acupuncture, a private practice specializing in complementary and alternative medicine, Phoenix, AZ. Review provided by VeriMed Healthcare Network. Source: [Goldenseal | University of Maryland Medical Center http://umm.edu/health/medical/altmed/herb/goldenseal#ixzz3ZgaGTq13](http://umm.edu/health/medical/altmed/herb/goldenseal#ixzz3ZgaGTq13).
- Steven Foster Group, Inc. - <http://www.stevenfoster.com/>
- Stritch, L. 2015. Wild Ginger (*Asarum canadense* L.). [http://www.fs.fed.us/wildflowers/plant-of-the-week/asarum\\_canadense.shtml](http://www.fs.fed.us/wildflowers/plant-of-the-week/asarum_canadense.shtml). Retrieved May 8, 2015.
- The Center for Agroforestry <http://www.centerforagroforestry.org/practices/ff.php>
- Upton, R. (ed.) *Black Cohosh Rhizome Actaea racemosa* L. syn. *Cimicifuga racemosa* (L.) Nutt. Standards of analysis, quality control, and therapeutics. American Herbal Pharmacopoeia and Therapeutic Compendium. Santa Cruz, CA. American Herbal Pharmacopoeia, 2002: 1-38.
- USDA National Agroforestry Center <http://www.unl.edu/nac/forestfarming.htm>

### **Exotic and native mushrooms**

- Field & Forest Products, Inc. (WI) [www.fieldforest.net/](http://www.fieldforest.net/)
- Mushroom Harvest (OH) [mushrooms@eureka.net](mailto:mushrooms@eureka.net)
- Mushroompeople (TN) [www.mushroompeople.com](http://www.mushroompeople.com)
- Northwest Mycological Consultants, Inc. OR. [www.nwmycol.com](http://www.nwmycol.com)
- Kentucky Shiitake Production Workbook, VHS/DVD/CD: *Growing and Marketing Shiitake Mushrooms on Natural Logs* (Kentucky)

## Chapter 7 NUT-TREE-BASED ALLEY CROPPING SYSTEM

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### Introduction

Alley Cropping is an agroforestry practice which uses agricultural or horticultural crops in the alleyways between widely-spaced tree rows. Alley cropping can have unlimited planting combinations. Common examples include wheat, corn, soybeans, or hay cultivated between black walnut or pecan tree rows. Other trees and shrubs that have been used include chestnut, hazelnut, persimmons, and decorative willows. Alley cropping can be applied to most agricultural landscapes by selecting trees and crops that are well-suited to the particular field. When properly applied, alley cropping can enhance and diversify farm income avenues, increase crop fertility, improve the surroundings, create wildlife sanctuaries, and give protection to the crops planted in the alleyways.

Crops that are planted in the alleyways may consist of perennials or annuals. Perennials are crops that grow year after year after year in their life cycle. Annuals are crops that grow in one year to complete their life cycle. If perennials and annuals are combined, multiple crops can be produced throughout the year to create income at different seasons. Growing a variety of crops can yield multiple crops and incomes in more than one month, and better utilize space, time, and other resources to the landowner's advantage. When trees are established in rows separated by wide spacing that allows the growing of a different species or crop in that between-row space an alley cropping system has been created. Spacing between the tree rows will affect the amount of sunlight in the alleyways which will also affect which crops can be grown there. Understanding plant needs and producers' desire will help you design an alley cropping system that can be satisfying.

Crops that can be planted in full sun are:

- Tomatoes, corn, and blackberries
- Grasses, grains, and oilseeds
- Plum and nut trees
- Wildflowers
- Christmas trees
- Shrubs (many kinds)
- Landscaping plants (selected varieties)
- Timber
- Wood fiber plants

Crops that can be planted in the shade are:

- Ginseng, goldenseal, and black cohosh
- Ferns, mayapples, and Jack in the pulpit
- Mushrooms

### **Advantages of Alley Cropping**

- Diversity of incomes (have multiple cash crops throughout the year)
- Improved soil health (nutrient-rich soil for growing plants)
- Improved crop health (increase crop yields)
- Short-term cash flow from annual plants (incomes for short-term plants)
- “Sun” crops compete with weeds (decrease growth of weeds)
- Trees and other permanent vegetation control erosion (stop soil from moving away from fields)
- Trees act as wind barriers and protect crops (trees protecting crops from wind)
- Long-term incomes from tree products (wood, nuts, and fruit income from planted trees)
- Diversity of farm products (variety of crops from trees and crop plantings)
- Diversity of wildlife habitats
- Diversity of pollinator habitats (example: bees)

### **Disadvantages of Alley Cropping**

- Trees can be an obstacle during cultivating (trees branches may interfere with farm equipment).
- Trees may compete with companion crops for sunlight, water, and/or nutrients (trees may take away sunlight, water, and/or nutrients from annual crops).
- Companion crops may compete with trees for water and/or nutrients (annual crops may take water and/or nutrients from trees).
- Integrated management is often more complex and often requires more knowledge and specialized skills (trees and crops may be difficult to grow at the same time).

### **Design**

Alley cropping is a multiple crop system. Two or more crops grow on the same area of land at the same time. Alley cropping systems also take the advantage of positive crop interactions. Understanding how different crops respond to site conditions will be an invaluable tool in designing a highly successful alley cropping practice. Species selection is vital. Spacing requirements are different for different plants. When making the design, space the trees, shrubs, and herbaceous plants for their mature size, or plan to thin them before competition can reduce

their productivity. If starting with existing trees, thinning may need to occur in order to reduce the number of trees to the desired density. If starting with no existing trees, plant them at the correct density at the beginning.

### **Between-Row Spacing**

For the alley cropping system to be successful, spacing between the rows of trees need to be considered (Figure 7.1). There is a direct correlation between distance between tree rows and the number of years a shade-intolerant crop can be produced. When the space between rows of trees is increased, the years an alleyway may be cultivated with minimal light competition from the tree is increased. The spacing you choose will be based on many factors, which include whether the emphasis is on a tree-related crop such as nuts or wood production, or on maintaining crop production in the alleys between the tree rows.

If choosing to emphasize nut production, the alleyways will need to be wide enough to allow for full development of the tree's crown and spacing to make sure nut harvesting equipment can be used. If choosing to emphasize on wood production, choose a narrower alleyway in order to have the greatest number of trees per acre. The alleys will still generate income from an annual companion crop. With narrower alleys, it will be necessary to plan for an earlier change to a companion crop which can grow successfully in shaded surroundings.

If the desire is to maintain an annual income from specific alley-grown crops, then alleyways must be designed wide. Many alley crops are not shade-tolerant, for example, row crops, forage, or small berry crops. Shade tolerant crops must be produced in alleys wide enough to meet their sunlight needs. The spacing will influence the number of years a given crop can be grown in the alleyways. The spacing between rows must be wide, such as 75 feet or more, if a shade-tolerant crop is to be grown in the alleyways for more than 5 to 10 years.

### **Within-Row Spacing**

Space between trees/shrubs within a row will have a strong influence on their growth and development (Figure 7.2). Trees that are grown tightly spaced will have a tendency or habit to grow up towards the light. This type of tree growth is highly desirable when growing trees for quality wood for manufacturing processes. As these tightly spaced trees begin to produce shade on one another, each of their branches in the shade will begin to die and eventually fall off. This is known as "self-pruning".



Figure 7.1. Between-row spacing in an alley cropping system.

Picture courtesy: G. D. L. Boyd.



Figure 7.2. Spacing between trees within a row.

Picture courtesy: G.D.L. Boyd.

Self-pruning is desirable when trying to grow high quality wood for manufacturing because the wood will have fewer knots and other defects.

When trees are spaced far apart, they tend to grow out and up. This creates larger tree crowns. The additional light on lower branches encourages a tree to keep the branches. While this is not highly desirable in trees grown for wood manufacturing, it is desirable if trees are being grown for nut production. For example, pecan trees are planted with the intention of harvesting nuts. A wider spacing at the initial establishment will help branch development and growth, creating a better tree for nut production. Since sunlight is important to producing a nut crop, the wider-spaced trees will allow for more sunlight to reach each tree's crown for a greater number of years before a thinning within the rows is needed. For nut production, a beginning space of 30 feet between trees may be the best. It is likely that some trees will need to be removed at some point in the future with this spacing.

### **Row Direction**

Row direction is an additional consideration when setting up an alley cropping system. By setting up tree rows on an east-west orientation, more sunlight gets to the alleyways. If erosion or wind control is a major concern, trees may be set up on the contour to minimize erosion, or perpendicular to seasonal winds. In these situations, although available sunlight may not be maximized, crop yields can be maintained by addressing other issues that limit production.

### **Multiple Tree Rows**

Trees and shrubs within the rows can be arranged in various ways such as single rows, double rows or other multiple row designs. Factors that influence the number of rows and the spacing of the trees within the rows should be considered based on a number of potential benefits.

#### *Advantages of Single Row Plantings*

- Less ground is dedicated to trees which can limit future planting options.
- Better for nut production.
- Maintenance is simplified.
- Fewer trees to plant.

#### *Advantage of Multiple Row Plantings*

- Enhanced erosion control.
- Better growth of trees for wood production.
- Improved wildlife value for species that prefer trees and shrubs.

### **Equipment Needed for Alley Cropping**

The alley between the tree rows should be wide enough to allow a clear passage to the widest piece of equipment to be used in this design. This includes allowing space for the growth of the tree crowns. This is particularly important in nut production when early crown development is

desired. Plan alleys so that full or multiple passes of the equipment are possible. An example is using a 13-foot-wide disk. Using the disk, it may be desirable to have an alleyway 60 feet wide. This width would allow for four passes with the disk at 52 feet and a buffer of eight feet to ensure damage is not done to the tree trunks. The available equipment will determine the design and spacing of the alley cropping system.

## **Alley-Crop Management**

### **Below-ground management**

#### *Root systems*

Plants that have roots in the same depths of soil are going to compete for water and nutrients. These plants will also impact the yield and growth of each other. The ideal situation is one where the tree selection for an alley cropping system has a deep root system in order to minimize competition with crops in the alley. If erosion is a major concern, trees with a shallower root system may provide better soil stability. One method of reducing root competition is to prune the roots. This pruning will prevent the roots from occupying the same space.

Root pruning can lower the competition between trees and crops grown in the alley. Start early to train roots to grow deeper. If existing trees that are in your design need root pruning, partial pruning in steps is recommended to reduce plant shock. Pruning too many roots from older trees will damage their ability to collect water and nutrients for proper growth and survival, and will be evident by die-back in the tree's crown. Pruning in steps involves pruning part of the tree's root system over a period of years. At the very least, begin by only pruning roots on one side of the tree in a given year. Once the process has started, prune tree roots every year or two so as to keep them from growing into the cropped alleys.

Forcing the blade of a spade into the soil or digging a trench around the tree is considered manual root pruning. Mechanized root pruning is done with some sort of machine such as a tractor with mounted ripper, coulter, or chisel plow. The machine should cut with subsurface knives attached to sever deeper roots. The closeness of your cut to the trunk depends where the plants in the alleys are growing. Pruning tree roots inside a tree's drip line, which is the outer edge of the tree crown, is done cautiously to minimize damage to the tree.

#### *Fertilization*

Using extra fertilizer for the trees is usually not necessary. Trees benefit from alley-crop fertilization. Where concern exists over trees taking nutrients from the crops, then competition can be minimized by root pruning or by using fertilizers. Nutrients can be added in the form of chemical fertilizers, animal manure, or a wide range of other materials. This may include also the use of living mulches or green manures. The following website can be useful for further information: [www.attar.org/attar-pub/covercrop.html](http://www.attar.org/attar-pub/covercrop.html).

## **Tree Canopy Management**

If too much shade is being produced, the canopy can be pruned to allow more sunlight to reach the understory plants and alley crops. Start by removing branches that are low on the tree to raise the height at which the canopy begins. This procedure will allow more sunlight to reach the ground from the side. Removing leaves and branches may reduce the growth of the tree significantly. A good rule of thumb is to always leave at least 75 percent of the tree height in live crown in order to maintain good tree growth.

Trees with small fine leaves will allow more sunlight through the canopy to the understory. These leaves decompose very fast and allow nutrients to be recycled into the soil faster, and at the same time this will begin to improve overall soil health. Consideration may include the use of trees that leaf out late in the spring and/or drop leaves early in the fall season to minimize shade on the other crops. If the crop in the alleys matures in early spring like winter wheat, or heads out in late fall like milo, a tree species should be incorporated that is best suited for the sunlight needs of that specific crop.

## **Ground Management**

### *Weed Control*

Weeds are plants that we do not desire in the alley cropping system. Weeds compete for sunlight, water, and nutrients with the income-producing plants. Weed management can be done in a variety of ways including herbicides, cuttings, or cultivation. Possible methods for controlling weeds adjacent to trees include mulching, fabric barriers, or living mulches (plants that do not compete with marketable crops, but help reduce unwanted weeds). The control of undesirable plants or weeds will better ensure the success of your alley cropping system.

### *Irrigation*

On some sites, irrigation may only be required for the first year or two until root systems are well-established. In very dry areas, your tree plantings may need permanent irrigation of some sort. If irrigation is not an option, make sure to choose trees, shrubs, and herbaceous plants that will grow in the climate that is suitable for your growing conditions.

## **Economic Considerations**

Economic budgeting can be a very flexible process. Effective use of budgets requires an understanding of the alley cropping system that is designed. Alley cropping poses some unique economic budgeting problems because it involves multiple components with different cropping cycles such as trees, row crops, forages, and/or livestock. First of all, unlike most agricultural crops, alley cropping has a planning horizon of greater than one season due to the trees or shrubs factors. A planning horizon is simply a time period which covers all costs and income for your design. For alley cropping, a simple planning horizon may be as long as 50 to 70 years when the wood value of the trees is taken into account. The planning horizon may also include but not be limited to tree incomes much sooner than 50 years. The time it takes to begin realizing a money return from the tree crop depends on the product being harvested. The harvesting of the trees may take 50 years or more while the harvesting of profitable nut crops may take 10 years that

repeat on an annual basis. The planning horizon is for the duration of the alley cropping system and may include multiple income situations.

Next, since alley cropping systems have such a long planning horizon, many of the incomes and costs do not occur at a regular or predictable time frame throughout the entire operation, but are irregular occurrences. Finally, since alley cropping systems are typically incorporated into a fixed tree or shrub component with an alleyway crop, the crop may change over time. For example, an alley cropping system may start out as soybeans grown between rows of black walnut trees, but when the trees start producing nuts, hay may be the crop grown between the rows of trees because a smoother surface is required to mechanically harvest the nuts and less sunlight is available in the alleyways. These three items of an alley cropping system require a specific type of budgeting method that is flexible enough to allow for producing variable crops and being detailed enough to show annual incomes for the entire planning horizon.

Alley cropping budgeting is a two-step process. The steps are to develop income budgets, and combine the income budgets into a cash flow plan. An income budget is a complete, detailed listing of all of the costs and income expected for each single crop such as corn, livestock, or nut and wood trees. A cash flow plan combines the details from the different income crop budgets in the alley cropping system and adds a time schedule. The income budget provides a framework for reporting and monitoring the profitability of each income item, and the cash-flow plan provides the information necessary to assess and forecast the economic feasibility of the chosen alley cropping design over time.

Economic analysis is not meant to be a one-time process. It is a road map to help determine the profits of the alley cropping system and to assist in understanding when costs might occur over the life of the planting. For information on profiting from trees and other alley cropping systems visit [www.centerforagroforestry.org/pubs/economichandbook.pdf](http://www.centerforagroforestry.org/pubs/economichandbook.pdf).

## **Technical and Financial Assistance**

### **Government Agencies**

1. USDA National Agroforestry Center ([www.unl.edu/nac/alleycropping.htm](http://www.unl.edu/nac/alleycropping.htm)).
2. Environmental Quality Incentives Program (EQUIP)-USDA-Natural Resources Conservation Service.
3. Wildlife Habitat Incentives Program (WHIP)–USDA Natural Resources Conservation Service.
4. Conservation Stewardship Program (CSP)-USDA Natural Resources Conservation Service.
5. Sustainable Agricultural Research and Education Program (SARE) USDA-National Institute of Food and Agriculture.

### **Universities**

1. University of Missouri Center for Agroforestry. [www.centerforagroforestry.org](http://www.centerforagroforestry.org)

2. UMCA Research Publications. [www.centerforagroforestry.org/research/pubs.asp](http://www.centerforagroforestry.org/research/pubs.asp).

### **Book to Order**

ASA Book Chapter:

Garrett, H. E. and R. I. McGraw. 2000. "Alley Cropping". In: North American Agroforestry: An Integrated Science and Practice (H. E. Garrett, W. J. Rietveld and R. F. Fisher, eds.). American Society of Agronomy, Inc. Madison, WI.

### **Success Stories**

**James Burkart:** Alley cropping has given my farm a boost in revenue. I had 65 acres of land that was not being utilized. Talking with Dr. Boyd made me realize the potential my farm had. I implemented some of the techniques needed for an alley cropping system and never looked back.

**Wendy Jamison:** I had 15 acres of land that was given to me by my grandmother. I talked with Dr. Boyd, and she suggested that I try alley cropping. I called the nurseries that she gave me and found the one that suited my pocketbook. I have grown row crops such as peas, greens, and cabbage. I incorporated pecan trees on my property as a nut-producing crop when the trees mature. I found that alley cropping would benefit me the most.

### **Hands-On Activity**

1. Create three alley cropping plans using trees of your choice and crops of your choice.
2. Estimate the cost of each plan. Examples: trees cost \$45-52 each; vegetable seeds cost \$6-9/bag; irrigation system \$10,000-15,000.00; and fencing \$1,500-2,000/acre.
3. Pick one of the three plans that is the most suitable for your farm.

### **Key Points**

1. Alley cropping can diversify your farm.
2. Alley cropping can be done on your farm.
3. Alley cropping is a good way to generate incomes for your farm.

## Chapter 8 RIPARIAN BUFFERS

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### Introduction

Five unique recognized agroforestry practices in the United States are windbreaks, silvopasture, alley cropping, riparian buffers, and forest farming (Gold et al. 2013). The Department of Agriculture (USDA 2011) notes that “Agroforestry is a unique land management approach that provides opportunities to integrate productivity and profitability with stewardship.” Agroforestry has been defined as the “intensive land-use management combining trees and/or shrubs with crops and/or livestock with four important characteristics of being intentional, intensive, integrated, and interactive; a characterization referred to as the “four Is” (Center for Agroforestry 2013). The riparian or streamside buffer is one of the most widely adopted agroforestry practices employed in the USA and many developing countries. Fischer and Fischel (2000) have proposed a comprehensive definition of riparian buffers stating that “they generally can be described as long, linear strips of vegetation adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water.”

The establishment and management of riparian buffers are important to natural resource professionals, farmers, ranchers, and landowners to protect and maintain the long-term sustainability and value of their lands, as well as to protect diverse ecosystems and habitats. These diverse habitats are necessary to support the range of plants, animals, and microorganisms across the landscape. The presence of these biotic species, together with their relationship with each other and their interaction with the abiotic components (e.g. soil, water, climate, and topography) of the environment, are vital for sustaining the overall health of ecosystems. Furthermore, these relationships and interactions help to ensure the realization of ecosystem benefits on a sustainable basis for the good of society.

### Role of Riparian Buffers

One of the major roles of riparian buffers is to provide shade and protect the nearby ecosystem from the impacts of adjacent land uses. The protection of the ecological integrity and dynamics of aquatic ecosystems are additional reasons why riparian buffers are established and/or maintained. Soil conservation and stream-bank protection are important benefits which landowners and society realize from riparian buffers. Fully functioning riparian buffers offer efficient and cost-effective flood-control (Hendee et al. 2012). They are most effective when used as a component of a total resource management system including nutrient management, pest management, erosion, runoff, and sediment control practices. Figure 8.1 depicts an example of a functioning riparian buffer.



Figure 8.1. View of a functioning riparian buffer.

Not all riparian buffers produce the desired results, in part, because of design flaws and/or lack of function (Fischer and Fischenich 2000). Given the foregoing, however, it can be surmised that the functions, purposes and effects of riparian buffers are many and varied. According to Christian et al. (2012), Hendee et al. (2012), and Fischer and Fischenich (2000), these functions and purposes are as listed below.

- Reduce amounts of sediment, organic material, nutrients, pesticides, and other pollutants in surface runoff and in shallow ground water flow.
- Create shade to ameliorate water temperatures (i.e. summer cooling and winter warming) to improve habitat for fish and other aquatic organisms.
- Provide a source of detritus and large woody debris for fish and other aquatic organisms.
- Provide breeding, cover, feeding habitats, and corridors for terrestrial wildlife including migratory species.
- Improve forage production for domesticated stock.
- Provide room for water courses to establish geomorphic stability and physical structure of streams.
- Increase plant biomass and structural diversity.
- Maintain and/or enhance aesthetics of the landscape.
- Reduce farm operation costs and provide additional income.

In the rest of this discussion about riparian buffers, the structure of riparian buffers, the economics, sources of assistance (technical and financial), and information will be outlined. Some practical hands-on and demonstration activities will be suggested. The module will conclude with a summary of the key points presented.

## The Basics

As is common in any venture, adequate thought and consideration should be given in the process of development of agroforestry. Such prior consideration and in-depth analysis help to clarify project goals and objectives, identify required resources, spot potential challenges, determine overall viability of proposals, and point to the best ‘road map’ for successful implementation. Evaluation of the strengths and weaknesses of the buffer project as well as identification and consideration of opportunities presented and threats faced (i.e. SWOT analysis) should be an important step in the overall analysis process (Gold et al. 2013). This business-like approach is true of any agroforestry venture including the establishment of riparian buffers.

Riparian buffers generally consist of three management zones (Zone I which is normally at least 35 feet wide; Zone II which may be 12-15 feet wide; Zone III ranging between 15-25 feet wide), each of which has a unique design and serves a different function (see section on Management Zones, below). The design of riparian buffers is strongly influenced by and linked to management objectives. The perceived levels of effectiveness of each management zone will, to a large degree, be influenced by the prevailing circumstances – design, establishment approach, geology and soil type, topography, hydrological regime, climatic and environmental conditions, past and current land uses, among others.

“Agroforestry begins with placing the right plant, in the right place, for the right purpose” (USDA 2011). Local grasses, forbs, herbs, shrubs, and tree species should be used in the establishment and restoration of riparian buffers whenever feasible. The use of local species has several advantages. First, local species are adapted to local environmental conditions (such as climate, pests, and occasional flooding) and therefore these natives are likely to grow best. In fact, many riparian plant species require access to a permanent or seasonal water supply and do not do well under high water stress conditions (Cooper and Merritt 2012). A second reason for favoring local over non-local species is that the planting materials are likely to be more readily available. Anticipated reduced costs of planting material, lower transportation costs of planting materials, and the maintenance of genetic diversity in the area are additional possible benefits.

There is general agreement on the positive benefits of riparian buffers. However, riparian buffers do present some limitations. These limitations include decreased drainage capacity, crop loss due to the presence of wildlife, difficulty in control of noxious weeds, inability to use buffer zones for some agricultural activities, and the variability of nutrient removal and sediment trapping (Green and Haney 2010).

## Management Zones

**Zone I** – This zone is generally dominated by trees (Figure 8.2). It starts at the normal water line or at the upper edge of the active channel and extends a minimum distance of 35 feet, measured horizontally on a line perpendicular to the watercourse or water body. In the state of Alabama, for example, 35 feet wide streamside management zones are the absolute minimum size recommended in actively managed forested areas (Alabama Forestry Commission 2007). Zone I constitutes the strip closest to the stream or water body. The well-developed root systems of trees in this zone contribute to stream-bank stabilization and reduction in soil erosion. Trees also provide ‘woody trash’ that contributes to diversity of fish habitat in the aquatic ecosystem. In

many instances the fruits of the trees in Zone I of the riparian buffer may be a useful food source for aquatic species.



Figure 8.2. Illustrations of riparian buffer zones I and II. Zone I is dominated by trees.

Source: <http://www.bing.com/images/search?=-ripariCD0E9&selectedIndex=0>

Zone II is a narrower (12 - 15 feet wide) strip, inland from Zone I, which is dominated by fast-growing native shrubs that can stand some flooding. The size of this zone is sometimes influenced by site characteristics, needs of the landowner, and/or land use management objectives. This zone plays a very important role in accomplishment of the intended purpose and desired function of the buffer. Zone II could also be managed, in part, for the commercial production of fruits and floral products (Christian et al. 2012).

Zone III is a 15 to 25 feet wide strip between crop fields, grazing lands or actively managed forest lands and the shrub zone (Zone II) of the riparian buffer. Contrary to most widely accepted riparian management approaches, in some riparian buffers Zone II is either absent or not clearly evident (Figure 8.2). Whereas the absence of Zone II reduces the overall effectiveness of any riparian buffer, such a buffer can still be effective if the other two zones are well-developed and managed. Zone III filters and absorbs nutrients and chemicals from the adjacent crop fields, grazing lands, and/or forests. The native grasses, forbs, sedges, reeds, and wild flowers recommended for use in this zone are good for their multiple benefits and ability to withstand changing conditions (Christian et al. 2012). The three management zones typical of riparian buffers are further illustrated in Figure 8.3 and Figure 8.4.

## Riparian Buffers

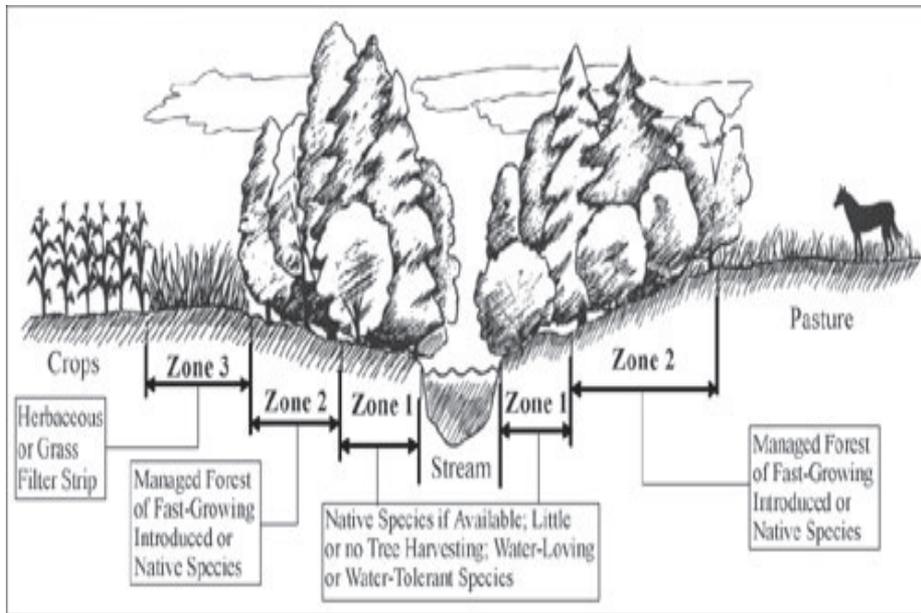


Figure 8.3. Illustration of the three riparian buffers zones.

Source: [http://www.aftaweb.org/riparian\\_buffers.php](http://www.aftaweb.org/riparian_buffers.php)

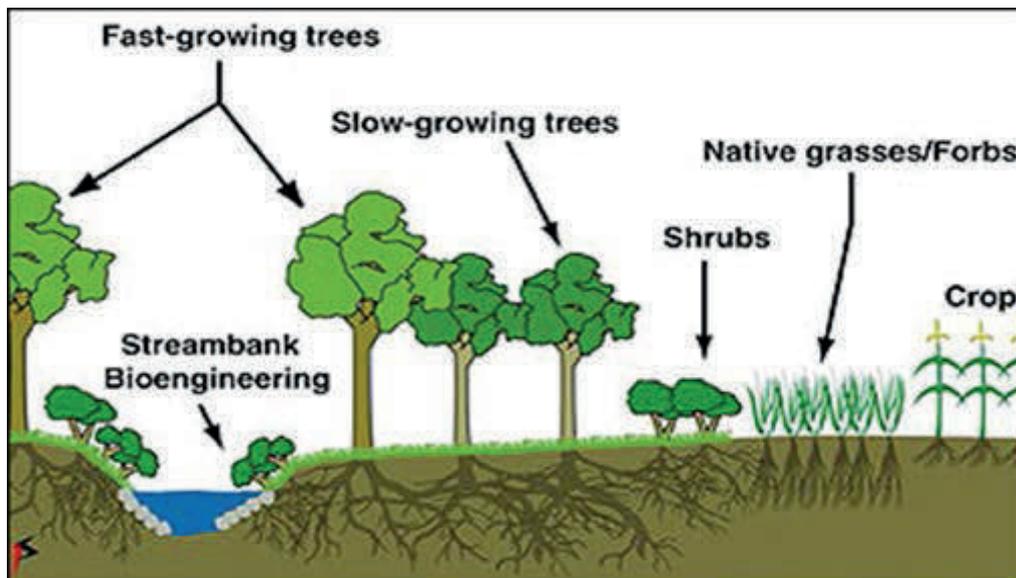


Figure 8.4. Establishing and managing riparian buffers.

Source: <http://extension.missouri.edu/p/AF1009>

### Design

The first critical step in the design of riparian buffers is the need for development of “clear goals and objectives that represent desired outcomes” (Benedict and McMahon 2006). In general, the composition and density of vegetation species used, the number and width of buffer zones,

topography, and soil characteristics determine the ability of riparian buffers to meet specific management objectives (Bentrup 2008).

The next important consideration is the spatial placement of riparian buffers in the watershed. Buffers located along headwater streams have a more profound effect on water quality than buffers located downstream (Fischer and Fischenich 2000). Grebner et al. (2013) report that the required width and structure of riparian buffers often are defined in local, state, or national laws or in organizational guidelines commonly referred to as ‘best management practices’. Yet some suggest that there are no well-established criteria for determining the ideal dimensions of riparian buffer zones in order to meet specific, predetermined objectives (Fischer and Fischenich 2000).

There may be some variation in the accepted width of the individual buffer management zones. Thus, whereas the three-zoned riparian buffer design described above is the most common encountered in agroforestry and resource management operations, it should be noted that all three zones are not always included in the design of riparian buffers. In essence the design of riparian buffers may vary in response to management’s objectives (Schultz et al. 2000) and prevailing conditions in the given location.

### Management and Maintenance of Buffers

For best results, active riparian buffer management is necessary. Certain activities such as unnecessary soil disturbance, ditching, and draining activities should be prohibited within the boundaries of riparian buffers. As far as possible, the housing and grazing of animals, storage and stockpiling of materials, and off-road vehicular travel activities should be kept out of riparian buffers. Large-scale timber harvesting

Table 8.1. Sample of typical riparian-buffer zone species suitable for the Southeastern US.

Common name	Scientific name
<b>Trees</b>	
Green ash	<i>Fraxinus pennsylvanica</i>
White ash	<i>Fraxinus americana</i>
Baldcypress	<i>Taxodium distichum</i>
River birch	<i>Betula nigra</i>
Cotton wood	<i>Populus deltoides</i>
Hackberry	<i>Celtis occidentalis</i>
Shellbark hickory	<i>Carya laciniata</i>
Boxelder maple	<i>Acer negundo</i>
Silver maple	<i>Acer saccharinum</i>
Red maple	<i>Acer rubrum</i>
Bur oak	<i>Quercus macrocarpa</i>
Pin oak	<i>Quercus palustris</i>
Nuttall oak	<i>Quercus nuttallii</i>
Laurel oak	<i>Quercus laurifolia</i>
Cherrybark oak	<i>Quercus pagoda</i>
Native pecan	<i>Carya illinoensis</i>
Persimmon	<i>Diospyros virginiana</i>
Sugarberry	<i>Celtis laevigata</i>
Sycamore	<i>Platanus occidentalis</i>
Black walnut	<i>Juglans nigra</i>
<b>Shrubs</b>	
Hazel alder	<i>Alnus serrulata</i>
Bottonbush	<i>Cephalanthus occidentalis</i>
Giant cane	<i>Arundinaria gigantea</i>
Silky dogwood	<i>Cornus amomum</i>
Rough leaf dogwood	<i>Cornus drummondii</i>
Green hawthorn	<i>Crataegus viridis</i>
Deciduous holly	<i>Ilex opaca</i>
Swamp privet	<i>Forestiera acuminata</i>
Eastern wahoo	<i>Euonymus astropurpureus</i>
Black willow	<i>Salix nigra</i>
Coastal plain willow	<i>Salix caroliniana</i>
<b>Grasses and forbs</b>	
Eastern gamagrass	<i>Tripsacum dactyloides</i>
Butterfly milkweed	<i>Asclepias syriaca</i>
Bee balm	<i>Monarda didyma</i>
Indian grass	<i>Sorghastrum nutans</i>

Source: Adapted from Christian et al. 2012 and Schultz et al. 2000.

operations are not compatible with sustainable riparian buffer zone management. In general, the use of mechanical equipment for harvesting, site preparation, and/or planting is prohibited within riparian buffers. The use of natural regeneration methods, hand planting, and direct seeding are the recommended best management practices in streamside management zones for the establishment of vegetative cover (Alabama Forestry Commission 2007).

There are certain activities and practices which may be permitted within riparian buffers however. Activities permissible within functioning riparian ecosystems include periodic maintenance, and passive or low impact recreational activities. Gathering of fruits, nuts, and flowers, photography, and hiking are possible. Research, data collection and monitoring which may include water quality monitoring and stream gauging are acceptable operations within the riparian buffers.

### *Materials*

The types and characteristics of plants (trees, shrubs, grasses, and forbs) that are most suitable and often used in the establishment of riparian buffers should be developed as part of the planning and design stage. It is critical that the species under consideration are adapted to the site condition, such as periodic flooding and waterlogged soils. If the landowner has multiple management objectives a balance in the mix of species selected for planting is recommended. Generally, the selected species should include some favored by wildlife, some cash crop species (both in the short term and long term), some that offer good soil protection, and some likely to enhance the aesthetics of the landscape. The importance of selecting a variety of native trees, grasses, forbs, and shrubs appropriate to the location cannot be over-emphasized.

Consideration should be given to the protection of planted seedlings (e.g. protect from beaver attack) where appropriate (Christian et al. 2012). Input and recommendations should be solicited from relevant agencies and professionals such as the Agricultural Cooperative Extension agency, the county forester, and the local plant nursery manager. Consulting of plant guides and relevant manuals may prove helpful. A listing of species suitable for planting in riparian buffers in the southeastern US is presented in Table 8.1.

## **Economic Considerations**

### **Costs**

The cost of establishment and management of riparian buffers will depend on the land management or conservation problems which require solution and the nature of possible solution (Christian et al. 2012). Establishment costs are likely to be higher in situations where extensive engineering works for streambed improvement and stream bank stabilization are necessary. Generally, engineering works and planting costs are one-time initial investments. The use of heavy equipment and materials (e.g. rocks and stones) for streambed modifications can cost from \$10 to \$100 per foot whereas the estimated cost of labor and planting materials for streamside activities could cost between \$500 and \$1000 per acre (Christian et al. 2012). Periodic replanting of grasses and periodic maintenance of any initial engineering works will be additional recurring costs.

## **Products and Services**

Riparian buffers are usually established for long-term environmental and conservation values. However, when properly planned, designed, implemented, and managed, riparian buffers can also produce other benefits. These benefits could include the gathering and sale of decorative plant and plant parts to local florists and craft sales outlets. Fruits (e.g. blackberry, currants, elderberry, and pawpaw) and nuts (e.g. chestnut, pecan, and black walnut) are saleable products which may also be obtained from riparian buffers. In the current global atmosphere of environmental awareness, many florists, fresh fruit vendors, craft sales outlets, and consumers have a strong preference for sourcing, selling, and purchasing products that are produced locally and under environmentally sustainable conditions.

In some situations riparian buffers may offer opportunities for other managed extractive activities such as fee hunting, fee fishing, selective timber harvesting, and controlled firewood collection. Medicinals and botanicals [e.g. black cohosh (*Cimicifuga racemosa*), ginseng (*Panax quinquefolius*), mayapple (*Podophyllum peltatum*), goldenseal (*Hydrastis canadensis*), and bloodroot (*Sanguinaria canadensis*)] are possible products which may be produced in, and harvested and marketed from buffer zones. In fact, Hill and Buck (2000) reported that a large number of botanicals are currently used to manufacture pharmaceutical compounds and products known to have healing and therapeutic effects on a range of illnesses. Non-extractive benefits which the landowner and society can realize from riparian buffers include nature/farm tourism, related wildlife viewing, hiking, and opportunities for photography. Spiritual reflections, stimulation of creative spirit, enjoyment of solitude, environmental enhancement, and opportunity for picnicking are also possible.

## **Sources of Assistance and Information**

### **Technical**

There are several possible sources of available technical assistance and financial support for the establishment and management of riparian buffers. A summary of these possible sources of assistance and the nature of assistance are presented in Table 8.2.

### **Financial**

Any farmer/landowner has the opportunity to seek financial assistance to support establishment of riparian buffers from federal and state agencies. The Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) are two federal agencies which offer cost-share and small loan programs respectively to landowners, particularly underserved and minority landowners, to support soil conservation, wetland protection, and fire protection activities (Christian et al. 2013). Interested landowners and farmers are therefore strongly encouraged to visit the local FSA Service Center and NRCS offices or agents to determine the availability, nature and level of possible assistance. These agencies may also participate in larger efforts that landowners can benefit from such as the Landscape Conservation Cooperatives (LCCs). In some states, for example in Alabama, the Forestry Commission and other similar State agencies occasionally allocate and/or source funds to support private landowners' conservation and environmental management practices. These are additional possible sources of financial assistance which should be explored and investigated by interested landowners.

There are also non-governmental organizations (NGOs) such as the US Endowment for Forestry and Communities, National Network of Forest Practitioners, and National Wildlife Federation, which support environmental management and conservation oriented initiatives. NGOs currently support projects in the Southeast and generally tend to work through landowners' organizations or cooperatives rather than with individual landowners. These NGOs do support unique sustainable land use programs advanced by landowners' organizations or cooperatives.

Table 8.2. Sources and nature of technical assistance and financial support for riparian buffer establishment and management.

Source	Nature of Assistance
NRCS/Conservation District	Maps and information about soils, plan development, practice design, and support for cost-share participation.
State Agricultural Cooperative Extension Services	Identification of problems/opportunities and development plans. Advice on planting material.
Local University Faculty	Provide current information on designs and evaluation of buffers. Provide guidance and support for monitoring and research services.
State Forestry Commissions	Information on suitable native trees, shrubs, forbs, and grasses. Also advice on best streamside management practices.
State Fish and Wildlife Service	Information on fish and wildlife habitats

Source: Adapted from Christian et al. 2012.

## Conclusions

Riparian buffers, one of the five recognized agroforestry practices in the USA, if properly designed, implemented, and managed, have the potential of contributing to sound land-use management, environmental protection, and new income opportunities to landowners. Although riparian buffers generally follow a standard design, some aspects of the final design may be influenced by a landowner's goals and objectives as well as prevailing topographical and soil conditions. One of the important design considerations is the selection of species (e.g. trees, shrubs, and grasses) to be used in the buffers. Local species are recommended whenever possible. Federal and state agencies provide some level of technical and financial assistance to interested landowners. Assistance may also be available from non-governmental organizations and university faculty. Of course establishment costs are usually higher than annual maintenance costs.

## Hands-on Activities and Demonstrations

Field visits to selected riparian buffer sites will be undertaken where possible in an effort to get a better appreciation for what constitutes a riparian buffer, the zones which make up that buffer, the design concepts which influence and shape the buffer, the flora and fauna components of the buffer, and the aquatic, edaphic (soil), and climatic factors which influence the design of riparian buffers. Alternatively, selected property maps will be used to support some hands-on exercises.

For each site, participants, either individually or in teams, will be expected to undertake the following tasks:

1. Identify and map an estimated 328-984 feet section of an existing riparian buffer and, in the process, depict the different zones (Zone I, Zone II, and Zone III as appropriate). The average width of each zone will be recorded and the percentage of plant groupings (trees, shrubs, herbs, and grasses) estimated. Wildlife sightings will also be recorded, and the three most abundant species will be identified.
2. Small groups of participants will assess the design, management, and overall health of the riparian buffer and make recommendations for enhancement and more effective management. Recommendations should be based on best management practices.
3. Another team of participants will develop a 5-7 item questionnaire (or verbal interview) to assess the perception and perspectives of property owners and potential heirs about the factors which motivated the establishment of riparian buffers, sources of assistance to undertake the project, benefits and savings being realized, challenges experienced, and long-term vision. The team will analyze the data and share results in a report with the rest of the participants.
4. Teams will seek to undertake some level of comparative analysis between riparian buffers established along stream/river banks as opposed to those established around other water bodies. Issues such as width of buffers, the dominant plant groups/species, topography, hydrology, and noticeable wildlife among other site characteristics will also be assessed and evaluated.

### **Key Points**

1. Riparian or streamside buffers are one of the five agroforestry strategies employed in the USA and in many developing countries.
2. Riparian buffers have been defined as long, linear strips of vegetation adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water.
3. A fully functioning riparian buffer probably offers one of the most efficient and cost-effective flood-control methods.
4. The functions, purposes, and effects of riparian buffers are many and varied, but are influenced by management objectives, design, and location in the watershed.
5. Riparian buffers generally consist of three management zones (Zone I: at least 35 feet wide; Zone II: 12-15 feet wide; Zone III: 15-25 feet wide), each of which has a unique design and serves a different function.
6. The perceived levels of effectiveness of each management zone will, to a large degree, be influenced by the prevailing circumstances – design, establishment approach, geology, soil type, topography, hydrological regime, climatic and environmental conditions, and past and current land uses among other factors.
7. Whenever feasible, local grasses, forbs, herbs, shrubs, and tree species should be used in the establishment and restoration of riparian buffers. The use of local species has several advantages.

8. Establishment costs are likely to be higher in situations where extensive engineering works for streambed improvement and stream-bank stabilization are necessary.
9. Generally, engineering works and planting costs are one-time initial investments. The use of heavy equipment and materials (e.g. rocks and stones) for streambed modifications can cost from \$10 to \$100 per foot whereas the estimated cost of labor and planting material for streamside activities could cost between \$500 and \$1000 per acre.
10. In addition to the long-term environmental and conservation values, when properly planned, designed, and implemented, riparian buffers can also produce other benefits. These benefits could include the gathering and sale of plant and plant parts to local floral, craft, or other sales outlets.

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## Chapter 9 WINDBREAKS

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### Introduction

A windbreak, or shelterbelt, can be defined as any living barrier that reduces troublesome winds by creating a wind shadow to leeward side. Such windbreaks are continuous but not solid structures. When designed and planted correctly on a farm, a windbreak can improve income opportunities and the environment, define property lines, and create wildlife habitat. By looking at how the windbreak (trees and shrubs) relates to the neighboring fields or buildings, you can see how its layout can meet your production or protection needs. Excess wind can be detrimental to both residential and agricultural areas. Residential areas and even highways reap the benefits of windbreaks as they prevent wind damage to homes and vehicles.

In the agricultural realm, research findings support that plant growth and development can increase by sheltering through windbreak practices. A windbreak is one that utilizes single or multiple rows of trees and/or shrubs that are integrated into crop, livestock, or human activities for environmental and economic purposes. This agroforestry practice is conveniently multipurpose. A windbreak becomes important by enhancing production or conservation as it modifies air movement and wind speeds which results in microclimatic changes. Windbreaks are used to protect crops and livestock, control erosion and blowing snow, define boundaries, provide habitat for wildlife, provide tree products, and improve landscape aesthetics. Windbreaks separate areas, create borders, and serve as filters and living fences. Of all these purposes, a windbreak's major function is to mitigate wind speed. Many people think windbreaks take up land that could be producing a cash income, even though windbreaks do increase yields and subsequently incomes. The production of many fruit and vegetable crops improve with protection from wind and from early or late season frost. For example, these protections can improve flower and fruit quality of peppers, tomatoes, melons, and strawberries or the stems of cut-flowers. Windbreaks protect livestock from too much heat and cold, lower animal stress, and increase their weight gain or milk production. Windbreaks can help save energy in home and on the farm by keeping cold wind away from buildings in winter months. Other examples of windbreak uses include screening for home privacy, barrier protection for fields, and farmstead protection (Figure 9.1).



Figure 9.1. Examples of windbreak systems: screening (A), field protection (B), and farmstead protection (C).

Source:

[http://www.nrcs.usda.gov/Internet/FSE\\_PLANTMATERIALS/publications/txpmcot5584.pdf](http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/txpmcot5584.pdf)

## Importance of Windbreaks

Windbreak systems are important as they serve to reduce loss from strong wind and add value simultaneously in a sustainable way. They prevent wind damage and protect the soil from erosion and detrimental materials. The systems can increase yield and productivity of the farmland. They also promote wildlife diversity. A major key to a successful windbreak is recognizing what you want it to do on your land. The next step is to understand how a successful windbreak works and what makes a good design. The final step is planting the kinds of trees and shrubs in the windbreak that will make it work for you. Even a relatively low value fencerow that you already have, with some imagination, common sense, and a little effort, can be converted into a valuable windbreak investment (Idassi 2012).

In planning, think about your land, what you want to do, and the wind-related problems. What do I want from this planting? What needs to be protected: crops/orchards, livestock, roads or fields/soil, buildings, privacy? A careful look at your land and your goals brings up questions such as listed below.

- Which direction(s) does wind cause the most problem(s)?
- When do your livestock or crops need the most wind protection?
- Are there concerns about summer air movement in the livestock area or planting zone?
- Are you interested in choosing tree and shrub types and a design that will add beauty, or attract songbirds or wildlife to your yard?

## Aspects of Windbreaks

### Functions

The functionality of the windbreak system is mainly to serve as a barrier between blunt wind force and an area in need of protection (Figure 9.2). This is achieved by altering the pattern of wind flow in order to reduce the pressure on the specific area of interest. Windbreaks can alter this flow either above (upward), down-wind (leeward) or through the system structure. Based on the wind orientation and structure makeup of the windbreak, different areas will be protected. Windbreaks functionality can be broken down into two distinct ways. They first modify air

currents that change the flow of air, sound waves and odor plumes in the microclimate. Microclimate management is the second function of windbreaks. Wind speeds are reduced due to the canopies of forest trees present. This area is referred to as the microclimate. Factors such as temperature, precipitation, relative humidity, and carbon dioxide concentration are altered and, therefore, impact the exchange process between foliage and the above surface environment. Other important attributes altered are: radiation, air and soil temperatures, precipitation, humidity, and evaporation. If canopies are placed properly, these environmental factors can be influenced for the benefit of all sectors of the windbreak system. Windbreak practices trap or filter airborne contaminants such as sediment, snow, nutrients, pesticides, and volatile organic compounds. All these factors contribute to the microclimate or localized environment of the area affected by the windbreak.

### Properties

Windbreak properties can be broken down into the various aspects that are associated with the design of the system. Below are some of the windbreak structural elements to determine windbreak effectiveness as outlined in The University of Missouri Center for Agroforestry Training Manual. These elements are height, density, orientation, length, width, and continuity/uniformity. Each of these elements is discussed below.

**Height (H)** can be considered the most important factor in evaluating the downwind protection area. Height is directly proportional to the area in need of protection. This means, the taller the system, the more protection will be provided. Wind can be reduced by two to three times the height on the upwind (against the direction of the wind) side of the windbreak and 30 times the height of the downwind side (in the direction that the wind is blowing). The actual height is determined by the tallest row of plants in the windbreak system.

**Density** determines both how much wind gets through and length of the wind shadow. This can be found by the ratio of the solid portion of the barrier to the total area of the barrier. Systems that are 60 to 80 percent dense will achieve the maximum wind reduction with a short wind shadow. Systems that are moderately dense (40%-60%) will have less wind reduction but longer wind shadows. Windbreak density can be divided into two categories:

- Dense: maximum wind reduction but short wind shadow

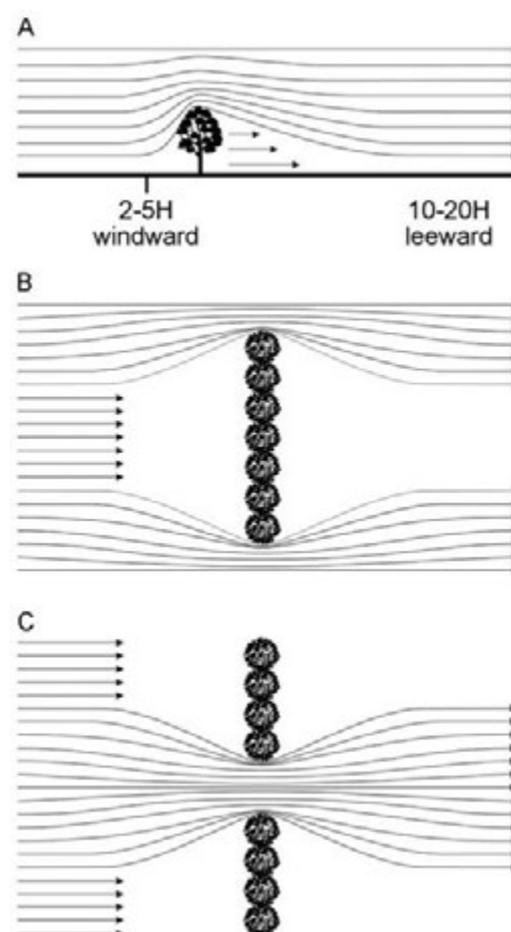


Figure 9.2. Windflow patterns: over (A), around (B), and through (C) a windbreak system.

Source: Bradle et al. 2009.

- Moderately dense: less wind reduction but longer wind shadow

You can adjust the density of the windbreak to create different wind-flow patterns. This allows you to establish your desired areas of protection. To determine the density of a windbreak, you compare the solid portion of the barrier to the total area of the barrier. The choice of plant materials and the way that the plants are arranged changes the density of the windbreak. Density is the ratio of the solid proportion of the barrier to the total area of the barrier. It is important to note that winds flow through open portions of windbreaks. Therefore, the more solid (dense) the windbreak is, the more protection of the area will be. The density level is manipulated by the choice of plant material and the way the plants are arranged in the windbreak. Dense material should be covered in three levels: shrubs at the low level, medium trees at the medium level, and tall trees at the high level. The slowing of the wind by the canopy and solid portions of the windbreak are integral for protection of the area.

The percentage refers to the canopy width of the plantings present in comparison to the amount of free space present in the system. The density percentage is dependent upon plant selection and arrangement. Using a combination of shrubs and trees will allow for different levels of protection at once. However, this protection can alter seasonally when foliage is lost. Figure 9.3 depicts the wind speed reduction at different distances from the windbreaks with various densities.

**Orientation** refers to the location and layout of the system. This influences the protected area directly, although the outcome can be altered by weather changes. Windbreaks are most effective when placed at right angle to the wind flow. However, determining the best orientation is dependent on the purpose of the system. **Length** determines the total area that receives protection. In order to achieve optimal

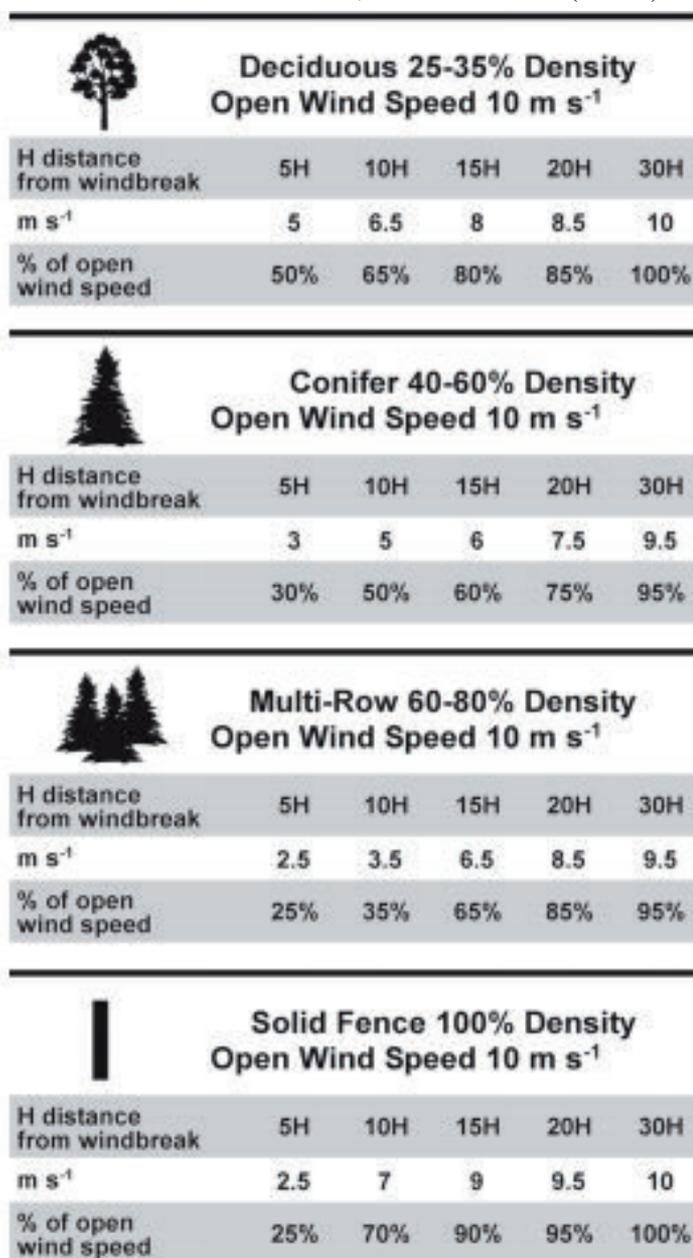


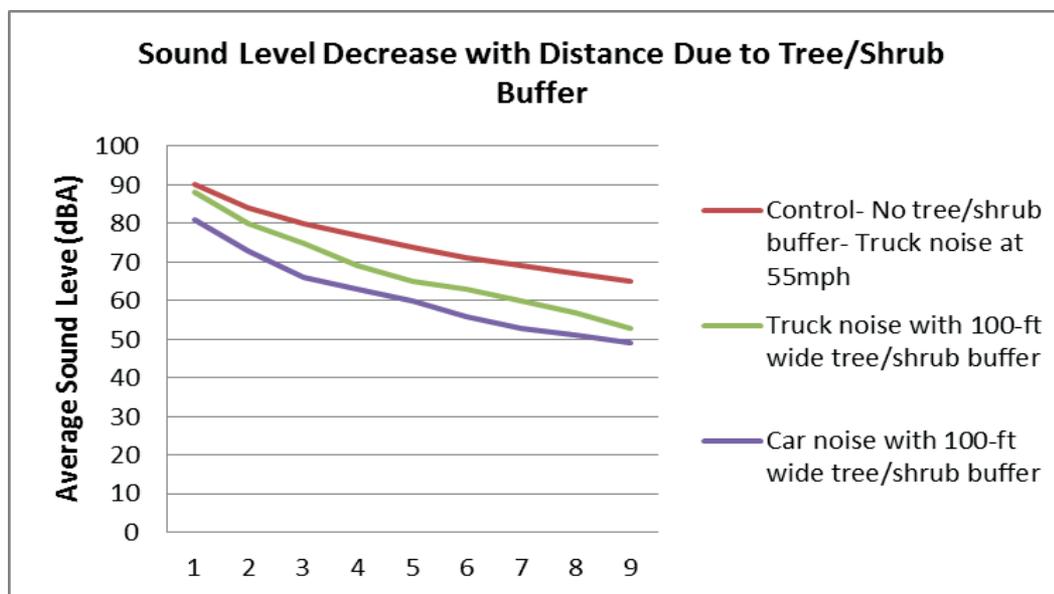
Figure 9.3. Wind speed reductions at different distances to the lee of windbreaks with different densities, where H is the height of the windbreak. Source: Brandle et al. 2009.

protection, the windbreak should extend across the entire area of need. Doubling the length of the windbreak will generally increase the protected area by four times. A 10:1 ratio of height to length may also maximize efficiency. The **width** of the windbreak system influences density, wildlife values, wind trapping capacity, and efficiency (University of Missouri Training Manual for Applied Agroforestry Practices 2013).

**Continuity and uniformity** refer to the continuous planting of windbreak plants. Efficiency is increased as continuity increases. This feature reduces gaps in the system and therefore decreases the likelihood of wind entering the protected area

### Applications

Windbreak practices are commonly used for several purposes to include odor mitigation, screening, traffic noise remediation, visual appeal, wildlife protection and prevention, and snow fencing. Commonly, windbreaks are used around highways or residences in order to reduce noise in the area (Figure 9.4). Other applications such as erosion control specifically pertain to the prevention of top soil loss (Brandle et al. 2009). All of these applications reduce costs or raise value of property as they eliminate common issues for landowners. Choose the site carefully for planting the windbreak. Space trees so that there are no gaps big enough to funnel wind, but the trees and shrubs are dense enough to break the force of the wind. Ask for assistance when making decisions about the technical parts of installing the practice, like how many rows to plant, how to space the trees, and if the types of trees and shrubs you want to grow will grow well on the planting site.



Distance from Noise Source (Feet)

Figure 9.4. Sound level decreases because of the windbreak systems.

Source: [http://nac.unl.edu/buffers/guidelines/6\\_aesthetics/4.html](http://nac.unl.edu/buffers/guidelines/6_aesthetics/4.html)

### **Advantages**

There are many benefits associated with the windbreak system. In traditional uses that are already in place, windbreaks can be seen as beneficial for reducing soil erosion, protection of plants and stimulation of growth, snow management, shelter, reducing energy needs and therefore costs, improvement of wildlife habitat, and enhancing aesthetics. As far as plant and soil relations are concerned, windbreaks deter damage to both the soil and plant that is commonly caused by excess wind. Erosion, a major hindering factor to the positive development of plants, can be reduced as the windbreak system will block winds that could potentially displace soil sediment. With this, plants are also protected and growth is promoted. This same protection also prevents excess snow from reaching plants and livestock while promoting an improved microclimate and habitat. Emerging benefits include noise moderation, screened views (privacy), reduction of airborne chemical drift, improved irrigation efficiency, increased carbon storage, and mitigation of odors. These benefits can add to the aesthetic value, atmosphere, and overall efficiency of the windbreak system. More specifically, windbreak benefits can also be grouped into three categories: economic gains, protection or deterrence of wildlife, and protection of crops and farm buildings.

Economically, windbreaks can provide farmers with greater profits because of increased production and fewer expenses. The use of windbreaks can result in reduced feeding bills (reduction of animal stress causes less feed expense), increased milk production, improved calving success, and greater profits due to reduced damage to crops and homesteads (Houck, no date). In regards to wildlife, windbreaks help create a habitat for animals, such as quail, which are hunting game. In addition, they also protect livestock as wind chill can cause stress for livestock. In addition to protecting game animals and livestock, windbreaks can also provide protection from unwanted animals. Trees add value to material for wildlife barriers, as in the case of deer (Straight and Wright 2013). In dealing with homesteads, windbreaks can serve as a protective barrier to high tunnels and other seasonal structures as they are more susceptible to damage from strong winds. Windbreaks also deter tornados and other strong winds. Particularly, in North Carolina, windbreaks are invested in to serve as privacy barriers. They also serve in residential areas to block airborne sediments that could cause damage to the human respiratory system.

Windbreak systems are efficient because they can be multipurpose. A multi-row windbreak can be designed to function as a windbreak and allow woody biomass harvesting for energy needs. In this case, additional rows need to be incorporated into the design to allow rotational harvesting. Windbreaks sustain birds that eat insect pests, improve hunting opportunities, and provide a focal point for family outdoor activities. You can add wildlife benefits to windbreak plantings whether your main goal is to shelter crops, livestock, roads, or a home or farmstead (Idassi 2012).

### **Disadvantages**

Along with the advantages of the windbreak system, there are also disadvantages taken into consideration. For example, certain air flow can deposit mold spores that negatively affect crops such as tomatoes and tobacco. Though the main goal of windbreaks is to deter wind, without its presence, unwanted airborne material will be physically trapped (Straight and Wright 2013).

Also, root competition can occur between the trees and crops, which can reduce crop yield nearby the windbreak. The windbreak might affect field orientation as well. In addition, the windbreak system requires a more intensive management system than what is required for traditional farming. That noted, windbreak management can turn out to be costly and time consuming if the managers need training to effectively conduct the system. Also, because the system requires a large area of space for tree planting, issues may arise as it will remove land from annual crop production use.

## Windbreak Design

Designing windbreaks requires the planner to be able to manipulate the different structural components of a windbreak in order to achieve the desired buffering effect. Climatic and physical effects such as wind speed, apparent air temperature, snow deposition and evapotranspiration are modified as a result of the structural characteristics of the windbreak. The effective design of a windbreak system is impacted by height, density, orientation, length, width, and continuity. The height is determined by the tallest row of plants in the windbreak. This is to ensure that the height of the windbreak effectively covers the height of the plantings that need to be protected.

For effectiveness, larger areas need windbreaks every 10H to 20H. The height is the most important factor because it determines the downwind area of protection. On the upwind side of the windbreak, it will reduce wind speed by 2 to 5 times H. On the downwind side of the barrier, it will reduce wind speed by up to 30 times H. The area protected is directly proportional to H. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases. Therefore, knowing what areas need protection and which direction unfavorable winds come from is critical. You can get data from local weather stations, climate databases, and your own observations. Wind roses are effective tools for determining prevailing wind directions. This tool shows both the frequency and the velocity of winds during a specified period. More specifically, a wind rose shows how often the wind blows from particular directions during a specific period of time. Each circle stands for a different frequency, starting at zero in the center to higher as the circles get larger (Figure 9.5).

The length of a windbreak determines the total area that receives protection. For full protection, the windbreak needs to extend past the width of the area that needs protection. Doubling the length of a windbreak will generally increase the area protected by four times. A length of at least ten times the height of a windbreak allows for successfully protecting the land from the curved motion of winds at the ends of the rows. Although the height of the windbreak determines the extent of the protected area downwind, the length of a windbreak determines the amount of total area receiving protection. For maximum efficiency, the uninterrupted length of a windbreak should exceed the height by at least 10:1. This ratio reduces the influence of end-turbulence on the total protected area.

The width of a windbreak affects its density, trapping capacity, efficiency, and wildlife values, such as increased food, cover, and protection. As the width of the windbreak increases, its density, wildlife value, and trapping efficiency all increase. Wider windbreaks allow the use of more types of plant species, which increases site diversity (Straight and Wright 2013). To protect structures, the windbreak should have a density ranging from 60 to 80 percent during the

## Windbreaks

period requiring maximum protection. To achieve the minimum level of this density range, plant at least three rows of trees and shrubs with at least one row being a conifer.

Continuity refers to the continuous flow of the windbreak in regards to the amount of gaps present in the system. It is critical that wind barriers do not have any gaps. A gap creates an end effect that generates high winds, which is counter to its purpose. The wind velocity through a gap can accelerate to 120 percent of open wind velocity, which can result in crop damage or snow-drift problems (Missouri 2007).

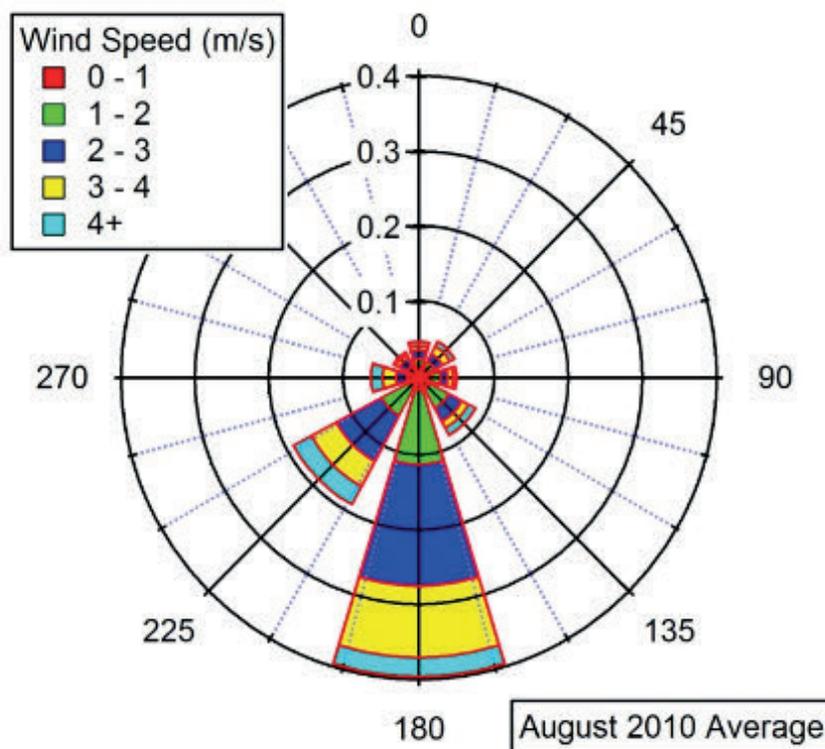


Figure 9.5. A wind rose used in determining prevailing wind directions.

Source: <http://www.vebidoo.com/winds+roses>

### Windbreaks and Livestock

When windbreaks were first used, they were primarily used to prevent soil erosion and protect crops from drying winds. Today, windbreaks are being used for a variety of purposes, such as increasing yields of agricultural fields, and reducing energy needs around the farmstead and livestock. Livestock windbreaks, when properly placed, can provide benefits to feedlots, pastures, and calving areas. By reducing wind speed in winter, they lower animal stress, improve animal health, and increase feeding efficiency. They protect livestock in both the winter and the summer, and will provide economic benefits in the long term. The time spent on layout, site preparation, weed control, and replanting is paid back many times throughout the life of a windbreak.

## Windbreaks and Desired Wildlife

Wildlife can be greatly impacted by the presence of woody areas such as windbreak systems. It has been reported that these systems are sometimes the only source of habitat for wildlife that prefer woody areas. Windbreaks provide essential woody cover, especially in areas where no native woodlands exist. Wildlife has three essential needs for survival: food, water, and cover. Cover is necessary for nesting and protection from the environmental elements. Well-designed windbreaks provide a variety of habitats and can create travel corridors to link wooded areas together. Permanent homes for wildlife can be created when locating the planting adjacent to a water source, such as a pond. The presence of windbreak systems also increases game species that can reach an estimated economic value of 30-35 million dollars in various states within North America. Along with game also comes a variety of insect life that seeks habitat within the windbreak system (Missouri 2007)

## Materials and Equipment for Windbreak Development and Management

Materials for windbreak development can be found at local hardware and home improvement stores such as Lowes. Others can be ordered from various suppliers across the nation. Most suppliers also offer management advising as well. Some of these suppliers are listed below.

### Irrigation and Equipment

- A.M. Leonard Company - <http://www.amleo.com/>
- Lowe's - <http://www.lowes.com/>
- MPR Supply Company - <http://mprsupply.com/>
- Rain Bird - <http://www.rainbird.com/>
- Grow Native Listings  
<http://grownative.org/index.cfm?fuseaction=wherebuy.landscapeservices>
- University of Missouri Irrigation Site - <http://agebb.missouri.edu/irrigate/index.htm>

### Plants

- Forrest Keeling - <http://www.fknursery.com/>
- Musser Forests - <http://www.musserforests.com/aboutus.html>
- Vans Pines - <http://www.vanspinesnursery.com/catalog.cgi>
- Cascade Forestry - <http://ww2.cascadeforestry.com/>
- Grow Native Retail Garden Centers and Nurseries Listings  
<http://grownative.org/index.cfm?fuseaction=wherebuy.retail>
- Missouri Department of Conservation Seedling Order Form - <http://mdc.mo.gov/your-property/seedling-orders-and-planting-guide/seedling-order-how>

### Weed Control & Fabric Mats

- Dewitt Company - <http://www.dewittcompany.com/>

Note: This list only reflects a few common sources of suppliers. Internet searches can be used to find more case specific materials and local suppliers.

## Planting Recommendations

Dependent on the windbreak type and tree species (Table 9.1; Figure 9.6), windbreak systems can take up 0.5 to 1.5 acres of land. Assistance for planting recommendations comes from various sources. Seedling planting information should be retrieved from local foresters in state forestry agencies, wildlife managers, territorial and tribal fish and wildlife offices, the Association of Fish and Wildlife Agencies, NRCS district conservationists, or USDA Service Center. Planting recommendations will vary based on soils, locations, and climatic conditions. For example, the evergreen Shortleaf Pine is commonly used in difficult soils while the evergreen ‘Green Giant’ Arborvitae can be used where there is sufficient irrigation available. Consideration can be given to use of trees native to your planting area and whether the plants have the tendency to become weedy (e.g. redbud) or suffer insect/pest problems under prevalent growing conditions. Seeking guidance from local and state officials is most beneficial (Bentrup 2008). The number of rows necessary for planting can be evaluated based on the landowner’s purpose for windbreaks (Table 9.2).

Table 9.1. Suggested list of evergreen and hardwood tree from the USDA-NRCS.

Evergreen trees	Hardwood trees
Eastern redcedar ( <i>Juniperus virginiana</i> )	Little walnut ( <i>Juglans microcarpa</i> )
Arizona cypress ( <i>Cupressus arizonica</i> )	Hackberry ( <i>Celtis occidentalis</i> )
Austrian pine ( <i>Pinus nigra</i> )	Bur oak ( <i>Quercus macrocarpa</i> )
Rocky Mt. juniper ( <i>Juniperus scopulorum</i> )	Redbud ( <i>Cercis canadensis</i> )
Arborvitae ( <i>Thuja</i> spp.)	Green ash ( <i>Fraxinus pennsylvanica</i> )
Ponderosa pine ( <i>Pinus ponderosa</i> )	Desert willow ( <i>Chilopsis linearis</i> )
Afghanistan pine ( <i>Pinus elderica</i> )	Chickasaw plum ( <i>Prunus angustifolia</i> )

Source: Houck (no date).

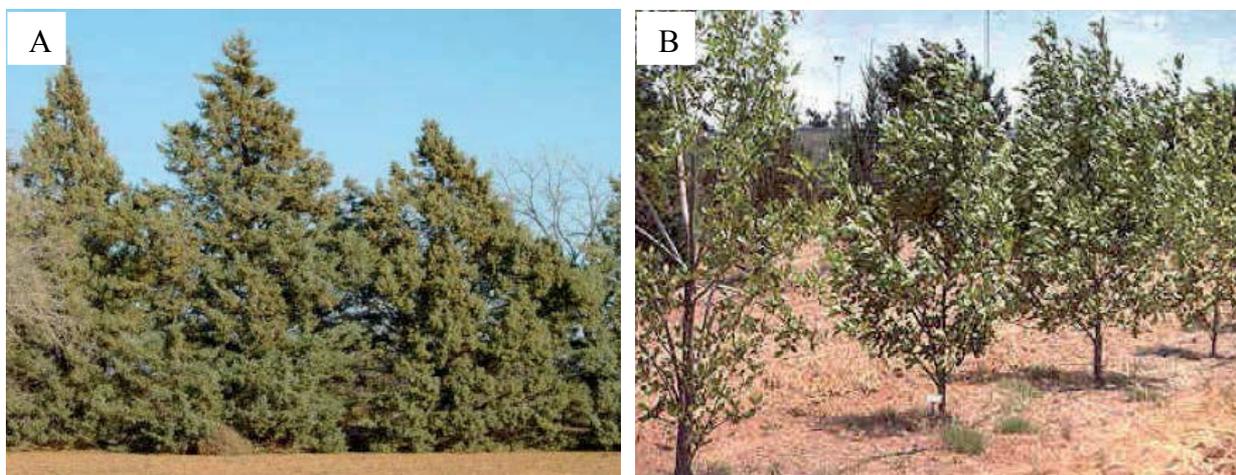


Figure 9.6. Examples of suggested plantings for windbreak systems (A) Arizona cypress (*Cupressus arizonica*) (B) Green ash (*Fraxinus pennsylvanica*)

Source: Hauck (no date).

### Start-up and Recurring Costs

For start-up, the windbreak system will of course need the desired plantings and containers for each type of plant in the system. Aside from this purchase, there are also costs associated with mulching, irrigation, and plant maintenance such as disease control and weed prevention that can recur over time. Below is an example budget for a windbreak system in Missouri including several different costs (Missouri 2007).

### Incentives

Many incentives are offered for the purpose of windbreak systems. The practice is seen as an environmentally sustainable feature that can therefore be funded through various governmental agencies.

Table 9.2. Suggested minimum row(s) for windbreak systems by purpose.

Windbreak type	Minimum rows
Farmstead/Shelterbelt	3
Feedlot	3
Odor	3
Screens	
High traffic (noise)	6
Medium/low traffic (noise)	3
Visual	2
Wildlife	5
Field	2
Living Snow Fences	1

Source: The University of Missouri 2007.

Table 9.3. Example budget for investment costs of a windbreak system.

Trees, shrubs, and grasses (plants, planting, and maintenance) costs					
Rows	Plants	Total feet	Cost per 100 feet	Total plants	Plant investment Cost
1	Indian grass	500	\$1.21	0	\$6.06
2	Gray dogwood	500	\$25.80	100	\$129.00
3	Silver maple	500	\$14.63	55	\$73.15
4	Eastern red cedar	500	\$208.90	51	\$1,044.48
Total			\$250.54	206	\$1,252.69
Establishment costs					
Item	Quantity	Unit	Unit cost	Site investment cost	
Temporary irrigation needed	500	feet	\$1.50	\$750.00	
Temporary irrigation not needed		feet	\$0.14		
Mechanical site preparation	3.25	acres	\$44.79	\$145.57	
Chemical site preparation		acres	\$25.36		
Total initial investment cost					\$2,148.25

Source: <http://agebb.missouri.edu/commag/shelterbelt/ExBudget.htm>

Note: Input the total number of feet for each row, establishment cost, and estimated annual maintenance costs.

## **Sources of Financial and Technical Assistance**

### **USDA Agencies**

The United States Department of Agriculture holds several branches that offer financial assistance to landowners as they endeavor to create windbreak practices. The USDA Farm Service Agency (FSA) provides three different programs. The Conservation Reserve Program (CRP), Continuous Conservation Reserve Program (CCRP), and the Conservation Reserve Enhancement Program (CREP). All these are offered to assist with both windbreak and shelterbelt practices. Specifically the CCRP directly benefits landowners for startup on land that is considered to be environmentally sensitive (Idassi 2012).

The USDA Natural Resources Conservation Service (NRCS) also offers three incentive programs: The Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentive Program (WHIP), and Conservation Stewardship Program (CSP). All these focus on conservation planning as they can relate to windbreak systems. For some incentives such as EQIP, basic requirements for eligibility are listed below:

- Be an agricultural producer
- Be in compliance with the highly erodible land and wetland conservation provisions of the 1985 Farm Bill
- Provide the Social Security number of all individuals who will benefit from the assistance
- Develop an EQIP plan of operations

The USDA National Institute of Food and Agriculture offers Sustainable Agriculture Research and Education (SARE) through a producer grant that provides up to \$15,000 for the landowner group and up to \$10,000 for an individual producer/landowner (Missouri 2007)

### **Material Suppliers**

Regional or county offices of a Forestry Commission or State Division of Forestry can usually supply the seedlings necessary for windbreak practices. The materials necessary for windbreak construction and development are found in various places. Material is sold in bulk or by the meter for larger windbreak practices. Specialized materials such as waterproof fabric can also be purchased from various vendors such as those listed below (Missouri Plant Guide, no date).

#### **Plantings**

- Commercial Nurseries by State/Province
- Forestry Commission by State/Province
- Division of Forestry by State/Province

### **Hands-On Activities and Demonstrations**

Your farm has approximately 40 acres, but it has 20 acres of land for grazing livestock. Your grandmother, father, and mom, and your young brother are currently living on the farm. A

windbreak would be a beneficial practice to protect the farmland from wind and by adding long-term timber-use while still producing hay.

In small groups, participants will be involved in the following activities.

- Assess the design, management, and overall health of the windbreaks.
- Make recommendations for enhancement and effective windbreaks based on best management practices.
- Sketch a rough plan of the windbreak that includes single or multiple rows of trees needed to protect your farm.
- Take your time and share your plan with the group (convey your vision to the group and ask them for their views and questions).

### Key Points

1. A windbreak, or shelterbelt, can be defined as any living barrier that reduces troublesome winds by creating a wind shadow.
2. Windbreak systems are important as they serve to reduce loss and add value simultaneously in a sustainable fashion that can be used for years.
3. Windbreaks perform in two distinct ways. First, they modify air current to mitigate undesired odor and sound. Secondly they serve as a trap for undesired air particles.
4. Windbreak design is dependent on height, distance, orientation, continuity, density and width.
5. Windbreak systems play an important role in either providing a significant amount of wildlife habitat or the protection of livestock dependent on landowner purpose.
6. The types of plants and spacing used in windbreak systems can be determined by determining the purpose of the system. It is also important to consider the environment in which the system will be placed.
7. Agencies such as the NRCS under the United States Department of Agriculture offer incentives for landowners that utilize windbreak practices.

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## Chapter 10 ECOSYSTEM SERVICES

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### Introduction

Agroforestry is an approach which seeks to optimize the integration of trees and/or shrubs with agricultural crops and/or livestock for production purposes, conservation benefits, and furtherance of land stewardship practices (Gold et al. 2000). All five internationally recognized agroforestry practices, some more so than others, contribute to the realization of sustainable flow of ecosystem services. In the process of trying to understand the concept of ecosystem services, it is important to get an appreciation for what constitutes an ecosystem. An ecosystem has been defined as "...a system that includes all living organisms (biotic factors) in an area and its physical environment (abiotic factors) functioning together as a unit" (Biology Online.org). Burton (2008) stated that "...an ecosystem consists of plants, animals, and microorganisms that interact with one another and with the non-living features of the environment such as water, soil, and rocks". An alternative definition offered by Grebner et al. (2013) is "...the complex mixture of all living and nonliving objects in a defined space that interact, depend on, or regulate each another in some way". In summary an ecosystem is a biological community of interacting organisms and their physical environment.

The common threads of these definitions are: (a) both the biotic and abiotic components make up the system, (b) these organisms and elements, both individually and as a group, interact with and influence the other components of the ecosystem, and (c) organisms and elements also help to shape and have an effect on the ecosystem. Ecosystems vary in size and may be as small as a rock or may be as large as a forest (Figure 10.1). There are land-based or terrestrial ecosystems such as a meadow or a forest and water-based or aquatic systems such as a pond, a river, a lake, or an ocean/sea. Figure 10.2 depicts more than one type of ecosystem - scenic waterways, woods and wetlands - in the Five Rivers landscape. The Five Rivers site is where the Mobile, Spanish, Tensaw, Apalachee, and Blakeley rivers flow into Mobile Bay in Alabama. The boundaries of an ecosystem may be well-defined as is the case in a lake ecosystem, but in many instances the ecosystem's boundaries are not very obvious. In some situations there is a gradual transition from one ecosystem into another. Consequently, the boundaries between adjacent ecosystems may be somewhat 'blurred'.

As indicated in Figure 10.3, there is an organized flow of energy in an ecosystem, starting from sunlight energy absorbed by green plants to animals which feed on green plants [i. e. herbivores] and to the animals which feed on other animals [i.e. carnivores] (Burton 2008). The cycling of nutrients is yet another important characteristic of a healthy and functioning ecosystem (Hendee et al. 2012). The components which constitute an ecosystem may vary but each undisturbed ecosystem is a 'functioning unit of nature'. Thus, sound ecosystem management is an ecological approach that seeks to incorporate social, physical, economic, and biological needs and values to ensure ecosystem viability and sustainability. Ecosystem services are derived from ecosystems.



Figure 10.1. Examples of ecosystems: a rock (A) and a forest (B).

Source:

<http://www.bing.com/images/search?q=a+rock+ecosystem&qvvt=a+rock+ecosystem&FORM=I GRE#view=detail&id=EEE160D1E1782B361B946B6548BCB815A691EE32&selectedIndex=7>

### Definition of Ecosystem Services

The concept of ecosystem services has been receiving much attention in the literature, and at national, regional, and international forums about sustainable development, resource management approaches, and human well-being. Grebner et al. (2013) have defined ecosystem services as the “...positive outcomes naturally provided by the environment” as well as “...the benefits that ecosystems provide for both human societies and Earth itself”. Based on this definition a range of benefits such as erosion control, water, recreation, food (e.g. meat, fruits, and mushrooms), timber, and climate amelioration are all important and critical ecosystem services vital for human well-being. Thus, ecosystem services “...are products, functions, and process” of value to society and the environment (Grebner et al. 2013).



Figure 10.2. Five Rivers in Spanish Fort, southern Alabama.

Source:

[http://www.outdooralabama.com/sites/default/files/images/Image/5Riv\\_Aerial\\_shot.jpg](http://www.outdooralabama.com/sites/default/files/images/Image/5Riv_Aerial_shot.jpg)

Constituents of human well-being include *security* (i.e. personal safety, security from disasters, and secure resource access), *health* (i.e. strength, feeling well, and access to clean air and water), *basic material for good life* (i.e. adequate livelihoods, sufficient nutritious foods, shelter, and access to goods), *good social relations* (i.e. social cohesion, mutual respect, and ability to help others), and *freedom of choice and action* (i.e. opportunity to be able to achieve what an individual values being and doing).

## Brief History

The philosophy driving natural resource management on public lands in the US has been changing over time, all in an effort to accomplish more effective resource management outcomes. On the arrival of the colonizers in the eastern United States there was evidence that the native Indians had impacted, though only on a relatively small scale, the forest resources through their agricultural and hunting practices. European colonizers exploited what they perceived then to be vast, inexhaustible supplies of timber. This era of forest exploitation was followed by an era of resource preservation, which gave way to an era of resource conservation approaches. The many environmental issues of the 1960s and 1970s led to a call for action and this gave birth to the environmental movement (Bonnicksen and Burton 2003).

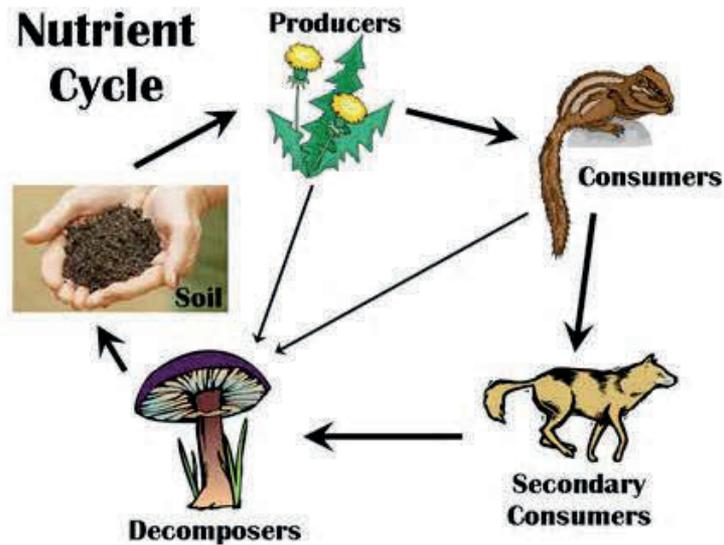


Figure 10.3. Nutrient recycling in an ecosystem.

Source:

<http://www.bing.com/images/search?q=Nutrient+Cycle&Form=R5FD15#view=detail&id=033C82874E2B71C8E6FB899767D6860CC8661CA2&selectedIndex=2>

The current philosophy of ecosystem management of natural resources on public lands was officially adopted in the 1990s during President Clinton's administration. This approach seeks to integrate social sciences with biological and physical sciences (Jenson and Guthrie 2006; Hendee et al. 2012). The ecosystem management philosophy came about in part because of the possible loss, at the time, of several bird species which highlighted the potential of reduced biological diversity across the landscape (Hendee et al. 2012).

## Types and Functions of Ecosystems

### Types of Ecosystems

Ecosystem services can be grouped into four broad categories: (i) provisioning services, (ii) regulating services, (iii) cultural services, and (iv) supporting services. Further description of each category is presented below.

*Provisioning Services*

The provisioning services which society obtains from an ecosystem include food, fiber, energy resources, biochemical, air, and fresh water (Moldan et al. 2007). These are outputs which are used directly by humans and other organisms (Figure 10.4).

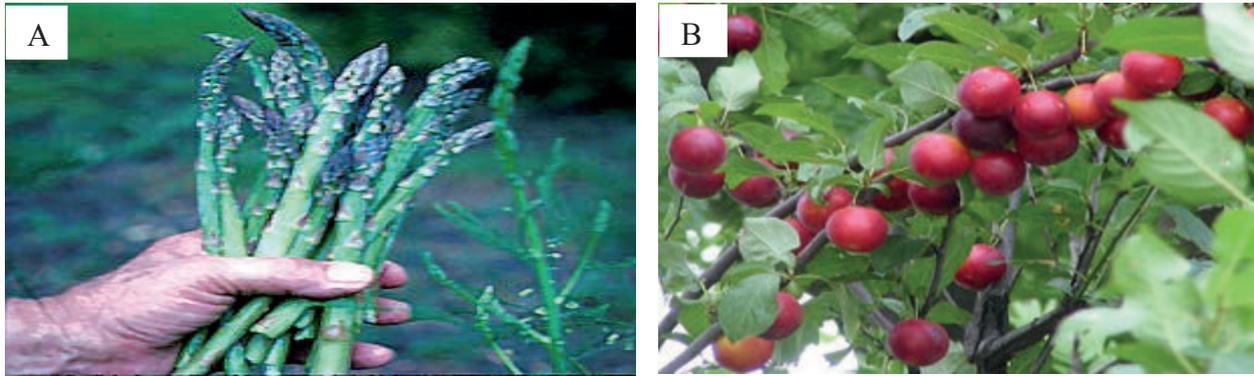


Figure 10.4. Examples of edible wild plants and fruits: asparagus (A) and red cherry plum (B).

Source:

<http://www.bing.com/images/search?q=wild+fruits+in+alabama&qpv=wild+fruits+in+alabama&FORM=IGRE#view=detail&id=01634841206B0B303C6BBA02D2D7E0C1652C77B5&selectedIndex=46>

*Regulating Services*

Regulating services encompass and support the maintenance and regulation of ecosystem processes. These processes include climate regulation (Moldan et al. 2007), water purification, flood control, and disease regulation (Grebner et al. 2013). Shoreline protection and stabilization are also important regulating services. The extensive wetlands of the Everglades do not only serve as habitat for a large number of unique plant and animal species but also serve critical water purification and flood regulation functions (Figure 10.5).



Figure 10.5. Wetlands in the Everglades National Park, Florida.

Source:

<http://www.google.com/search?q=Everglades+National+Park+Images&rls=com.microsoft:en-US:IE->

### *Cultural Services*

The cultural services derived from natural systems focus on the social benefits humans value from ecosystems (Grebner et al. 2013). These social values comprise outdoor recreation (Figure 10.6), spiritual, tourism, aesthetics, intrinsic, and religious dimensions among others. In the Southern US, some of these benefits contribute in a very direct way to the socio-economic development of the region. For example in Alabama, tourism and outdoor recreation are among the state's primary revenue generators and are a part of the employment sector.



Figure 10.6. Deer, one of the important species hunted in Alabama.

Source:

<http://www.bing.com/images/search?q=images+of+species+hunted+in+alabama&qpv=images+of+species+hunted+in+alabama&FORM=IGRE>

### *Supporting Services*

Supporting services include the group of services and benefits which aid in the development and provision of other types of ecosystem services. Such services include "...processes such as primary production, photosynthesis, soil formation, nutrient cycling and water cycling" (Grebner et al. 2013), pollination, and carbon sequestration.

Figure 10.7 summaries and graphically represents the categories of ecosystem services. A listing of the range of specific services derived by society under each category is also presented.

## **Economics and Environmental Values of Ecosystem Services**

### **Environmental Values**

National and international communities now recognize the important contribution of ecosystem services to socio-economic development and human well-being. Consequently, in addition to using regulations to guide and control development, many countries are turning to the invisible hand of the market to fight climate change and to protect biodiversity and other components of the environment (Block, no date). Given the recognition of the importance of ecosystem services, a framework for determining the economic valuation of such services has been pursued and captured in the global markets. "Such markets promote conservation funding at a time when financial resources are scarce" (Block, no date).

### **Economic Considerations**

Many years ago the ability to attach an economic valuation to natural resources and the public benefits associated with natural resources proved elusive. However, today after much research and global acceptance of the fact that there is indeed an economic dimension to such resources in addition to the other ecological, biological, and social dimensions, the international community has agreed on strategies to assess the economic value of ecosystem services. Market-based

approaches now are used to assign an economic value to ecosystem services such as erosion control, flood buffers, and clean air. By assigning an economic value to services such as erosion control, flood control, and clean water, these approaches allow countries to use the ‘invisible hand’ of commerce to protect biodiversity, habitats, and water supplies (Block, no date). “Ecosystem services are indispensable to the well-being and health of people everywhere. In addition to providing life's basic needs, changes in their flow affect livelihoods, income, local migration, and, on occasion, political conflict” (Millennium Ecosystem Assessment 2005).

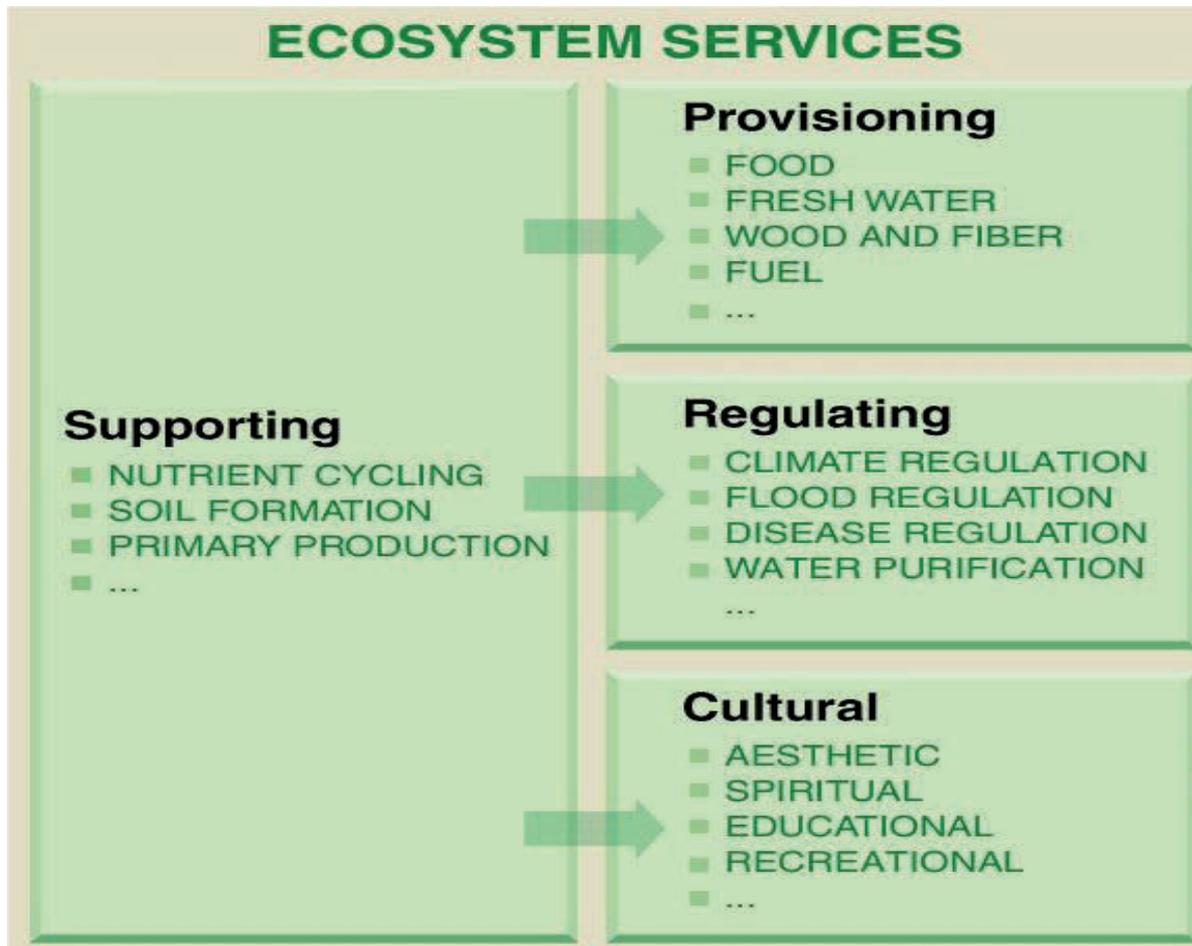


Figure 10.7. Categories of ecosystem services.

Source: <http://www.ecologyandsociety.org/vol11/iss1/art28/figure1.html>

The type of ecosystem influences the nature and mix of ecosystem goods and services possible. For example, climate regulation, flood regulation, disease regulation, and water purification are the range of regulating services possible from forest ecosystems, whereas climate regulation and disease regulation are the two primary ecosystem regulating services provided by oceans (Figure 10.8).

Overall respondents to a Florida survey of public agency representatives’ non-industrial private forest (NIPF) landowners to assess their perspectives found that ‘enjoyment of scenery’, ‘quality of drinking water’ and ‘environmental quality for recreation’ as the most important ecosystem services. Furthermore, NIPF landowners ranked ‘quality of drinking water’ as the most important

ecosystem service. Public agency representatives, however, identified ‘habitat/natural resources conservation’, and ‘recreation’, and ‘water quality/water resource management’ respectively as the most important ecosystem categories (Figure 10.9).

### Types of Ecosystem Services

	Forests	Oceans	Cultivated / Agricultural Lands
<b>Environmental Goods</b>	<ul style="list-style-type: none"> <li>• Food</li> <li>• Fresh water</li> <li>• Fuel</li> <li>• Fiber</li> </ul>	<ul style="list-style-type: none"> <li>• Food</li> </ul>	<ul style="list-style-type: none"> <li>• Food</li> <li>• Fuel</li> <li>• Fiber</li> </ul>
<b>Regulating Services</b>	<ul style="list-style-type: none"> <li>• Climate regulation</li> <li>• Flood regulation</li> <li>• Disease regulation</li> <li>• Water purification</li> </ul>	<ul style="list-style-type: none"> <li>• Climate regulation</li> <li>• Disease regulation</li> </ul>	<ul style="list-style-type: none"> <li>• Climate regulation</li> <li>• Water purification</li> </ul>
<b>Supporting Services</b>	<ul style="list-style-type: none"> <li>• Nutrient cycling</li> <li>• Soil formation</li> </ul>	<ul style="list-style-type: none"> <li>• Nutrient cycling</li> <li>• Primary production</li> </ul>	<ul style="list-style-type: none"> <li>• Nutrient cycling</li> <li>• Soil formation</li> </ul>
<b>Cultural Services</b>	<ul style="list-style-type: none"> <li>• Aesthetic</li> <li>• Spiritual</li> <li>• Educational</li> <li>• Recreational</li> </ul>	<ul style="list-style-type: none"> <li>• Aesthetic</li> <li>• Spiritual</li> <li>• Educational</li> <li>• Recreational</li> </ul>	<ul style="list-style-type: none"> <li>• Aesthetic</li> <li>• Educational</li> </ul>

Figure 10.8. Mix of ecosystem services society obtains from different ecosystems.  
 Source: <http://ecojesuit.com/valuing-ecosystem-services/4272/>

### Agency Responses to Ecosystem Services Provision

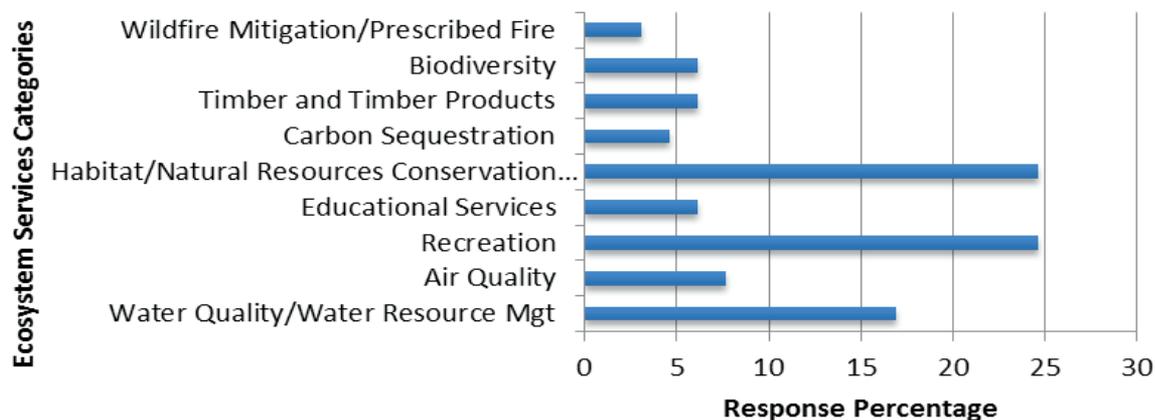


Figure 10.9. Results of survey of representatives of public land agencies in Florida.  
 Source: Stein et al. 2012.

## **Management and Policy Dimensions**

The critical elements of sound ecosystem management approaches likely to contribute to sustainable ecosystem services include recognition of need for protection of ecosystems, the role of an appropriate legislative framework, the effectiveness of law enforcement, and the need for mobilization of public support and participation in the process. The acknowledgement of the integral relationship between effective management of ecosystems and ensuring a continuous supply of quality ecosystem services is an important first step. Understanding of the concept and underlying principles of sustainable development is also critical. These concepts and principles must not only be acknowledged but should be reflected, demonstrated, and evident in all public policies across sectors. Very importantly, an integrated approach and inter-sectoral linkages should be the cornerstone of all public policy decisions and initiatives.

Research has shown that public education and awareness help build and strengthen public support for public policies. An informed public, recognizing the importance of certain public goods and services to their personal health and economic survival, will be more supportive of programs and strategies aimed at the protection and efficient management of the resources which form the basis for these public goods and services. Thus, long-term awareness building and education are important strategies for sensitizing and motivating the public to action to protect ecosystems and ensure the continuous flow of ecosystem services.

A comprehensive and integrated legislative framework is also very important for controlling and reducing environmental pollution, the destruction of ecosystem assets, and for the prosecution and punishment of violators. Whereas education and awareness building will contribute to public involvement in ecosystem protection, a small percentage of the public may not be very respectful and supportive of ecosystem protection programs and initiatives. Periodic review of approaches and procedures as well as possible amendment to relevant legislation may be required from time to time to reflect and adapt to loss of biodiversity, ecosystems, changing technologies, societal values, and societal aspirations. The guiding principle behind ecosystem management is that overall management efforts are directed towards the maintenance of healthy and holistic ecosystems (Hendee et al. 2012). To be successful in this effort, it is important to recognize the inter-related nature of natural and socio-economic systems (Figure 10.10).

## Ecosystem Services

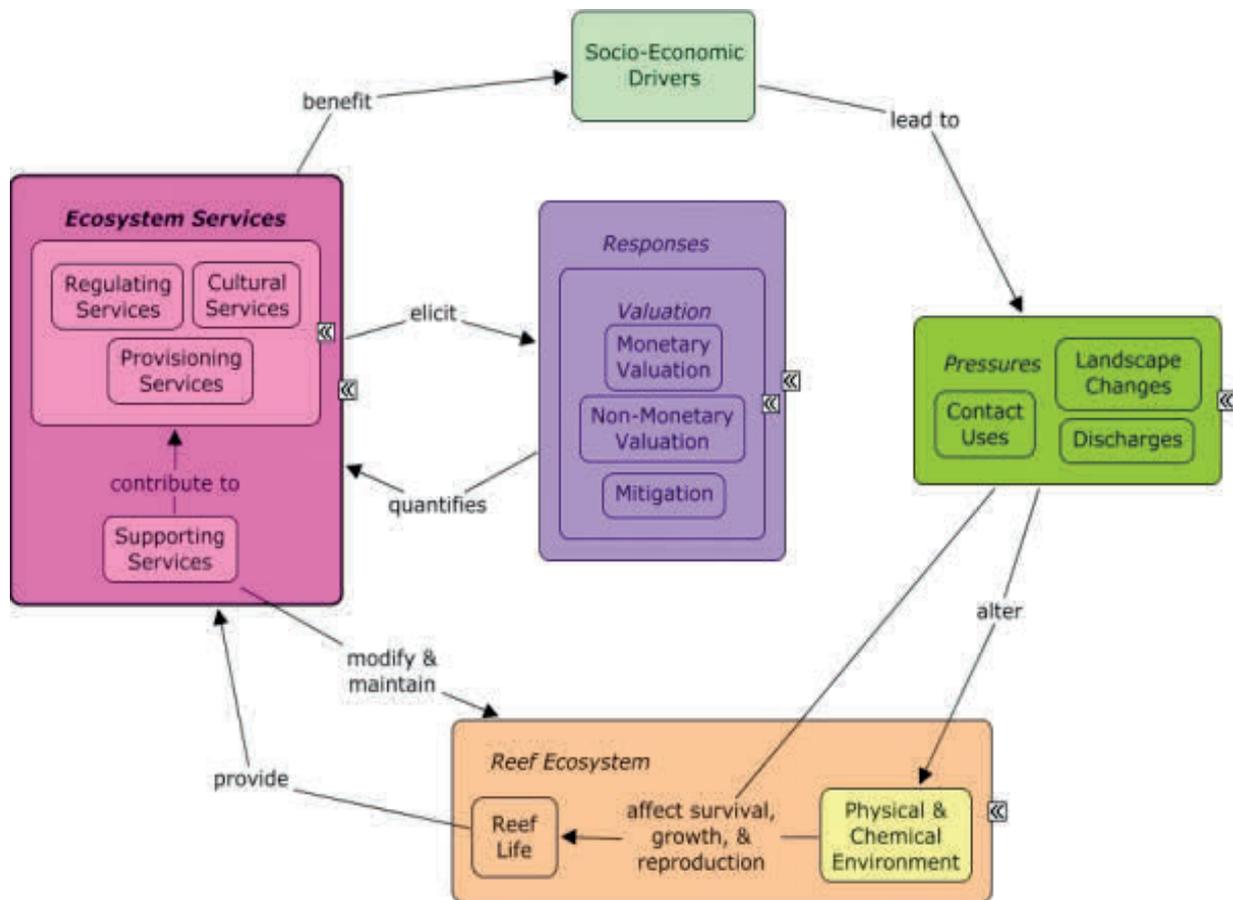


Figure 10.10. Schematic presentation of the inter-relationship among ecosystem services and related concepts.

Source:

<http://www.bing.com/images/search?q=ecosytem+services+in+alabama&qs=n&form=QBIR&pq=ecosytem+services+in+alabama&sc=0-19&sp=-1&sk=#view=detail&id=4787273531EC267D770EB650A808864D5C73C80D&selectedIndex=11>

## Hands-on Activities and Demonstrations

A three-component field exercise followed by a class presentation will be undertaken to help reinforce classroom discussions. Ecosystem identification techniques will be demonstrated and course participants will be expected to list and explain the reasons for their decisions. Participants, working in small groups, will have the assignments for identification of ecosystems in different geographic areas and advance logic and reasons for selection. Participants will also be expected to identify ecosystem benefits derived from the ecosystems identified. Further details of field assignments are captured below.

1. Identification of Ecosystems: As a first step participants, working in small teams, will be asked to identify and describe the different ecosystems in a particular geographic region or landscape. Participants will be expected to justify their conclusions, i.e. explain the rationale for their choices.

## Ecosystem Services

2. Summarizing: Having identified the different ecosystems in a specific geographic zone or landscape, participants will seek to identify the perceived ecosystem services to be realized from each ecosystem unit and the cumulative ecosystem services the society derives from the geographic zone under investigation.
3. Categorizing Ecosystem Services: The third step of the exercise will be for participants to group the ecosystem services identified in accordance with the four categories of ecosystem services and advance the reasons for their decision model.
4. Group Presentations: Each team will have the opportunity to present and defend final decisions and conclusions before the entire workshop class.

To facilitate the exercises outlined above, worksheets will be made available to participating teams. These worksheets will facilitate the comparison of groups' outputs and rationale and form the basis for classroom presentation by the teams.

### Key Points

1. Ecosystems are self-sustaining natural units.
2. Ecosystems may be small or large.
3. Ecosystems may be aquatic, marine, or terrestrial based.
4. Society derives a range of services or benefits from ecosystems. These are generally referred to as ecosystem services.
5. Ecosystem services can be categorized into four broad groups namely 'Supporting Services', 'Provisioning Services', 'Regulating Services', and 'Cultural Services'.
6. Ecosystems and ecosystem services are vital for sustainable development and overall human well-being, particularly in the context of developing countries, rural communities, and emerging nations.
7. Sustainable ecosystem management and ecosystem services are only possible in an environment where appropriate public policies, administrative and legislative frameworks, and effective law enforcement mechanisms are evident.
8. The relevant knowledge-base, attitude, and behaviors of members of the public towards the environment and ecosystem management have a profound impact on the sustainable flow of ecosystem services.

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## **Chapter 11 ECONOMICS OF AGROFORESTRY SYSTEMS**

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### **Valuing Agroforestry Systems**

Farmers and landowners can obtain increased economic benefits by adopting agroforestry practices relative to their existing monoculture operations (forestry, crops, or livestock production) either through diversified income options or through reduced input costs. Different types of agroforestry systems have been discussed in the previous chapters. The increased benefits and associated costs of the agroforestry practices can be assessed using an enterprise budget, partial budget, and financial analysis applying a cost and returns approach. In addition, sensitivity analysis can be done to determine how changes in some of the key parameters would affect the economic returns. The returns to agroforestry practices are sometime highly sensitive to the timing and quality of certain practices, such as pruning. To effectively demonstrate the benefits and financial returns from agroforestry systems, each component of the system must be assigned a corresponding monetary value. Edward (1991) analyzed and compared the profitability of a wide variety of agroforestry practices in Senegal using Net Present Value (NPV), Benefit/Cost ratio, and Rate of Return (ROR). According to AFTA (1997), Alavalapati and Nair (2001), and Nair (1994), integration of agroforestry practices into traditional farming systems yields greater rates of return than monoculture practices alone.

### **Economic Analysis of Agroforestry Practices**

Agroforestry systems have unique characteristics: a) Long planning horizons, b) Irregular cost and revenue occurrences, and c) Fixed tree component with variable crop or livestock components (Godsey 2010). Because of such characteristics, the economic analyses of agroforestry practices require various considerations. The major tools used for economic analysis of agroforestry practices are enterprise budget and cash flow management. Similarly, the economic performance of agroforestry practices can be measured using net present value, internal rate of return, and annual equivalent value. Economic analysis of agroforestry practices is an ongoing process until the final harvest of the trees. Therefore, the seasonal or annual cash flow is very important to compare the revenues of different crops and livestock enterprises between successive years until the final harvest of the tree component. The following sections illustrate a comparison of the agroforestry systems, considering the economic aspects of each system. For detailed descriptions of the different types of agroforestry systems, please refer to the preceding chapters.

### **Pasture versus Silvopasture**

Pasture is the land use for production of adopted forages for livestock production and management. Pastures largely represent those management practices where land is seeded with

forage crops using agronomical practices and livestock grazing. It is different from range land in the basis of management and agronomical practices as range land is natural and controlled by livestock grazing. Unlike the pasture system, silvopasture systems also consist of trees. Because of the diversified components, silvopasture systems reduce the economic risk by producing multiple products. The production costs are reduced and marketing flexibility is enhanced by distributing management costs among the tree, forage, and livestock components (USDA/NRCS 2008). Silvopasture has a higher internal rate of return (13.4) in comparison to coastal pasture (6.1) and plantation (8.8) options (Hamilton 2008).

The initial establishment cost of the silvopasture may include the following expenses per acre depending on the mechanical or chemical application used and condition of the site ([http://www.silvopasture.org/pdf\\_content/Module%201%20Required%20Reading.pdf](http://www.silvopasture.org/pdf_content/Module%201%20Required%20Reading.pdf))

- Herbicides and/or labor for removal of competition and weed management = \$50 - \$250
- Prescribed burning = \$20-25
- Tractor/equipment work for site preparation. On old agricultural fields, disking/sub-soiling = \$25-50 and on cutover forestland = \$100-150
- Costs of seedlings \$40-75 per thousand bare-root; and \$100-125 per thousand containerized
- Labor for planting = \$35-45 for southern pines

Similar to these, the information in Table 11.1 also shows costs that can be incurred for establishing silvopasture per acre. The equipment cost for silvopasture establishment is presented in Appendix Table A.

Similarly, the cost estimates for forage management per acre may include the following:

- Establishment (seed+ planting costs + labor and equipment) = \$275
- Annual nutrient costs = \$85
- Annual hay harvesting costs \$20/ton = \$60
- Periodic lime cost every two to three years/acre = \$24

#### *Benefits Associated with Silvopasture*

Silvopasture is a form of agroforestry that combines spatial and rotational growth of timber, forage, and livestock, and has many associated environmental benefits (Husak and Grado 2000). Silvopasture may be able to mitigate some of the negative impacts of cattle production while providing some environmental services to the public. There are many benefits associated with silvopasture, which fall into several categories such as water quality improvement, soil conservation, carbon sequestration, and improvement of wildlife habitat (Shrestha and Alavalapati 2004). The examples in Tables 2 and 4 suggest that converting timberland to silvopasture could be more economically attractive than adding timber to existing cattle operations. Table 11.10 also confirms that production of pasture, hay, crop, and agroforestry yields higher return per acre than just having timber. Recently published data by Husak and Grado (2002) seem to support this conclusion, except for the lowest (5%) interest rate investigated (Table 11.2 and Table 11.4).

*Equivalent Annual Income*

Equivalent Annual Income (EAI) is often used to compare forestry and agricultural investments. EAI represents a net present value (all revenues minus all costs discounted to the present) of an investment expressed as an annual dollar amount. At the lowest interest rate (5%) pine plantation produced the highest EAI and silvopasture was a close second. However, at seven and nine percent interest rates, cattle were the most profitable (Table 11.2). On average, silvopasture was more profitable than pine plantation, but not as profitable as cattle operations. The reader is cautioned to consider these conclusions in the context of current market conditions and differences in management regimens. For example, one commodity not included in the analyses summarized in Table 11.2 is pine straw, which is not produced in loblolly pine plantations.

Table 11.1. Silvopasture establishment cost (\$/acre).

Activities	Cost (\$)/acre
Moisture conservation and weed control	100.00
Tree bare root, planted (100/acre)	150.00
Perennial grass seed mix [pounds/acre (18) @3.50/acre]	93.00
Fertilizer (placed with seed)	60.00
Equipment total	57.36
Mobilization	12.71
Operation & maintenance	12.71
Total cost	485.78
Benefit	
Accrued benefits (\$8 & \$25 /acre/year from timber & forages respectively)	33.00

Source: Adapted from Gordon (no date).

When properly implemented, silvopasture can provide many economic and environmental benefits. Some of these are linked, e.g., reduced need for nitrogen fertilization in grass/legume silvopasture leaves more dollars in landowners' pockets, and lowers the risk of ground water contamination with possible leaching of nitrates. Not all benefits will be possible in every silvopastoral system. Some may be more applicable than others to a particular landowner, depending on silvopasture design, level of management, external circumstances, and management objectives. Research models show loblolly pine-forage-cattle practices in the Coastal Plain may have up to 70 percent greater net (Dangerfield and Harwell 1990).

Table 11.2. Equivalent annual income from loblolly pine-based silvopasture, cow-calf operations, and loblolly pine plantation in 1999 dollars.

Interest Rate	Silvopasture	Cattle	Pine Plantation
%	Cost \$/acre		
5	67.06	55.31	69.26
7	51.15	55.01	45.00
9	38.27	53.70	26.62
Average	52.16	54.67	46.96

Source: Adapted from Husak and Grado 2002. present value than a pure forestry operation

NCDNR (1997) used the parameters/activities in this silvopasture system as shown in Table 11.3 and as listed below.

- Loblolly pine was planted at a density of 454 trees/acre @ 4ft\*8ft\*20ft and maintained on a 30-year saw timber rotation.
- Commercial thinning to a residual basal area of 70ft<sup>2</sup> was conducted at ages 15, 20, and 25 years to improve the growth and value of the stand.
- Final harvest occurred in Year 30.
- Prescribed burning was used annually from ages four to 30 years to reduce fire hazards and plant competition, kill brush, improve access, and simulate forage growth.
- Residual trees were pruned following thinning to reduce taper and increase volume.
- Timber prices used were: \$405/mbf<sup>1</sup> for saw timber; \$79/cord for chip ‘n’ saw; and \$18/cord for pulpwood.
- Cattle were introduced to the system in year two to allow time for forage and tree establishment.
- Calves were sold in their second year because two-year-old steers and heifers, weighing 1,000 lb, yield higher prices than yearling calves.
- A permanent summer grass mixture composed of bahiagrass, bermudagrass, dallisgrass, and other mixed grasses and Mount Barker clover were planted, fertilized, and maintained annually beginning in Year 1.
- Annual maintenance costs, which included land rent during years 0 to30, forage establishment, and maintenance costs were incurred between years 1 and 30.
- Revenues from the sales of steers and heifers occurred during years 3-30.
- Pine straw production, even under low yield and price conditions, can add as much as \$35/acre/year to a forestland owner’s income.

Table 11.4 delineates the costs and revenues for silvopasture, soybeans, rice, cattle, and pine plantation systems at real interest rates of five, seven, and nine percent. Land expectation value (LEV), Equivalent Annual Income (EAI), and ROR were calculated for each system without regard to risk and inflation (Table 11.4). At five percent interest, the LEV and EAI were greatest for the pine plantation followed closely by silvopasture, soybean production, and cattle production. Rice production had the lowest LEV and EAI at five percent interest. At seven and nine percent interest, soybean production yields the highest LEVs and EAIs, while the pine plantation yields the lowest LEVs and EAIs. These values indicate that, at low interest rates like five percent, the preferred uses for the land are pine plantations, silvopasture, or soybean production. At higher interest rates, like seven and nine percent, soybean or cattle production is the preferred land use. EAI represent the NPV (i.e., all revenues minus all costs discounted to the present) of an investment expressed as an annual amount (Bullard and Straka 1998). Although

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<sup>1</sup> Board-foot/foot, board measure, which is a unit of measurement for the volume of lumber. It is the volume of a one-foot length of a board one foot wide and one inch thick.

RORs should not be used for ranking purposes, they provide some idea of the average rate of interest earned on capital over the life of the investment. For this analysis, the highest RORs were 10.10 percent for pine plantation followed by 5.9 percent for silvopasture. Similarly, RORs were lower for cattle, soybeans, and rice. The negative ROR for rice can be attributed to the higher annual rent required for rice production, which creates negative annual returns on the investment.

Table 11.3. Costs and revenues for a silvopasture system (US 2002 dollars).

Year	Activity	Cost (\$/acre)	Revenue (\$/acre)
0	Establishment	77.73	-
0 to 30	Land rent	52.5	-
1 to 30	Management	159.19	-
2, 12, 22	Cow purchase	179.46	-
12, 22	Cow sales	-	134.59
2 to 30	Supplemental feed	21.6	-
2 to 30	Animal maintenance	5.4	-
3 to 30	Steer/heifer sales	-	234.75
4 to 30	Prescribed burning	13.25	-
4 to 30	Hunting leases		4.89
Every 5 years	Bull purchase	12.29	-
Every 5 years	Bull sales	-	7.12
10, 14, 18, 22, 26, 30	Pine straw	-	1.5*
15	Thinning	-	152.28
15	Pruning	38.08	-
20	Thinning		66.42
20	Pruning	23.63	-
25	Thinning	-	501.65
25	Pruning	16.15	-
30	Harvest		2,352.23
Total		599.28	3,455.43

\* Net revenue/acre after raking, baling, and fertilizing.

Source: Adapted from Grado and Husak 2004.

Sharma (2006) reported that the economic benefits derived from large cardamom agroforestry in Sikkim showed increased gross income from US\$1.9 million in 1975-76 to \$5.7 million in 1985-86, and to \$6.4 million in 1995-96. Of the two systems compared, (a) large cardamom dominated agroforestry and (b) maize-potato dominated in Sikkim, the household income and per person per day incomes were almost doubled for large cardamom than for maize-potato dominated systems.

Table 11.4. Land expectation value (LEV), Equivalent Annual Income (EAI), and Rates of Return (ROR) for five production systems (2002 US\$) at various interest rates.

Production system	Interest rate (%)	LEV (\$/acre)	EAI (\$/acre)	ROR (%)
Silvopasture	5	1253.11	62.66	5.90
	7	693.83	48.57	5.90
	9	411.83	37.06	5.90
Soybeans	5	1157.73	52.50	1.40
	7	842.70	51.52	1.40
	9	667.69	50.58	1.40
Rice	5	1049.58	47.60	-2.50
	7	763.98	46.71	-2.50
	9	605.31	45.85	-2.50
Cattle	5	1126.95	56.35	4.00
	7	806.02	56.42	4.00
	9	619.57	55.76	4.00
Pine plantation	5	1284.43	64.22	10.10
	7	614.55	43.02	10.10
	9	298.84	26.90	10.10

Source: Adapted from Grado and Husak 2004.

### Forest Farming versus Alley Cropping

A system that is suitable for many areas of the United States with tree cover is forest farming or multi-story cropping. Forest farming establishment cost per acre varies from location to location. Many high-value specialty crops are now being cultivated under the protection of a forest canopy that has been modified to provide the appropriate microclimatic and light conditions. For details of forest farming, please refer to Chapter 6 of this handbook.

### Alley Cropping

Alley cropping is planting trees in rows with a companion crop grown in the alleyway between the tree rows. Details about the alley cropping are presented in Chapter 7. This system can increase crop production, improve landscaping aesthetics, enhance wildlife habitat, and provide protection for the crop. According to AFTA (1997), Alavalapati and Nair (2001), and Nair (1994), an alley cropping system has fast-growing, preferably leguminous woody species in single or grouped rows in agricultural fields. Prunings from the woody species are applied as mulch into the agricultural production alleys to increase organic matter and nutrients, or removed from the field for other purposes such as animal fodder in the tropics. In the tropical system, trees are planted in single or grouped rows within agricultural or horticultural fields with crops grown in the wide alleys between the tree rows (USDA-NAC-NRCS-FS 2012).

*Measuring Alley Cropping Using Partial Budget Analysis Approach*

A partial budget starts with the current farm condition, and then looks at how changes affect the farm's budget. It investigates the cost of the change and the benefit to the farmer. It is referred to as a "partial budget" because it does not look at the whole farm budget, but rather examines only the changes in income produced by a change in activities. Table 11.6 is an example of partial budget that displays typical cost and benefit of alley cropping. It is worth discussing some of the valuation questions in assembling partial budgets. The most important concept in the partial budget is the opportunity cost of a change. For example, in introducing alley cropping to a farmer's corn field, one of the things being given up is the corn that could have been grown in the space the trees are now using. This is an opportunity cost. To demonstrate partial budgeting, an example analysis (Table 11.6) on adopting a sorghum-Leucaena alley cropping system in a semi-arid region of India (Singh et al. 1981) is reproduced here. For the ease of calculation, details of equipment cost for establishing alley cropping are presented in Appendix Table B.

Table 11.5. Cost for alley cropping establishment (\$/acre).

Activities	Cost (\$)/Acre
Moisture conservation, weed control	100.00
Tree bare root, planted (100/Acre)	150.00
Perennial grass seed mix [pounds /acre (18) @3.50/acre]	93.00
Fertilizer (placed with seed)	60.00
Equipment total	31.83
Mobilization	15.00
Operation & maintenance	15.00
Typical cost	464.83
Benefit	
Accrued benefits (8 & 50 /acre/year from timber & crop)	58.00

Source: Adapted from Gordon (no date).

The introduction of Leucaena alleys is considered to be an addition to the current practice of mono-cropping sorghum. Therefore, the opportunity cost is the sorghum forgone for adopting the sorghum-Leucaena system. Table 11.6 provides a summary of the partial budget analysis and gives the opportunity cost on top and the gains from alley cropping on the bottom. It appears from this analysis that the net-gain from converting from a sorghum mono-cropping system to the sorghum-Leucaena alley cropping system is 5,015 Indian rupees (INR) per hectare.

To complete Table 11.7, it is assumed that the investment in alley cropping in the example requires: 1) an investment of Indian rupees 10,000 per hectare in the year before cropping begins, 2) the discount rate the farmers use is 20 percent, and 3) the project's benefits last for five years. Economists have found that a 40 percent return is the minimum general rate that small farmers will accept. However, this figure is not uniformly accepted. The discount rate used by farmers is a suitable subject for research.

Table 11.6. An example partial budget analysis.

Cropping system	Yield (ton/ha)	Price (Indian rupees/t)	Revenue (Indian rupees/t)
<b>Sorghum (sole crop)</b>			
Grain	1.55	2250	3488
Stover	5.1	500	2550
Total			6038
<b>Sorghum-Leucaena alley cropping</b>			
Grain	1.09	2250	2453
Stover	3.9	500	1950
Fodder, in-season	7.2	250	1800
Fodder, off-season	3.1	500	1500
Fuel, stems	6.5	300	1950
Stumps	3.3	400	1320
Seeds	0.4	200	80
Total			11053
Net gain			5015

Source: Adapted from Singh et al. 1981.

Table 11.7. A hypothetical 5-year project analysis.

Cropping system	Year 1	Year 2	Year 3	Year 4	Year 5
<b>Sorghum (sole crop)</b>					
Total revenues	6038	6038	6038	6038	6038
Less input costs	2000	2000	2000	2000	2000
Net income	4038	4038	4038	4038	4038
<b>Sorghum-Leucaena alley cropping</b>					
Total revenues	11053	11053	11053	11053	11053
Less input costs	4000	4000	4000	4000	4000
Net income	7053	7053	7053	7053	7053
Net gain from adopting alley cropping	3015	3015	3015	3015	3015
Discount formula <sup>4</sup>	1/1.20	1/1.20 <sup>2</sup>	1/1.20 <sup>3</sup>	1/1.20 <sup>4</sup>	1/1.20 <sup>5</sup>
Discount factor	0.833	0.694	0.579	0.482	0.402
Present value	2511	2092	1746	1453	1212

Note: <sup>2, 3, 4, and 5</sup> denote discounted factor corresponding to the respective year.

Source: Adapted from Singh et al. 1981.

### **Economic Analysis of Silvopasture Systems**

Godsey (2008) presented case studies regarding economic analysis of the following farms:

1. **The Williams Farm** that practiced Silvopasture in 7 acres of Eastern Black Walnut (*Juglans nigra* L.) which was planted in 1977. A rotational grazing system was done. The silvopasture practice increased income as follows:

Income:

- 40% - 60% increase over standard pasture rental rates of \$25 per acre i.e., \$35 - \$40 per acre
- Sold seed nuts from 1996 – 2008 to a local nursery
  - 800 lbs x \$1.50/lb = \$1,200 per year
- Sold nutmeat from 1987 – 1996 to a local market
  - 50 lbs per year at \$3 per pound (net) = \$150 per year
- Sold nuts to local nut huller from 1987 – present
  - 500 lbs x \$0.10 per lb = \$50 per year

Cost:

- Cost to establish silvopasture /acre: \$762
- Annual maintenance costs /acre/year: \$65

2. **The Wurdack Farm** was established in 2002, beginning with a commercial thinning. This site was designed to test the interaction between livestock, trees, and forages.

Recommended costs to establish silvopasture site: \$398/acre

**a. Cost**

- i) Clearing and site prep: \$79/acre
- ii) Soil amendments: \$210/acre
- iii) Grass establishment: \$125/acre
- iv) Water and fence: \$134/acre

**b. Income**

- i) Commercial thin income: \$150/acre

**c. Costs** to establish silvopasture /acre (A-B) =398

Support for establishing silvopastures and other agroforestry practices can be obtained from USDA/NRCS programs (Appendix Tables C and D).

### **Economic comparison of agroforestry systems**

Agroforestry, in general, provides a greater economic return than other cropping combinations. For example, agroforestry provides the highest returns of the four land-use regimes considered in Table 11.8 followed by timber, nuts, and soybean/wheat rotation.

Table 11.8. Financial measures of alternative land-use regimes, medium-quality land, 60-year rotation for black walnut.

Land use	Present net worth per acre (interest rate 4%)	Internal rate of return (%)	Annual equivalent value per acre (interest rate 4%)
Agroforestry	\$2,096	11.7	\$92.64
Timber and nuts	\$2,022	10.8	\$89.38
Soybean/wheat rotation	\$695		\$30.84
Timber	\$146	4.3	\$6.47

Source: Kurtz et al. 1996.

### **Agroforestry Cash-Flow Plan Using Monoculture (Hay) and Alley Cropping**

Information in Table 11.9 shows an alley cropping practice with eastern black walnut trees that may receive Conservation Reserve Program (CRP) payments for the first 10 years of the planning horizon but not after that period. Income from nut production may start at Year 10 or 12 and continue until the tree is harvested for wood at Year 60. Once enterprise budgets are created, a cash flow plan for the agroforestry practice can be developed. It is important to understand that an agroforestry practice may include more than one enterprise. For example, a well-established alley cropping practice may combine a tree enterprise with hay and livestock enterprises. As mentioned earlier, often the tree enterprise is fixed while the crop or livestock enterprises vary over time.

Economics of Agroforestry Systems

Table 11.9. Agroforestry cash-flow plan using hay and eastern black-walnut-based alley cropping.

Revenues	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	...	Year 60
Tree: Eastern Black Walnut	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$255.00	\$1,343.00
Crop: Hay	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$120.00	\$120.00
Total revenues	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$62.00	\$375.00	\$1,463.00
Variable Costs													
Tree: Eastern Black Walnut	\$650.50	\$19.10	\$19.10	\$26.70	\$26.70	\$26.70	\$44.50	\$44.50	\$44.50	\$44.50	\$44.50	\$202.00	\$202.00
Crop: Hay	\$34.50	\$30.00	\$30.00	\$44.50	\$30.00	\$30.00	\$30.00	\$44.50	\$30.00	\$30.00	\$30.00	\$60.00	\$64.50
Total Variable Costs	\$685.00	\$49.10	\$49.10	\$71.20	\$56.70	\$56.70	\$74.50	\$89.00	\$74.50	\$74.50	\$74.50	\$262.00	\$266.50
Fixed Costs													
Tree: Eastern Black Walnut	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$11.00	\$26.00	\$26.00
Crop: Hay	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00	\$34.00
Total Fixed Costs	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$45.00	\$60.00	\$60.00
Net Income	\$668.00	\$32.10	\$32.10	\$54.20	\$39.70	\$39.70	\$57.50	\$72.00	\$57.50	\$57.50	\$57.50	\$53.00	\$1,136.50

Source: Adapted from Godsey 2008.

### Net Return/Acre by Product Type

Land use changes from crop or timber production to agroforestry can provide opportunities for additional income. Agroforestry land may still be used for hay or forage production. Net return by product type is presented in Table 11.10 that shows lowest amount of return per acre from timber.

Table 11.10. Typical net returns (\$/acre) based on product types.

Product types	Net return (\$/acre/year)
Timber	\$5 - \$30
Pasture	\$10 - \$50
Hay	\$50 - \$300
Crop	\$100 - \$500
Agroforestry	\$5 - \$500

Source: Adapted from Gordon (no date).

### Hands-on Activities

Participants will be engaged in learning by doing the following activities.

1. Calculation of agroforestry establishment costs
2. Economic comparison of various agroforestry production systems
3. Economics terminology
4. Partial and enterprise budgeting

### Key Points

1. Agroforestry is the intentional integration of trees and/or shrubs into crop and animal farming systems to create environmental, economic, and social benefits. Each type of agroforestry excels over mono-cropping though amount varies significantly from one system to another.
2. Agroforestry, in general, provides a greater economic return than other cropping combinations. The major tools used for economic analysis of agroforestry practices are enterprise budget and cash flow management.
3. Agroforestry is a long-term plan/investment. When the return on investment over a long period such as 50 years or 60 years is considered, the investment could be highly profitable. Rate of return in agroforestry seems to have very competitive ranging from eight to twenty percent because every agroforestry operation will express unique profit potential because of varying input costs and selection of differing production practices.

4. Partial budget basically deals from small changes or refinements to farm operations. It focuses only on parts that change, whereas enterprise budget is to estimate costs and revenues for a single enterprise to assess feasibility or profitability.

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## APPENDICES

Table A: Details of equipment cost for silvopasture establishment (\$/acre).

Equipment/installation (\$/pass/acre)	Passes	Machinery	Labor	Total
Two-wheel Drive 70 HP	8	4.27		
Mold-Board (MB) Plow 4-bottom	1	9.96	6.57	16.53
Tandem Disk 11ft	2	2.32	3.58	5.9
Dixon Harrow	2	3.75	2.19	5.94
Cult packer	1	6.07	1.86	7.93
Spreader (fertilizer)	1	5.99	0.91	6.9
Grass seed Drill	1	6.47	3.42	9.89
Equipment total		38.83	18.53	57.36

Source: Adapted from Gordon 2000.

Table B: Details of equipment cost for alley cropping establishment (\$/acre).

Equipment/installation (\$/pass/acre)	Passes	Machinery	Labor	Total
MFWD Tractor 200 HP	6	9.34		9.34
Chisel Plow 15ft	2	2.46	2.1	4.56
Roller packer	1	1.59	1.75	3.34
Offset disk	2	3.15	2.92	6.07
Grain dill	1	5.57	2.94	8.51
Total		22.11	9.71	31.82

Source: Adapted from Gordon 2000.

The followings are some of the ways for receiving state and federal support for adopting agroforestry practices.

Financial and technical assistance can be found through:

Federal Farm Bill Programs (CRP, EQIP, WHIP), Conservation Easements, State Programs, Agricultural Commodity Organizations, Wildlife and Nature Organizations

Table C: Authorized NRCS maximum payment rates by program and cost category.

Cost category	Maximum payment rate (%)	
	Regular program	Program for historically underserved people
Materials	75	90
Equipment and installation	75	90
Labor	75	90
Mobilization	75	90
Operation and maintenance	N/A	N/A
Acquisition of technical knowledge	75	90
Foregone income	100	100
Risk	N/A	N/A
Administration and permit costs	N/A	N/A

Source: Gordon (no date).

\* States may make payments less than the maximum payment rate.

Program payments are nationally developed and can be seen in the field office technical guide (Section I) or by visiting the county USDA service center.

Table D: EQIP program payment examples for nine agroforestry practices.

Conservation practice	Payment
Windbreak/Shelterbelt Est.	\$.20 - \$3.00/Foot
Forest Management Plan	\$1,000 - \$5,000/Each
Hedgerow Planting	\$1.22 - \$3.36/Foot
Tree & Shrub Establishment	\$100 - \$2,700/Acre
Riparian Forest Buffer	\$100 - \$3,000/Acre
Tree & Shrub Site Preparation	\$30 - \$700/Acre
Forage Harvest Management	\$4 - \$168/Acre
Forage and Biomass Planting	\$53 - \$180/Acre
Forest Stand Improvement	\$60 - \$900/Acre

Source: NRCS general manual 440-512-subpart D - program payment schedules - 512.33. Payment rates.

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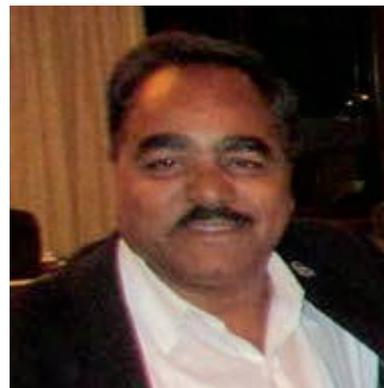


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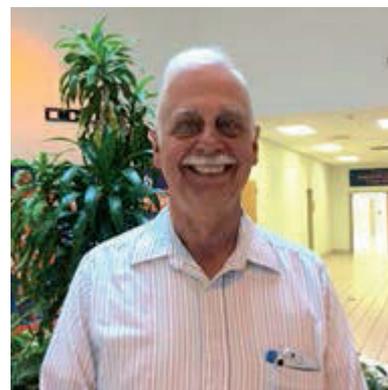
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Trainees are learning to collect soil samples.



Trainees are learning to prune tree branches.



Trainees are learning to measure and calculate tree diameter at the breast height.



Trainees are learning and practicing to inoculate Shiitake mushroom spawn into logs.



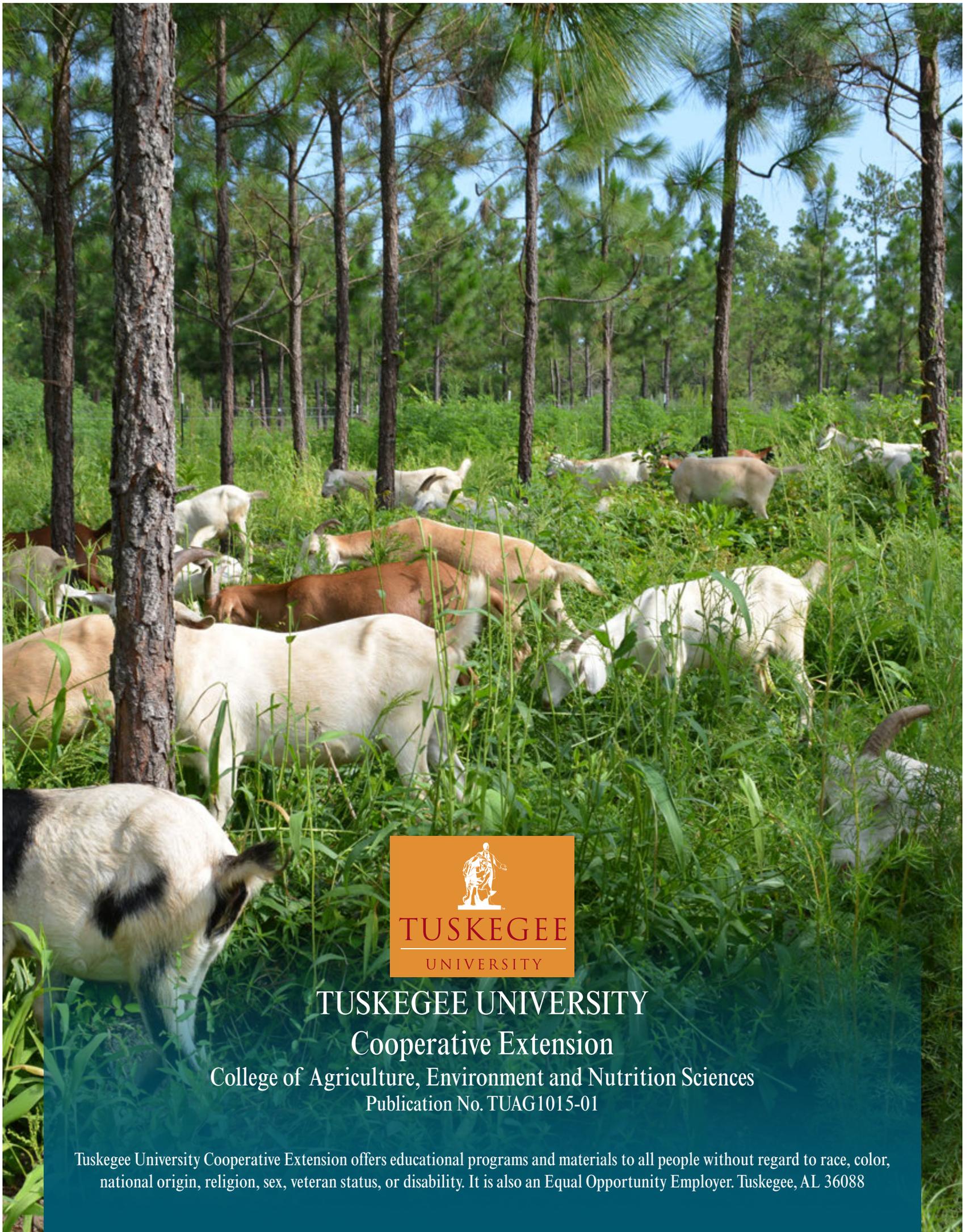
Trainees are bringing logs home they inoculated with Shiitake mushroom spawn.



Trainees are learning about beekeeping and tasting raw honey.

Trainees are engaged in demonstration and hands-on activities of different agroforestry aspects.





# TUSKEGEE UNIVERSITY

## Cooperative Extension

College of Agriculture, Environment and Nutrition Sciences

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