TRAINING MANUAL
FOR AGROFORESTRY PRACTICES

2025 Edition













Center for Agroforestry
University of Missouri

Acknowledgments

This publication is the result of the collaborative efforts of several individuals and organizations. The University of Missouri Center for Agroforestry acknowledges the USDA National Agroforestry Center and the Mid-America Agroforestry Working Group for contributions to the text of this publication. Portions of this material are also credited to the "Forest Landowner's Guide to Evaluating and Choosing a Natural Resource-Based Enterprise," published by the Natural Resource, Agriculture, and Engineering Service (NRAES) Cooperative Extension program, Ithaca, New York.

View this Training Manual online at: www.centerforagroforestry.org

Editors: Michael Gold, Hannah Hemmelgarn, Caroline Todd, Kelsi Stubblefield, Alan Helland, Olga Romanova, Gina Beebe, & Mallory Daily. Cover photo credits: (top row, left-to-right) USDA National Agroforestry Center, UllrichG/Adobe Stock, Hannah Hemmelgarn; (bottom left and middle) Mallory Daily, (bottom right) USDA National Agroforestry Center.

Training Manual for Applied Agroforestry Practices
2025 Edition

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Original funding for this work was via the United States Department of Agriculture North Central SARE with Agreement Number H003044602 and NCR-SARE Project Number ENC12-129. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the USDA.

This work was also funded through the University of Missouri Center for Agroforestry under cooperative agreements 58-6227-5-029, 58-6227-2-008 and 58-6227-5-028 with the United States Dept. of Agriculture (USDA) Agricultural Research Service. Special recognition is given to the USDA, ARS, Dale Bumpers Small Farms Research Center, Booneville, Ark. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the USDA.

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Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

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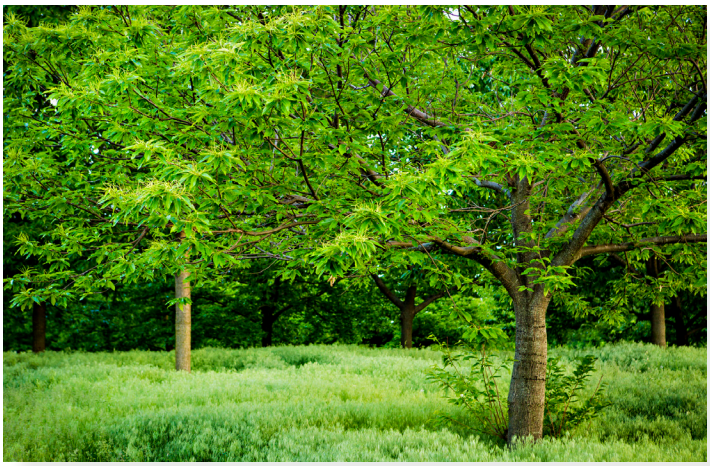
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User's Guide to the Training Manual

Farmers, land stewards, and others drawing sustenance from the land often strive to produce goods through methods that are economical, conservation-minded and socially acceptable. Agroforestry practices are unique and multifunctional. Through proper application, these practices can meet each objective of economic viability, conservation of resources, and social acceptance.

Agroforestry practices are designed to fit specific niches within the farm to meet diverse objectives. When properly planned and managed, agroforestry practices can achieve a balance between diverse, and often seemingly opposed, goals. This manual will examine six agroforestry practices and their various applications. Additionally, this manual is designed to assist in the decision-making process so that, when established and managed, the given agroforestry practice is most effective at achieving the desired objectives.





About this manual

This training manual is designed to provide easy-to-use information about agroforestry. The intended audience includes forest and agricultural land stewards and producers, natural resource professionals, and other educators; yet, anyone interested in establishing or managing trees for multiple functions on the landscape can use the agroforestry guidelines to assist in achieving success. This updated edition of the training manual is not intended to function as a comprehensive source of information on agroforestry. Agroforestry is both an art and a science. Therefore, do not use this training manual as your only source of information. Rather, it is designed as a tool to assist in the decisionmaking process. There are countless ways for trees to meet conservation, economic and societal goals, and we learn more each day about effective designs that better ensure agroforestry systems meet one or more of these specific objectives.

How the manual is organized

This manual is divided into specific chapters describing agroforestry practices and management. Please note that Chapter 2 is intended to establish a path for applying your knowledge of agroforestry in a step-by-step planning process, and it is best utilized when frequently referenced while reading other chapters in this training manual. The appendices contain information and crop sheets for selecting the appropriate trees, shrubs, grasses, and forbs for your agroforestry practices. You may pull out chapters and appendices and use them independently as needed.

Let's begin

From specific land management practices designed to conserve limited resources to the marketing of specialty, non-commodity products, the information in this manual can improve the likelihood of your success. We hope it is both a useful tool and a source of inspiration for additional management practices that utilize trees or shrubs on the farm for multiple benefits. Land management practices that integrate trees and shrubs with agriculture can provide benefits to the farm and the surrounding landscape for generations. Our objective in sharing this manual is to help land stewards and their communities achieve long-term satisfaction from working harmoniously with the soil, water, air, forests and wildlife of this Earth.

About The Center for Agroforestry

Established in 1998, the Center for Agroforestry seeks to understand the science and practice of agroforestry, the integration of trees and shrubs with crops or livestock on farms of all scales. Through research, outreach, and educational programs, the Center has developed an enduring reputation as a critical source of information on agroforestry and perennial specialty crops for Missouri, the Midwest region, and beyond. The Center's intergenerational insights on the science behind agroforestry and our collaborative work to translate scientific advancements into accessible training programs for diverse audiences has resulted in new profitable perennial crop industries, such as chestnut and elderberry, for farms throughout the region.

Agroforestry practices help farmers and land stewards diversify harvests, markets and farm income; improve soil and water quality; and reduce erosion, non-point source pollution and flood damage. The integrated practices of agroforestry enhance land and aquatic habitats for fish and wildlife and improve biodiversity while sustaining land resources for generations to come. For nearly three decades, our team of scientists and researchers have explored the ecological, economic, and social dimensions of agroforestry with special focus on tree and shrub crop breeding, silvopasture, enterprise budgeting, horticultural best management practices, ecosystem services, nutrition, and human health.

Our training programs translate academic and scientific findings to diverse groups of stakeholders in agroforestry, including farmers and ranchers, land stewards, natural resource professionals, policymakers, and the general public. Our offerings span multiple formats, topics, and experience-levels, including webinars, YouTube tutorials and presentations, field workshops, symposia, and more. The Agroforestry Academy is our signature training program offered annually in late spring as a 5-week online course paired with an optional 3-day field experience on Mizzou campus and surrounding farms. To date, the Academy has trained more than 350 farmers, educators, and natural resource professionals since it's inception in 2013.

The Center for Agroforestry hosts the only agroforestry graduate degree program in the United States. Our online master's program was developed to provide working professionals with advanced study and experience in agroforestry and related fields not readily available at other colleges and universities in the U.S. or abroad. Our agroforestry graduate certificate is also offered online. The campus-based M.S. thesis option is designed for individuals who wish to gain the skills required to conduct original research resulting in refereed publications. We also support doctoral students pursuing a Ph.D. in Natural Resources with emphasis in agroforestry.

This work is made possible by significant collaborative funding from the USDA Agricultural Research Service Dale Bumpers Small Farms Research Center in Booneville, Arkansas. The Center is housed in the University of Missouri School of Natural Resources within the larger College of Agriculture, Food, and Natural Resources (CAFNR) in Columbia, Mo. More information on our offerings can be found at centerforagroforestry.org.



NOTES

Chapter 1: Defining Agroforestry

Chapter Highlights

- Agroforestry practices must meet the 4 "I" criteria: *Intentional, Intensive, Integrated, and Interactive.*
- The United States Department of Agriculture formally recognizes five temperate agroforestry practices: riparian forest buffers, windbreaks, alley cropping, silvopasture, and forest farming. Among many agroforestry organizations and practitioners, urban and community forest gardens is also acknowledged as a key agroforestry practice.
- In order to successfully expand agroforestry across the U.S. landscape, supportive peer-to-peer learning opportunities, professionals, partnerships, and programs are needed.

What is agroforestry?

Agroforestry is a new word for an ancient set of practices. In simplest terms, agroforestry is the intentional combination of trees and/or shrubs with crops and/or livestock. Agroforestry presents promising opportunities for new market ventures, sustainable agriculture practices, responsible land stewardship and succession planning, farm income diversification, and community development. When appropriately designed and managed, agroforestry systems can improve soil health, conserve water, reduce erosion and non-point source pollution, mitigate damage due to flooding and droughts, enhance air quality, improve biodiversity, and create wildlife habitat. These economic and ecological benefits can be achieved while the system produces nutrient-dense specialty crops with the potential to improve human health and regional food security.

Agroforestry practices can be designed to fit niches that meet specific objectives for farms and communities. For example, agroforestry systems can be designed and strategically located to provide greater resiliency in agricultural landscapes so farmers can meet production objectives when faced with extreme weather (e.g., drought, floods). Tree-based practices sequester significant amounts of carbon that can help meet future potential greenhouse gas reduction goals.

Definition of temperate agroforestry: *intensive land-use management that optimizes the benefits (physical, biological, ecological, economic, social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock.*

Agroforestry Key Criteria

Four key criteria characterize agroforestry Practices. Application of the 4 "I" criteria are key to determine what is, and what is not, an agroforestry practice.

Intentional

Combinations of trees, crops, and/or livestock are intentionally designed, established, and/or managed to work together and yield multiple products and benefits, rather than as individual elements which may occur together but are managed separately. Agroforestry is neither monoculture farming nor is it a mixture of monocultures.

Intensive

Agroforestry practices are created and intensively managed to maintain their productive and protective functions, and often involve cultural operations such as cultivation, fertilization, irrigation, pruning and thinning.

Integrated

Components are structurally and functionally combined



into a single, integrated management unit tailored to meet the objectives of the land steward. Integration may be horizontal or vertical, above- or below-ground, simultaneous or sequential. Integration of multiple crops utilizes more of the productive capacity of the land and helps to balance economic production with resource conservation.

Interactive

Agroforestry actively manipulates and utilizes the interactions among components to yield multiple harvestable products, while concurrently providing numerous conservation and ecological benefits. For example, specialty mushrooms can be grown on logs in a forest farming practice for additional income throughout the year.

Recognized Agroforestry Practices

The United States Department of Agriculture formally recognizes five temperate agroforestry practices: *riparian forest buffers, windbreaks, alley cropping, silvopasture,* and *forest farming*. Among many agroforestry organizations and practitioners, *urban and community forest gardens* is also acknowledged as a key agroforestry practice.

1. Riparian and upland forest buffers

Riparian forest buffers are strips of permanent vegetation, consisting of trees, shrubs, and grasses, planted or managed between agricultural land (usually cropland or pastureland) and water bodies (rivers, streams, creeks, lakes, wetlands) to reduce runoff and non-point source pollution. Forest buffers are usually planted in three distinct zones near an agricultural stream for stabilizing streambanks, improving aquatic and terrestrial habitats, and providing harvestable products. Upland buffers with cool- or warm-season grass alone or combined with shrubs and/or trees are also used to reduce nonpoint source pollution and prevent gully formation in agricultural watersheds.

2. Windbreaks

Windbreak practices (and variations, e.g., shelterbelts, timberbelts, hedgerows, and living snowfences) are planted and managed as part of a crop or livestock operation to enhance crop production, protect crops and livestock, manage snow distribution, and/or control soil erosion. *Field windbreaks* are used to protect a variety of wind-sensitive row crops, forage, tree, and vine crops to control soil erosion, and to provide other benefits such as improved insect pollination of crops and enhanced wildlife habitat. *Livestock windbreaks* help reduce animal stress and mortality, improve feed and water consumption, enhance weight gain and calving success rates, and control odor. Timberbelts are managed windbreaks also designed to increase the value of the forestry component.

3. Alley cropping

This practice combines trees planted in single or multiple rows with agricultural or horticultural crops cultivated in the wide alleys between the tree rows. High-value hardwoods such as oak, walnut, ash, and pecan are favored species in alley cropping practices, and can potentially provide high-value lumber or veneer logs in the long-term. Crops or forages grown in the alleys, and nuts from walnut, pecan and chestnut trees, provide annual income from the land while the longer-term wood crop matures. Specialty crops (herbs, fruits, vegetables, nursery stock, flowers, etc.) can be grown in alleys, utilizing the microclimate created by trees to boost economic production from each acre.

4. Silvopasture

This practice combines trees with forage (pasture or hay) and livestock production. Silvopasture can be established by adding trees to existing pasture, or by thinning an existing forest stand and adding (or improving) a forage component. Trees are managed for high-value timber or sawlogs, and at the same time they provide shelter for livestock, reduce heat stress and improve food and water consumption. In the winter, the protection of trees reduces cold stress — therefore, animals do not lose as much energy keeping warm and are able to gain more weight. Forage and livestock provide short-term income at the same time a crop of high-value sawlogs is being grown, providing a greater overall economic return from the land.

5. Forest farming

In forest farming practices, high-value specialty crops are cultivated under the protection of a forest overstory that has been modified and managed for sustained timber production or other forest objectives and to provide the appropriate microclimate conditions. Shade-tolerant specialty crops like ginseng, shiitake

mushrooms, and decorative ferns grown in the understory are sold for medicinal/botanical, decorative/handicraft, or food products. Overstory trees can be managed to produce timber and veneer logs, or for other multifunctional purposes.

6. Urban and community forest gardens

Forest gardens are multifunctional perennial (woody and herbaceous) polycultures designed and managed to mimic the structure of early successional forests or forest edges, where multiple "layers" of edible, medicinal, or ornamental plants and fungi share a single unit of space. Unlike conventional rural farms, forest gardens may be planted in relatively small areas. They require careful design to accommodate the challenges and opportunities of their high levels of diversity and unique site circumstances. They are intentionally referred to as "forest gardens" (rather than "food forests") in this publication to illustrate their ability to provide more than food products and to highlight their parallels to intensively-managed garden spaces.

A key concern in developing agroforestry nomenclature is overlap and confusion with mainstream land use management disciplines, e.g., forestry, agriculture, and livestock production. There is a fundamental need to develop a definition and criteria that would effectively distinguish practices that are agroforestry from those that are not. Application of the four criteria defining agroforestry (*intentional, intensive, integrative, and interactive*) provide the key to determine what is and is not an agroforestry practice.

Characteristics of Agroforestry Practices

- Land-use practices deliberately integrated into the whole farm
- Contain complex interactions among components suited to particular environments and human needs
- Competition and its management is critical
- Has two or more outputs
- The "cycle" of an agroforestry practice is always more than one year
- Even the simplest agroforestry practice is more complex ecologically (in terms of structure and function) and economically than monocropping
- For the farmer, success is often judged by the bottom line: does it pay?

Perspectives on Farmer Adoption

Although there are efforts underway to quantify farmer adoption of agroforestry via the Census of Agroforestry and the National Agriculture Statistics Service, it is safe to say that the adoption and application of agroforestry practices is rapidly accelerating. A significant focus on access and equity in the expansion of agroforestry in the U.S. will require increased attention on the four "P"s of adoption: peer-to-peer learning, professionals, partnerships, and programs.

Peer-to-peer learning

- Identify diverse and respected farmers who practice agroforestry.
- Connect agroforestry producers with other producers not currently practicing agroforestry.
- Gain understanding of local customs and culture, employing methods and tools such as:
  - Inclusive farmer meets farmer spaces.
  - On-farm demonstration sites and workshops.
  - Social networks, including social media.

Professionals

- Increase the number and diversity of professionals with agroforestry expertise are essential to provide the technical, educational, marketing assistance requested by producers.
- Advance agroforestry literacy through:
  - Regional/state agroforestry training programs (e.g., the Center for Agroforestry Agroforestry Academy)
  - Agroforestry degrees and certificates offered by universities (e.g., online M.S. and graduate certificate offered by the Center for Agroforestry)
  - Certification of agroforestry professionals (e.g., joint national "certified agroforester" program sponsored by professional societies)

Partnerships

- Bringing people together to increase awareness

and understanding of agroforestry, producer objectives, community, and watershed goals.

- Regional partnerships may be most effective. Examples include, but are not limited to: the 1890 Agroforestry Consortium, Agroforestry Northwest, Appalachian Beginning Forest Farmer Coalition, Cornell Agroforestry Program Work Team, Northeast Forest Farmers Coalition, Northeast & Mid-Atlantic Agroforestry Working Group (NEMA), Pacific Northwest Agroforestry Working Group, Southwest Agroforestry Action Network (SWAAN), The Agroforestry Coalition, Vermont Agroforestry Team.
- Lasting partnerships need a clear purpose and tangible project(s) to keep members engaged. For example, NEMA and SWAAN sponsor networking and educational activities to advance regional agroforestry interests.
- Establishing agroforestry communities of practices, e.g. the eXtension Forest Farming community of practice created by a team led by Virginia Tech with USDA support.

Programs

- USDA and other state/local programs provide vital resources that make it possible for professionals to provide the assistance that supports planning and establishment of agroforestry practices.
- USDA assistance helps advance agroforestry adoption and practice application includes:
  - The Natural Resource Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP) provides agricultural producers with financial resources and one-on-one help to plan and implement conservation practices.
  - The Sustainable Agriculture Research and Education (SARE) offers grants to farmers, ranchers and agricultural professionals for on-farm research, education, and professional and community development.
  - The National Institute of Food and Agriculture (NIFA) Renewable Resources Extension Act and McIntire-Stennis Cooperative Forestry Research programs.
  - The U.S. Forest Service's forest stewardship programs as well as their research & development programs.
  - The USDA Census of Agriculture collected in 2012, 2017, and 2022 track the growth in agroforestry in the US.
  - In 2023, the USDA invested in many agroforestry-focused Partnerships for Climate-Smart Commodity programs, including a $60M, 5-year project involving 29 States, titled The Expanding Agroforestry Project.
- Non-profit organizations such as Appalachian Sustainable Development, Savanna Institute, Interlace Commons, and the Appalachian Beginning Forest Farmers Coalition serve to collect, curate, and convene for agroforestry implementation and knowledge exchange.
- Farmer-led cooperatives connect both established and emergent specialty crops producers to support a wide variety of services including support with processing, marketing, distribution, and consumer awareness.
- The private sector, including farmland trusts and finance companies create financial opportunities and incentives for capital needs in agroforestry.

Additional Resources

Garrett, H.E., Jose, S. and Gold, M.A. (eds). (2022). *North American Agroforestry*. (3rd edition). Agronomy Society of America, Madison, WI.

Gordon, A.M., Newman, S.M., and Coleman, B.R.W. (eds). (2018). *Temperate Agroforestry Systems*. (2nd edition). CABI, p. 326

Kellerman, T., Feibel, S., Smith, M.M., Bentrup, G., Batcheler, M., and MacFarland, K. (2025). Agroforestry across the United States: Results of the 2022 Census of Agriculture. *Agroforest Syst* 99 (34).

Schoeneberger, M.M., Bentrup, G., and Patel-Weynand, T. (eds). (2017.) Agroforestry: Enhancing resiliency in U.S. agricultural landscapes under changing conditions. Gen. Tech. Report WO-96. Washington, DC: USDA Forest Service. p. 228

Gruley, K. and Keeley. K (eds). (2018). *Perennial Pathways: Planting Tree Crops*. Savanna Institute.

USDA. (2019). Agroforestry Strategic Framework, FY 2019-2024. Washington, D.C.

Please note: this is not an exhaustive list. When you begin researching agroforestry in your region and/or within your interest areas, you will find many more examples of relevant agroforestry organizations and events!

Agroforestry Organizations	Events for learning and building community	Website
Center for Agroforestry, University of Missouri	• The Agroforestry Symposium • Agroforestry Training Academy • Webinars, workshops, and field days	www.centerforagroforestry.org
Association for Temperate Agroforestry	• North American Agroforestry Conference	www.aftaweb.org
Cornell Agroforestry & Cornell Cooperative Extension's Agroforestry Resource Center	• Webinars, workshops, and field days	www.cornellagroforestry.org
Green Lands Blue Waters	• Continuous Living Cover Conference • Working groups	www.greenlandsbluewaters.org
Extension Forest Farming Community	• Webinars	www.forest-farming.extension.org
Midwest Cover Crops Council	• Annual meeting	www.mccc.msu.edu
Savanna Institute	• Perennial Farm Gathering • Webinars, workshops, and field days	www.Savannainstitute.org
USDA National Agroforestry Center	• Webinars	www.fs.usda.gov/nac
Virginia Tech Agroforestry	• Webinars, workshops, and field days	www.agroforestry.frec.vt.edu
Appalachian Sustainable Development	• Ask an Agroforester webinars • Trainings for natural resource professionals	www.asdevelop.org
ATTRA Sustainable Agriculture	• Annual conference • Latino Farmer Conference • Webinars, workshops, and field days	attra.ncat.org/topics/agroforestry/
The Agroforestry Coalition	• Working Groups	www.agroforestrycoalition.org
Southwest Agroforestry Action Network (SWAAN)	• Annual conference • Webinars	https://swaan-site.org/
The Appalachian Beginning Forest Farmer Coalition (ABFFC)	• Virtual office hours • Forest farming conference	https://www.appalachianforestfarmers.org/
Interlace Commons	• Field days and trainings	www.interlacecommons.org
Northern Nut Growers Association (NNGA)	• Annual Conference	https://nutgrowing.org/
Rural Action	• Webinars, workshops, and field days	https://ruralaction.org/

NOTES

Chapter 2: Introduction to Planning for Agroforestry

Chapter Highlights

- Agroforestry designs use a multifaceted approach to develop farm plans, evaluate economic considerations, and steward landscapes.
- Understanding the relationship between personal resources, business aspirations, climate, biophysical site characteristics, and market considerations is key for a successful agroforestry design plan.
- Planning for agroforestry is an iterative process. Keep learning and adapting as you go.

Why plan?

Developing a plan may seem tedious at the beginning, but the long-term benefits far outweigh the difficulties of plan creation. By having a plan, farmers and land stewards can better envision how to successfully integrate agroforestry onto their farm. The planning process will also help develop a familiarity with the management that is required in order to reach the goals, objectives, benefits, and economic outcomes that are desired. The best way to ensure success is by thoughtful and honest planning.

The development of a plan for integrating agroforestry practices to the farm system is as important as the actual establishment of the practice itself. Planning and the development of a timeline will help maximize the chances for the success of the agroforestry practice. Planning will not only assist in understanding how the practice and its placement on the landscape can accomplish specific on-farm goals, but will also provide assistance in identifying market opportunities for products that may be grown in the practice. *Remember: diagnosis precedes treatment.*

An agroforestry development plan is based on the capability of your land, your personal goals, your business goals, and your land stewardship objectives. These goals and objectives will be reassessed and changed as you obtain new information during the planning and initiation of an agroforestry development. Agroforestry practices are always changing; understanding and working with change will help you best achieve your goals.

Coupled with the *Handbook for Agroforestry Planning and Design* (available for free download at the Center for Agroforestry's website), these steps are designed to help guide you through the various stages of creating a plan for your agroforestry development area(s), and will assist you in gathering information on:

- Your objectives and priorities
- Personal resources (e.g., labor, equipment, buildings, animals, plants)
- Climate, soil conditions and physical features
- Current land use
- Land available to practice agroforestry
- A non-timber plant inventory (for woodland only)
- Market conditions for potential products

Handbook for Planning and Design

This chapter frequently references the ***Handbook*** (and the accompanying Workbook). You can download the *Handbook* for free by scanning the QR code or by visiting our website.

Steps to Developing an Agroforestry Plan

Personal Assessment

Step 1: Initial Objectives and Priorities

Step 2: Evaluate Personal Resources

Biophysical Site Assessment

Step 3: Identify Current Land Uses

Step 4: Map Area(s) for Agroforestry Development

Step 5: Climate Assessment

Step 6: Soil Assessment

Step 7: Physical Features (Terrain)

Step 8: Timber and Non-Timber Forest Crop Inventory

Agroforestry Development Ideas

Step 9: Agroforestry Ideas – Brainstorming

Step 10: Listing 'Best Bets'

Evaluating the 'Best Bets'

Step 11: SWOT Analysis

Step 12: Porter Five Forces Model

Step 13: Revising your 'Best Bets'

Marketing Strategy for 'Best Bets'

Step 14: Select and Describe Target Market(s)

Step 15: Adding Value to Products

Step 16: Getting Products to the Buyer

Step 17: Setting the Price

Step 18: Promoting Your Products

Agroforestry Practice Design & Management

Step 19: Revisit Your Objectives and Priorities

Step 20: Detailed 'Best Bets' Crop Information

Step 21: Designing Your Agroforestry Practices

The Agroforestry Development Plan

Step 22: A Five-Year Management Projection

Step 23: Yearly Activity Schedule

These steps, along with the information provided throughout this Manual, will allow you to identify what agroforestry products can grow on your land, which of these products you can sell profitably, and how to develop basic business and marketing strategies. The final steps are a five-year development plan and yearly activity schedule, outlining the work you plan to do to establish your agroforestry system(s). The time you put into researching, preparing and following your plan is an investment in your future agroforestry success.

The succession of steps has been organized to help you develop your plan logically. You need not complete each step in the order they are presented. In fact, the steps presented in the following pages are often interrelated. Information gathered in one step will likely impact information gathered in other steps. For this reason, the creation of your plan will likely require you to revisit (and expand upon) each step as you learn more and develop new ideas.

In addition to identifying available resources, site conditions and marketable plants, filling in the *Handbook* forms will help you explore and articulate your values and attitudes. Every land steward will have different personal and production goals for their agroforestry development. Your plan for your land will be different from someone across the country, state, or even across the road. To accommodate these differences, this guide is not based on a single set of goals. Instead, it has been developed to provide a set of tools that you can use to make informed decisions in creating a profitable agroforestry business.

There are many sources of information and advice available to assist you with your agroforestry development. Since agroforestry practices often involve the cross-pollination of expertise in conservation, agriculture, and forestry (e.g., forest management, agronomy, animal husbandry, horticulture, soil science, marketing, etc.), you may have to augment and expand your personal knowledge. Sources listed at the end of each chapter are designed to guide you.

How to proceed

As previously mentioned, the information in this chapter is also available in the *Handbook for Agroforestry Planning and Design*. The information, tools and links you need to complete your plan are found in chapters that follow. It is recommended that you read through these steps before you begin writing your plan.

Note: Depending on the size of your property, you may have one or more areas on which you want to develop agroforestry practices. Planning will be easier if you prepare separate forms for each separate development area, especially if potential agroforestry development areas have different site conditions and current uses.

Step 1: Initial Objectives and Priorities

Farmers and land stewards exploring multiple uses for their land face many preliminary decisions. Not least, if you have a number of different objectives for an area, some may seem to be in conflict. The choices each farmer makes reflect a set of individual values and attitudes. Your personal and business goals become the criteria for assessing the different possibilities for your land.

Your land management objectives and priorities will be specific to your circumstances and the area you want to develop for agroforestry. Among other possibilities, you may want to:

- Develop a new source of income from unproductive land (diversification)
- Reduce costs of an existing farm or forest operation
- Develop a source of long-term income
- Develop a source wof short-term income while awaiting long-term income from tree crops
- Reduce property taxes
- Protect or improve environmental conditions, and/or
- Increase grazing opportunities

Open the *Handbook for Agroforestry Planning and Design* and complete the table of initial objectives and priorities (p. 27). Remember that these initial objectives may change as you learn more about your land and your agroforestry business. After you finish this assessment, you will be able to weigh your objectives against what you can actually produce on each area of your land.

Step 2: Evaluate Personal Resources

In addition to your land base, your agroforestry development will require the input of other personal resources. An evaluation of the resources available to you will help determine which agroforestry options are best suited to your operation.

An evaluation should include:

- ***Management and labor availability***: periods during which you are not busy (between or after harvests) and the periods during which labor and management time will be committed to other activities.
- ***Equipment and buildings:*** buildings and equipment, including machines and hand tools, that can be used for this development.
- ***Livestock***: your operation may already have cattle, sheep, or other animals.
- ***Plant material:*** your own sources of seed, seedlings, cuttings and larger trees.
- ***Other materials:*** resources such as sawdust or shavings, manure and straw for mulch.

List these personal resources, as well as anything else that you consider of importance, in the table provided in the *Handbook*.

Step 3: Identify Current Land Uses

List the present uses of each area of your land and the products you harvest, and record them in your *Handbook*.

These uses could include:

- Residential
- Recreational
- Environmental use
- Farming (which crops)
- Grazing (type of livestock)
- Non-timber production
- Timber production

Step 4: Map Area(s) for Agroforestry Development

An agroforestry development may include all of your land or only specific areas, such as existing woodlands, open field, logged-over area, or riparian zone. In either case, identifying objectives and making decisions will be much easier if you break your land into separate development areas with similar current uses and site conditions (such as soil, moisture, and existing plants). Steps in the Handbook, including the sketch map, should be completed for each separate development area. Pages of the Handbook can be copied for this purpose.

For each agroforestry development area, you should:

- Draw a sketch map of the area you are targeting for agroforestry development. Using the legend

provided in the Handbook, indicate boundary lines, main geographic features, houses, other buildings and roads.

- Identify and measure the area approximately, marking these measurements on the sketch. This will help determine planting requirements wand potential crop production.

There is some overlap between Step 3 and Step 4, since you will indicate these uses on your sketch map. Step 3 gives an opportunity to provide information on land use in greater detail, and by thinking about land uses, you may decide to modify your sketch map.

Step 5: Climate Assessment

Climate on your site ultimately determines what you can grow on your land. Combining this data with the information provided in Appendices II and III will establish the range of possibilities for your agroforestry practice.

Hardiness zone - The USDA Plant Hardiness Zone Map has mapped plant hardiness zones for the entire country. Using the above website you can also locate a Plant Hardiness Zone Map specific to your state.

These zones rate the conditions affecting winter survival of plants. The primary factor is the minimum (coldest) winter temperature, with some consideration for the number of frost-free days, summer rainfall, maximum temperatures, snow cover and wind.

Most information sources and suppliers of seeds and plants list the minimum hardiness zone for particular plants. Plant breeding programs have resulted in cultivars or selections of many plants that differ in hardiness from their parent (check this carefully to prevent a costly error).

In some cases, the hardiness zone mapping is only an approximate guide for local conditions.

Enter hardiness zone information in the table provided in the *Handbook*. Additional information you may find, such as frost-free days and date of soil thaw, should also be included in the table.

Why Assess Your Land?

Assess climate, soil and physical features on each site on which you intend to develop an agroforestry practice. These assessments will allow you to determine:

- which plants you can successfully grow on each site.
- limitations to planting and growing these plants.
- the most effective management practices.

Assessments can be as detailed as you want, or as required by the project. The introduction of long-term or special-needs crops such as black walnut trees require a different level of site assessment than the planting of a shallow-rooted annual crop. Even if you plan to begin small, with a few tree seedlings on a fence line and a small planting of medicinal herbs, you should still assess the limitations and potential of your land.

The information provided here, and the accompanying form in the *Handbook*, provide a basic site assessment. More detailed assessments require added time, equipment and expertise. They are only worth doing if it will help with a critical aspect of your agroforestry development. For most developments, they are not necessary.

Step 6: Soil Assessment

Land capability classification

The Land Capability Classification shows, in a general way, the suitability of soils for most kinds of agricultural land use or field crops. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. There are two primary categories in this classification system, (1) the Capability Class and (2) the Capability Subclass.

The Land Capability Classification identifies the potential of local areas for agricultural production. County Soil Surveys contain the Land Capability Classification for all soils in your county. The County Soil Surveys also provide useful climate information.

Capability classes are ranked from I (highest) to VIII (lowest), but the capability subclasses refer to soil groups within a class. Classes I - IV are considered capable of the sustained production of common field crops. Crop species become limiting as the land capability declines from Class

Soil Information Sources

Information about various versions of a soil survey can be obtained with the following means:

- *By mapping your soil using the USDA Web Soil Survey.*
- *By contacting the appropriate state or local office of the NRCS or Soil and Water Conservation Districts.*

Additional information about Missouri soils can be found on the Missouri Cooperative Soil Survey website.

I to Class IV. Class V lands are only capable of producing perennial forage crops or specially adapted crops. Class VI lands are capable of providing sustained pasture. Class VII land are incapable of either arable culture or grazing.

Capability subclasses include: (e) runoff and erosion; (w) wetness; and (s) root zone or tillage problems (shallow, droughty or stony).

List the climatic, capability rating and limiting factors for your site, as well as any other information you believe might be useful, in your *Handbook*.

Soils are an extremely important feature of your land base because they are the material in which the plants of your agroforestry practice will grow. Soil survey publications represent a snapshot in time. They contain information that was current as of the indicated publication date. The text, tables and soil maps may have been updated since publication. The most up-to-date information is available on the NRCS Web Soil Survey.

Read about the soils (formation of soils), look at a soils map, then examine your soils. One way to gain an understanding of your soil is to dig several soil pits at least 18" deep, and examine your soils for several important features. However, soils are landform dependent, and samples taken should represent different landforms and positions on those landforms. It is recommended to dig one or two pits per acre, and more if the area/landform is not uniform. For more detail on soil assessment, see the additional resources at the end of this chapter.

Important note: If you are planning to practice agroforestry on a woodland area, plan to do a plant inventory. Since this requires setting up survey plots in a grid system, you probably want to do your soil assessments at the same time as your plant inventory.

Soil texture and composition

Mineral soils are particles of rock or minerals produced from rock by weathering and other geological processes. Soil textures are grouped into the three particle sizes shown in the table below. Sands and gravel are the largest particles, while clay and silt soils contain the smallest particles. The finer textured soils hold more water and dry out more slowly. Organic soil layers or horizons are derived from decaying vegetation, usually in a thin layer above mineral soils. Where found in a sizable layer, they tend to retain both water and nutrients.

In your *Handbook* list the soil type(s) found in each of your agroforestry development areas, and map the locations if there is more than one type.

Soil depth

Soil depth determines the rooting capability of the plants you may wish to grow. In particular, forest soils can be quite shallow, requiring extra care in management. You will notice distinct layers as you dig down and you may come across restricting layers such as: 1) stones and rock outcrops that can interfere with digging and cultivation, and can reduce the nutrient and water-holding capacity of the soil. Rock outcroppings are areas with very little soil; and 2) hardpan, a hardened layer below the surface of the soil that can prevent penetration of water and roots. Additional soil features that may be problematic include: fragipans, claypans, abrupt textural changes and general discontinuity. Deep-rooted plants such as alfalfa or black walnut will be severely impacted by hardpan. Neighbors and previous land stewards may know if there is a hardpan, but you may have to dig several holes to determine the extent.

Note and record in your *Handbook* the approximate percentage of rock fragments in the soil (stoniness), and depth and type of any restricting layers. Show their extent on the sketch map.

Soil moisture

Soil moisture, which is key to the establishment and growth of plants, is closely linked to soil texture. The

spaces (pores) between soil particles hold water and air needed by plants for good growth. Generally, coarser soils are well-drained and are often dry for longer periods, while soils with finer textures hold more water and are likely to remain moist longer. Other factors, such as ground water level or the presence of an impermeable layer that restricts drainage, also determine soil moisture.

As you dig your pit, is the soil dusty and dry? Does water seep into the bottom of the hole? Often, the time of year and recent weather will influence soil moisture.

High water table, standing water or flooding

Areas such as wetlands and parts of riparian zones which remain fully saturated for extended periods of time are of special concern. These areas are sensitive to access development and machine use, and are important for wildlife habitat and other environmental values. You will need to identify these areas of your land and plan to use especially careful management. Access may be limited for all or part of the year.

In your *Handbook* and on your sketch map, it is important to note any: wetland features, evidence of flooding, areas that experience overland flows or standing water during spring runoff, and areas with continual seepage or high water table.

Both very wet or dry conditions pose challenges for planting and management. However, some plants are particularly adapted to one or the other of these extremes (see Appendices II & III for a listing of suitable plants). Note the moisture conditions of various portions of your proposed development area on both your sketch map and in your Handbook.

Nutrients

The availability of nutrients in the soil affects the quantity and quality of products produced. You can undertake a soil test to determine the soil pH (acid/alkaline balance), specific nutrient levels, and recommendations for various crops. Tissue analysis is also an effective way (preferred in forest soils) to determine nutritional status of existing trees and plants. Although there are soil sampling field kits, soil and tissue samples are usually sent to a laboratory for analysis and interpretation.

In your *Handbook* note the status of soil nutrients that you have determined and attach any lab reports.

Step 7: Physical Features (Terrain)

The physical features outlined in Step 7 are closely related to – but also different from – the soil characteristics described in Step 6. For ease-of-use, physical features are described separately from soil characteristics. However, the information you generate through each step is entered into the same table in the Handbook. This allows you to easily see the relationships between physical features and soil characteristics. There are several physical features that can influence your capability to produce particular crops on a site.

Aspect refers to the direction toward which the site slopes (if any). South and southwest-facing slopes are usually warmer and drier than those facing north, and naturally support different plant communities. Terrain relief refers to whether the site is steep, flat, sloped, rolling, gullied or broken (steep slopes between benches). This will influence access and machine capability, water management, cold air drainage, and other micro-climate factors. Frost pockets are one additional feature to consider. Cold air flows downhill and pools in low areas. The resulting localized frosts can damage delicate flowers and shoots that start to grow early in the spring. Even crop plants correctly chosen for your hardiness zone can be affected. Assess low areas on your land for potential frost pockets; the absence of native berry plants can be a good indicator. Avoid these areas for frost-sensitive plants. Sloped or bench land that has good air drainage is a better choice.

Enter your observations of the physical features mentioned above in your *Handbook* and on your sketch map.

Step 8: Timber and Non-Timber Forest Crop Inventory

If you want to practice agroforestry in woodland areas, this chapter will help you inventory the variety of plants growing on your land—everything from trees to herbs on the forest floor. The inventory of trees described here is restricted to their potential production of non-timber products (e.g., medicinals, florals) and their interactions with other plants (e.g., shade, moisture, nutrients). A non-timber vegetation inventory can be used to help create a list of 'best bets'— plants that can be successfully grown on your land, and will also help you decide how to manage your woodland efficiently and productively (i.e., managing competition for sun, water and nutrients).

There is literature available elsewhere on timber inventory methods (see additional resources).

If you own more than a few acres of land, you should sample your land base, using inventory plots to obtain a 'best approximation' of the vegetation. Sampling is an excellent compromise between doing nothing (and having a very limited picture of your land) and trying to do the impossible: counting every tree, shrub and herb on your property.

A. Preparing your inventory

An inventory should give you a timely snapshot of your land; it should not take too long, nor should it be too difficult. Inventory plots are the sites where you record information about vegetation and other features on your land. They form a predetermined portion (or percentage) of the larger area you're interested in sampling. Multiplying your plot data by the number of plots that would fit in the larger area will give an estimate of what you would find if you actually measured everything. Size of inventory plots depends on what you're trying to survey and the vegetation cover on the plot. In your forest vegetation survey, you will actually take two separate surveys from the same plot center. This is because you need to collect information about very different types of vegetation beyond tree, including shrubs and other smaller plants.

Plot cruises can be used to estimate the number of plants in a forest by species, diameter, height, form class and grade. All fixed plot cruises have statistical sampling error which is important to know and understand before relying on the data. A plot cruise simply consists of counting and classifying all trees or plants species in a series of circular sample plots. Circular plots are usually 1/10-acre in size (37.2 feet radius). The plots are evenly spaced throughout the stand to provide an equal sampling of all forest types across all topographic changes depends on what you're trying to survey and the vegetation cover on the plot. In your forest vegetation survey, you will actually take two separate surveys from the same plot center. This is because you need to collect information about two very different types of vegetation: Trees; shrubs and other smaller plants. Plot cruises can be used to estimate the number of plants in a forest by species, diameter, height, form class and grade. All fixed plot cruises have statistical sampling error which is important to know and understand before relying on the data. A plot cruise simply consists of counting and classifying all trees or plants species in a series of circular sample plots. Circular plots are usually 1/10-acre in size (37.2 feet radius). The plots are evenly spaced throughout the stand to provide an equal sampling of all forest types across all topographic changes.

B. Doing your inventory

Locating your plots in the field. Following a compass line is a vital skill when conducting your vegetation inventory. It is beyond the scope of this training manual to review compass work in detail but here are a couple of points to remember:

- Make sure to get the right compass for the job. Ideally, you should have a 'ranger' type with a mirror in the lid, gunsight sighting, liquid dampened needle, and an adjustment for setting declination.
- Stay on track. With a little practice, staying on your traverse line is not difficult. Hold the compass level, line up the arrow in the mirror face, sight on the farthest object you can pick out through the gunsight (e.g., recognizable tree, rock, stump), and walk toward it. When you reach that landmark, sight again and find a new object to focus on.

Obtain a good guidebook to the plants of your area. Remember that quality can have a big impact on the prices you receive for non-timber forest products. That means you will have to make judgment calls when doing your inventory. Information on product specifications, including acceptable quality, can be found in Appendices II and III. It is also important to remember that you should contact buyers before you harvest, so that you can harvest to the correct specifications.

C. Using your inventory

First, make sure all areas inventoried are marked on your map(s). Next, you need to take the raw data from your inventory (plot sheets), compile it, and present it in a useful format. That means taking the information from your sample plots and organizing the information so it represents your entire development area.

Trees and/or other resources per acre

Among your survey information, you have recorded the number of each plant species that appears in each inventory plot. Now you want to convert that number

Tree Inventory

The tree inventory described here is only intended to determine the non-timber resources available (e.g., boughs, vines, bark, burls).

Number of trees and species. Record the number of trees of each species found at the plot. This will assist in determining what non-timber products can be obtained, and what plants can be grown under the canopy.

Tree age. This is optional, but can be useful to know. An increment borer is easy to use and will not harm the trees. Record the age of one or two average trees per plot.

Tree height. This is also optional, and only really useful for a timber inventory. Details on calculating height can be found in the University of Tennessee Extension guide, "Conducting a Simple Timber Inventory".

Condition of trees. Helpful in determining whether marketable non-timber products can be harvested. Also helpful in assessing the possible function as a windbreak.

Crown closure. The degree of canopy closure will determine the conditions for raising or enhancing shade-loving species in the understory.

Non-tree Inventory

Begin your inventory by identifying and listing all the harvestable non-tree species found in the plot on your plot sheet. Include plants that provide good browse if you intend to graze the area.

For each species, record the following:

Total number of plants for each species. Where possible/feasible, count the number of individual plants of each species found in the plot. This will be easier on an open forest floor than it will be on dense sites. You may choose to record sites like the latter simply as 'dense coverage.' This is one of those instances where judgment calls come in. Even an approximate number could be useful in developing a harvesting plan.

Estimate of the percentage cover for each species. How much of the plot do you think the species covers? Provide an estimate to the closest 10%.

Proportion of harvestable vs. non-harvestable individuals. The aim here is to estimate the amount of harvestable individuals for each species (none, 20%, 50%). Your decisions will be based on factors such as size, color, and insect or other damage. If many of the plants are not harvestable in their current condition, cultural practices such as fertilization and pruning may be available that would improve product quantity and quality.

into the number of plants per acre. This is done by first calculating the average number of trees per plot, and then multiplying this by the expansion factor (i.e. the plot size denominator).

For example, if you counted 8, 12, and 4 individual witch hazel shrubs in your 3 plots 1/10 of an acre, when:

- the average trees per plot is: (8+12+4) ÷ 3 = 8
- the expansion factor is: 10
  (where 10 is the denominator of 1/10-acre and 3 is the number of plots)
- total estimated number of witch hazel per acre is: 8 x 10 = 80

Once you know the approximate number of plants of a given species per acre you have a fairly good idea of the plant resources you have on your land. Record the information in the tables provided in the Handbook.

Step 9: Agroforestry Development Ideas – Brainstorming

After reading this training manual, you will probably come up with some ideas for agroforestry developments on your property. Once you have done this, it is time to engage in some brainstorming. In addition, check out Appendices II and III to develop additional ideas.

Brainstorming is the process of putting ideas down on paper as they come into your head. List them all and don't try to self-censor the ideas. You can reduce this list to 'best bets' later. Input from family and friends, as well as ideas from neighboring land stewards, can help generate useful ideas. This is also a point at which expert advice may expand the list of possibilities. For additional assistance consult the additional resources that are listed at the end of every chapter.

For each development area, sort the list by practice and

record this information in your Handbook. In general, more intensive agroforestry practices (e.g., forest farming) are suited for smaller units of land, while the more extensive practices (e.g., silvopasture) are suited to larger units of land.

Step 10: Listing 'Best Bets'

The intent of this short but important step is to create a list of potential crops that can be grown on your land. This list of 'best bets' will be based on the information you have gathered so far—including land and personal resources, site conditions and current land use—combined with the plant information provided in Appendices II and III.

Perhaps the easiest way to approach this list is by first determining what plants can grow under the climatic, soil and physical conditions that occur in each of your agroforestry development areas. Plants you already cultivate on your land, plants revealed by your non-timber inventory, and crop ideas you have developed while gathering information, will all form part of this list. You want this list to be as extensive as possible, so you can consider the widest possible range of options.

Your list can be refined by considering the resources at your disposal (e.g., labor, buildings, equipment) at different times of the year. These factors will limit the crops and crop combinations you can grow. Finally, you can further refine your list by revisiting the objectives you have for your land, such as income diversification, reduction of land taxes or environmental protection.

The list of 'best bets' you make in this part of your *Handbook* should include all the plants that can grow on your land, and the products that can be derived. Make sure you include timber products that can be made from trees you would plant as part of an agroforestry development. If you have done a timber inventory—in addition to the non-timber vegetation inventory list those possible timber products as well. Along with Chapter 10, the following steps will help you develop a marketing strategy, or marketing plan. Each step contains directions needed to complete corresponding sections in your *Handbook*. You should note that every part of every step might not apply to your situation.

Step 11: SWOT Analysis

Having analyzed the current situation of your farm with respect to objectives and priorities, personal resources, site assessment and vegetation inventory and brainstormed ideas of agroforestry practices, you can use that information to identify Strengths and Weaknesses, Opportunities and Threats or "a SWOT analysis" for the crops you think may produce. This can be helpful in defining and clarifying the issues you need to address in the rest of the planning process.

As detailed in Chapter 10, in identifying strengths and weaknesses, you will be focusing on factors that are internal to your business. Opportunities and threats refer to the external environment of your business. The plan you will develop will be shaped by both internal and external factors; it will build on your strengths and minimizing the impacts of your weaknesses while in the same time be responsive to the opportunities and threats your environment offers. In the SWOT Analysis worksheet, summarize the internal strengths and weaknesses and the external opportunities and threats for your business as you identify them today. Consider all aspects: natural, physical and human resources, marketing, operations, and finances.

Step 12: Porter Five Forces Model

The Five Forces Model (developed by Dr. Michael Porter of Harvard University) serves as a good framework for assessing different industries you would like to get in. The Five Forces Model identifies coordination and control aspects of an industry and provides a guideline for understanding the resources and relationships needed to be successful in a market. With the information and examples provided in more detail in Chapter 10, use the following ideas to evaluate the chosen crops in the context of the industry.

- Identify barriers to entry.
- Identify suppliers/bargaining power of suppliers.
- Identify buyers/bargaining power of buyers.
- Identify substitutes.
- Identify competitors and their competitive advantages.

Step 13: Revising Your 'Best Bets'

In Step 11 you identified the plants that can grow on your land, and which you can produce with the resources you have available.

After a thorough analysis using the SWOT Analysis and Porter Five Forces Model, the list of 'best bets' can be refined to include those plants and products you think have the best market potential. Consider the following when selecting a list of marketable 'best bets'.

- How difficult is to enter the market?
- Is the required supply available?
- Are there buyers nearby?
- What is the demand for the crop, relative to supply?
- How does harvesting and selling these crops fit in with the rest of your production system? For example, will the crop(s) require big inputs of labor during an already busy period?
- Is investment of resources (labor and capital) likely to provide an adequate return?
- How does that return compare to other possible crop/product options?

Where possible, use your vegetation inventory to list the approximate volumes of the crops you have for sale. For crops not yet planted, estimate how much you'll be able to sell so you have an idea of how much to plant.

Step 14: Select and Describe Target Market(s)

Refer to Chapter 10 to develop Steps 14-18, creating a marketing strategy. Your marketing strategy is about defining your customer or target market and tailoring your product, pricing, distribution and promotion strategies to the market's satisfaction. Target markets are most commonly characterized as either individual households or businesses. Begin your target market research by developing a customer profile. Customer profiles can help you determine if a market segment is large enough to be profitable. Break your target market up into segments based on differences in their geographic location, demographic characteristics, social class, personality, buying behavior or benefits sought.

Step 15: Adding Value to Products

As you think about the products your business will offer, try to describe them in terms of the value they will bring to your customers. List all value added opportunities and identify "pros" (how it will benefit the needs of each customer segment) and "cons" (e.g., costs, risks) for each of them. Identify unique characteristics that will differentiate your product from competitors. Define each product to address specific needs for each market segment.

Step 16: Getting Products to the Buyer

Now that you have a customer and product in mind, your next task is to identify how to move or distribute products from your farm to the customer's house or store shelves. Distribution strategies typically describe:

- ***Location:*** where will you sell your product?
- ***Distribution:*** which sales channels will your product follow?
- ***Transportation***: how will your product reach the buyer?

Example: Elderberry Consumer Preferences

Label considerations: Comparing average prices of a 12-ounce bottle:

- *Certified organic:* Compared to conventional, consumers paid on average $3.51 more.
- *Pesticide-free:* Compared to conventional, consumers paid on average $3.97 more.
- *Carbon neutral:* Compared to a bottle with no carbon emission information, consumers paid $1.91 more.
- *Origin of elderberrie:* Compared to juice made from European-grown elderberries, consumers paid $2.00 more for juice made from American-grown elderberries.

Changes in consumer trends: Frequently purchased value-added products:

- *Supplements*: 7% of consumers purchased this product in 2011 compared to 49.9% of consumers in 2022.
- *Juice*: 45.2% of consumers purchased this product in 2011 compared to 35.1% of consumers in 2022.
- *Carbonated drinks*: 33.3% of consumers purchased this product in 2011 compared to 8% of consumers in 2022.

Data sourced from Cai et al., 2022

Step 17: Setting the Price

In general, pricing strategies are based on two factors: prevailing market prices and your costs. In the long run, your price has to cover your full costs—including production, marketing and promotion—as well as a return for your time and investment. Try to identify prevailing market prices for similar products if they exist; learn about what customers are willing to pay and what prices your competitors charge. Also identify and document all your production, marketing and promotion costs.

Decide how you want to price your product for each market segment. Take all these aspects into consideration; try to establish a realistic price or range for each product.

- Do you want to undermine the competition by offering a lower price?
- Can you set a high price that reflects your quality image or market demand?
- Are you simply looking to cover costs? Do you have power to set a price?
- How sensitive is demand to price changes?

Step 18: Promoting Your Products

Promotion is very important to gain product recognition among customers. Promotional strategies often are built around a "message". The message that you deliver about your product or business is just as important as the product itself. Equally important is how and when you deliver that message through the use of advertising tools and media. Consider also the costs of each promotion method.

Step 19: Re-visit Your Objectives and Priorities

The first step in developing your agroforestry plan was to outline your initial objectives and priorities for your land-based business. Since then, you have gathered considerable amounts of information that will likely change at least some of those original goals. Record your revised objectives and priorities in the space provided in the *Handbook*.

Step 20: Detailed 'Best Bets' Crop Information

To develop the most functional and profitable agroforestry practices, you should know as much as possible about each plant you intend to grow. You will have gathered much of this information while filling out your *Handbook*, using your land assessment, plant inventory (where appropriate), market research, Appendices II and III, and possibly your own additional research.

Important information includes the biological requirements of each plant, the agroforestry practices they can be grown in, what other plants (and animals) they are compatible with, labor requirements for harvesting, potential volumes, value-added opportunities, and useful market information.

The table provided in the *Handbook* may include categories of information you do not have. You can exclude these or take extra time to find the information. There is also extra space for additional information you consider important but not specifically listed here.

Step 21: Designing Your Agroforestry Practices

Now is the time to arrange your plants into agroforestry practices that best meet the management objectives you outlined in Step 19. The information on each plant crop, and the management information provided earlier in this chapter, will allow you to design and manage agroforestry practices that best meet your objectives. Fill in a table in the Handbook for each agroforestry practice you intend to develop.

Note: Remember that price and marketability are not the only criteria for selection of the plants you will include in your agroforestry practices. Some plants may be chosen because they provide valuable ecological functions to your agroforestry practice, such as trees for shade and windbreaks, or legumes for nitrogen fixation

Step 22: A Five-Year Management Projection

Your five-year management projection is a schedule of the work you plan to undertake in the next five years to develop your agroforestry practices. The specific tasks and timelines you prepare will form the basis for your yearly activity schedule.

Don't worry too much about getting absolutely everything right on the first pass. Your plans will change over time and you can go back and adjust your projections accordingly. For now, you are mainly interested in conceptualizing the overall operation on paper. The

five-year management projection has four sections.

1. ***Area:*** *the size of the area to be managed.*
2. ***Practice:*** *the agroforestry practice and its associated products.*
3. ***Year:*** *the year that you want the management activity to take place.*
4. ***Management objective:*** *the specific objective you hope to accomplish.*

Use the template provided in the *Handbook* to create your own five-year management projection.

Step 23: Yearly Activity Schedule

The yearly activity schedule describes specific tasks that need to be done, when and by whom. This is the document you will use to plan your work schedule on a month-by-month basis. A good yearly activity schedule will allow you to identify potential time and business conflicts, and ensure you avoid overlapping seasonal activities that could create shortages of labor and resources.

A yearly activity schedule—one for each agroforestry practice—has five sections:

1. **Crop plan:** the plants that you have decided you can grow and market.
2. **Management objectives**: a record of objectives, transferred from your five-year projection.
3. **Task and time of year**: a list of specific tasks that must be accomplished to achieve each objective, including timelines associated with each task.
4. **Materials**: estimates of seed, seedlings, fertilizer, fencing, animals, feed and other items necessary for corresponding tasks.
5. **Labor and equipment**: a record of labor and equipment needs (if any) for each of the specific tasks.

Like the five-year management projection, your yearly activity schedule will likely change as you learn more. Remember to leave yourself plenty of time to complete all the work. As land stewards well know, most tasks take longer than expected. The yearly activity schedule will also be helpful in costing the materials, labor and equipment that are necessary for the cash flow projection of your business plan. For details on business planning, refer to *Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses* available through USDA SARE's website. The information in the Handbook will provide a good basis for a business plan that includes a comprehensive cash flow projection.

Building an Agroforestry Development Plan

The purpose of building an agroforestry development plan is to create a schedule of the work that needs to be done in the years ahead in order to fully develop your agroforestry area(s). Your completed Agroforestry Development Workplan will include specific tasks, timelines, and labor projections for each agroforestry practice on a year-by-year basis. You will need a Development Plan for each agroforestry development area.

The Development Work Plan is the final step in your Handbook, and will form the practical basis for your agroforestry development. You will no doubt change and adapt your work projections in the years ahead, but a good Development Plan will form a clear starting point and help focus your management efforts.

The Development Plan includes two distinct parts:

1. *A five-year plan outlining specific tasks for each agroforestry practice*
2. *A yearly activity plan, broken down into specific tasks for each month.*

Additional Resources

Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses. (2003). Minnesota Institute for Sustainable Agriculture.

Conducting a Simple Timber Inventory. The University of Tennessee Institute of Agriculture.

Cover Crop Economics Tool. Natural Resource Conservation Service (NRCS). *Scroll down page to Cover Crops Economics Header.*

Cropping Systems Calculator. Land Stewardship Project.

Financial Decision Support Tools. Center for Agroforestry, Univresity of Missouri.

Fruit and Nut Compass. Center for Integrated Agricultural Systems. University of Wisconsin-Madison.

Handbook for Agroforestry Planning and Design. (2013). Center for Agroforestry, University of Missouri.

Hannum, E. *Inspirations for Creating a Long-Term Agricultural Lease for Agroforestry: A Workbook.* Savanna Institute.

Lovell, S. Center for Agroforestry [@MizzouAgroforestry] (2020). *Introduction to Agroforestry* [Video]. YouTube.

Savanna Institute. *Perennial Pathways: Planting Tree Crops.*

Soil Survey Manual. Natural Resource Conservation Service (NRCS).

USDA Plant Hardiness Zone. United States National Arboretum.

USDA NRCS Web Soil Survey.

Subscribe to The Agroforestry Podcast!





Whether you're new to agroforestry or you're a seasoned professional expanding your knowledge base, the Center for Agroforestry's podcast series is a source for learning and inspiration. We explore topics ranging from forest farming medicinal plants and mushrooms, to soil and water conservation with hedgerows and buffers, and everything in between. Subscribe on your preferred podcast app, and stay tuned as we share the multitude of ways farmers and land stewards, researchers and educators are working to reintegrate diverse woody perennial plants into multifunctional landscapes.



NOTES

Chapter 3: Alley Cropping

Chapter Highlights

- Alley cropping is the use of perennial species (trees and shrubs) to create alleys which are used for agronomic, horticultural, or forage production. Alley cropping allows producers to make greater use of the same acreage.
- Alley cropping has numerous benefits including diversifying farm enterprises, enhancing quality and quantity of crops, and improving soil health.
- Alley cropping systems are complex to manage due to the needs of both the perennial species and intercrops through the system's long life. Light, water, and nutrient management change as perennial species grow into maturity, which can require significant modifications to management approaches as time progresses.

Alley Cropping

Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacings, creating alleys within which agricultural, horticultural, or forage crops are cultivated. The trees or shrubs may include valuable hardwood species, such as nut trees, or trees desirable for wood products. This approach is sometimes called intercropping and multi-cropping. Currently most of the emphasis and research focuses on pecan, chestnut, and eastern black walnut alley cropping applications. However, there are numerous other potential tree, shrub and crop combinations.

Role on the farm

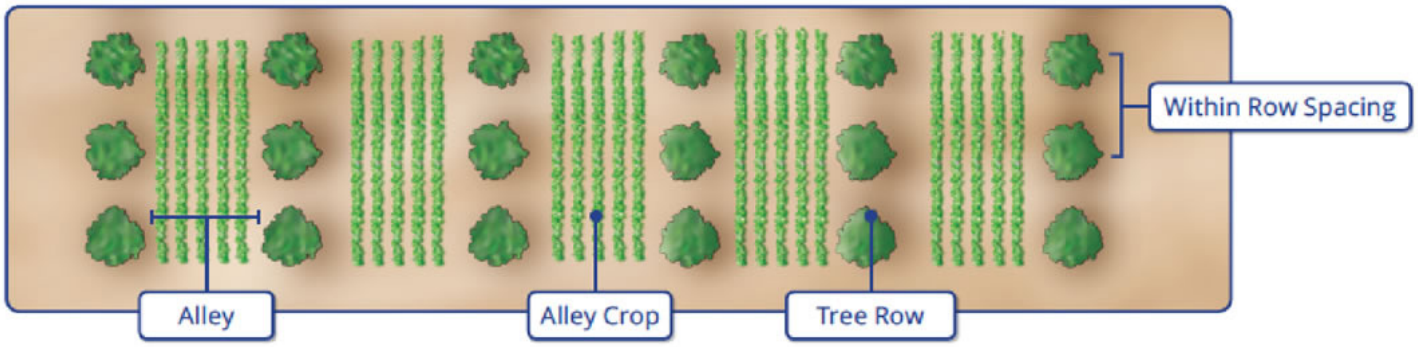
Alley cropping provides the opportunity to grow wood or other tree products such as nuts or fruit, while providing an annual income through the production of companion crops while at the same time realizing natural resource conservation. In this alley cropping example, soybeans are planted in the alleyways between nut trees for short-term income, nuts for medium-term income and in the long-term a possible timber harvest

Benefits of Alley Cropping

- *Diversify farm enterprise*
- *Reduce erosion*
- *Improve water quality*
- *Protect crops*
- *Enhance wildlife*
- *Improve aesthetics*

Diversifying farm products and supplementing income

Alley cropping diversifies farm enterprises by providing short-term cash flow from annual crops while also providing medium- to long- term products from woody



Alley cropping illustration. Courtesy of USDA National Agroforestry Center.

components. Timber and non-timber products may contribute to income generation from the farm. In addition to the potential for producing nuts, berries, and fruits, well-managed timber can provide a long-term investment.

Reducing soil erosion from wind and water

Soils with a high erodibility index (>8) are highly susceptible to damage and are difficult to protect when used as crop land. The soil erodibility index provides a numerical expression of the potential for a soil to erode considering the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Alley cropping protects fragile soils through a network of roots produced by the trees and supplemental ground-cover resulting from fallen leaves and the companion crop. Rows of trees, shrubs, and/or grasses planted on the contour of a slope will also serve to reduce soil movement down the slope.

Reducing erosion on sloping cropland

The interception of rainfall by the tree canopy and increased infiltration due to tree and herbaceous roots protects the soil; water quality is improved due to interception of sediment by herbaceous cover in tree rows and interception, sequestration, and decomposition of agricultural chemicals by tree and herbaceous root environment. Agricultural chemicals (e.g., nitrogen) leached beyond the root zone of the agronomic crops can be absorbed by the deeper root systems of the tree, hence minimizing the leaching of chemicals into the ground water resulting in improved water quality.

Micro-climate impacts

Trees and shrubs improve crop production by slowing wind speed and reducing wind erosion, modifying the crop micro-climate with similar effects to that of windbreaks (see Chapter 6 on windbreaks). Alley cropping can reduce crop evapotranspiration by 15-30 percent and increase water content in the tillage layer by 5-15 percent. Deep tree roots transport soil nutrients to leaves. Leaves contribute organic matter to soil and release nutrients as they decompose.

Protecting crops

Alley cropping reduces damage from insect pests by reducing crop visibility, diluting pest hosts due to plant diversity, interfering with pest movement, and creating habitat more favorable to beneficial insects.

Enhancing wildlife habitat and aesthetics:

Linear plantings of trees and/or shrubs in an agricultural landscape increases the habitat diversity for wildlife, both through increased amount of edge and/or as a result of the increased diversity (vertical and horizontal) of vegetation. Increased vertical complexity has been correlated with increased bird numbers. These areas can also serve as protective corridors for wildlife movement and provide a food source.

Limitations to Alley Cropping

Alley cropping, as with other forms of multicropping, requires more intensive technical management skill and marketing knowledge. The following limitations should be considered:

- *Requires a more intensive management system including specialized equipment for the tree management and additional managerial skills and training to manage multiple crops on a given site*
- *Removes land from annual crop production and may not provide a financial return from the trees for many years*
- *Requires a marketing infrastructure for forest products that may not be presently established Trees may be an obstacle to crop cultivation if not carefully planned and managed*
- *Trees compete with companion crops for sun, moisture and nutrients*
- *Companion crops may compete with trees for moisture and nutrients*
- *Herbicide drift from crops may damage trees*

Alley Cropping Functions

There are numerous mechanisms in which alley cropping impacts the landscapes to which it is applied, including water management, nutrient cycling, soil quality, micro-climate modification and pest management.

- Alley cropping impacts water management by

altering the hydrologic cycle through increased water infiltration via disruption of overland flow by the tree/grass strip. Water cycled through the system is more thoroughly filtered and any excess is gradually released.

- Nutrient cycling and soil quality are impacted as deeply rooted trees exploit lower soil horizons and cycle the nutrients to the surface through litterfall. Additional nitrogen is added to the nutrient pool if a nitrogen-fixing tree or shrub is used. Reduced soil erosion by wind and water help maintain soil quality. Additional moisture is added to the site through interception of rainfall by the tree canopy.
- Micro-climates are modified due to reductions in wind velocity which reduces air temperatures and evapotranspiration of intercropped plants and soil.
- Pest management can be strengthened through the structural diversity in the landscape developed by the intentional association of trees and crops. Alley cropping creates habitat to build up biodiversity and associated populations of natural enemies of insects, diseases, or weed pests and can interrupt pest cycles.
- Similar to the function of riparian forest buffers, alley cropping practices may help intercept, fix and biodegrade sediments, nutrients, pesticides, and other biological pollutants present on the site.
- Similar to the establishment of windbreaks, alley cropping may improve wildlife habitat by providing food, cover, nesting sites, and travel lanes for a variety of wildlife species. Incorporation of trees and shrubs add opportunity for additional products which are derived from the tree/shrub component (wood, nuts, fruit, foliage) as well as the option to plant sensitive crops which can be grown due to the protection from the trees.

Not all of these functions may exist with each application of alley cropping. The function is dependent upon the way the plant components are manipulated in the design process. There is also a lack of understanding of all the different interactions that can occur with the different combinations of tree/shrub/herbaceous (annual and perennial) plants. For a given design, we do not have enough information to evaluate all the different pest interactions to definitively state that beneficial insects will be favored and negative pests will be reduced, although there are examples of this.

Designs unique to each producer and site

Each alley cropping practice can be uniquely designed to reflect producer needs and site potential. However, there are physical interactions between the rows of woody species and the companion crop that should be understood and reflected in plans for the alley cropping practice design.

Physical growth traits of individual trees and how these influence the crop, are based on three factors:

A. Light Competition

B. Root Competition for Water and Nutrients

C. Allelopathy

A) Light competition (above ground)

A tree species should be selected that best accommodates the sunlight requirements of a specific crop. Some tree species have small leaves and feathery foliage casting a light shade and lend themselves well to alley cropping. When considering a tree species for an alley cropping practice, small leaves and light shade is preferable to heavy shade.

In what ways can light competition be reduced?

- *Spacing*. When the distance between rows of trees/shrubs is increased, the years an alleyway may be cropped with minimal competition from the trees is also increased.
- *Row Orientation*. An East-West orientation of tree rows will maximize the sunlight received by an alley crop, provided the topography permits this arrangement. Trees may have to be planted on the contour if erosion is a consideration. Trees may be planted in other orientations if prevailing winds have a negative influence on crop yields.
- *Maximizing available light*. Trees with small fine leaves will allow more light through the canopy. These leaves decompose rapidly and allow nutrients to be recycled into the soil faster. As decomposed materials contribute organic matter to the soil, the soil moisture-holding capacity is increased. Increased organic matter enhances soil microbe and earthworm activity. This also

improves soil tilth and health.

- *Understanding crown and foliage characteristics - phenology*. Utilize trees that leaf-out late in the spring and/ or drop leaves early in the fall. If the agronomic crop component matures in the early spring, such as winter wheat (*Triticum aestivum* L.), a tree that breaks dormancy late is ideal; alternatively, a crop that is harvested late in the fall is appropriate with a tree that drops its leaves early. Black walnut (*Juglans nigra*) is a good example of a tree that satisfies both scenarios.
- *Timely Thinning and Pruning*. Properly thinning trees within rows can maintain semi-open crown conditions. Maintained through regular thinning, these openings can help continue the vigorous growth of shade intolerant companion crops. Pruning basal branches before they reach 1" in diameter improves future wood quality and thins the depth of the canopy permitting more sunlight to reach companion crops.

B) Root competition (below ground)

Competition for water and nutrients between the tree and the intercropped species not only affects the yields of the companion crop but also the growth of the trees.

What ways can root competition be reduced?

- *Understanding rooting zones*. Vertical distribution of root systems varies among species. Deep-rooted species have a reduced volume of roots near the surface (good for minimizing competition with adjacent crops). Erosion can be addressed through ground cover establishment and management.
- *Which trees have deep roots?* Tree species have different site requirements. For instance, as a rule, wetland species tend to be shallow rooted. While potential species lists have been included in the appendices, it is always useful to consult your local forester for assistance in determining species suitable to your planting site.
- *What can be done if the trees are more shallow rooted?* Through the use of a Ripper, Coulter, or Chisel Plow, roots can be severed (the addition of sub- surface knives may also be used to sever more roots outside the rip). Trenching trials strongly suggest that even during the early years of tree development, competition for water and/ or nutrients is the major reason for reduced crop yields. With early (beginning with young trees) and repeated (annually or biennially) ripping lateral roots, the number of tree roots can be significantly decreased in the plow zone. The remaining roots will remain active deeper in the soil profile.

C) Allelopathy (chemical interactions)

Traditionally, the term allelopathy denotes the negative biochemical influence exerted by one plant on the growth of nearby plants. For example, pine needles may produce acids that inhibit growth of plants on the forest floor, while roots of black walnut trees produce a compound called juglone, which also inhibits the growth of other plants. A broader definition would also include positive influences. For example, some plants (e.g., legumes, European black alder, black locust) fix nitrogen that can benefit nearby plants.

Chemical interactions can be controlled by choosing plant combinations that work together. Juglone, for instance, does not affect all plants. Conversely, nitrogen-fixing plants are only useful to neighboring plants that require extra nitrogen.

Tree arrangement

The tree and/or shrub row(s) are placed at intervals across the crop field, depending on the purpose, either on the contour or perhaps even perpendicular to prevailing troublesome winds. Several factors are used



A black locus / soybean alley crop at the Savanna Institute's Memorial 4H Camp Demonstration Farm at Allerton Park in Monticello, IL.

to determine the interval between the row(s) of trees or shrubs including slope length, field width, crop light requirements and equipment width.

As mentioned earlier, producer objectives will determine the products to be harvested from the alley cropping practice. These objectives also determine the arrangement of trees/ shrubs and crops and the set of management practices needed to obtain those products. Alley cropping practices are highly diverse and range from simple to complex. Plantings can consist of a single tree species or a number of species. Similarly, single tree rows or multiple rows may be used. There are several key factors to consider when planning and establishing the practice on a given site:

There are several key factors to consider when planning and establishing the practice on a given site:

- *Single or mixed species*
- *Number of tree rows - single vs. multiple*
- *Alley width: between row spacing*
- *Within row spacing*

With a conservation perspective in mind, slope length relates to the spacing needed to reduce water erosion. The light requirement for the crop or forage to be grown in the alleyway must be considered prior to tree establishment. Finally, alley width must be set as multiples of the widest field equipment width.

Single vs. mixed species

The row(s) of trees can have either a single species in the row or mixed species. A single species is the easiest to plant but a mixed species planting with similar growth rates and site requirements may provide greater economic and environmental diversity. Factors to consider when deciding how many rows to establish and the arrangement of the trees within the rows may be based on a number of potential benefits including:

- *Annual crop being produced and area removed from production by tree/shrub rows*
- *Desired tree/shrub crops and management r to enhance production (such as weed contr pruning)*
- *Erosion concerns that multiple rows combinations of trees/shrubs/grasses can address*
- *Wildlife habitat created through multiple r combined trees/shrubs/grasses*

Single vs. multiple rows of trees

Single rows take up the least amount of space but the trees will probably require pruning to enhance the quality of the future wood product. Multiple rows, however, will result in self pruning of the interior row(s). Conifers are a good choice as the "trainer" trees in the outside rows since hardwood species will tend to bend toward the light in the alleyway thus reducing their wood value except as chips. Nitrogen-fixing "nurse trees" can also be used.



An aerial view of single, double, and triple row configurations for alley cropping at the Horticulture and Agroforestry Research Farm in New Franklin, MO. The illustration below shows a triple row of trees using conifers to train high-value hardwoods. A single-row tree strip is also shown.

Advantages to single rows:

- *Environment maintained*
- *Less tree to tree competition*
- *Reduced competition between components*
- *Wildlife habitat enhanced*
- *Plant-insect relationships increased*
- *Economics improved*



Single rows create the proper environment for nut trees to develop full crowns. Trees in single rows which are spaced further apart develop wider, more branched crowns. Conversely, if high value tree form is important, then closely spaced trees may encourage self-pruning and straight bole development. In single rows, trees are open on at least two sides, and therefore have less competition between trees within each row, when compared to multiple row configurations. Single tree rows add diversity to a typical row crop field. Researchers think the greatest value to wildlife of woody herbaceous buffers are the benefits created through breaking up the traditional monoculture setting associated with agriculture. Vegetation change and structural diversity is an important tool in controlling agricultural pests. Products coming from the farm are diversified through the addition of trees and their products.

Advantages to double rows:

- *Environment maintained*
- *Reduced competition*
- *Wildlife habitat*
- *Improved economics*

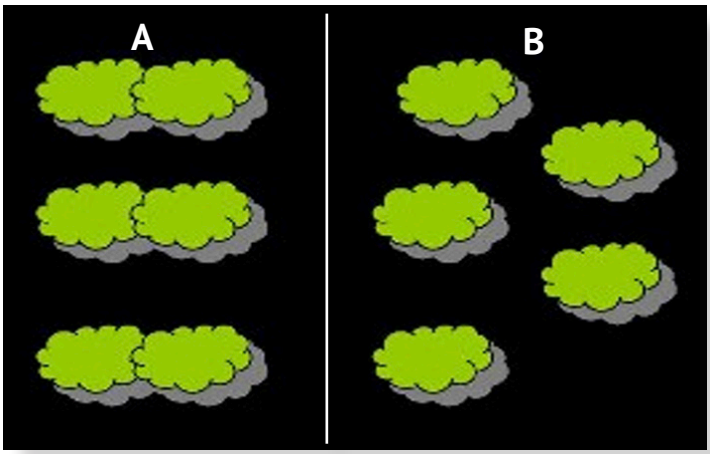
Competition for light between trees can be Economics When rows are offset, double rows of trees maintain similar advantages to that of single row plantings while improving the potential to realize environmental benefits, such as soil and water protection. Compared to rectangular grid patterns of tree planting, double rows allow maximum utilization of space for companion crops.

Competition for light between trees can be reduced through offset row configurations.* Multiple rows of trees planted in offset configurations maintain exposure of a majority of each trees crown/canopy to sunlight. Double rows provide the same benefits as a single row alley crop setting, but allow structure (vertical and horizontal vegetative layering and density components) and diversity (variety of species planted) to be increased. This creates an environment for greater utilization of the tree row by increased numbers of wildlife species. Finally, products coming from the farm are further diversified.

**As mentioned, caution should be observed since deciduous hardwood trees will exhibit a tendency to grow towards light. If an environment of unequal lighting is created (more light to one side of a trees' crown), most hardwood species will grow towards sunlight, and away from competition. This can cause devaluing of the tree for wood products due to sweep (stem curvature).*

Advantages to multiple rows:

- *Benefit from competition between tree rows*
- *Wildlife habitat*
- *Plant-insect relationships*
- *Economics*



Crown competition between adjacent trees (A) as compared to the increased growing space available to individual trees when planting in an offset configuration (B). Double or triple rows of long-needled hard pines (e.g., cold tolerant loblolly or pitch x loblolly hybrids) can be grown either as (A) or (B). A byproduct of a double or triple planting is the potential for pine straw production within tree rows.

Certain trees will benefit from some light competition. For high value wood, it is desirable to grow a single, straight stem. Trees and/or shrubs planted on either side of a high value tree species, can be used to train the stem of that tree. By using 'trainer' trees on either side of the high value tree, natural pruning and straight stem growth can be encouraged. Ultimately, this starts the process (may also require pruning) of producing a straight, clear (small or no knots) log of higher quality than might be grown in an open setting. However, choosing the correct 'trainer' species is important because you do not want the outside trees to outgrow your center tree. If they do, they will provide too much shade.

Wildlife habitat potential increases greatly with a wider row of trees. Increased numbers of animals will use this area for travel lanes and the interior creates protective cover opportunities for birds and small mammals.

Plant-insect benefits are the same for single and double row configurations, though some additional advantages may be realized by diversifying the species planted.

Economic benefits are similar to double row configurations. As with double rows, additional trees per acre in multiple row configurations may also qualify these plantings for cost-share assistance and create opportunities for medium-term tree crops to be removed for cash flow (e.g., trees grown for landscaping).

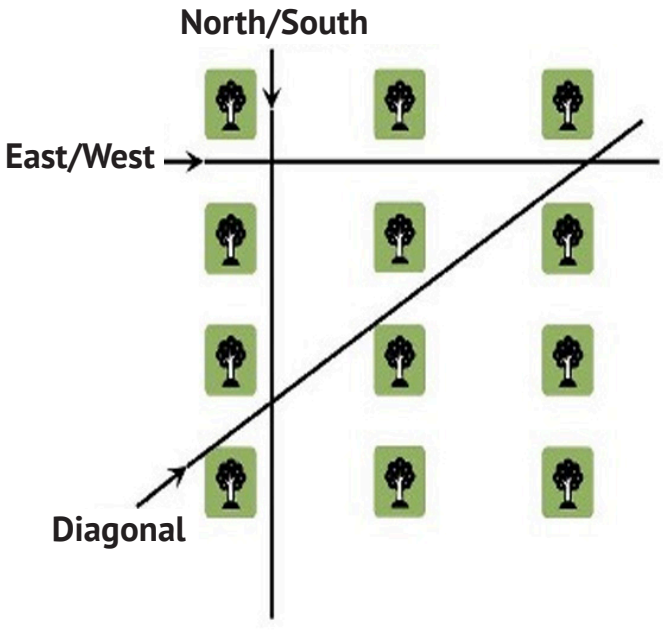
Tree and shrub arrangement

To enhance the growth of trees in multiple-row plantings, staggering the trees between adjacent rows will permit maximum crown development. Staggered spacing provides more room to grow.

Alley width: between tree row/set spacing

If wood production is of primary importance, closer row spacing is desirable. Wider row spacing is preferred when nut production is desired.

The spacing should also be adjusted based on multiples of the widest farm equipment to be used in the alley way. Spacing to accommodate equipment is particularly important in nut production when early crown development is desirable. Plan alleys such that full, or multiple, passes of the equipment are utilized. For example, if using a 13-foot wide disk it may be desirable to have an alleyway 60 feet wide. This allows for 4 passes with the disk (52 feet) and a buffer (to ensure damage is not done to the base of the tree) of 4 feet adjacent to each tree row (8 feet; 4 feet on either side of the cropped alley).



This diagram shows equipment travel lanes. The use of trees planted in rows can allow equipment passage in any number of directions.

The number of years that light-demanding crops are to be grown in the alleyways is another consideration:

- *60 feet spacing will generally allow crop production (e.g. corn, soybeans, cereals, etc.) for 5-10 years*
- *80-120 foot spacing will allow production for up to 20 years or more*
- *As the shade increases over the life of the trees, it may be necessary to change the companion crop being grown in the alley- way (see plant material section).*

Within tree row spacing

The primary objective for the trees, and the cost of the planting stock, will help determine the within row spacing. If erosion control is desired, a closer spacing would give better results. If the tree stock is of unknown origin and quality, a closer spacing would also be desirable to give more opportunities to select the best quality trees during succeeding thinnings. Closer spacing may also be required if minimum numbers of trees per acre are required to meet government cost share requirements. However, if expensive grafted tree stock is used for nut production, a wider spacing may be used to reduce cost. For example, trees that are grown tightly spaced will have a tendency to grow up, towards the light. This growth trait is highly desirable when growing trees for quality wood production. Additionally, as these tightly spaced trees begin to shade one another, each of their branches in the shade will begin to die and eventually fall off. This is called self- pruning, and is again desirable when trying to grow high quality wood in timber production.

Tree and Shrub Selection: Desirable Characteristics

There are a number of desirable characteristics for trees or shrubs that will be grown in an alley cropping system. It is not necessary (probably not possible) that all of the

following characteristics be exhibited by one tree species:

- *Produces a commercially valuable product or multiple products (i.e., timber, nuts) that has an acceptable local market.*
- *Is relatively fast growing (medium growth rate on high value trees is acceptable) or highly valued for production or conservation benefits*
- *Produces appropriate shade for the companion crop is adapted to a variety of sites and soils*
- *Is deep-rooted with minimal roots at the soil surface to minimize competition with crops in the alleyway*
- *Has foliage with minimal acid generating potential if companion crops prefer a pH neutral soil. Conifers acidify soil, combine well with acid loving crops.*
- *Does not produce growth inhibitory chemicals (allelochemicals) that would prevent some crops from growing near them (e.g., black walnut)*
- *Has a growing season that complements the companion crop*
- *Produces wildlife benefits*

Selecting companion crops

Companion crops are planted in the alleys between the tree rows. The choice of companion crop will vary depending on the types of trees selected and the crop(s) desired by the grower. There are three major groups of crops which can be grown in an alley cropping practice: 1) Row/cereal and forage crops; 2) Fruits and other specialty crops; and 3) biomass producing crops.

Initially, the growing environment in the alley will be favorable to row crops requiring full sun (corn, soybeans, wheat) or forages. Potential companion crops include row/cereal crops, forages, fruits and other specialty crops, biomass producing crops.

As trees grow taller and develop larger crowns, they will exert greater influence on the growing environment in the alley with increased shade, water and nutrient competition and humidity levels, along with decreased temperatures and decreased wind movement.

While availability of sunlight is a primary factor that determines how well row crops or forages perform in the alley, water and nutrient competition is even more significant. The tree canopy density will be partially determined by the spacing of the trees within a row and the width between tree rows. This spacing will also influence below ground competition.

Tree/shrub selection for row crops

Corn, soybeans, wheat, milo, barley, oats, potatoes, pumpkins, lettuce, peas, etc. have demonstrated success

Plant Materials: Trees for Alley Cropping

- **Black walnut:** Outstanding markets available for wood. Opportunities exist for the sale of wild nuts, cultivars provide a higher return. Produces light shade, has a short foliage period, and is deep rooted. The juglone allelochemical limits companion crop choices somewhat (esp. avoid nightshade plants).
- **Pecan:** Markets available for both wood and nuts. Markets exist for nuts from native wild pecans and for cultivars. Nuts more valuable than the wood. More shade produced than with walnut but no allelochemicals.
- **Oaks:** The wood has a high value and the acorns are good wildlife food. The oaks are relatively slow growing and produce fairly dense shade.
- **Chestnuts:** Chinese chestnut produce valuable nuts at an early age, are blight resistant and adapted to the climate of the eastern U.S. Prices are high and markets are growing for domestic producers. Nut or fruit bearing shrubs: Hazelnuts, pawpaws, blueberries, etc. could be used as stand-alone hedgerows or in combination with other taller tree species.
- **Nut or fruit bearing shrubs:** Hazelnuts, pawpaws, blueberries, etc. could be used as stand-alone hedgerows or in combination with other taller tree species.

in alley cropping. Most of these crops have high light demands. Using corn in the first few years speeds tree growth by creating a greenhouse effect for the tree rows. In an alleyway 60 feet wide, shade will limit their use after 5-10 years depending on the tree species.

Selection of forage crops

In an alley cropping practice, forage crops such as fescue, orchard grass, bluegrass, or alfalfa, are grown for hay production between rows of planted trees, but are not grazed. This distinguishes the alley cropping practice from a silvopasture practice.

Kentucky 31 tall fescue and orchard grass tolerate considerable shade and are very productive cool-season grasses. Other potential forages that show shade tolerance include Kentucky bluegrass, ryegrass, smooth brome, timothy and white clover. Winter annuals such as cereal grains, crimson clover, and hairy vetch must be reseeded every year and only provide one cutting of hay, but do not compete with the trees and provide good erosion control.



Bluegrass hay is harvested between rows of pecan trees in this alley cropping example at Shepherd Farm in Clifton Hill, MO.

Cool vs. warm-season forages

It is also necessary to consider whether a cool or warm season crop and/or forage may be more appropriate for the site conditions and objectives. Studies conducted by the University of Missouri have found that many cool-season legumes and grasses produce greater biomass when grown under partial shade as compared to full sun. Some warm-season grasses showed similar responses, but most were southern temperate zone species.

Advantages and disadvantages of cool season forages

Cool-season perennial species are most productive in the spring when temperatures are typically cool and moisture plentiful. They grow less or become dormant during the hot summer months when moisture is often limiting, then increase growth in the fall. Cool-season forages can be highly competitive with tree crops for moisture and nutrients, especially in the spring as trees break dormancy. As young trees are becoming established, it is desirable that no vegetation grow within a 3-foot radius. To maximize the growth of older trees, vegetation should be controlled in a diameter approximately equal to the crown diameter size. However, this may or may not result in the greatest economic gain.

Advantages and disadvantages of warm season forages

The root systems associated with warm- season forages are typically deeper than cool-season grasses. This makes them an excellent choice for controlling erosion and protecting sub-surface water from leached pesticides and nutrients. These forages will likely be less competitive in the early spring when many trees are beginning their annual growth. Warm season "clump" grasses provide excellent habitat for quail in combination with woody shrubs.

Warm-season forages grow vigorously in the hot summer months. Therefore, a consideration is that this may put them in competition with trees and other woody vegetation at a time of the year when water is quite

Warm-season forages

Warm-season perennial species grow most during the summer months. Though warm-season forages have a shorter growing season, they are still very productive.

Eastern gamagrass, bermuda grass, Switch-grass, Indiangrass, and big bluestem are examples of warm-season perennial grasses identified for use in Missouri. Southern climates may use bahiagrass or bermudagrass.

possibly the most limited resource. On the other hand, if a tree species puts on its growth in late spring, in certain instances a warm-season forage can make a good companion crop.

The point is that compatibility, even seasonal compatibility, must be considered when selecting trees, shrubs, grasses, and crops for an alley cropping practice.

Integrating specialty crops into an alley cropping practice

Most often associated with the forest farming practice, specialty crops also have potential for integration into alley cropping practices. Landscaping plants, Christmas trees, small fruit trees or shrubs and berries can be grown either temporarily between the permanent in-row crop trees or in the alleyways. As the alleyways become more shaded, shade tolerant species such as redbud, dogwood and spruce could be grown for landscaping if there is a nearby market. Plants which can be marketed for their medicinal, ornamental, or food values (including native plants for seed production, pumpkins, etc.) also provide unique opportunities for alley cropping. Species that are light demanding can be established in the alleyways while those requiring some shade can be planted within the tree rows as shade develops.





Top: lettuce intercropped until mid-June followed immediately by a pumpkin intercrop until October in Vineland, Ontario. Bottom: grain is alley-cropped in a young pecan orchard in Georgia, U.S.

Specialty crops that can be produced in full sun include:

- *Horticultural plants, such as tomatoes, pumpkins, and blackberries*
- *Forages, grains, and oil seeds*
- *Tree crops,such as nuts*
- *Native plants for seed production*
- *Shrubs and other landscaping plants*
- *Trees for lumber and wood fiber products*

Biomass crops

Both woody and herbaceous plants for biomass production could be an option for the alleyways. “Soft” hardwood species such as cottonwood, hybrid poplars, willow, sycamore and silver maple could be grown for pulp, paper or oriented strand board if markets are available. Herbaceous biomass crops (e.g. switchgrass) are another alternative.

Operation and Maintenance

Pest management

Periodic inspection of the crops and trees is recommended to detect and identify possible pests. Insects and diseases can be significant factors in reducing the health and vigor of both the tree crop and the intercrop. The corrective actions should minimize the impacts on beneficial insects.

Fertilization and nutrient management

A normal fertility program should be applied for the intercrop in the alleyway. Generally, fertilization of the tree crop is not needed, but fertilizing the intercrop may also benefit the trees. Competition for nutrients can be minimized by root pruning or by adding more nutrients. Nutrients can be added in the form of chemical fertilizer, animal manure or a wide range of other materials. This

may also include the use of living mulches or green manures.

Canopy management (pruning)

If there is too much shade under an existing stand of trees, the canopy can be pruned to allow more light to reach the understory plants. You may be able to accomplish this by clear-stem pruning for improved timber production. This involves the removal of branches low on the stem of a tree in order to raise the height at which the canopy begins. This allows more light to enter the understory from side angles while also creating adequate space for operating equipment. Re- member, removing more than 40% of the trees foliage will significantly reduce the growth of the tree. It is best to always have 40-50% of a tree's height in crown or foliage.

Periodic root "training" will improve crop yields

Based on research into tree and crop interactions it has been shown that even during the early years of tree development, competition for water and/or nutrients is the major reason for reduced crop yields. By early (beginning with young trees) and repeated (annual, biennial) deep ripping of lateral roots, the number of tree roots can be significantly decreased in the plow zone. Row crops will continue to pro- duce commercial yields even as shade levels increase.



Paulownia and winter wheat example in China. Through careful pruning, the proper shade canopy can be developed and light levels can be manipulated. Often, the intercrop will transition to more shade tolerant crops, or extensive tree removal by thinning will be needed in order to maintain light levels.

Weed control

Weed control for an alley cropping includes both the rows of trees and the intercrop. For the tree row(s), weeds need to be minimized usually for the first three to five years in a band about three feet on each side of the trees. Weed removal can be done a number of different ways, from herbicides and cutting to cultivation and mulching. An additional consideration for use in controlling weeds adjacent to trees may include fabric barriers or living mulches.

Maintenance tasks specific to trees:

- *Replanting: Replant all trees or shrubs that have failed for the first 3 years.*
- *Branch pruning: Pruning of the trees may be necessary to improve wood quality, the microenvironment for the companion crop, allow equipment access, or correct storm damage. Root Pruning: Deep ripping of tree roots (up to 24 inches deep) projecting into the companion crop area will reduce competition. Unless down from the outset, do not rip both sides of the trees the same year. Allow a 2-year interval before ripping the other side. Deep ripping will need to be repeated on an annual or biennial interval.*
- *Thinning: The tree rows will normally need to be thinned to increase light in the alley- ways and speed production of high value crop trees. To achieve the objective of maximum tree growth rates throughout the timber rotation, growers must be willing to periodically thin trees. Failure to do so dramatically and adversely impacts future tree growth rates and rotation length.*

Financial and Technical Assistance for Alley Cropping

There are many agencies offering programs that can be used to establish and maintain agroforestry practices. One of the most significant of these is the USDA Natural Resource Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP) that may be used to support startup costs of establishing an alley cropping practice. The EQIP program is designated to address environmental concerns associated with agricultural production. Landowners engaged in livestock or agricultural production can apply for 1 to 10-year contracts through a competitive application process based on environmental benefits. Eligible lands include



Alley cropping example of black walnut and oats. Photo courtesy of Hugh Pence.

cropland, rangeland, pasture, forestland, and other farm and ranch lands. Conservation practices are designed with the help of USDA/NRCS and other agencies to address the locally-identified priority resource concerns. NRCS Standard 311 identifies the guidelines for establishing an alley cropping practice for EQIP.

Alley cropping is the tree or shrub component of an overall conservation management system for cropland or hayland. To be an effective conservation management system, several other conservation practices are often considered for inclusion in the system depending on the objectives to be achieved. The list below outlines NRCS conservation practices that often compliment alley cropping objectives (the numbers in parentheses are NRCS conservation practice codes).

- *Conservation Crop Rotation (328)*
- *Crop Residue Management (329, 344)*
- *Contour Farming (330)*
- *Contour Buffer Strips (332)*
- *Contour Orchard & Other Fruit Area (331)*
- *Filter Strip (393)*
- *Forage Harvest Management (511)*
- *Grassed Waterway (412)*
- *Stripcropping, Contour (585)*
- *Terrace (600)*
- *Pasture and Hayland Planting (512)*
- *Pest Management (595)*
- *Wildlife Upland Habitat Management (645)*

Please note that financial assistance rates vary by state and by year. For more the most updated information, contact your local USDA/NRCS office. Additional programs exist to support producers in establishing and maintaining alley cropping systems. Read more about current funding opportunities in an addendum to this publication available at centerforagroforestry.org/training-manual.

Summary

Alley Cropping is part of an overall management system including crop rotation, crop residue management, combinations of buffer practices, pest management, and nutrient management. Alley Cropping can help diversify farm enterprises, protect soil, improve air and water quality, enhance fish and wildlife habitat, conserve biodiversity, and beautify the landscape.

Additional Resources

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Fifteen+ years of chestnut & winter wheat alley cropping at Cedar Hill Farms in Marshall, Missouri

At a glance: Cedar Hill Farms maintains 1,500 Chinese chestnut trees on 22 acres in a chestnut and winter wheat alley cropping system in north central Missouri. The family currently sells more than 7,000 pounds of chestnuts per year (with 14 acres yet to reach bearing age). The farm also has six acres of American elderberry and cash rents row crop acres to a neighboring farmer.







Overview: Bill and Sue Ellen Stouffer's 130-acre Cedar Hills Farm has been in their family since 1812. Prior to establishing chestnuts in 2009, the family's operation included 2,500 row cropped acres in a no-till corn/soy rotation and 250 head of cattle. As they approached retirement age, Bill and Sue Ellen began looking for something that could offer a higher return per acre in order to keep the farm in the family without burdening future generations. As the Center for Agroforestry developed its chestnut improvement program and began sharing horticultural best practices with producers, the Stouffer's decided a chestnut venture would meet their primary goal to sustain the farm for multiple generations.

Orchard establishment: The soil type on the farm is primarily Higginville silt loam derived from windblown loess, which is well suited for chestnut production. In the spring of 2009, the Stouffer's planted 250 chestnut rootstock and, in 2010, began field grafting varieties well suited to central Missouri. Since then, they have added approximately 100 trees per year to their production orchards. As a strategy to to accelerate the timeline for harvestable yeilds, initial plantings were more closely spaced than typically recommended for chestnut orchards, with tree thinning expected as trees mature. Today, they have expanded to 22 acres of chestnuts including six varieties, with 'Qing' being the most productive. The orchard is fully irrigated and is surrounded by an 8-ft deer fence.

Alley crop: After trialing other alley crops (pumpkins, hay), the Stouffer's decided no-till winter wheat was the best fit for their operation for a variety of reasons:

- The wheat crop uses excessive moisture in the spring when the chestnuts can suffer from waterlogged soils.
- The late leafing of the trees allows enough sunlight for the wheat crop to mature before it is harvested in June.
- After harvest, the wheat straw acts as a mulch, preserving soil moisture, reducing weed pressure, and creating a mat that keeps chestnuts clean after they drop from the burr. The straw mat also allows for efficient hand-harvest with nut wizards.
- The wheat eliminates the need to mow and provides additional income.

Marketing and sales: The Stouffer's trees started yielding small quantities of nuts for sale around 2013. Today, their chestnuts are sold direct-to-consumer for approximately $8.00/lb. Sales occur primarily through their website and are mailed to customers across the country. They promote their product mainly through word of mouth and a returning customer mailing list. Since the trees started producing, the Stouffer's have sold out of chestnuts almost every year. Some years, the bulk of their product is claimed before the nuts even hit the orchard floor.

ALLEY CROPPING REVIEW QUESTIONS

1. **What factors affect the width between your rows?**
2. **What are some of the advantages and disadvantages to alley cropping?**
3. **What are advantages and drawbacks of utilizing narrow vs. wide alleyways?**
4. **Identify two management practices that are critical to maintaining tree growth over time.**
5. **Why is root pruning performed on tree/shrub species in alley cropping?**
6. **Removing what percent or more of the tree's foliage can have a serious impact on the growth of the tree?**
7. **How do you determine how far apart to plant trees in a tree line and how far apart to plant the tree rows? Is there such a thing as a wrong distance, such as too far apart or too close together?**

ANSWER KEY

1. The producer's goals and objectives, desired crops, uses for trees, and width of existing crop production equipment all impact between and within row widths.
2. *Advantages*: Short-term cash flow, trees benefit from crop fertilization, sun crops compete with weeds, reduce runoff, form of windbreaks, and provide increased economic diversity and long-term payoff. *Disadvantages*: Tree rows are obstacles for cultivation, provide competition for sunlight, moisture, and nutrients, and require more intensive management. Herbicide drift from crops may damage trees. Sun crops will need to be exchanged for more shade tolerant crops over time.
3. Narrow alleys with more tree rows permit greater production of trees and shrubs per acre of land putting an emphasis on the value of the woody crop. Narrower alleys will also become shaded within just a few years forcing a shift from sun to shade loving crops. Wide alleys permit sun loving crops to be grown for many years and are often more compatible with farm equipment
4. Ongoing weed control around the base of the trees, using herbicides, mulch, fabric barriers or living mulches is absolutely essential for rapid tree growth and establishment. As the trees age and grow, thinning out crowded trees within the row will enable the trees to maintain maximum growth rates over the long haul.
5. Tree roots can be pruned (severed) or "trained" to reduce competition for water and nutrients.
6. Removing over 40% of the crown of the tree will reduce its growth.
7. Depending on the emphasis of nut or wood production, and what kinds of crops are planned on, the width of the alleys must be adjusted to meet these plans. Wood production is compatible with narrow rows and multiple rows; nut production requires single rows and wide spacing between trees. A "wrong" distance would be any planting configuration that does not meet the producer's short-, medium- and long-term objectives resulting in lower production from desired crops or reduced tree growth or poor tree form. Row-to-row distance also must match with existing equipment.

Chapter 4: Silvopasture

Chapter Highlights

- Silvopasture is the intentional combination of perennial species (trees and shrubs), forage, and livestock into a management system.
- Silvopasture can benefit livestock by providing shade in the summer and shelter in the winter. Moderating the extreme temperatures livestock are exposed to enhances their health and weight gain.
- Forage quality and soil health can be improved by rotational managed grazing in a silvopasture system. A shaded environment can improve forage quality.
- Trees and shrubs integrated into silvopasture systems can diversify farm enterprises.

Defining Silvopasture

Silvopastoral practices intentionally integrate the management of trees, forages, and grazing livestock for a production benefit. It is important to note that allowing livestock to graze in a natural woodland area without active livestock/forage grazing management is not considered agroforestry. Silvopasture can be created using two different approaches:

1. **Establish trees into existing pasture.** The right choice of tree crop (often matched to soils) allows you to carry on a profitable livestock operation while creating a long-term investment in timber and/or forest products. Young trees allow plenty of light for forage production. Additionally, as the tree component develops, shade and wind protection will enhance livestock performance. Success and longevity of the practice hinges on two primary factors: control of the grass growth around young trees (necessary for early tree development) and proper management of tree densities (necessary for light management and long-term forage production).
2. **Establish forages in the woods.** By establishing select forages in an intensively managed forest environment, the area can then be jointly managed for grazing and timber production. In most forests, the key to successful silvopasture will be forage production. Levels of forage production will hinge on two factors: having the light necessary for forage growth and response, and proper rotational grazing. Soil fertility should be adjusted to enhance forage development, and light should be adjusted by reducing tree density and managing tree spacing. It is important to recognize that long-term timber value and silvopasture viability hinges on selecting site appropriate, high-quality trees. Forages should be selected that match grazing objectives and light availability.



Hardwood silvopasture under white oak at the University of Missouri Wurdack Extension and Education Cemter near Cooks Station in the northeast Ozarks.

General Benefits of Silvopasture

- *Diversifies farm enterprises*
- *Improves growth of high quality trees*
- *Reduces stress and improves animal productivity*
- *Improves nutrient cycling*
- *Enhances wildlife habitat*

Properly applied on a landscape, silvopasture can enhance and diversify farm income opportunities, provide environmental benefits and create wildlife habitat. Current research is focused on understanding the dynamics of silvopastoral practices (i.e., interactions between trees, forages and livestock). The expected outcome is that silvopastoral practices will improve the productivity of the grazing animal as well as the quality and diversity of forage available to the grazing animal and wildlife, while effectively incorporating timber stand improvement across a wide array of forested land.

General Limitations of Silvopasture

- *Producers should already be practicing some type of rotational grazing*
- *Distance and access to water*
- *Challenges establishing young trees*
- *Challenges introducing forages to existing woodlands*
- *Maintaining proper light levels*
- *Fencing issues*

Converting all of a pasture grazing system to silvopasture is unlikely on a wide scale. Many farm managers have a wide variety of existing land resources. Prioritize pastures where tree growth could be ideal and mix with compatible forage(s). Management Intensive Rotational Grazing (MIRG) helps to divide the farm into management units. Use silvopasture strategically to compliment the grazing system. Creating small, fenced paddocks to rotate cattle builds in "recovery periods" for the forage and protects the soil and the trees. Grazing recovery periods can only be achieved when well-designed livestock water supplies and cross fences are used.

Components of Silvopasture

Silvopasture practices are different from other types of agroforestry because they require farmers and ranchers to manage livestock, as well as trees and forage plants. This three-way interaction means that producers must consider multiple factors when designing their agroforestry practice.

The following five variables can be managed in a silvopastoral system: livestock, grazing practice, tree species, tree density, and forage species. The majority of research conducted has evaluated silvopastoral practices under conifers (mostly pine) with only limited evaluation of hardwood-based practices. Most hardwood research has been conducted with either oak species or nut-bearing species (e.g., black walnut, pecan). In certain instances under deciduous tree stands, forage production has been reported to be equal or even greater than in open exposure to sunlight. Fescue and orchardgrass production has been shown to be greater under a 35-year-old walnut canopy than in open pastures.

Managed grazing practices, similar to open pastures, should be developed and implemented to maximize forage production in a silvopastoral practice. The increased forage production under a canopy would result in increased stocking rate potential and greater productivity per unit of land.

A. Livestock

Animal performance can be enhanced via use of silvopastoral practices. This occurs from reduction of heat stress and improved forage availability and nutritional quality. There may also be instances where browsing livestock, such as species of goats, can be used to eliminate undesirable understory vegetation. In these instances, the livestock receive forage benefits from the woodland, and the woodland is enhanced when invasive or undesirable vegetation is eliminated. Selecting appropriate livestock will help farmers and ranchers achieve their objectives.

The greatest difference between silvopastoral and "open" management of cattle or sheep is the contrasting environmental conditions. In the open, such as a conventional pasture or range, radiant heat can be much more intense than in a shaded environment. Shade has been shown to improve animal performance, with primary emphasis placed upon reducing heat stress. Research with cattle has shown that compared to unshaded or sparsely-shaded pasture, uniformly-distributed shade results in maximum grazing time.

Heat and cold stress can adversely affect cattle throughout much of the temperate zone in North America. Protection from cold can be important for livestock in northern climates. Properly positioned trees and shrubs can provide much needed protection for pastures, feedlots, and calving areas. Reducing wind speed lowers animal stress, improves animal health and increases feeding efficiency of livestock. It takes careful management to ensure livestock do not damage young trees. Success will depend on your understanding of livestock behavior.

Grazing considerations

- Early stages: protect trees from livestock in early stages of growth. Electric fencing works well. Once tree limbs are out of reach of stock, there is less to worry about.
- Later stages: Tree growth will likely reduce annual forage production once a full canopy develops. Choosing a shade-tolerant forage is important. More aggressive forages are less of a problem. Ensure that silvopasture practices fit into the overall grazing "system".

Special water considerations for silvopasture

- *Consider using portable water tanks*
- *If installing permanent tanks, consider concrete tanks*
- *Consider using tank covers on permanent tanks*
- *Consider installing water within 600 feet travel distance*

Animals acquire water through drinking and from the moisture in the forage they eat. As air temperature increases, water requirements also increase. This becomes especially critical as air temperatures exceed 77^0 F. The need for available drinking water is compounded because forages become drier at higher temperatures. At 90^0 F, a 600 pound growing steer needs about 13 gallons of water per day. At 60^0 F, that need falls to eight gallons per day. One distinct advantage of a silvopasture system is that shade is distributed throughout the pasture and greatly reduces high temperature stress on livestock.

Water requirements vary for the kind, size, age, and breed of livestock. For example, *Bos taurus* breeds of cattle (European types) generally consume more water than *Bos indicus* breeds (such as Brahman-influenced breeds). Dairy breeds need significantly more water than beef breeds.

The rule-of-thumb used by some livestock managers is one gallon of water per day per 100 pounds of body weight per animal. Water use also varies considerably depending upon the animal's health, air temperature, water temperature, stage of lactation, and other environmental factors.

Water distribution

Daily intake of water increases when travel distance is less than 600 feet. Water consumption may be 15 percent higher in small paddocks with water in every field (less than 600 feet of travel) than in similar systems with water available at a single source (where cattle may travel between 600 and 2,000 feet to water). When water is located close to the forage resource, the herd's "social structure" is modified such that animals tend to water more frequently as individuals. This tends to keep the herd dispersed throughout the paddock and results in a greater portion of time spent grazing.

Of course, it is not always possible to install the "ideal" water system and many successful grazers utilize water in pastures larger than 32 acres with travel distances to water greater than 600 feet. Dedicated travel lanes have been successful to allow cattle to travel to central water locations. This approach, however, is best suited to level terrain and locations with only slight erosion hazards. To compensate for less than ideal situations, special care must be taken to monitor grazing impacts on trees and forages. Adjusting the stocking levels and grazing rotation periods can help protect both the forage and the trees in a silvopasture practice with water distribution problems.

Water supply options for silvopasture include wells, creeks, ponds, springs and even municipal or rural water systems. Ponds can provide a good reliable source of drinking water for livestock and wildlife, as well as providing other benefits. Consider utilizing portable livestock tanks that can be removed during tree management or harvesting operations.

Browsing

Poorly managed livestock can cause two types of damage to trees: browsing and trampling. Livestock preferences are predictable; they will choose grass before they browse conifer trees. However, conifers are attractive to livestock when they are flushing in spring, so that is a good time to keep animals and trees apart. In hardwoods/deciduous trees, livestock browse can be a problem at any time. When available, livestock will seek out nutritional forage. The browsing of terminal shoots by domestic or wild animals will result in deformity and loss of tree growth. It is therefore desirable to have physical protection around hardwood seedlings. Wire cages, or a single strand of high tensile electric wire along both sides of a seedling (usually 3 feet from seedlings), or seedling row, have been shown to be effective at reducing browse damage.

Fencing

Proper pasture rotation provides "recovery periods" for the grazed forage, minimizes soil compaction, and protects trees in a silvopasture system. There are several key components in an effective and easily managed fencing system:

- *An energized fence is primarily a psychological barrier and can only be effective if the fence carries enough current to deliver a "deterrent" shock. Alternating current (AC) powered units are generally the best choice for energizing a fence if 220-or 110-volt power is available. For remote areas, battery powered systems with solar recharge may be necessary. In a silvopasture practice, the potential for malfunction increases with the risk of falling branches or trees damaging the system.*
- *To assure effective operation, the energized fence should have a proper-sized energizer. Generally one-joule output per mile of fence is sufficient. Be properly grounded with a minimum of three feet of ground rod per joule output. Be protected from lightning by installing a surge protector at the power source, a lightning choke at the fence, and an additional ground rod every 3,000 feet of fence.*
- *High tensile wire is recommended when using energized fences for border areas and it's also used for cross fencing. The number of strands depends upon the type of livestock being grazed. Generally,* ***a minimum of four- to six- strands is recommended for border fencing and one to three strands for cross fencing cattle****. Other types of livestock often require special considerations such as distance above the ground of the bottom wire, and distance between wires for smaller livestock like goats and sheep.*
- *Polywire or polytape can be used for temporary or portable cross fencing to create smaller paddocks for intensive grazing or to allocate stockpiled pastures for winter grazing. This enhances the manager's ability to provide optimum forage recovery periods*

Trampling damage

Livestock damage, such as stepping on (or against) a seedling or rubbing off bark, is the number one cause of tree seedling death. Generally, trees are most susceptible when less than 16 inches tall, and during the period of rapid growth in early spring. Trampling damage causes deformation and weakening of the stem, and may also provide an entry point for pests and disease.

You can also use obstacle planting to create patterns that will help control livestock movement. When planting trees, it's important to visualize where animals could be encouraged to walk. With that in mind, you can use a tractor to position small logs or logging debris in rough lines to guide the livestock and keep them away from seedlings. Unlike a standard planting grid pattern, obstacle planting in a row creates a 'fence' that steers animals on pasture pathways between and around tree seedlings.

Levels of Management for Livestock

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

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

Poor: "Dumping" livestock on an area and leaving for extended periods of time, causing overgrazing of forages and damage to trees. Planting an obstacle row creates a 'fence' that steers animals on pasture pathways between and around tree seedlings.

B. Trees

Typically, reforestation is designed to produce quality trees for wood production.

Consequently, initial planting densities do not often coincide with producing good livestock forage. Even where good forage is available, supply decreases dramatically once the canopy closes past 50 percent. If trees are planted at 12-foot intervals, then, depending on site conditions, that may happen after only 5 to 10 years.

However, with the selection of appropriate tree species and changes in planting design, it is possible to grow more than 300 trees per acre while maintaining good forage for a longer period. As an example, this can be

Desirable Characteristics of an Agroforestry Tree Species

- **Marketable.** This includes both the wood itself and other products such as nuts or fruit, which would provide another source of income.
- **Compatible** with the companion crops or forage you choose. Some trees produce growth-inhibiting chemicals which may affect what you can grow.
- **High quality**.
- **Fast growing or** of such a **high value** that a species of **medium growth** rate is acceptable.
- **Deep-rooted** so the trees do not compete with the crops or forage for moisture.
- Have **rapidly decomposing foliage**.
- **Site tolerant**, suited to either a wet or dry site.
- The leaves should **produce a light shade** rather than a heavy shade. This will be especially important as the trees mature and the canopy closes. The lighter the shade that is produced, the longer you can grow crops or forages.
- **Capable of producing the products you desire.**



accomplished by planting at 8-foot intervals between trees with 18 feet between rows.

Conventional planting is done on a grid pattern. However, by using different configurations, such as the planting scheme mentioned above, or by establishing tree clusters across a pad- dock, the time between required thinnings may be increased and the area available for forage growth may be maximized. Much wider spacing between tree rows is feasible and depends upon the land steward's objectives. In all but the most widely spaced initial plantings, such as 40 feet by 40 feet, thinnings will at some point be necessary in order to maintain light levels sufficient for forage production.

Tree arrangement on the land

The proper design plan of any silvopasture practice should consider the spacing between select trees and shrubs, both within a tree/shrub row and between tree/shrub rows. Tree arrangement, either during tree establishment in pastures or as a result of thinning trees within managed forested stands, can vary greatly among trees in single, double or multiple rows; individual widely-spaced trees; and/or clustered or grouped trees.

Advantages of single and multiple row plantings

Single row

- *Better crown space for nut production*
- *Maintenance is simplified (such as mowing)*
- *Some shade landscape is created*
- *Possible tree crop harvest capacity*

Multiple row

- *Enhanced erosion control*
- *Better growth of trees for timber*
- *Improved wildlife value*
- *Greater diversification of farm products*

With each tree arrangement, different results should be expected. Producer objectives will determine the best

Left: an aerial view of the Horticulture and Agroforestry Research Farm shows a silvopasture research area pattern. Double rows of tree plantings are shown on the left; triple rows are on the right. Multiple rows provide large volumes of wood without overly sacrificing forage production.

arrangement of trees and the forages to be used, and it must be remembered that silvopasture management is intensive and dynamic over time. There are several key factors to keep in mind when establishing the practice on a given site and determining the width of the alley between rows of trees. Key factors include equipment size, forage, changes through time and thinning and pruning.

Factor 1: Equipment size

A silvopasture design that plans for occasional forage removal by mechanical means must provide space between the trees so that equipment can move freely. The alley between tree rows should be wide enough to allow clear passage of the widest piece of equipment and should be organized so that full passes of the equipment are utilized. Ultimately, the design should recognize the branch and crown development over time for a given tree species, especially when associated with the production of specialty tree products. For example, when planting trees for nut production, where large crowns are desirable, wider space between tree rows should be planned.

Factor 2: Forage

Closer tree spacings may be designed for forages which are more shade tolerant, keeping in mind equipment requirements. However, most forages need a minimum of 50 percent light, so plan to manage tree densities to produce adequate light for forage growth.

Factor 3: Changes through time

Increased shading occurs as trees mature. As this happens, a change toward a more shade tolerant forage will be necessary to maintain suitable yields. These changes can also be offset by timely thinning of lower quality trees and through prunings that reduce branch density in a tree's crown.

Factor 4: Thinning and pruning

Timely thinning can be used to maintain semi open crown conditions. While used as a tool to manage the light available for forage production, thinning also serves to increase the resources (light, water, and nutrients) available to the remaining higher value trees and, therefore, should enhance their growth rate. Another dual purpose management practice is pruning. Proper pruning of the lower branches, to develop a high-value butt log, can increase log value and increase the space available for operation of equipment. At the same time, this also increases sunlight available to the forage.

Finally, crown management through pruning may be beneficial if the desired tree product is nuts. An open crown not only allows more light to reach interior branch tips (necessary for flowering and fruiting), but also allows increased light to filter through to the forage.



A single row of pine and fencing allows for managed paddock grazing based on forage response to grazing.

C. Forage

As feed for livestock, forage is a vital component of silvopasture practices. Choose forage(s) that will do well in the level of shade produced by the tree cover and meet the nutritional needs of the chosen livestock. Tree size, density, and pattern all influence understory forage production. Typically, combined canopy coverage must equal or exceed 35 percent before it significantly impacts forage production. However, many cool season grasses and legumes perform well in 50 percent shade. Recognize that shade produced by the canopy will increase over time as the trees mature.

Special considerations for tree spacing

Within a row

- *Federal/State subsidy program requirements*
- *Production vs. conservation benefits*
- *Wood production vs. other tree products*
- *Grafted vs. seedling planted stock*
- *Markets for small-diameter material*

Between a row

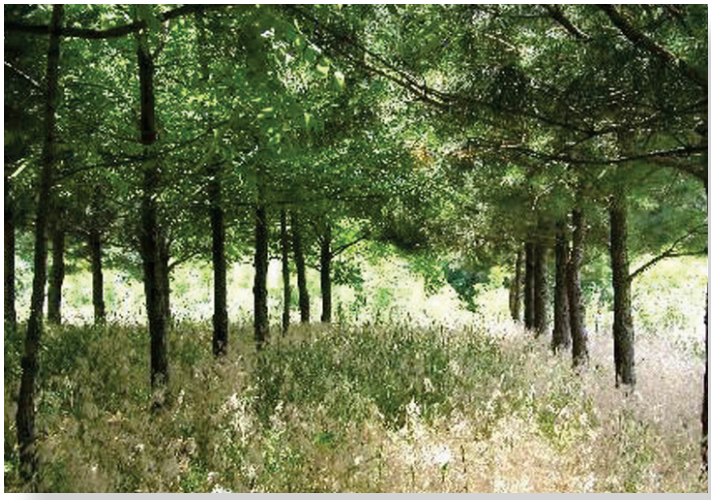
- *Production vs. conservation objectives*
- *Wood production vs. other tree products*
- *Light requirement of forage*
- *Duration of grazing regime*
- *Width of farm equipment*

Establishing pastures in the forest

1. Prepare your site for seeding as soon as possible after thinning (crop tree) or harvesting (selection cutting or improvement harvest) from the forest, so native vegetation doesn't have a chance to respond to canopy removal and invade the site.
2. Seed immediately after site preparation (light fire or disking, and necessary soil amendments like lime or fertilizer) to give domestic forage the jump on native competitors.
3. Lay out pastures and fencing for rotational grazing.
4. Install water supply to meet livestock requirements.

Forage growth and interaction

The forage component of a silvopastoral practice can be either competitive or complementary with your trees. Your management decisions will influence which way the practice develops. As the selected forage begins to develop and fill an area, it may be beneficial for tree growth to eliminate the forage that would otherwise grow directly adjacent to the tree.



Annual rye and timothy grass grow well in shaded environments, as shown here under 8-year-old walnut grown between rows of pine.

It is desirable to use a weed mat, herbicide or some other form of control to eliminate grass growing within two to three feet of seedlings for up to five years. Tree growth will greatly benefit.

Cool season forages have their peak production in the spring when temperatures are cool. Later, they are harvested or allowed to become dormant during the summer. These forages should be grazed no shorter than three inches and should be six inches in height at the end of the growing season.

Cool season plants tend to:

- *be competitive for spring soil moisture*
- *be less competitive for water in the summer months when moisture may*
- *be limiting to tree growth*
- *perform reasonably well under partial shade (many species)*

Warm season grasses should be grazed no shorter than 8 inches during the growing season and by the end of the growing season, the last grazing rotation should leave the forage with a height of 10 inches. These grasses achieve most of their growth in the summer months.

Warm season plants tend to:

- *be less competitive in the early spring when many trees are beginning their annual growth*
- *be more competitive for water during the summer months when trees are putting on the majority of their diameter growth*
- *not perform well under partial shade (most warm-season grasses native to Missouri)*

Can forage be grown in the shade?

Research at the Center for Agroforestry has shown that many cool-season grasses and legumes, when planted under 50 percent shade, will perform equally to or better than open grown plants. Better performance means overall growth will improve (better yields) and often means that quality will improve, as well as digestibility.

Why?

Tree canopies modify the ground-level climate. The combination of modified climate and change in light levels causes many grasses and legumes to both 1) increase growth (due to modified climate and moisture)

and 2) have less lignin in their leaves (improved quality).

Summary

Managed, rotational grazing methods are essential to effective silvopasture. As a part of grazing considerations, do not forget to supply adequate water for the livestock. As a rule, keep livestock within 600 feet of water.

As a part of a farm's grazing system, a silvopasture practice can be a nice addition. Silvopasture offers many opportunities to enhance livestock productivity through modified climate and production of improved forage.

Advantages of a silvopasture practice:

- *Trees improve climate for grazing*
- *Complements ongoing pasture operations*
- *Shade enhances growth of some forages*
- *Livestock address short-term cash-flow*
- *Improved nutrient cycling*
- *Nitrogen-fixing forage crops also benefit trees*

Disadvantages of a silvopasture practice:

- *Fencing cost may be increased*
- *Management intensive grazing is required*
- *Equipment operation may be more difficult*
- *Possible additional tree maintenance labor*

Frequently Asked Questions

Does the silvopasture practice have any long-term effects on soil compaction?

Soil compaction is a valid concern, both from the standpoint of optimizing tree growth and from the potentially negative influence compaction can have on forage productivity. Any pasture may have problems from soil compaction. While it may be more challenging to see the effects of compaction on tree growth, it is visible in forage productivity. Therefore, one of the best ways to gauge whether or not the soil is being overly compacted is by the stand of forage being produced. If a forage stand is thin and does not grow back following removal of the livestock, then soil compaction may be a problem (this assumes that drought or lack of nutrients is not the factor limiting production). Always strive to not overuse pasture. Sound management, such as management intensive grazing, is the best method for limiting soil compaction, and will be evidenced by good forage development. If the forage in a silvopasture practice is maintaining growth and productivity, then compaction is not likely a problem.

Major factors influencing forage production:

- *Tree species*
- *Tree spacing*
- *Tree age*
- *Forage shade tolerance*
- *Forage selection*

If you live where it's dry...

Forage can compete with trees for scarce moisture. Seed at lower rates and have livestock available to graze before the forage becomes competitive. By taking these precautions and by matching tree and forage selections, your results should be:

- *More palatable forage*
- *More efficient grazing*
- *More vegetation removal*

Will rows of trees planted to a pasture develop an open growth form?

There is the potential that trees established in pastures will develop a more open-grown form. This form, wide crowns and increased branching, while not desirable if trees are grown for timber, is more desirable for trees grown to produce a nut crop. However, in either case, pruning will likely be necessary to enhance productivity and quality. Nut trees require pruning in order to ensure that light reaches flowers and results in nut development. Timber trees will likely require pruning for correction to their form and to enhance their quality. If trees are grown for timber, another option may include planting shrubs/trees adjacent to the timber tree in order to shade its trunk and encourage upright growth. Trainer trees will help reduce side branch development and cause the tree to grow up towards better light.

Is the practice of silvopasture sustainable?

Sustainability refers to the long-term potential of a practice to continue through multiple harvests. And, yes, the silvopasture practice of planting trees in the pasture is sustainable. However, it becomes sustainable through proper planning and management. Planning should include creating an activities schedule that predicts when certain management will need to take place in the life of the practice. For instance, as newly established trees develop and produce increasing levels of shade, when will thinnings need to take place to maintain light levels adequate for forage production? The timing of thinnings can typically be predicted, at least within a range. You can do this by looking at the forest site-index from the soil survey and judging the trees' height development over time, and, of course, this will also be dependent on the initial planting density. This is just one example, but it illustrates the importance of planning and management (really, the thought process of looking out to the future) for creating a reasonably sustainable practice.

Is "pasture in the forest" a proven silvopasture practice?

No. Experimental trials are underway and show promise. However, long-term impacts of cattle on existing trees in a forest stand, potential for cost-effective regeneration of trees and long-term maintenance of forage under forest canopies are under investigation. Finally, landowner willingness to use management-intensive grazing for pasture in the forest is critical.

Additional Resources

Center for Agroforestry [@MizzouAgroforestry]. (2024). *Agroforestry Symposium: Silvopasture in Practice* [Video playlist]. YouTube.

Center for Agroforestry [@MizzouAgroforestry]. (2021). *NRCS Agroforestry Assistance: Implementing Silvopasture Techniques* [Video]. YouTube.

Conway, A. Center for Agroforestry [@ MizzouAgroforestry]. (2024). *Silvopasture: The Power of Livestock with Trees* [Video]. YouTube.

Farming with Trees [@FarmingWithTrees]. (2023). *Northeast Silvopasture Case Studies* [Video series].

Lemus, R. (2016). *Silvopasture: Grazing Systems Can Add Value to Trees.* Mississippi State University Extension.

Pent, G.J., Fike, J.H., Orefice, J.N., Sharrow, S.H., et al. (2022). Chapter 6: Silvopasture Practices. In Garrett, H.E., Jose, S., & Gold, M.A. (eds). *North American Agroforestry.* Third Edition. (pp. 127-162). Agronomy Society of America.

Pfost, D., Gerrish., J., Davis, M., & Kennedy., M. (2007). *Pumps and Watering Systems for Managed Beef Grazing.* University of Missouri Extension

Silvopasture [Online forum]. NING. Silvopasture.org

USDA National Agroforestry Center. (n.d.). *Silvopasture.*

USDA National Agroforestry Center & USDA Natural Resources Conservation Service. (2019). *Silvopasture: Establishment & management principles for pine forests in the southeastern United States* [free online course]. Silvopasture.org.

USDA Natural Resources Conservation Service. (n.d.) Silvopasture Conservation Practice Standard

Woodland Stewards. (2024) *Silvopasture: Managing Your Woodlands & Livestock in a New-Old Way* [Webinar series].

Hungry for more fodder for thought?

The Center for Agroforestry dedicated its 2024 Agroforestry Symposium to exploring all-things-silvopasture. Scan the QR code to watch each session on the Mizzou Agroforestry YouTube channel, including:

- *Long-term silvopasture research at the Center for agroforestry*
- *Silvopasture adoption and technical assistance insights*
- *Confronting the realities of silvopasture implementation and land repair*
- *The real impacts of silvopasture systems*
- *Silvopasture across regions and climates*

https://centerforagroforestry.org/annual-symposium/

Transitioning row crops to silvopasture at Rusted Plowshare in Concordia, MO







(Top) Josh Payne tours Agroforestry Academy participants around his managed intensive grazing operation. (Middle) Newly established silvopasture in 2025 using the "overpass" technique. (Bottom) Additional tours of young chestnut & hazelnut silvopasture plantings at Rusted Plowshare.

At a glance: Rusted Plowshare is a part of Payne Farms, which was historically a fence-row-to-fence-row operation with heavy tillage and chemical inputs since the 1960s. Josh Payne, owner and lead farmer at Rusted Plowshare, began transitioning to agroforestry in 2020. Rusted Plowshare works closely with the Center for Agroforestry to study the economics and best practices related to silvopasture.

Overview: Josh began his agroforestry journey with an interest in chestnut orcharding. However, upon learning he was allergic to herbicides, Josh switched his operation to a sheep silvopasture grazing system, a concept that he explored while attending the Center for Agroforestry's Agroforestry Training Academy. After grazing sheep in the orchard, Josh says he has never looked back.

Establishment and transition: To help finance the establishment of his silvopasture system, Rusted Plowshare used NRCS EQIP funds to establish the orchard's interior fence, grasses and forage, water systems, and temporary shade structures. Both the financial and technical assistance were beneficial in aiding Josh in his design plans, and he felt that NRCS was much more flexible than expected. However, challenges were also present in working with the NRCS including the timing of NRCS assistance and the amount of paperwork required.

Josh notes that one his greatest successes has been the farm's transition from a conventional row crop operation to a regenerative silvopasture sheep operation with the support and blessing of the farm's older generation. When Josh's grandfather bought the farm, the first thing he did was take out the trees. At the beginning of transitioning the farm to silvopasture, his older relatives were opposed. However, through time and demonstrated success, the older generation of conventional row crop farmers are fully in support of Josh's agroforestry ambitions. Conversely, Josh states that one of his biggest obstacles "is the learning curve of a completely new endeavor, much of which has never been done before, at least in my immediate area." Josh adds, "Or maybe, better said, it hasn't been done since the early 1900s and before." Building community around these novel farming practices has been helpful to Josh throughout establishment and into the initial years of management.

Design and management: Rusted Plowshare farm consists of 70 acres of silvopasture, 230 acres of adaptively managed pastures, and three acres of windbreaks. Josh states that the final piece of the silvopasture puzzle "came from Trees for Graziers [Austin Unruh] and their Overpass technique that allows animals to freely flow through a pasture with minimal management." This innovation allows for larger scale establishment of tree planting for both direct marketing and fodder for livestock. Josh uses Plantra tree tubes to protect his trees.

Marketing & sales: Rusted Plowshare sells sheep directly to consumers, has several wholesale contracts, and sells to livestock auctions. Josh considers free-market financing options rather than government financing as one future improvement that may help farmers and ranchers adopt agroforestry practices.

Josh's advice to producers getting started in silvopasture is to contemplate mixtures of fast-growing trees (like hybrid poplars and black locusts) along with trees that eventually drop fruit. He also suggests considering the potential for livestock to cashflow a long-term enterprise, like grazing sheep and pigs to cashflow eventual chestnut production.

SILVOPASTURE REVIEW QUESTIONS

Please select all correct answers for each question.

1. **The USDA description of silvopasture includes which of the following key components:**
    A. Annual grazing income helps cash flow the tree crop component over time.
    B. Silvopasture is the deliberate integration of trees and livestock on the same unit of land.
    C. Livestock options are limited to cattle, sheep, or goats.
    D. Silvopastures can increase wildlife diversity and improve water quality.
    E. Well-managed silvopastures require little management.
2. **Which of the following practices can be used to establish silvopasture (not limited by USDA NRCS practice standards)?**
    A. Thinning an existing wooded area to accommodate forage production with management intensive grazing.
    B. Planting trees into an existing pasture to create shade, protection, and potential fodder for livestock.
    C. Allowing livestock to graze extensively in an existing forested area.
    D. Conversion of a tree plantation or alley cropping to silvopasture with establishment of forage and proper tree protection.
3. **Silvopasture requires consideration for the following design and management practices:**
    A. Protection of trees from livestock damage.
    B. Establishment of warm season grasses as forage under tree canopies.
    C. Including as much plant and animal diversity as possible.
    D. Effective management of forage and fodder availability.
    E. Compatibility of trees, animals, and forage.
4. **The following is true for cool season forages (select all true answers).**
    A. They put on most of their growth during the heat of summer.
    B. They are only suitable for open pastures.
    C. In spring, they initiate growth under a silvopasture tree canopy earlier than in open pastures.
    D. They're known to be more nutritious when grown under some shade.
    E. They can grow well beneath up to 50% shade.
5. **With effective management, silvopastures have been shown to result in the following benefits:**
    A. Improved livestock welfare and weight gain.
    B. Enhanced tree growth with nitrogen-fixing forage plants.
    C. Increased fencing costs.
    D. Silvopastures can effectively complement open pasture rotations.
    E. Decreased management inputs.

SILVOPASTURE ANSWER KEY

Bold items listed are correct answers.

1. **The USDA description of silvopasture includes which of the following key components:**
    A. **Silvopasture is the deliberate integration of trees and livestock on the same unit of land.**
    B. **Annual grazing income helps cash flow the tree crop component over time.**
    C. Livestock options are limited to cattle, sheep, or goats.
    D. **Silvopastures can increase wildlife diversity and improve water quality.**
    E. Well-managed silvopastures require little management.
2. **Which of the following practices can be used to establish silvopasture (not limited by USDA NRCS practice standards)?**
    A. **Thinning an existing wooded area to accommodate forage production with management intensive grazing.**
    B. **Planting trees into an existing pasture to create shade, protection, and potential fodder for livestock.**
    C. Allowing livestock to graze extensively in an existing forested area.
    D. **Conversion of a tree plantation or alley cropping to silvopasture with establishment of forage and proper tree protection.**
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    C. Including as much plant and animal diversity as possible.
    D. **Effective management of forage and fodder availability.**
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    C. Increased fencing costs.
    D. **Silvopastures can effectively complement open pasture rotations.**
    E. Decreased management inputs.

Chapter 5: Upland & Riparian Forest Buffers

Chapter Highlights

- Effective buffers include three zones: a forested strip by water, a managed tree zone, and a grass/shrub area to slow runoff.
- Buffers filter pollutant, stabilize streambanks, and slow runoff, improving watershed health and protecting aquatic habitats.
- Buffers provide food, shelter, and corridors for wildlife, supporting diverse species and enhancing ecosystem connectivity.
- Buffers can generate income through timber, agroforestry crops, carbon credits, or conservation incentives, depending on species selection and land steward goals.
- Success depends on proper site prep, species selection, and ongoing upkeep, including invasive control, replanting, and monitoring.

Properly applied on a landscape, riparian and upland forest buffers can enhance and diversify farm income opportunities, improve the environment and create wildlife habitat. By developing an understanding of the interactions between a riparian buffer (trees, shrubs and grasses), the stream, and the adjacent upland area, its layout can effectively meet the goals for which it has been established. A similar understanding of the interactions of upland buffers with landscape position and annual crops is necessary to meet the design goals of these buffers. By understanding the requirements of each of the components of the buffer, it can be managed to maintain effectiveness over time, and also sustain its contributions to the farm as an integrated agroforestry practice.

What is a Riparian Forest Buffer?

Riparian forest buffers are designed combinations of trees, shrubs, grasses, forbs, and bioengineered structures adjacent to or within a stream channel designed to mitigate the impact of land use on the stream. The term riparian applies to what is commonly called the floodplain, and designed buffers often occupy only a portion of that landscape. At the landscape level, riparian forest buffers link land and aquatic ecosystems, and perform vital ecosystem services. By establishing or managing trees, shrubs and grasses in the zone adjacent to streams, water quality and aquatic ecosystem health can be sustained or enhanced. However, to be effective, buffer design and management strategies must include plants that are adapted to specific riparian environments (channel conditions, flood regimes, soils, water table depths, and upland topography), as well as provide management guidelines land stewards are willing to follow to keep buffers healthy and effective.

What is an Upland Forest Buffer?

Upland forest buffers are areas of trees, shrubs, grasses and forbs planted on the contours of the upland areas of watersheds, within agricultural fields. They provide many of the same benefits as riparian forest buffers, but differ in location and are often narrower in width. They are not to be confused with the woody portion of an alley cropping system (see Chapter 3) or windbreaks (see Chapter 6) as they are primarily planted to reduce nonpoint source pollution and erosion, and prevent gully formation. However, depending on the site and farmer/land steward objectives, upland forest buffers could provide some of the same benefits as these other two agroforestry practices.

Advantages of a Riparian Buffer

- *Reduce sediment, organic material, nutrients and pesticides in surface runoff and reduce nutrients and other chemicals in shallow groundwater flow*
- *Create wildlife habitat and provide wildlife corridors*
- *Create shade and lower water temperatures to improve habitat for aquatic organisms*
- *Provide a source of detritus and large woody debris for aquatic and terrestrial organisms Provide a harvestable crop of timber, fiber, forage, fruit or other crops consistent with other intended purposes*
- *Stabilize eroding stream banks and reduce scour erosion in the floodplain*
- *Increase carbon storage in plant biomass and soils*

Disadvantages of a Riparian Buffer

- *Possible intensive management required, depending on design and harvestable products*
- *Loss of crop ground or pasture*
- *Flooding may damage harvestable products*
- *Challenges with artificial subsurface drainage (tile)*

Advantages of an Upland Buffer

- *Stabilize crop field soils by providing a frictional perennial plant surface that slows surface runoff and traps sediment and associated nutrients*
- *Provides a zone of improved soil quality that allows high infiltration rates of water into the soil, allowing runoff to be filtered by the buffer before it reaches the shallow ground- water*
- *Provides a refuge for beneficial insects that may help control crop pests*
- *Provides wildlife habitat*
- *Slows wind that can increase evaporation from drying crop plants*

Disadvantages of an Upland Buffer

- *Loss of crop ground or pasture*
- *May reduce available soil moisture for crops adjacent to the buffer*
- *Provides shade which may reduce growth of crops adjacent to the buffer*
- *Provides habitat for wildlife that may feed on adjacent crops*

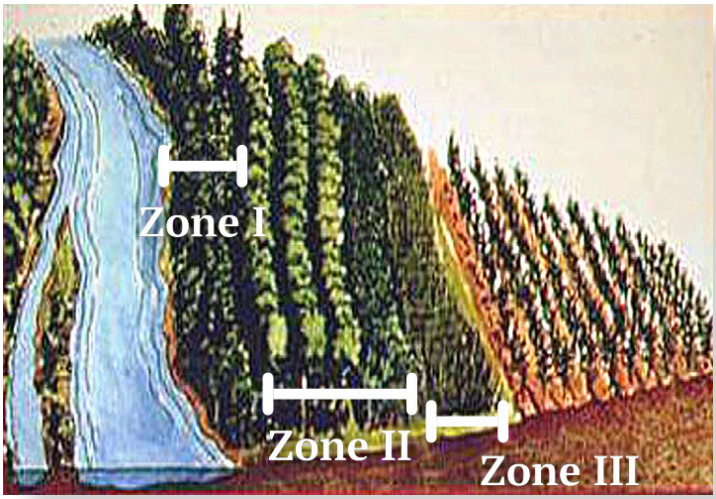
Riparian Forest Buffer Zones and Benefits

A riparian forest buffer is typically composed of three management zones, planted parallel to the stream:

Zone 1 – A zone closest to the stream bank that can include a mixture of fast growing native bottomland trees, shrubs, grasses and forbs that are designed to grow rapidly to stabilize stream banks. This vegetation should be able to tolerate periodic flooding and is not harvested to provide natural interactions with the stream channel, including shading of the stream and providing large woody debris to the channel following natural mortality or loss resulting from undercut stream banks.

Zone 2 – A much wider managed zone adjacent to Zone 1 consisting of trees, shrubs and grasses and forbs that can tolerate periodic flooding and high water tables. Upland trees and shrubs can be planted in riparian areas adjacent to deeply incised channels that have lowered water tables. Their primary water quality purpose is nutrient uptake and storage and flood mitigation. Woody stems, especially of multi-stemmed shrubs, slow floodwater and trap floating debris within the buffer keeping it out of the adjacent crop field or pasture. This zone can be managed for specific wildlife and additional income from nuts, berries, woody florals, or biomass products.

Zone 3 – An area adjacent to crop fields or pastures that provides high infiltration, sediment trapping, nutrient uptake and can help disperse concentrated runoff.



The three distinct zones of a riparian buffer require individual management decisions to optimize their benefits. For example, in Zone 1, seek plants that help stabilize the bank and provide long-term support for aquatic habitat. In Zone 2, decorative woody florals, fruit-bearing shrubs and fast-growing trees are an excellent choice for additional income and to diversify wildlife habitat options. Zone 3 is well suited for native grasses and forbs.

Native grasses and forbs are normally preferred for their multiple benefits and adaptability, but dense, stiff stemmed introduced grasses may also be effective. Grass and forb seeds can be harvested and sold for other projects, or grasses may be harvested for hay or other biomass.

Riparian Forest Buffers and Market Opportunities

Infiltration of nutrients, trapping sediment in surface runoff and debris from floodwaters, and stabilizing stream banks are the important water quality process functions of riparian forest buffers, but they can also provide a farmer/ land steward with value-added market opportunities and enhanced wildlife habitat. Edible berries and decorative woody florals, such as red osier dogwood and curly willow, may be planted in Zone 2 of the riparian buffer. These are valuable components of the floral and decorating industries. Nut- or fruit-bearing trees or fast-growing biomass trees planted in Zone 2 also contribute to income opportunities from buffers. Wildlife habitat for game and non-game species is significantly enhanced with the implementation of a diverse species riparian forest buffer, and lease hunting may be another economic opportunity gained through a riparian buffer system.

Planning and Design for Upland and Riparian Forest Buffers

Establishing a buffer for specific goals.

When considering riparian or upland forest buffer design and implementation, it is important to understand farmer/ land steward objectives and concerns; major functions of the buffer; present land-use of the proposed buffer site; soils and relief; stratigraphy and water table location; establishment methods to be used; short and long-term management methods; government support programs; and market opportunities for potential products of the buffers.

The challenge to designing and maintaining a buffer system is to achieve your desired goals while also retaining the buffer's critical environmental benefits. For example, riparian buffers established for reducing stream bank erosion require designs which incorporate plant materials both on and adjacent to the eroding bank that have deep and fibrous roots that better stabilize soil. Buffers created for filtering sediment and associated chemicals and nutrients from agricultural runoff work best by slowing surface runoff, and improving soil quality that supports rapid infiltration, so water can move through plant root zones before it enters the adjacent water body. This can best be accomplished by establishing stiff stemmed grasses and forbs. Once in the soil, plant roots and soil organisms capture, transform and store non-point source pollutants that would otherwise end up in aquatic systems.

Considering your desired outcomes for a buffer is a necessary first step in creating a functional design. Land stewards are strongly encouraged to work with a natural resource professionals to design the buffer and identify problem areas, such as severe bank erosion, grass waterways and gullies that exit into the existing perennial riparian plant community, drainage tiles, etc. Trees, shrubs, grasses and forbs should then be planted in appropriate zones to accommodate any unique problem areas. For example, trees, shrubs, and deep-rooted native grasses and forbs should not be planted directly above field drainage tile lines. Shallower rooted, native or non-native grasses are more appropriate for these sites. It is important to also be realistic about the time you have available for managing plants in buffer systems. In the case of many large scale row crop and/or livestock farms, the time required for buffer maintenance and harvesting of plants may not be available because

these occur at the same time as intensive farming activities. In these cases, selecting lower-maintenance plants, or hiring a natural resource management professional to oversee the maintenance aspects of the buffer may be appropriate.

A list of plant species, their planting location and spacing are a critical part of the design sketch. The most effective riparian buffer, which can be as wide as 180 ft. (55 m) has three zones of vegetation, each planted parallel to the stream, as indicated in the section "Riparian Forest Buffer Zones and Benefits." Upland buffers do not have specific zones as they are typically only 6-16 ft. (2-5 m) wide.

Many streams are deeply incised and are no longer in contact with their floodplain. Along these kinds of channels, upland as well as riparian tree and shrub species can be planted, depending on both functional and market objectives of the farmer/ land steward.

A functional riparian buffer often requires additional riparian management practices. Examples of these kinds of practices include: 1) stream bank stabilizing bio-engineering techniques, 2) small wetlands or biofilters to intercept field drainage tiles, 3) saturated buffers where tile lines are intercepted by lateral tiles that run parallel to the buffer causing their flow to move through the riparian soil profile to the stream, 4) stream channel stabilizing boulder weirs, and 5) controlled flash grazing practices.

Dick Schultz, professor in the Department of Natural Resource Ecology & Management at Iowa State University, offers suggestions for preparing to establish a buffer:

"Before you select the kind of buffer to install along your stream, think of what you would like the stream and riparian zone to look like, and what you would like the site to accomplish. Once you have identified your objectives, walk the site with natural resource professionals and explain your objectives and desires. They may use the Natural Resources Conservation Service 'Stream Visual Assessment Protocol' or a similar tool to help you identify functional problems within the riparian zone. Once the site problems and objectives have been identified, select the buffer type that addresses your specific site's needs.

Keep in mind that riparian forest buffers and grass filter strips may not solve all of the identified problems along your stream corridor. They are primarily designed to reduce surface runoff of sediment and agricultural chemicals, bank erosion, subsurface movement of agricultural chemicals in the shallow groundwater, and degradation of aquatic or upland habitat. They are not designed to stop bank erosion along deep channels with vertical banks or stabilize the channel bed. They have no impact on groundwater moving directly through drainage tile networks, and they are not usually designed to accommodate livestock grazing. However, riparian buffers are but one tool among a number of riparian management practices."

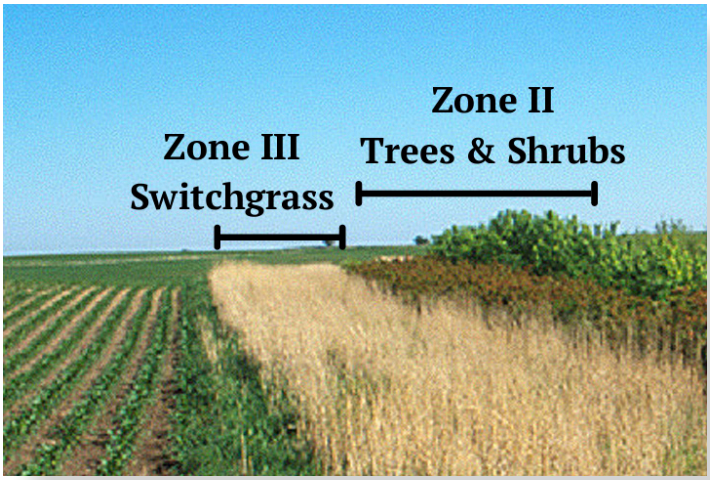
Key areas for consideration

Stream channel – This involves an assessment of the shape and form of the stream channel, the material found in the stream bed and the shape and vegetative cover of the stream banks. Channel lengths that have been straightened create problems both up and downstream of the channelized section.

Straightening the channel increases the slope of the channel which increases the velocity and erosive potential of water moving through the channel. This can lead to increased downcutting of the channel both up and downstream of the channelized section. Once downcutting has reached a resistant bed material and/ or the strength of the bank soil reaches an unstable height, the banks will begin to collapse, widening the channel and encroaching on the riparian zone. Channels can be stabilized with practices such as boulder weirs and bioengineering techniques.

Adjacent to the stream (Zones 1 and 2) – Plants growing on land in direct contact with the upper edge of the stream bank can both stabilize bank erosion and serve as a living filter. This area also functions to slow flood waters, filter flood debris, and provide both upland and aquatic wildlife habitat. Selection of the species to provide these functions will depend on their ability to withstand the frequency, magnitude and length of the flooding regime of the site and the depth to the water table during the growing season.

In Zone 1, deep rooted plant species can serve to provide bank stability along deeply incised channels. Longer lived woody roots can provide reinforcement of the bank soils and shade and organic matter inputs to the stream channel. If the channel is incised, fast growing



bottomland trees (such as silver maple, willow, cottonwood, green ash, and box elder) should occupy the first two rows adjacent to the channel to allow rapid stabilization of stream banks. These two rows of trees should be allowed to mature and die without removal to provide continuous shade and organic matter for the aquatic ecosystem, unless they are along streams with tile or other drainage roles. If drainage tile outlets are present, these rows of trees should be allowed to reach maturity but should be harvested to reduce the chance of contributing large woody debris to the channel thereby restricting drainage.

Where woody plant inputs to the channel are not desired, shrubs or deep-rooted grasses and forbs can be planted, although they do not provide the same strength to vertical banks because of their more rapid turnover. Where banks have a slope of 3 to 1 or less, these grasses and forbs can provide very effective stability.

The next two or three rows of trees or shrubs (Zone 2) can consist of bottomland or upland species along deeply incised channels where the water table during the growing season is an average of 4 or more feet (1.2 m) below the surface.

Where flooding is frequent and flood waters carry significant debris, several rows of multi- stemmed shrubs should be planted at the outer edge of the woody zone (Zone 2) to trap the debris and keep it from being deposited on the grass/forb outer zone or the adjacent crop field or pasture.

Select species adapted to the soil conditions on the site. Depending on land steward objectives, trees and shrubs that provide potential marketable timber or specialty crops can be used. Use a mix of tree and shrub species either by planting a different kind in each row or by block planting. A mixture prevents loss of benefits if one species fails and provides a more diverse wildlife habitat.

In areas with frequent flooding, trees and shrubs should also be less densely planted so a ground cover of grasses and forbs can be established. Where the trees and/or shrubs completely shade the soil, surface erosion from flood waters can be extensive and counter productive to the function of the buffer system. It is therefore important to maintain a woody plant spacing that allows enough sunlight to reach the soil to support a grass/forb cover.

This spacing depends on species and is usually wider than that recommended for planting timber trees but narrower than widths suggested for major nut growing plantations.

Outer edge (Zone 3) – This zone provides the initial treatment of direct runoff from adjacent land uses. This runoff is usually in the form of concentrated flow associated with ephemeral gullies. Sheet flow or broad shallow flows are rare in cultivated field settings. As a result the intercepting plant community must present a dense and stiff barrier that can slow the concentrated flow, causing it to spread and drop its sediment load before entering the grass/forb zone and then move into the zone where high infiltration rates will allow the water to enter the soil filter.

Mixtures of grasses and forbs can be used effectively if the zone is wide enough. Width will depend on the length and slope of the adjacent crop field. If the grass zone has been established on previously cultivated riparian soil it will take at least 5-10 years to redevelop the maximum infiltration potential of the undisturbed soil. Where Zone 3 intercepts a grass waterway, a wider, triangular-shaped area should be developed to provide an apron for the water to spread over before entering Zone 3. Native warm- and cool-season grasses with associated forbs are best suited for this zone, as they remain upright under the flow of water and have deeper root systems than introduced cool-season grasses. These deep root systems, much of which are replaced annually, provide large amounts of organic matter to the soil. Organic matter improves soil quality by increasing amounts of large soil aggregates that create large macropores, which in turn favor high water infiltration rates and increased microbial activity for non-point source pollution processing.

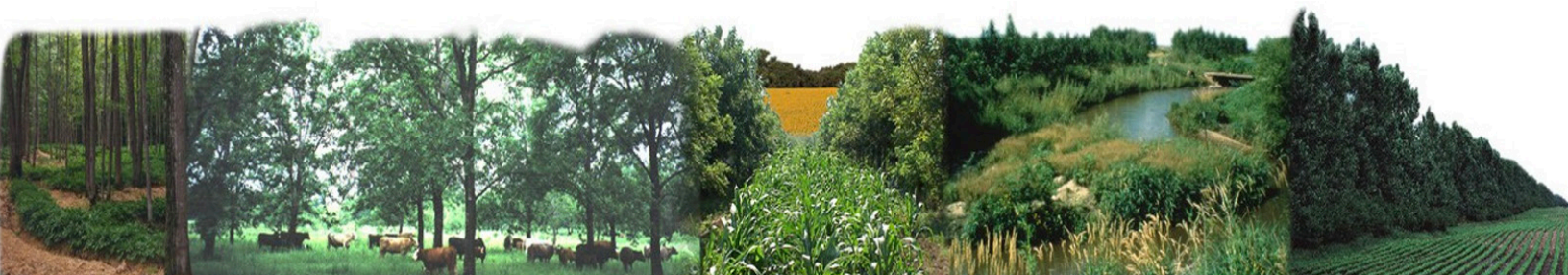
Introduced cool-season grasses can be used but often require a zone that is twice as wide as that made up of

Understanding the Buffer Zone: Function and Management

Comprised of two or three zones, these zones become areas where specific plants and management are combined to create a forested riparian buffer that is highly effective at improving and maintaining water quality and aquatic habitat.

ZONE	FUNCTION	MANAGEMENT
Zone 1 Beginning near the edge of the stream *(fast growing trees and shrub species)*	• Shade the stream and moderate water temperature • Provide bank stabilization • Enhance aquatic habitat with organic matter • Final filter of material moving through the buffer • Reduce velocity of over-the-bank flood waters	• Unmanaged zone, trees allowed to mature & fall into stream contributing important large woody debris • Large woody debris not allowed in streams with tile drainage or other specific drainage functions. • Use selective harvest, with replacement from planting or coppice resprouting • Logging equipment excluded • Grazing is excluded
Zone 2 Beginning at the edge of Zone 1 *(fast and slower growing trees and shrub species)*	• Provide maximum infiltration • Uptake of Non-Point Source (NPS) nutrients and chemicals • Storage of NPS pollutants • Breakdown NPS pollutants • Provide forest-grown products • Enhanced wildlife habitat • Reduce velocity of over-the-bank flood waters • Trap debris moving in flood waters to keep it out of crop fields	• Active management encouraged • Marketable products encouraged from trees and shrubs were feasible • Harvest should stimulate new growth • Avoid soil compacting activities • Grazing excluded • Wildlife activities such as bird watching or lease hunting
Zone 3 Beginning at the edge of Zone 2 *(grass and forb species)*	• Slow surface runoff converting concentrated flow to sheet flow • Slowed runoff drops most sediment/ debris at outside edge of zone • Remaining sediment is filtered from sheet flow • High infiltration of water delivering NPS nutrients & chemicals to soil filter • Uptake of nutrients and chemicals	• Maintain vigorous vegetative growth • Remove biomass – mow and bail so as not to smother remaining plants. • Remove biomass – flash grazing possible with fencing of woody zones • Remove biomass – burn on 3-5 year cycle • Work accumulated sediments away from the buffer edge, back into the field

On non-recreational or non-incised streams, Zones 1 and 2 are often combined, and management becomes more closely aligned to that of Zone 2 alone. In each of the zones, it is important to recognize the role that buffer health plays in maintaining function. Healthy and actively growing vegetation provides the best capture and utilization of problem NPS nutrients and chemicals prior to their entering waterways.



native grasses, and may have less of an impact on improving soil quality.

The introduced grasses are easier to establish and can provide more fodder for livestock, but native grasses and forbs provide a more diverse habitat for upland game birds, such as pheasant and quail, and non-game species. As with the other zones, make sure to select those species that are adapted to the soil moisture and flooding regime of the site. It is important that the grass zone be well managed to maintain vigorous growth of the grasses and forbs (see section on Management and Maintenance of Forest Buffers). For native grass/forb filters burning or baling of the biomass on a 3-5 year rotation is required. For introduced grass strips mowing and baling or flash grazing can be used. If grazing is used, the woody zones (Zones 1 and 2) should be fenced.

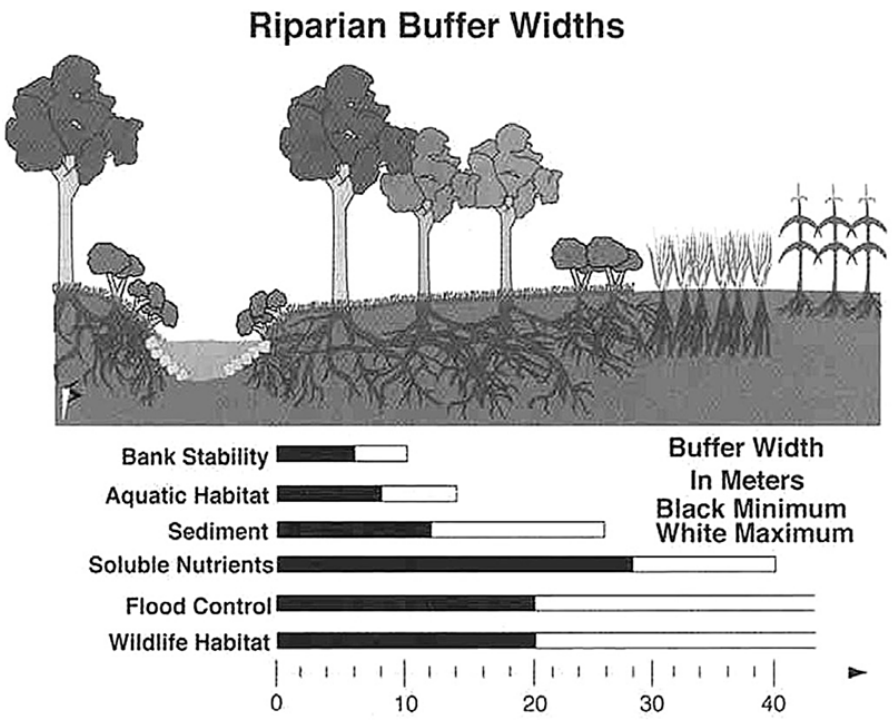


Figure 1. Riparian forest buffer widths by various sections (Schultz et al. 2009).

It is imperative that the woody plant zone also have a grass/forb filter zone on the outside edge of the buffer. Most surface runoff from adjacent crop fields is in the form of concentrated flow. When that flow is intercepted by a woody zone that has minimal ground cover, gullies can easily form through the buffer. This is also true for grass waterways that are intercepted by woody zones without a grass/forb filter. Gullies that form in the riparian forest convey sediment to the stream and gullies can develop and move up into the crop field or the grass waterway. This is commonly the case for "remnant" forest buffers that land steward often believe act as effective buffers. If no grass filter is possible, then wider spacing of the trees and shrubs to allow a dense grass covered soil is necessary.

Additional Considerations

Width: Widths of Zones 1, 2, and 3 can vary depending on the physical characteristics of the site and the functional requirements needed to improve water quality and aquatic habitat. USDA Conservation Reserve Program (CRP) requirements will also dictate allowable widths of each of the zone. If CRP is not used to establish a forest buffer, then zone widths can be adjusted to meet management and functional objectives.

When determining the width of your buffer, it is a good rule of thumb that "wider is better." If surface runoff is the only problem, a grass/forb filter 30-60 feet wide may be sufficient depending on the slope and width of the adjacent crop field. Concentrated flow in the form of ephemeral gullies or grass waterways may require a wider apron at the intersection of the two features. If bank stability is an issue, especially if the channel is deeply incised with vertical banks, a woody tree and/or shrub zone should be included. Buffer width may vary to address runoff hotspots as mentioned above or to adjust to field widths, especially along meandering channels. Widths of the various zones can be adjusted depending on the "needs" of the site. For example, if the crop field is relatively flat and the channel is deeply incised with vertical banks, the grass filter width could be reduced; if the crop field had significant slope and numerous areas of concentrated flow, the grass filter would remain at its designed width and the woody zones would be adjusted

Length: A zone of perennial vegetation should be included along the entire length of any stream channel. If a zone of woody or herbaceous species already exists, a survey should be conducted to determine the fate of any concentrated flow entering the zone including that moving down a grass waterway.

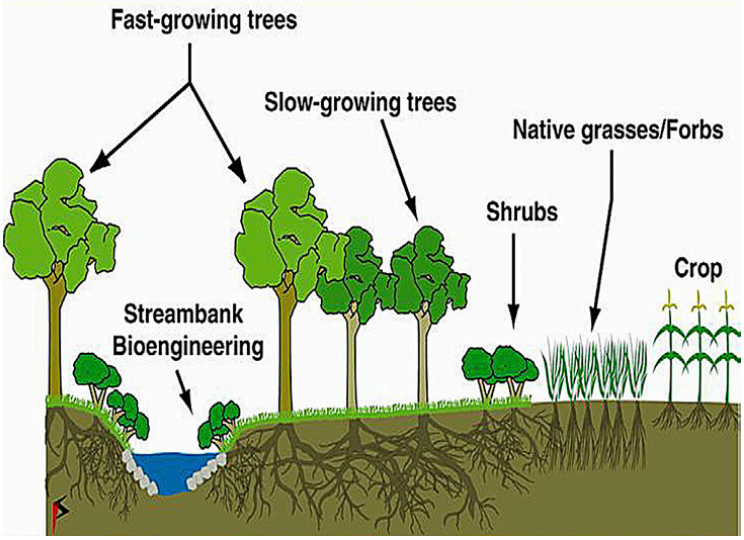


Figure 2. Selecting the appropriate species for a riparian buffer will help ensure its success and longevity (Schultz et al. 2009).

If gullies exist from the edge of the field through the native plant community, a grass/ forb filter zone should be added or widened. While buffers along the channel of an individual property can significantly reduce the sediment and nutrient load from the adjacent crop field, buffering only a small percentage of the entire length of a channel may not result in measurable improvements in water quality or aquatic habitat in the larger stream ecosystem.

Ideally streams should be buffered starting at their source and moving downstream. But any buffer along any portion of the channel is a positive contribution either directly in terms of improving water quality and aquatic habitat or by providing a role model that often stimulates other farmers/ land steward along the stream follow suit.

Impacts on wildlife habitat: Buffers can also be designed to improve wildlife habitat. If upland birds like pheasants and/or quail are desired, a wide zone of native grass/forb filter with or without woody zones is ideal. If a diversity of non-game birds in addition to upland game birds is desired, combinations of diverse woody and native grass/forb zones will provide the largest diversity. Continuous buffers along a channel will provide a connective corridor for wildlife movement.

Species Combinations

Here are species combination possibilities that could provide important riparian buffer functions.

- Increase timber product or floral and/or fruit product options or provide more diverse wildlife habitat. Various combinations of trees and shrubs and grasses and forbs can be used to more closely mimic the kind of riparian habitat that might have been native to an area. For example, where a shrub thicket of willow and shrubs might have been typical and the channel is not deeply incised, the trees can be replaced in Zones 1 and 2 with a combined shrub zone.
- Plant the entire buffer area to warm-season prairie grass. Some bank-stabilization may be needed (i.e., willow or red osier dogwood planted on the stream bank) to provide long-term stability. This system is best suited to riparian areas that are still in contact with the channel where banks are not high and are gently sloped.
- Where riparian grazing is desired and adjacent crop fields are more than several hundred feet from the stream, plant a native grass/forb mixture in a 15- to 20-ft (4.6-6 m) strip along the stream and completely fence that area. Fencing keeps livestock off the banks and can direct livestock to armored crossings and access to water for drinking. Ideally these would be minimal with watering sites provided away from the stream.
- Use direct seeding and broadcast or randomly plant a mixture of tree and shrub seeds or seedlings in both tree and shrub zones to naturalize the planting and avoid rows. *(Source: Iowa State University Extension, "Stewards of our Streams" series, 1997)*

Planting Tips and Species Selection

The selection of appropriate tree, shrub, grass and forb species is essential for the success of the buffer. When possible, select species of plants adapted to the site conditions. Often this is best accomplished by using native plants. Native plants - with proper management - will spread through underground rhizomes, bulbs or other vegetative means and are an excellent choice for the zones of a riparian forest buffer.

Compared with the roots of most non-native cool-season grasses, warm-season grasses and forbs have deep, extensive root systems that help improve soil quality and processing of non-point source pollutants. These native plants can withstand long periods of dry weather, and do not require watering unless the buffer is established in an urban setting and is less than one year old. The main considerations are: 1) selecting species that grow on potentially moist sites; 2) choosing species based on the severity of surface runoff from adjacent crop fields or grazed lands; and 3) making certain that seed of desired natives is both available and affordable. Most nursery information includes a description of sites suited for different species.

These seeds can be expensive. Most native seed nurseries have several mixtures that can be appropriate at varying levels of cost. Specific mixtures are also provided to meet specific CRP conservation practice standards.

Many forest nurseries carry one to two-year old seedlings of most tree and shrub species for planting in Zones 1 and 2 of the buffer. Use high quality stock with good root systems. Quality hardwood seedlings should have a minimum of four to five large lateral roots. Trees and shrubs should be planted in early spring, soak seedling root systems in water for up to 12 hours before planting and make sure the planting holes are completely closed so the roots do not dry out.

Consider as wide a variety of species as possible to develop diverse wildlife habitat and reduce potential diseases and insect infestations with associated loss of plants. If you plan to sell products from your buffer, identify markets prior to purchasing seeds or plants. Non-natives may also have good market value, but take care to avoid establishing invasive exotics.

To determine the most suitable species for your design, ask the following:

- What are the functional needs of the site?
- What are my objectives?
- What are the problems?
- Which species will do well on my site?
- Which species are available from local nursery sources?
- Will harvesting products from these species occur at the same time as other land management activities (field cultivation, planting, harvesting, etc.)?

Resource professionals at your local NRCS, state department of conservation or natural resources, or university extension office can assist you with species selection.

Planting an Upland or Riparian Forest Buffer

Woody species planting is best done with seedlings. Direct seeding can be done in some situations but the density of the ensuing stand of trees often is too dense to allow a complete herbaceous ground cover to develop. Preparing a site for tree planting depends on the existing cover of the site. If the buffer is to be planted into an existing crop field, seed the area to a mixture of perennial ryegrass and timothy. Seedlings can be planted directly into this minimally competitive grass mixture. After planting, spray a 4 foot wide strip centered over the trees with a grass killing herbicide.

Mow the grass strips between the tree rows for the first three to four years. Late season mowing will reduce winter habitat for rodents that can girdle seedlings. Distance between tree rows should be wide enough to

Brad Riphagen, field coordinator for Trees Forever, a non-profit organization founded in 1989, offers suggestions for planting trees, shrubs and grasses.

"When seeding grass and forbs, a firm seedbed is needed to ensure that the small seeds are in contact with the soil yet remain close to the surface. You can drill directly into soybean stubble and into sod that has been killed. When planting trees and shrubs into a crop field, it is a good idea to drill grasses, like timothy or perennial rye, which won't out compete the trees and help to prevent erosion.

Order trees and shrubs early, up to four months before scheduled planting time to assure receiving the desired species. For direct seeding of most trees or shrubs, collect or purchase seed and plant in the fall. Direct seeding in the spring is possible if you can purchase seed from a dealer. Plant tree and shrub seedlings as early in the spring as site conditions allow. Grasses and forbs should also be planted in the spring."

support the mowing equipment that is available and to allow grass cover to remain throughout the life of the buffer. If the woody species are going to be planted into an existing grass or mixed grass- and forb covered riparian zone, four foot wide strips should be cleared prior to planting. Once seedlings are planted, keep this strip grass- and forb-free for the first 3-4 years and mow the strips between the rows of trees. Spacing of trees should range from feet (3-4.6 m) between rows and 8-10 feet (2.4-3 m) within the rows.

Site preparation for planting Zone 3 grasses and forbs in a filter strip can take numerous forms. If the site was previously in pasture, removal of the existing pasture vegetation in the fall and again in the spring, and then using a prairie seed drill can result in a good stand of plants. If the site was previously in row crops, light tilling of the surface to kill early weed species, followed by surface packing with a cultipacker and then using a seed drill will provide a good stand. Annual rye or oats can be mixed in with the native grasses and forbs if rapid cover is desired, especially in areas that are prone to flooding. For woody plant establishment, site preparation should begin in the fall, followed by spring planting.

Management and Maintenance of Upland and Riparian Forest Buffers

Managing an existing streamside forest for a riparian buffer system

Buffer function should be a primary consideration in management. Therefore, management of existing buffers should focus on either maintaining or enhancing buffer function. Although plant materials may be alive and growing, they may not be growing vigorously and be in the best of health. Plants with vigorous growth will have enhanced uptake and use of nutrients. This also equals greater storage of materials that would otherwise travel into the water system. Management strategies need to look toward creating stronger plants, resulting in plants that are more likely to survive environmental stress, such as seasonal flood events. Natural life spans of plants should also be considered. Under proper management woody plants will grow vigorously until they have matured at which point their physiological processes will reach a plateau and begin to decline. When woody plants have reached this point they no longer add major stores of agricultural nutrients and chemicals and should be harvested and replaced with young seedlings or coppice stems from stumps or roots.

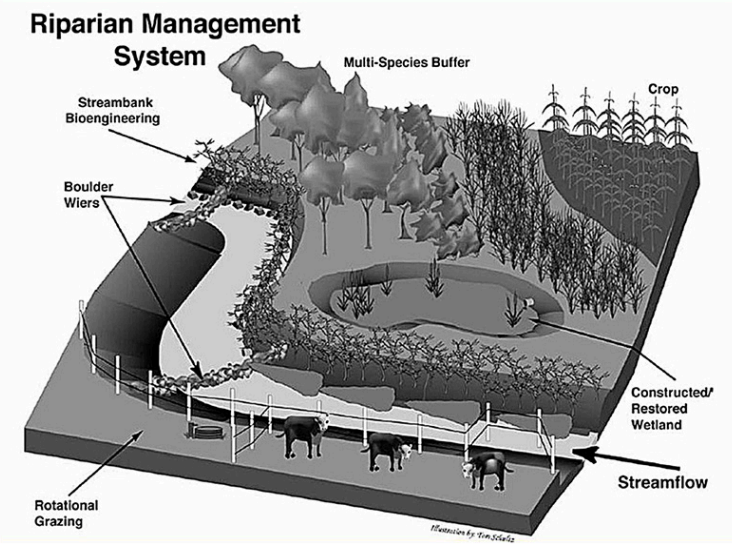


Figure 3. Riparian management system with livestock access restricted by fencing (Schultz et al. 2009).

Densities of woody plants in existing stream side forests are often too great to support good perennial plant cover on the soil surface. Therefore one of the most important management tasks for maintaining buffer function is to thin the forest to allow light to reach the forest floor. If this is not done, gullies will form in the forest at points where concentrated flow, either from ephemeral gullies or from grass waterways entering the existing forest. These gullies are sources of sediment in the stream and will ultimately work their way out of the forest buffer and into the adjacent crop field or pasture.

Management and maintenance of planted forest buffers

Function is maintained when the buffer zones are maximizing their potential for plant growth. For grasses and forbs, this may mean mowing or selectively applying flash or rotational grazing at appropriate times of the year (such as dry and not wet periods). This can assist in minimizing the accumulation of dead grass material and enhance overall grass and forb growth and vigor. However, it is crucial that access to adjacent woody zones or the stream or creek be limited. One method of limiting access is to only have fenced access available in small, planned areas (Figure 3). Additionally, grass zones adjacent to crop fields may occasionally need to have accumulated soils pulled back into the field. This can be accomplished by directionally disking such that soil is moved away from the grass edge.

In the shrub zones, management may include such practices as cutting the shrubs back and control of invading grasses and weeds. In the timbered zone, thinning and selective harvest may be used to keep the remaining trees and herbaceous ground cover in a state of health and vigorous growth. Also, your management plan in the timbered zone should take into account the need for regeneration and the establishment of new seedlings. This can either be natural or artificial, such as when planting new seedlings. It is important to remember that as trees age, slower growth rates and death are natural. One management tool then, is to harvest mature trees prior to their death, degradation, or breakdown, when they may otherwise become debris in the waterway that inhibits proper flow or release stored nutrients back to the ecosystem.

Enhancement

From time to time, in spite of any maintenance that may be completed, it may also be necessary to enhance or enrich the buffer to maintain the desired functionality. This may be as simple as planting additions (overseeding grass zones or planting trees or shrubs in openings created by harvest or loss from flood damage). Remember, the goal is to have a healthy and vigorously growing buffer, and one without gaps that would allow water to channel through.

Maintenance begins at the time of buffer establishment and may include mulching, mowing, and/or herbicide application for weed control until trees and shrubs are large enough to compete on their own. A native grass and forb zone planting requires about 3 years to become well established. During the first 2-3 years it is important to mow the grass and forb zone as high as possible to reduce annual weeds, but without removing the young grasses and forbs.

You can increase the filtering capacity and potential economic returns by trimming, cutting back, mowing, or harvesting the shrub, grass and forb species. By keeping the plants in a state of vigorous growth, they will actively filter more soluble nutrients from the water.

Finally, inspect the buffer annually and after significant storm events to determine the need to remove excess sediment at the cropland edge of the buffer that can prevent shallow runoff from flowing evenly through the buffer, or to repair concentrated flow cuts through the buffer.

Replanting and reseeding

Replanting and reseeding are important maintenance practices during the first few years following establishment of a riparian buffer and can be done in the spring or fall. Replace significant losses of tree and shrub seedlings during the first three years to ensure the desired plant density of the mature buffer. If more than three or four consecutive seedlings have died they should be replaced. Spot planting can be done quickly with just a bucket full of water, seedlings and a shovel. Protecting young trees and shrubs from deer, rabbits and beaver can be expensive, but may be necessary in some cases.

Replanting in the native grass/forb zone may be a bit more involved, depending on the density and quality of the grasses and forbs. If there is poor establishment, remove existing competing vegetation followed by re-drilling seed. If there is some establishment, but not as dense as desired, the site can be directly reseeded. If the areas needing reseeding are large a prairie seed drill can be used, if they are small, hand-spreading the seed and raking it into the ground is acceptable.

During the life of a forest buffer, trees will begin to compete with each other as they do in a natural forest, and without pruning and thinning they will not maintain an optimal growth rate. They will also provide such a dense shade that no living ground cover that completely covers the soil to reduce erosion from out-of-bank events will be able to exist. Depending on spacing, fast-growing trees such as cottonwoods and poplars will be competing with each other within 10 years of planting. After 8 to 9 years, every second or third tree may have to be harvested to increase water availability and growth space for remaining trees.

Prescribed burning

Fire is a good maintenance tool for native grass and forb plantings associated with upland and riparian forest buffers. To reduce weed competition and invigorate the grasses and forbs during the year, prescribed burns are usually performed early in the spring. During this time, many of the competing introduced cool-season grasses, weeds and woody plants begin growing while the warm-season native prairie plants are still dormant. Always develop a prescribed burn plan prior to burning. Assistance for developing a prescribed burn plan may be available through your state department of natural resources or conservation.

While different burning frequencies may be used, an annual spring burn for the first three or four years is recommended. Following establishment of a good stand of desired grasses and forbs, a burning cycle of once every three to four years can be used. The burning cycle is usually defined by the accumulation of dead plant material on the ground, weed species invasion and general vigor of the plant community. Fall burns also can be used to stimulate forb growth more than the grass growth. However, they may be problematic if adjacent crops are not harvested, and will reduce winter habitat for wildlife.

Burning the native grass and forb component of an upland or riparian buffer can be tricky due to the close proximity of shrubs and trees. Such a burn requires numerous people, careful planning, attention to fuel sources and amounts, and attention to wind. Using a small, slow backfire (a fire that burns into the wind) helps to keep the fire more controlled while it is close to neighboring shrubs and trees. A fire break is often mowed or raked between the shrubs and/or trees and the native prairie component. The fire break can be wetted if the fuel is dry.

A good strategy is to burn when steady wind (10-15 mph) (16-24 kph) is blowing away from the woody zones. This way, a backfire can be started with a drip torch along a firebreak and allowed to burn into the prairie grass filter. The fire moves slowly because it is burning into a prevailing wind. Once the backfire has burned a strip of 10 - 15 feet ((3-4.6 m) in width, a head fire (burning with the wind) can be lit and allowed to burn rapidly with the wind. If there is heavy corn stover left along the crop edge, care must be taken to keep the fire out of the field. This can be done by raking or wetting the stover or running a disk along the edge of the grass/forb zone just before the fire is lit.

The crew, equipped with fire rakes, fire swatters, and backpack sprayers, should patrol the burn to keep it contained. Fires should be kept small and well controlled (start small to test the wind, moisture conditions, and to train your crew). A water tank in a pickup truck fitted with a small pump and garden hose can be very useful for wetting the fire break and corn stover. If you have not performed a controlled burn before, you should ask for assistance from a local natural resource professional who has experience dealing with controlled burns. Consideration should be given to the influence of burning on nesting birds and small mammals.

Ideally, you should burn in sections; burn only one side of the creek or break the grass/forb zone into three or four sections and burn one each year. Fall burns eliminate winter cover and late spring burns can destroy nests. How- ever, fire helps to maintain native plant health. Most native prairie plants will grow more vigorously, produce more flowers and produce more seed after a fire. The active growing points of most prairie plants are below or just at the soil surface, and are therefore unaffected as the fire rapidly passes over. After the fire, these plants are stimulated by warmth of the blackened ground and the nutrients that were released from burned plant material.

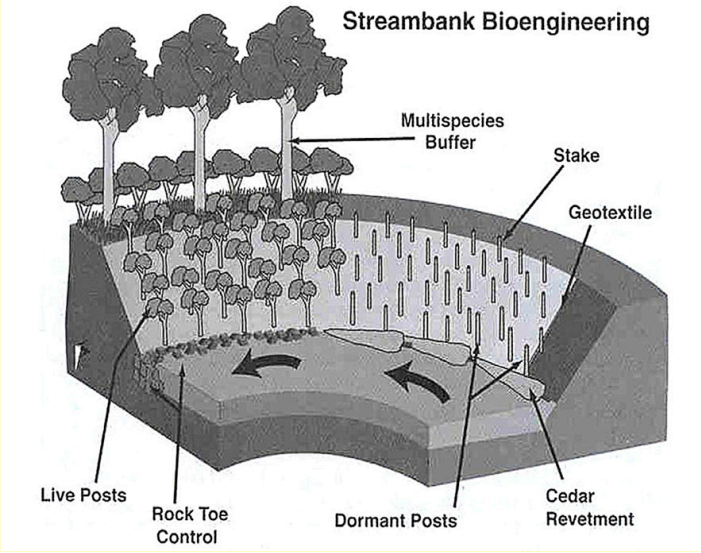


Figure 4. A combination of live and dead materials used in the stream bank bioengineering practice (Schultz et al. 2009).

Other Riparian Practices

Specific considerations for stability: Stream bank structures

In some cases, erosion caused by runoff and/or sloughing of stream banks is too excessive to be stabilized by a Forested Riparian Buffer alone. Therefore, to quickly stop erosion, it may be necessary to use stream bank bioengineering. This is an expensive and intensive practice and is only appropriate for specific trouble spots.

Stream bank bioengineering can:

- *be used to change the steep angle on actively eroding banks to a more gradual slope on which plants may then become established*

- *slow water movement and reduce erosion by adding frictional material to stream banks*
- *reduce undercutting*
- *reduce stream sediment loads*
- *improve water quality*
- *improve aquatic habitat and wildlife habitat.*

The following bioengineering practices and structures can be used singly, or in combination, to create a more stable stream channel and bank.

Rock rip-rap. Rocks anchored to the toe of the stream bank. This type of stabilization is useful in areas of severe undercutting. Size of the rock is directly related to stream size, and the volume and velocity of water flow. Larger streams with increased water volume and velocity will require larger rock. A mixture of rock sizes is often appropriate to provide a surface with minimal openings that allow water to move through turbulently.

In no case should large chunks of concrete be used for this purpose as they often allow large gaps that water is forced through at higher velocities and turbulence that can erode the soil behind the concrete slabs.

In order to avoid undercutting of the anchored rock, the rip-rap should extend to stable material in the channel bottom. In some cases, it may be necessary to reshape the stream bank prior to rock placement.

Tree revetments. In smaller streams, (1st-3rd order) cut trees can be anchored along the toe of the bank in place of rock rip-rap, with the butt of the tree facing upstream. Eastern red cedar is ideal for this purpose, as it can hold its leaves for more than a year following cutting; however, bundles of branches from other tree species can also be used. The dense branches provide significant friction that slows water and drops sediment, creating a stable bank toe on which other plants can become established. Logs and branches can also be hiding places for aquatic organisms. Planting willow cuttings and/or red osier dogwood seedlings above the cut trees or branch bundles can increase the stabilizing potential of this practice.

Geotextile fabrics. Fabrics of jute, coconut, or other fibers may be used in conjunction with any of the living structures. These fiber mats will hold soil in place while the live plant material becomes established. The fabric can be held in place with stakes and/or placed in the trench with fascines and covered with a shallow layer of soil.

Live post and stakes. By using dormant plant material, stream banks can be quickly stabilized. Dormant material (cuttings) of a few selected tree and shrub species (particularly willows) will quickly develop root structures below ground and produce live shoots above. Stakes of 1/2 inch diameter and larger are driven into an eroding bank. The longer the stake, the better stability that is provided because the more roots will sprout along the stem. Lengths may range from 2-3' for stakes, and up to 10' for posts. Installation should begin with the larger stakes being placed at the base, along the water line, and the smaller stakes planted into the upper stream bank.

Live fascines. Also known as wattles, these are bundles of live, dormant branches (whips) primarily of willow species. The material used is often the smaller diameter tops associated with the stakes that were installed as described above. Individual whips should be at least 4 feet (1.2 m) in length. These branches are then overlapped, with all butts and buds pointed in the same direction, to form bundles of up to 8 inches (20 cm) diameter and 10 to 20 feet (3 – 6 m) in length. As with live stakes, it is desirable to use species which will quickly root. Place the fascines in shallow trenches, leaving the upper live buds exposed. Soil should be tamped into place around the bundles and a dead stake used to anchor them in place. By placing fascines along the contour, small branch dams are formed against soil movement. This will create a terraced effect on stream banks. Bundles should be spaced from 3 to 6 feet (0.9 - 1.8 m) apart with narrower spacings used on steeper banks.

In-stream structures. Where channel incision is still actively occurring and stream banks are unstable, or where there is a lack of in-stream habitat, rock structures, such as boulder weirs can be constructed. These structures are constructed of properly sized rock and are no more than 1.5 to 2 ft. (0.5 – 0.6 m) high at their center. They are usually constructed with a slight V in the center to direct flow down the center of the channel. They have an upstream rock apron with a 4:1 slope and a downstream apron with a 20:1 slope. These aprons reduce the turbulence of the water, while allowing enough to improve oxygenation of the water. These structures are usually used in series, allowing the pool of the downstream weir to back up to the apron of the upstream weir. This placement reduces channel bed erosion. Providing pools that are 1.5 to 2 ft. (0.5 – 0.6 m) deep reduces the critical bank height at low flow, thus reducing bank erosion.

Field tile structures. Artificial subsurface drainage (field tiles) passes directly through riparian forest buffers with no treatment of the water flowing in them. For any treatment of contaminants in the tile water to occur, the water in the tile must exit the tile and move through the living soil filter of the buffer. Two promising new techniques can achieve significant treatment of tile flow: biofilters and saturated riparian buffers.

Biofilters consist of passing the tile flow through a large volume of wood chips that have been buried in pits in the soil. The wood chips provide a habitat for microorganisms that can reduce nitrate and other contaminants. These pits can be developed as part of the grass/ forb filter or can be placed directly upslope of Zone 3. Pits are usually about 4 feet (1.2 m) deep with an average size of 15 ft. by 100 ft. (4.6 – 30 m). A soil layer is placed over the buried chips and planted to grass. Equipment can travel over the pits although planting row crops directly over them is not recommended. The wood chips will need to be replaced periodically, perhaps every 10-20 years.

Saturated buffers consist of intercepting a field tile before it flows below the riparian buffer and splitting the flow into lateral tiles that run parallel to the buffer. The water in these lateral tiles then flows through the living soil filter of the riparian buffer. In an early test of this system at least 60% of the flow from the primary tile was diverted into the laterals and water moving through the buffer soil showed over 90% reduction of nitrate-nitrogen.

Considerations for Wildlife

One of the most notable benefits of using native plant species in a buffer is the creation of effective wildlife habitat. Native grasses and forbs provide different heights, densities, shapes of stems and leaves, different flowering times, and different flowers and fruits to attract different species of wildlife. The key is to plant as wide a mix of species as possible to achieve the maximum wildlife benefit.

Planting pure native warm-season grass strips with one or two species is more effective than just one species of introduced low-growing cool season grass, but planting 5 or 6 species of native grass and 25 forbs provides much more habitat potential. Similarly, planting mixtures of trees and shrubs will provide more diverse structural habitat, but if a land steward is mainly concerned with upland bird habitat, trees provide perches for predator raptors that may prey on the prairie birds. In a recent

Jim Wooley, field operations coordinator for Quail Forever, a non-profit organization dedicated to the protection and enhancement of pheasant and other upland wildlife populations through habitat improvement.

"Quail Forever and Pheasants Forever are interested in riparian buffers and other buffer systems because of the habitat that these types of practices provide for pheasants and other wildlife, including non-game wildlife. Beyond that, establishing a buffer offers an exceptionally good economic benefit for a landowner. He's taking ground that in a lot of cases is productive, but may have some problems associated with it. In some cases, we're looking at cash rentals and incentives that approach two hundred dollars per acre. That's an excellent return on the ground, and the buffer is providing many benefits, not only to the landowners, but to society in general."







Lease hunting is an opportunity for income from the wildlife habitat created by your riparian buffer. (MDC photo) Improved wildlife habitat for species such as ducks, pheasant and quail, are another benefit of riparian buffers.

study of bird use of riparian forest buffers over 40 species of birds were found in a three-zone riparian buffer where only 12 species were found in an area similar to the prebuffer condition of the site.

Market Opportunities with Upland and Riparian Forest Buffers

Many products grown in the buffer have monetary value in addition to their functional conservation benefits. A trip to a local florist or craft store will give you an idea of the diverse uses of plants and plant stems that could be harvested from an upland or riparian buffer with the proper species. It may also be helpful to ask if local stores are interested in purchasing locally and sustainably grown materials. At that time, inquire how they would like to receive the material (condition and packaging).

Decorative woody florals and craft products. Decorative woody florals can be planted in Zone 2 of a riparian forest buffer for additional income. This category includes any woody plant species that has a colorful or unusually shaped stem, bud, flower, fruit or leaf. Common examples include pussy and curly willows and red- and yellow-stemmed dogwoods. These plants, and many others, are regularly used in the floral industry to add height and breadth, enhance line and form, and add a splash of color. They retain their bright colors for a long time, extending an arrangement's usable life. Woody florals accent cut-floral arrangements and enhance consumer perceptions of size and value, and can make a statement even when used alone in a vase design. They can be sold to retail or wholesale florists by the stem or the bundle at competitive prices.

Market Opportunities	
Examples of 'marketable' products	Timeframe to reach market potential
Floral and craft products	Beginning approximately 2 years after establishment, and if done correctly (i.e. plants re-sprout), continuing for many years
Berries and nuts	From 2 to 15 years, depending on the crop
Biomass	3 to 20 year rotation, market dependent
Timber trees	In most cases, 40+ years

Learn more about decorative woody florals through research conducted by the University of Nebraska Extension Forestry Program.

Berries and nursery stock. Various species of edible berries, including elderberries, blackberries and raspberries, can be grown in the shrub zone of a riparian buffer for additional income. Markets for fresh berries can be found by contacting local farmers' markets, grocers and specialty health food stores.

Harvesting nut crops. Planting nut-bearing species including pecan, hazelnut, and black walnut in Zone 2 can provide income from nut harvests. Nut crops are readily sold at farmers' markets, roadside stands or to retail and wholesale grocers. The University of Missouri Center for Agroforestry is conducting extensive research to identify outstanding cultivars of chestnut, pecan and black walnut. Technical guides and research updates.

Timber trees. Planting trees in Zone 2 of your riparian buffer for a future timber harvest requires a management plan and patience, but can be very profitable over the long-term. In Missouri, when the market is right, Silver Maple brings almost as much as oak species (price per board feet).



Integrating riparian buffers into your current land use practices can maintain the integrity of stream

channels, reduce the impact of upland sources of pollution, generate income and optimize performance for environmental protection and economic production. With thoughtful consideration to site characteristics, land steward goals, species selection and environmental and wildlife benefits, riparian buffers provide an additional source of sustainable production with multiple conservation benefits.

Financial Resources

There are many agencies offering programs that can be used to establish and maintain agroforestry practices on private land. One of the most significant of these agencies is the USDA Farm Service Agency (FSA), through the various elements of the Conservation Reserve Program. Each of the programs are designed to take environmentally sensitive and highly erodible land out of production by offering a soil rental payment, financial assistance for the establishment of various conservation practices and other financial incentives to land stewards who offer to set aside their land.

Riparian buffers have become a priority for most USDA agencies. Under the requirements of the FSA riparian forest buffer practice (CP22) or the NRCS 391 practice farmer/ land stewards must establish at least a two-zone buffer. The total width of the riparian forest buffer will vary depending on the size of the stream and land steward objectives. For first and second order streams, the buffer must be at least 50 feet (15 m) wide and cannot exceed 180 feet (55 m). Buffers along third order streams must be at least 100 feet (30.5 m) wide. Riparian forest buffers along the Missouri and Mississippi Rivers may be increased to 300 feet (91 m). Buffers may be extended beyond 180 feet or 300 feet (55-91 m) for the purpose of improving water quality benefits. For more information, contact your local USDA FSA or NRCS office.

Additional USDA programs to establish and maintain riparian forest buffers are offered through the Forest Service (FS) and the Sustainable Agriculture Research and Education (SARE) program. The United States Fish and Wildlife Service (USFWS) also offers assistance. Read more about current funding opportunities in an addendum to this publication available at centerforagroforestry.org/training-manual.

Summary

When incorporated on the farm landscape, forested upland and riparian buffers can effectively improve water quality and limit soil loss. A buffer can be established and become productive in a relatively short time period. One of the keys to the successful buffer is the choice of materials and plant species that are suitable for the selected site. The next step is to understand the dynamics of the watershed and stream with respect to adjacent land-use issues so that the buffer design will adequately address the problem. Finally, be clear on the management needed in order to maintain the effective functioning of the buffer over time.

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Riparian buffers for financial diversification and conservation enhancement in Wabaunsee County, Kansas



At a glance: Dr. Phil Gipson, a lifelong tree enthusiast and wildlife biologist, has dedicated extensive efforts to ecological restoration and conservation. Growing up in Arkansas, his passion for trees has driven him to implement large-scale tree planting initiatives across multiple properties he owns in Wabaunsee County, Kansas. He views agroforestry not only as an environmental investment but as a fundamental part of a farm's long-term financial plan. In recognition of his outstanding contributions to agroforestry and conservation, Dr. Gipson received the Kansas Agroforestry Award.

Overview: While Phil has undertaken numerous conservation efforts across his holdings, this case study highlights one particular property located north of Council Grove and south of Alta Vista along Munkers Creek. Since 2004, Phil has implemented a range of restoration efforts, beginning with the establishment of buffers to rehabilitate a previously channelized section of the creek.

Plantings cover 160 acres of the 760-acre property. Previous owners used the land for upland cropland, primarily growing soybeans and corn, with occasional wheat. Recognizing the tremendous opportunity for forestry plantings along streams, Phil transitioned the land into a diverse tree and shrub ecosystem that would provide long-term financial returns and enhance natural resources. The initial tree and shrub plantings were strategically designed to widen and enhance the riparian buffer along Munkers Creek, improving water quality, stabilizing the streambank, and creating wildlife habitat.

Phil recognizes that tree planting is not just an ecological practice—it's an investment in the future. High-value species like black walnut and bur oak will mature over decades, serving as a financial asset that can be harvested sustainably. He has instilled in his son the importance of this long-term strategy, emphasizing that while forestry may not provide immediate financial returns, it will serve as a valuable retirement investment. Timber production will allow the farm to generate income while maintaining a healthy, resilient ecosystem.

Income diversification and financial assistance: With the transformation of this former terraced cropland into a diverse ecological landscape, Phil has identified additional financial opportunities. The property is now a prime hunting destination, supporting populations of deer, turkey, coyotes, and bobcats. Following crop harvests, large numbers of ducks and geese land in the fields to feed. With good cattle grazing land, shelterbelts, and diverse vegetation—including big bluestem and edge forests along streams—the property is a boon for wildlife. "You got to figure out how to make money," says Phil. "You can have good cattle, grass, shelterbelts, and a hunter's paradise on places you wouldn't even think about hunting, and that's one of your money makers." Phil notes that, in some cases, revenue from hunting leases can surpass cattle income. By leveraging the natural resources on his land, he has created an opportunity to generate income from hunting while maintaining and enhancing the ecological integrity of the property.

Phil collaborated with Kansas Forest Service, NRCS, the Soil Conservation Service, and FSA to implement tree plantings and conservation efforts. These agencies provided technical assistance and funding opportunities that made the project feasible. Phil's work exemplifies how forestry can be a cornerstone of a farm's economic and conservation strategy. By focusing on tree planting, wildlife habitat, and natural resource management, he has created a model for sustainable land use that balances ecological health with long-term financial stability. His story serves as a testament to how investing in trees today can secure a prosperous future for generations to come.

RIPARIAN FOREST BUFFER REVIEW

1. **Why are warm season grasses viewed as an essential component of a well-designed riparian forest buffer?**
2. **Due to the effectiveness of warm season grasses at slowing the movement of water headed towards streams and waterways, sediments accumulate at the up slope side of the buffer. Is this a problem in the long run and can it be managed?**
3. **If I manage my grass/shrub/tree buffer for the first three to five years and it has become well established, can it be left alone to take care of itself from that point onward?**
4. **As their name implies, warm season grasses do not begin active growth until late spring. However, fertilizers and other soil amendments are applied early in the spring. Also, while crops are being planted and getting established, the soil is relatively unprotected from rainfall and prone to serious erosion. Given this situation, how effective are warm season grasses as buffers?**
5. **How wide should my buffer be?**

ANSWER KEY

1. Warm season grasses are typically stiff-stemmed clump grasses. Once established, their roots penetrate deeply into the root zone. These two attributes contribute two essential functions to the buffer. First, the stiff stems hold up against water movement, forcing water to slow down as it moves through the grasses. Second, coupled with the well-developed deep root profile and well aerated soil, flowing water will have adequate residence time to percolate into the soil. Soluble nutrients enter the root zone, and atrazine can be detoxified by plant roots and microorganisms.
2. Yes, this can become a problem without proper management and periodic maintenance. RFBs are living filters, and like all filters, they need to be "cleaned" periodically to function properly.
3. RFBs must be managed continuously to maximize their buffer function. To maintain active growth and out-compete fescue and other invasive woody species, warm season grasses and forbs must be burned periodically. Trees must be thinned to maintain active growth rates. Similarly, many shrubs selected for RFBs must be coppiced (cut back close to the ground) to maintain vigorous root and shoot growth.
4. Warm season grasses are an essential component of an effective RFB. The above problem is their biggest weakness. Warm season grasses need to be used in combination with both cool season grasses and woody perennials for effectiveness on a year-round basis. Cool season grasses begin growth early in the spring, and even though they are relatively shallow-rooted and lack stiff stems (water will knock them down and flow right over the top), they are a first line of defense against water, soil and nutrient movement early in the growing season. Combined with shrubs and trees, some of which are active early in the growing season (e.g., willow species), RFBs are fully functional.
5. The general rule of thumb is that wider is better. However, this is a very broad generalization. Buffer width depends on many factors including the purpose(s) for the buffer, the associated cropping pattern and related conservation practices being employed upslope, the specific soil and slope conditions, and whether or not government financial assistance programs are involved which require certain minimum widths. Buffers may be designed for bank stability, aquatic habitat protection and improvement, sediment control, removal of soluble nutrients from adjacent crop fields, flood control or wildlife habitat. To stabilize streambanks and protect aquatic habitat, effective buffers can vary from 30 to 90 feet wide. For sediment and flood control or to improve wildlife habitat, buffers must be wider, ranging from 60 feet to well beyond 150 feet.

Chapter 6: Windbreaks

Chapter Highlights

- Windbreaks reduce wind speed, control soil erosion, protect livestock and crops, improve energy efficiency, and enhance biodiversity. They can also provide wildlife habitat, sequester carbon, purify air, reduce noise, and make aesthetic improvements to the landscape.
- Effective windbreaks consider height, density, orientation, and species selection to optimize wind reduction and minimize turbulence. Proper spacing between trees and rows influences windbreak efficiency, with multiple-row designs offering better protection and longevity.
- Proper windbreak design is crucial to avoid unintended impacts like increased turbulence, snow drifting in unwanted areas, or reduced protection due to gaps, which could worsen conditions rather than improve them.

Agricultural practices benefiting from properly applied windbreaks include:

- *Crop production*
- *Soil conservation*
- *Livestock and dairy cattle husbandry*
- *Livestock confinement facilities.*
- *Nut, fruit, and berry crops*

Crops that can be produced from actively managed windbreaks include:

- *Nuts, fruits, berries*
- *Timber, fencepost, firewood*
- *Christmas trees*
- *Boughs, cones, wreaths*
- *Landscape plants*
- *Shade-tolerant plants such as those grown in the forest farming practice*
- *Lease hunting opportunities when managed for wildlife benefits*



This chapter is intended to help you design and manage the interactive agroforestry practice of windbreaks. Properly applied on a landscape, a windbreak can enhance and diversify farm income opportunities, improve the environment and create wildlife habitat. By developing an understanding of the interactions between the windbreak (trees, shrubs and grasses) and the adjacent land area, its layout can be most effective at meeting the goals for which it is, or has been, established. By understanding the needs of each of the windbreak's component parts, the windbreak can be managed to best maintain its effectiveness over time, and also sustain its contributions to the farm or ranch. Read more about current funding opportunities in an addendum to this publication available at centerforagroforestry.org/training-manual.

Windbreaks Defined

A windbreak is any barrier (natural or artificial) that reduces troublesome winds by creating a wind shadow to the leeward (down-wind) side. Its major function is to reduce the velocity of the wind. A windbreak must be 2.5 feet or higher to have a significant effect. Many kinds of materials can be used for a windbreak, including trees, shrubs, tall perennial or annual plants (e.g., switchgrass or sunflowers) that will attain a sufficient height to create the desired wind shadow.





Seven Windbreak Structural Elements that Determine Effectiveness

1. *Height*
2. *Density*
3. *Orientation*
4. *Length*
5. *Width*
6. *Continuity/ uniformity*
7. *Cross-sectional shape*

The windbreak or shelterbelt practice, uses intensive management for growing trees, shrubs and/or grasses adjacent to other agricultural practices, and consists of one or more rows of closely spaced trees and/or shrubs planted at right angles to the prevailing winds. A windbreak becomes important to the agricultural system by enhancing production, or conservation, as it modifies air movement and wind speeds resulting in microclimatic changes. The terms windbreak and shelterbelt can be used interchangeably.

How Windbreaks Function

Windbreak height. Height (referred to as 'H') is the most important factor determining the downwind area of protection. The windbreak 'H' is the height of the tallest row of trees in the windbreak. The windbreak will reduce wind speed for 2 to 5 times the height of the wind- break (2H to 5H) on the upwind side and up to 30H on the downwind side of the barrier. The area protected is a direct result of the height and density.

Windbreak density. Density is the ratio of the solid portion of the barrier to the total area of the barrier. Wind flows through the open portions of a windbreak, thus the more solid the windbreak, the less wind passes through. By adjusting windbreak density, different wind flow patterns and areas of protection are established.

Density level is manipulated by choice of plant materials (e.g., deciduous vs. conifer); and plant arrangement. By combining low growing shrubs with medium and tall deciduous trees, dense plant material is provided at three levels (low, middle and upper) of the windbreak during the growing season. However, during the winter, the density would decrease due to the loss of foliage. Consequently, a conifer component would be desirable for year-round protection.

- **Dense (60-80%)** = *maximum wind reduction but short wind shadow*
- **Moderately dense (40-60%)** = *less wind reduction but longer wind shadow*
- **Under 40%** = *effective for snow distribution across a field*

The term windbreak porosity may also be used to characterize this structural element. The percentage of porosity is the amount of open spaces in the windbreak when viewed perpendicular to the windbreak. In other words, porosity is the inverse of density, i.e., a 60 percent

Deciduous 25-35% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	5	6.5	8	8.5	10
% of open wind speed	50%	65%	80%	85%	100%

Conifer 40-60% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	3	5	6	7.5	9.5
% of open wind speed	30%	50%	60%	75%	95%

Multi-Row 60-80% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	3.5	6.5	8.5	9.5
% of open wind speed	25%	35%	65%	85%	95%

Solid Fence 100% Density
Open Wind Speed 10 m sec^{-1}

H distance from windbreak	5H	10H	15H	20H	30H
m sec^{-1}	2.5	7	9	9.5	10
% of open wind speed	25%	70%	90%	95%	100%

Fig. 1. Wind speed reduction to the lee of windbreaks with different densities.

dense windbreak would be 40 percent porous.

The degree of density will impact the extent of the area being protected and the magnitude of protection as shown in Figure 1. A solid fence (100% density) provides maximum wind reduction, but the area of wind reduction is shorter than with a dense tree windbreak. The dense windbreak (60-80%) provides a greater area of protection, and the magnitude of wind reduction is as good as the solid structural fence or wall. For the moderately dense wind- break (40-60%), the magnitude of wind reduction is somewhat less but the wind shadow is at its maximum. Once the density drops below 40%, the effectiveness of the windbreak begins to decline. However, the 25-35% density level is very effective for even distribution of snow across a field for moisture management. This density level is not as good for stopping wind erosion.

Windbreak orientation. Windbreaks are most effective when oriented at right angles to prevailing or troublesome winds, (Fig. 2 a, b, c, below). The best orientation for each windbreak depends on the objectives for the windbreak. A key point to remember is that although the troublesome wind may occur primarily from one direction, it rarely blows exclusively from that direction. As the wind changes direction and is no longer blowing directly against the windbreak, the protected area decreases.

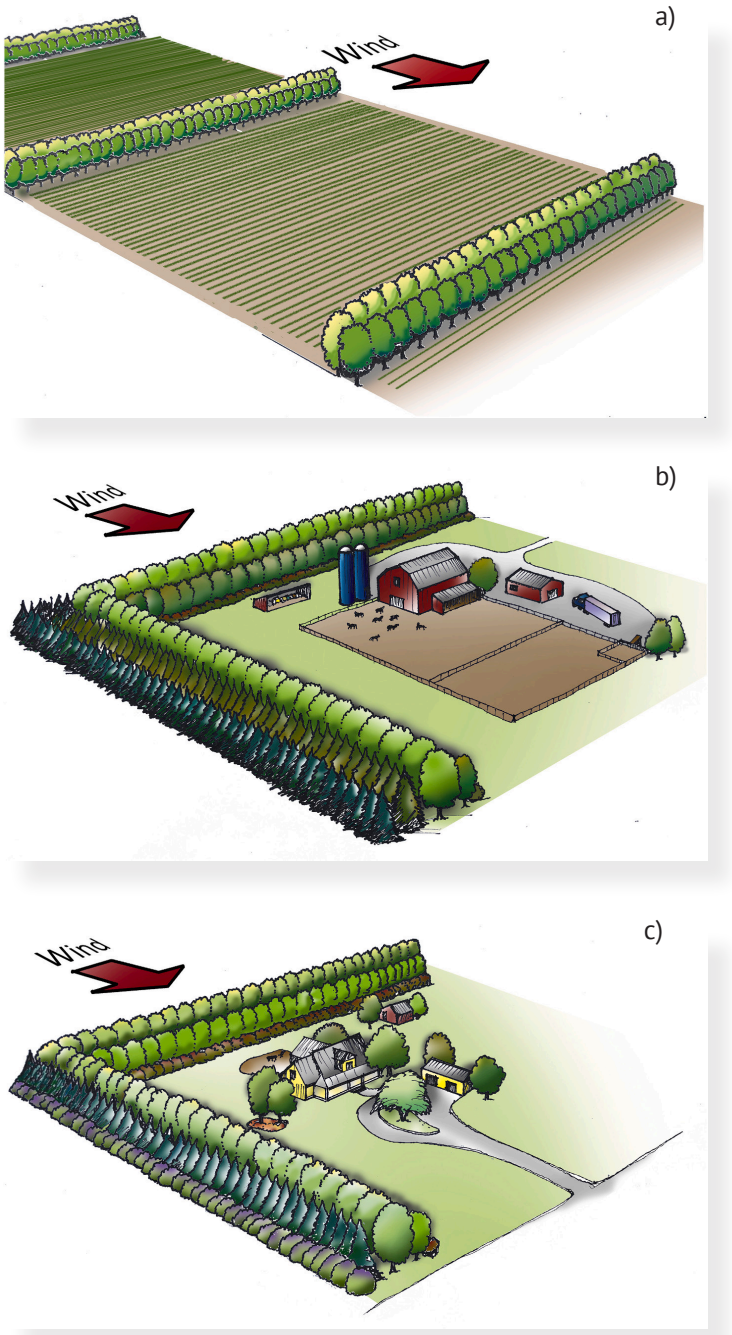


Fig. 2. Conceptual diagram of: a) field windbreak, b) livestock windbreak, c) farmstead windbreak (Smith et al., 2021)

Advantages of Windbreaks

- *Enhance crop yield*
- *Protect soil from wind erosion*
- *Shelter livestock and crops*
- *Capture water runoff and nutrients*
- *Improve irrigation efficiency*
- *Filter and reduce dust*
- *Help control odors*
- *Screen unsightly areas*
- *Provide wildlife travel corridors and habitat*
- *Protect structures (homes, outbuildings, roads)*
- *Reduce noise*
- *Improve aesthetics*

Disadvantages of Windbreaks

- *Require more intensive management*
- *Need specialized equipment for tree/ shrub management*
- *Remove land from annual crop production*
- *Financial returns increase gradually as a windbreak grows*
- *May harbor harmful crop pests, e.g., insects & weeds*

Windbreak length. 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 (i.e., a windbreak 30 feet tall needs to be at least 300 feet long). The ratio reduces the influence of end-turbulence on the total protected area.

Windbreak width. The width primarily serves as a means to manipulate the desired density of the windbreak. The number of rows, the distance between trees, and species composition are factors controlling windbreak density. Increasing the number of rows or decreasing the distance between trees increases density and provides a more solid barrier to the wind. A wider windbreak can also increase the value of the windbreak for wildlife and offers opportunities to produce products.

Windbreak continuity. Continuity influences efficiency. Gaps in a windbreak become funnels that concentrate wind flow, creating areas on the downwind side of the gap in which wind speeds often exceed open field wind velocities. Gaps will decrease the windbreak's effectiveness. Access lanes through a windbreak should be avoided or minimized.

Windbreak cross-sectional shape. Some windbreak guides call for a "hip-roof shape" to assist in "lifting" the wind. However, the cross- sectional shape of windbreaks with equal densities has minimal influence on wind velocities within 10H of the leeward side of a barrier. Beyond 10H, straight sides provide slightly more protection than slanted sides because more wind passes through the trees and extends the protected area farther to the leeward.

Windbreak Benefits

Windbreaks offer a variety of potential environmental and financial benefits to a farm or ranch enterprise through protection of crops and livestock. The rural community also benefits from improved air quality through wind speed reductions and the physical capture of airborne particulates including dust, smoke, pesticide droplets and odors. Windbreaks also provide aesthetic diversity by adding trees in an agricultural landscape and enhance wildlife habitats and corridors through the addition of tree, shrub and herbaceous cover.

Benefits for the soil

Windbreaks have been widely recognized as a key tool to reduce wind erosion. When wind speed is reduced, the wind erosion process cannot start. Wind erosion can rob land of precious topsoil containing nutrients and organic matter. This loss can lead to reduced productivity and the need to add more nutrients. Wind erosion potential is the greatest when fields are very wide and the soil is bare and smooth. Windbreaks combined with other wind erosion control measures (e.g., reduced tillage, herbaceous wind barriers) create a conservation approach to tolerating wide weather extremes.

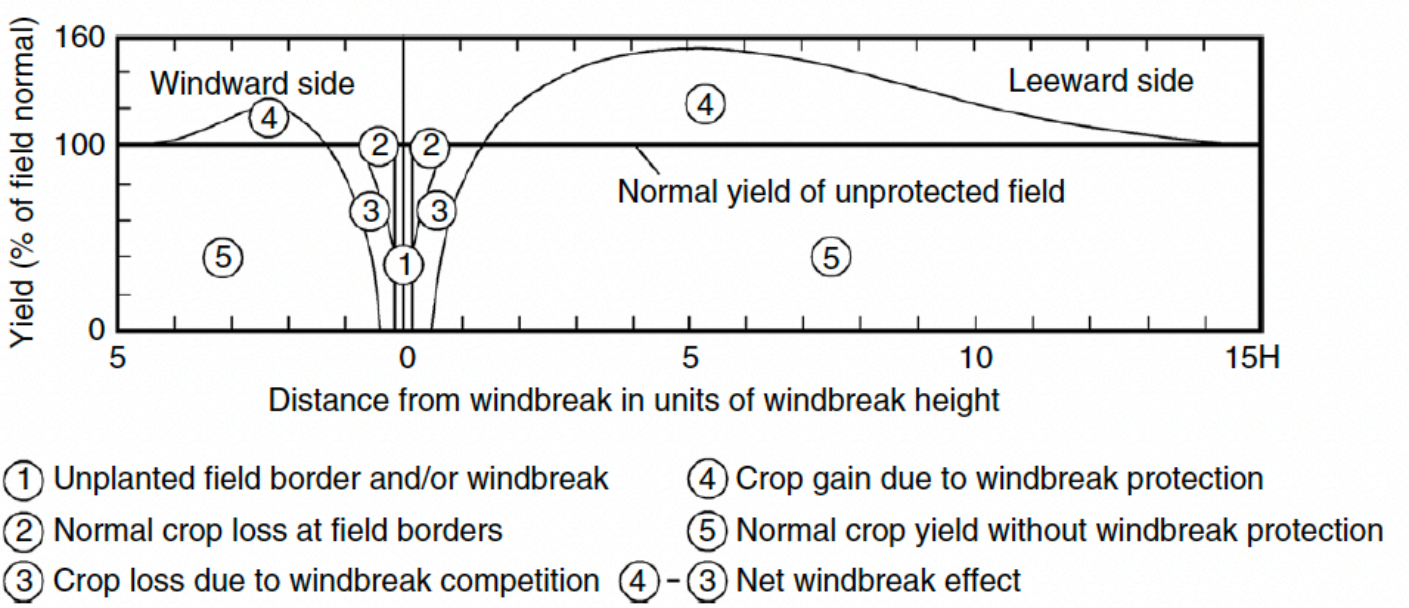


Figure 3. The generalized case for crop yield responses for a field windbreak in the Great Plains. (Brandle et al., 2021)

Benefits for crops

Windbreaks improve crop production and quality by modifying the micro-climate and reducing wind erosion. They protect crops from insect pests by reduced crop visibility, dilution of pest hosts due to plant diversity, interference with pest movement, creation of environments less favorable to pests and more favorable to beneficial insects. They can be designed to manage snow drifting to maximize use of the moisture for crops. Windbreaks improve irrigation efficiency by reducing evaporation losses; and improve water quality through interception of sediment and interception, sequestration and decomposition of agricultural chemicals in the tree, shrub and herbaceous rhizosphere.

When field windbreaks are suggested to land stewards, they often have a mental image of crop reduction and/or loss adjacent to the windbreak and from the space occupied by the windbreak. What is often not recognized is the potential for increased crop quality and quantity on the leeward (downwind) side of the windbreak. Many years of field research have shown there is a yield advantage for many crops when protected by a windbreak. This yield increase generally occurs from 1.5/2H to 10-12H on the leeward side of the windbreak (Fig. 3). The amount of yield increase will vary from year to year due to different weather conditions. There will also be some variation due to soils and the types of trees used in the windbreak (i.e., less competitive trees result in greater gains). The yield advantage is normally more than enough to offset the decrease in yield immediately

Crop Windbreaks: Weighted Average Crop Yield Increase			
Corn	**12%**	**Soybeans**	**13%**
Barley	**25%**	**Winter Wheat**	**23%**
Hay	**20%**	**Spring Wheat**	**8%**



This field windbreak is designed to provide year-round protection by incorporating cedar and pine outer rows with an interior row of deciduous shrubs.

adjacent to the windbreak and the land occupied by the windbreak. Some land stewards will plant a deep rooted crop such as alfalfa adjacent to the windbreak in the area most impacted by competition and are able to gain good quality forage.

Benefits to orchards and vegetable crops

In addition to the traditional commodity crops, windbreaks are also used to protect a variety of horticultural crops including many fruit and vegetable crops. Some of the key benefits of protecting these types of crops include: improved crop quality from reduced bruising, better pollination from insects due to less wind, and early maturing of the crops resulting in possible marketing advantages. Windbreaks around orchards are also being examined for their use in preventing off-site drifting of pesticides. Many orchards and other farms are being engulfed by housing developments. Windbreaks can help buffer potential land-use conflicts.

Benefits to livestock

Windbreaks provide valuable protection to livestock especially for young animals and in areas with cold northerly winds during winter and early spring. Reducing the wind impacts lowers animal stress and improves general health resulting in better livestock production by increasing feed efficiency and weight gains, improving survival of newborns and increasing milk production. Windbreaks can also provide living screens to separate incompatible uses (i.e., livestock facilities from suburban residences).

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 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. Ask yourself: what needs to be protected? Crops/orchards? Soil? Livestock and/or livestock buildings?

Step 1. Determining the windbreak purpose

As noted previously, a windbreak can have a variety of purposes ranging from crop protection to snow management. The design of the windbreak is dependent upon the purpose(s) desired. To determine the purpose(s) requires understanding the desired objectives of the land steward and the physical site characteristics.

The first step in design is to interview the land stewards to ascertain their objectives or purposes for the windbreak. A questioning strategy can be effective such as:

Crops

- *Have you had any wind erosion from your fields? If so, when did it occur?*
- *From which direction(s) does the wind cause the most problem(s)?*
- *Are you using other wind erosion control practices, e.g., reduced tillage?*
- *Have you had any crop damage or loss from the wind or blowing soil?*
- *When did it occur?*
- *From which direction(s) does the wind cause the most problem(s)?*
- *What crops are you growing that may be wind sensitive?*
- *Are you growing crops that need pollination?*

Livestock

- *When do your livestock need the most wind protection?*
- *What livestock pastures, lots or structures need wind protection?*
- *Do we need to be concerned with summer air movement in the livestock area?*
- *Which access roads need to be kept clear of snow?*
- *Is there a drainage issue associated with rain or snowmelt runoff?*

Step 2. Site evaluation

The next step is to evaluate the site conditions that may affect windbreak design and application. Use a conservation plan map or photo to identify fields in need of protection, existing windbreaks, soil problems, utilities, direction of prevailing erosive winds, property lines, roads and access lanes. (Fig. 4)

- *Identify all areas needing protection based on the troublesome wind direction(s).*

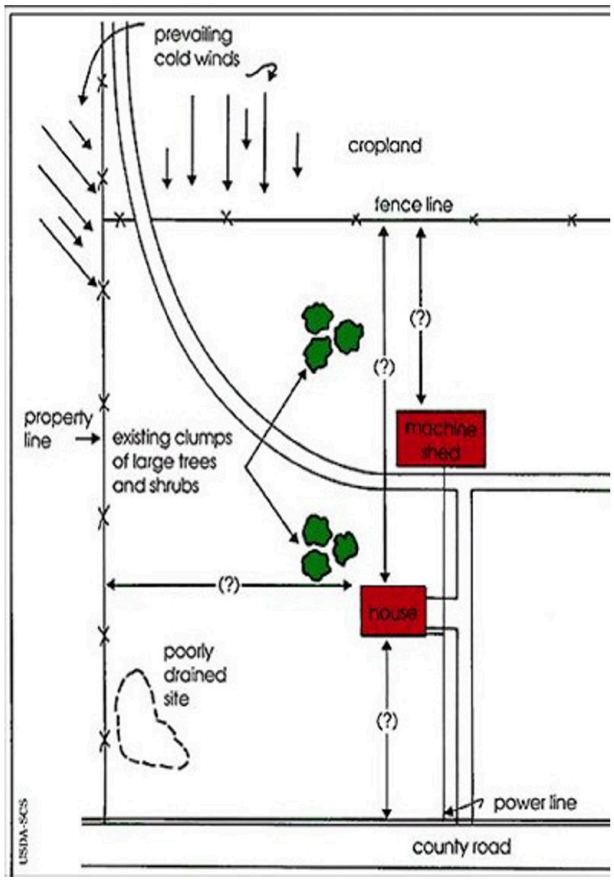


Figure 4. Area sketch for site evaluation.

- *Inventory the soils. Begin a starter list of species adapted to the soils.*
- *Observe the topography to determine any drainage concerns either into or away from the windbreak (especially snowmelt and feedlot runoff)*
- *Locate property lines, overhead and underground utilities (electric, telephone, gas, and/ or sewer), and existing trees or shrubs which may be within or adjacent to the proposed windbreak.*
- *Identify any access roads or lanes that could cause gaps in the windbreak.*
- *Locate the windbreak to avoid obstructing the winter sun, or oncoming traffic near driveways. Identify protection needs for the windbreak, such as fencing to keep out livestock.*
- *Observe any existing plant species which may be alternate hosts for pathogens, e.g., cedar-apple rust.*
- *Inventory existing wildlife habitat and wildlife species in the area so the windbreak may complement.*

Step 3. Design considerations for different windbreaks

Windbreak design tips for crop fields

- *For crop protection/production and/or uniform snow distribution, windbreak-to-windbreak intervals should be 15 to 20H. For crops highly susceptible to damage from wind or small amounts of wind-blown soil during some portion of the growing season, a spacing interval of 6-10H provides a high degree of protection.*
- *For erosion control purposes, NRCS uses a rule of thumb of "no erosion out to 10H leeward" – leading to a windbreak-to-windbreak interval of 10H plus the distance protected by the agronomic system (i.e., standing crop, crop residues, cropping pattern, ridging) being used.*
- *Different design densities and heights result in different snow drift patterns. For example, if the land steward wants to spread snow evenly across a field to improve soil moisture in a crop field, the windbreak design density should range from 25 to 35 percent. This would be roughly equivalent to a single row of deciduous trees without leaves at a wide spacing (15 to 20 feet). If soil erosion is a potential problem during the time the windbreak is at this density level, additional conservation measures will be needed.*

Plan for:

- ***40-60% density for crop & soil protection***
- ***25-35% density for snow distribution***

Windbreak design tips for livestock

- *Greatest wind protection occurs from 2H to 5H leeward of the tallest tree row.*
- *For wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area.*
- *Allow room for snow deposition outside of the feeding area. Care must also be taken to accommodate the drainage both from the clean water runoff from the windbreak (i.e. snowmelt) and drainage from the livestock feeding area. Effluent from the feeding area can harm and sometimes kill trees and shrubs.*

- *Critical temperatures for beef cattle are determined in part by the condition of the coat. Below the critical temperature, livestock must expend more energy to keep warm.*

Livestock Critical Temperatures *adapted from D.R. Ames, Kansas State University*	
Coat Description	**Critical Temperature**
Summer coat or wet	59°F
Fall coat	45°F
Winter coat	32°F
Heavy winter coat	18°F

General design considerations

- *Avoid creating gaps with access roads cut through a windbreak. Wind flow increases through gaps decreasing windbreak effectiveness. Where needed, design the opening at an angle to prevailing winds. Lanes or roads through single-row barriers should be avoided; where necessary, locate them 100 to 500 feet from the ends of the windbreak (Fig.5).*
- *Locate new rows of trees 50 feet from existing trees.*
- *Stay away from subsurface drain fields and overhead utilities.*
- *Avoid locating windbreaks within 200 feet of road intersections to prevent poor driver visibility.*

Selecting tree and shrub Species

All species of trees and shrubs do not grow at the same rate nor do they grow to the same mature height. Likewise, adapted species vary in their growth on different soils within a geographical area. The amount of available soil moisture during the growing season and soil aeration are two important factors affecting tree and shrub growth. These factors are largely determined by soil texture, soil depth and climate

Windbreak Plant Materials

- Select plants adapted to climate and soils.
- Select plants to meet objectives, including: foliage density characteristics, height potential, and/or wildlife needs.

Conservation tree and shrub suitability groups have been developed as a guide for selecting species best suited to different kinds of soils, and climate, predicting height growth at 20 years, and measuring effectiveness. These guides should be available in the NRCS Field Office Technical Guide. Information about different plants can also be obtained from the USDA plants database.

In addition to selecting plants adapted to the climate and soil, plants need to be selected that have the greatest potential for meeting land steward objectives. The primary objective is to select plants that will provide the desired level of wind protection in a reasonable length

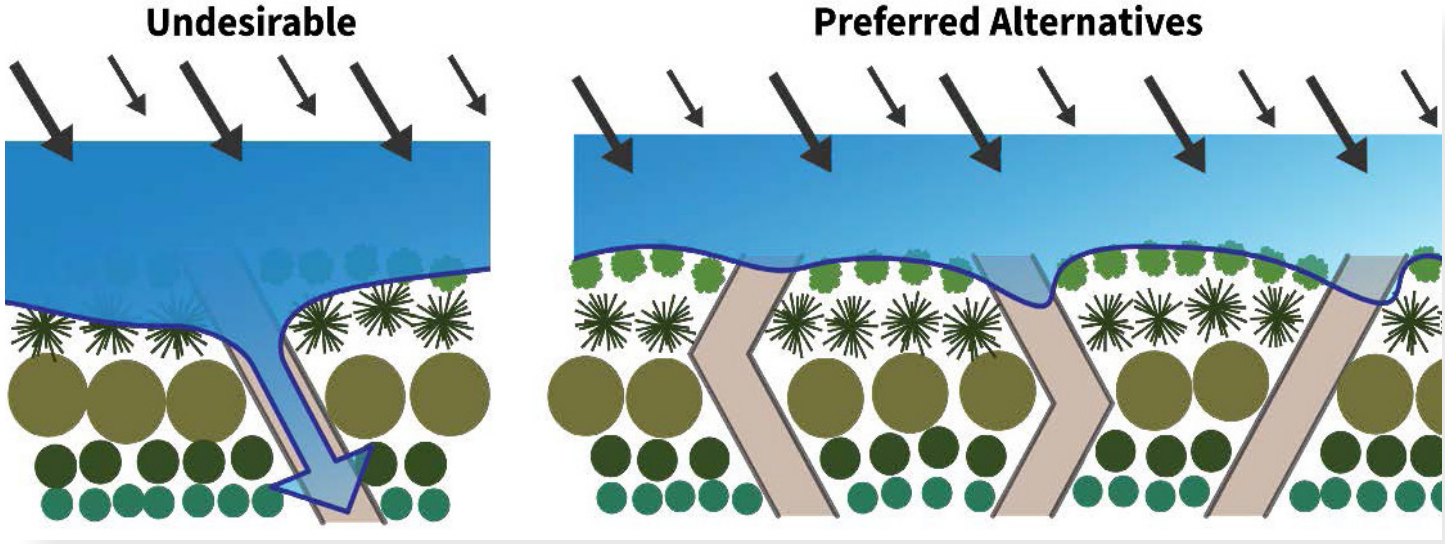


Figure 5. Windbreak designs for access lands or roads. (Kafer & Straight, 2022)

of time (within 10 years). This means selecting species that will give the appropriate level of density and optimum height for the site. For example, conifers need to be considered if optimum year round wind protection is desired. If wildlife is desired, select appropriate plants for the desired animals or birds.

Productive Windbreaks

For most of the other agroforestry practices, e.g., Alley Cropping and Silvopasture, a marketable product is typically produced from the woody component. Windbreaks have historically been a conservation practice providing benefits to the adjacent area by reducing wind impacts. The trees and shrubs in a windbreak have rarely been managed to sell a product. In older windbreaks planted in the 1930's and 1940's, plants were chosen that could provide fruit for home consumption and trees were cut for use as fence posts and rough lumber on the farm. The concept of producing usable products from windbreaks and other conservation practices has recently been revived and promoted in Productive Conservation: Growing Specialty Forest Products in Agroforestry Plantings.

For example, nut and fruit producing plants could be incorporated into a windbreak design with the intent of harvesting the fruits/nuts as a product. The harvesting would not impact the other benefits of the windbreak. Some commonly harvested fruits include chokecherry, highbush cranberry, sand cherry, currants, Cornelian-cherry dogwood, jostaberry, Nanking cherry, chokeberry, buffaloberry, pawpaw, persimmon, and many others. All are harvested for home consumption, but many are also gathered for commercial use as fresh fruit, jams, jellies, syrups, juices, concentrates, confections and wines.

A second possible enterprise could be decorative woody florals. Any woody plant species that has a colorful or unusually shaped stem, bud, flower, fruit or even leaf can become a decorative floral product. Some plant examples include stems from red and yellow-stemmed dogwoods; and curly, pussy, flame and basket willows. Even though the stems of these plants will be harvested, most of them will resprout from the roots restoring their value as part of the windbreak.

With any of these concepts, careful advanced planning is needed. Some unique challenges include understanding available markets, timing of harvest, perishability of the product, available labor, wildlife pressure, year-to-year production, etc. Once these issues have been resolved, thought is needed to decide how to incorporate the plants into the windbreak design. If the plants that will be harvested are primarily shrubs, the design can be fairly easy since shrubs typically are included in the outer or inner rows which will make access easier. Growing specialty forest products in windbreaks can provide supplemental income while at the same time improving the environment. Another advantage is that the windbreak will receive more management care and could result in a longer lasting planting. Success will only occur if the grower is a skilled manager and an effective marketer.

Windbreak Site Preparation, Planting and Maintenance

Site preparation

Site preparation is an important first step to ensure successful survival of the trees and shrubs in the windbreak. The goal is to maximize the amount of moisture at the site and to minimize the potential for weed competition. The type of site preparation used depends on the soil and existing vegetation at the site. With sandy soils, care must be given to avoid wind erosion problems. On sloping sites, precautions must be taken to prevent water erosion. Site preparation can be accomplished either mechanically (e.g., tillage equipment including chisel plow, disc, rototiller, or scalper), chemically (pre and/or post emergent herbicides) or a combination of both.

Site preparation

- *Maximize moisture*
- *Minimize competition*
- *Match the site*
- *Be timely*
- *Care for plants*
- *Plant at correct depth*

Planting

Tree planting methods include using either a tree planting machine or hand planting tools. For both methods, some key techniques need to be followed:

- *Do not plant on hot, windy days.*
- *Prevent roots from drying out.*
- *Do not plant when the temperature is freezing or below.*

- *Plant seedlings in a vertical position with root collar 1" below soil surface.*
- *Prepare a trench or hole deep and wide enough to permit roots to spread out naturally; avoid "J-rooting" - prune roots as needed to prevent J roots.*
- *Pack soil firmly around roots to eliminate air pockets.*

In arid areas where trees are difficult to grow shrubs or tall native grasses may be used to provide crop protection, to control wind erosion, and to capture snow for crop production.

Maintenance

The goal is to maintain the health and vigor of individual trees and shrubs while maintaining the overall structure of the windbreak as an effective wind barrier. With proper care, a windbreak will serve a long life of protection.

Windbreak Maintenance

- *Weed/grass control for the first 3 to 5 years with optional cover crop between rows*
- *Use supplemental water to ensure early survival and development*
- *Replant to fill gaps*
- *Protect from animals and pests*
- *Use corrective thinning and pruning*
- *Do not fertilize (cost prohibitive)*

Weed/grass control: Weeds need to be minimized usually for the first three to five years in a band about three to four feet on each side of the rows of trees or shrubs. The area between the rows can be planted to an annual cover crop (e.g., grain/forage sorghum, oats, corn, millet, wheat, rye, or sunflowers) which can help control weeds, provide wildlife cover, and protect young tree seedlings from soil or wind abrasion.

Supplemental irrigation: Irrigation (e.g., hand, drip, sprinkler, furrow or flood) is not a substitute for good site preparation and weed/grass control. Irrigation should be used when soil moisture conditions are extremely dry at planting time or during a prolonged drought after planting.

Replanting: Replant all trees and shrubs that have failed in order to fill in the gaps in the windbreak. Replant annually for at least three years after the initial planting and continue until a full stand of trees is attained.

Animal protection: Establish appropriate fencing to prevent livestock and large mammal damage. Controlling small mammals can include repellents, traps, special fencing, and seedling protectors (e.g. plastic tubing or mesh netting). Consult with local and state game/wildlife specialists for control measures for your area.

Pest control: Periodic inspection of the crops and trees is recommended to detect and identify possible pests. These inspections and in some cases the use of pheromone traps will help determine when corrective action is warranted.

Pruning: Hail, wind or snow storms often cause breakage of limbs and sometimes the main trunk(s) of the trees and shrubs. Remove broken limbs and tops.

Fertilization: Generally, fertilization of windbreaks is not recommended. It is not practical, economical, or feasible, in most cases. The only situation where fertilization may be justified would be a small, high-valued windbreak planted on soils that have obvious soil nutrient deficiencies. Apply fertilizer according to soil test results.

Summary

Windbreaks protect crops, soil, and livestock while also improving air and water quality, broadening biodiversity, and beautifying the landscape. One of the keys to the successful windbreak is recognizing what the land steward wants to accomplish through its application on the landscape. The next step is to then understand the properties of a successful windbreak. And finally, choose species to plant in the windbreak that will enable it to work as expected. With a little planning upfront, a windbreak can provide a variety of benefits from improving crop production to maintaining livestock health.

Non-Agroforestry Uses of Windbreaks

1) Windbreaks for homes

Windbreaks reduce energy consumption by reducing air infiltration into buildings resulting in less heat loss and by reducing the amount of snow removal from roads and around buildings.

Windbreak Design To Protect Homes and Outbuildings

When utilizing windbreaks to protect structures such as the farmstead, roads, and other buildings, position the windbreak as close to perpendicular to the most troublesome wind direction. "One-leg" windbreaks are sufficient if winds come from one direction only, but a "two-leg" or network of windbreak(s) provides greater protection for variable wind directions.

Plan for 60-80 % density for maximum protection. Locate windward row 100 - 200 feet from area needing protection. In areas with variable winds, multiple-leg windbreaks provide greater protection to the field or farmstead than single-leg windbreaks.

Design tips

- *For wind protection only, the tallest row needs to be 2-5H (H = planned height of the tallest row) from the primary area needing protection.*
- *However, for wind and snow protection, the most windward row needs to be 100 to 200 feet from the windward edge of the primary protection area. The distance between the area needing protection and the windward row varies with the amount of space needed for snow storage. Once this critical distance is met, check to see if the area needing protection is still in the 2-5H zone, i.e. a house. Areas and objects more than 10H from the windbreak will receive reduced wind protection. To protect structures, the windbreak should have a density ranging from 60 to 80 percent during the 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.*
- *Extend the windbreak a minimum of 100 feet past structures needing protection to accommodate wind turbulence at the end of the windbreak and end-drifts of snow.*
- *Locate access roads from 100 to 500 feet from the ends of the windbreak. If a lane must cut a windbreak, it should cut through the windbreak at an angle to prevailing winds to prevent funneling of wind and snow drifting.*



Community windbreaks

Planned community windbreaks can provide extra protection for the entire development and be an economic gain for the developer and homeowner from increased property values. Windbreaks in the rural-urban interface can also reduce potential conflicts, such as blowing dust, privacy, odors or noise between land uses. High quality windbreaks between agriculture and communities can prevent windblown soil and snow. Sediment in the yard, dust in homes and pesticide drift can be great aggravation to both rural and urban homeowners.

For more information see Working Trees for Communities.

Two designs for protecting a structure from snow:

Traditional multi-row windbreak: A basic farmstead windbreak consists of three to eight rows of both conifers and deciduous trees and shrubs. Conifers or shrubs should be located on the windward side with tall deciduous species in the center. A row of shrubs on the interior or leeward side completes the design.

Modified twin-row, high density wind- break: In areas with frequent heavy snows consider adding a row or two of shrubs 50 feet to the windward side to trip snow before it reaches the main windbreak. An auxiliary planting of shrubs on the leeward side of the windbreak can also add good emergency cover for wildlife. This can be supplemented with a food plot between the main windbreak and the auxiliary planting.

For more information see Windbreaks for Rural Living.

2) Windbreaks for living snow fences

Blowing and drifting snow jeopardizes public safety and emergency services, interrupts businesses, increases road maintenance costs and causes wildlife mortality.

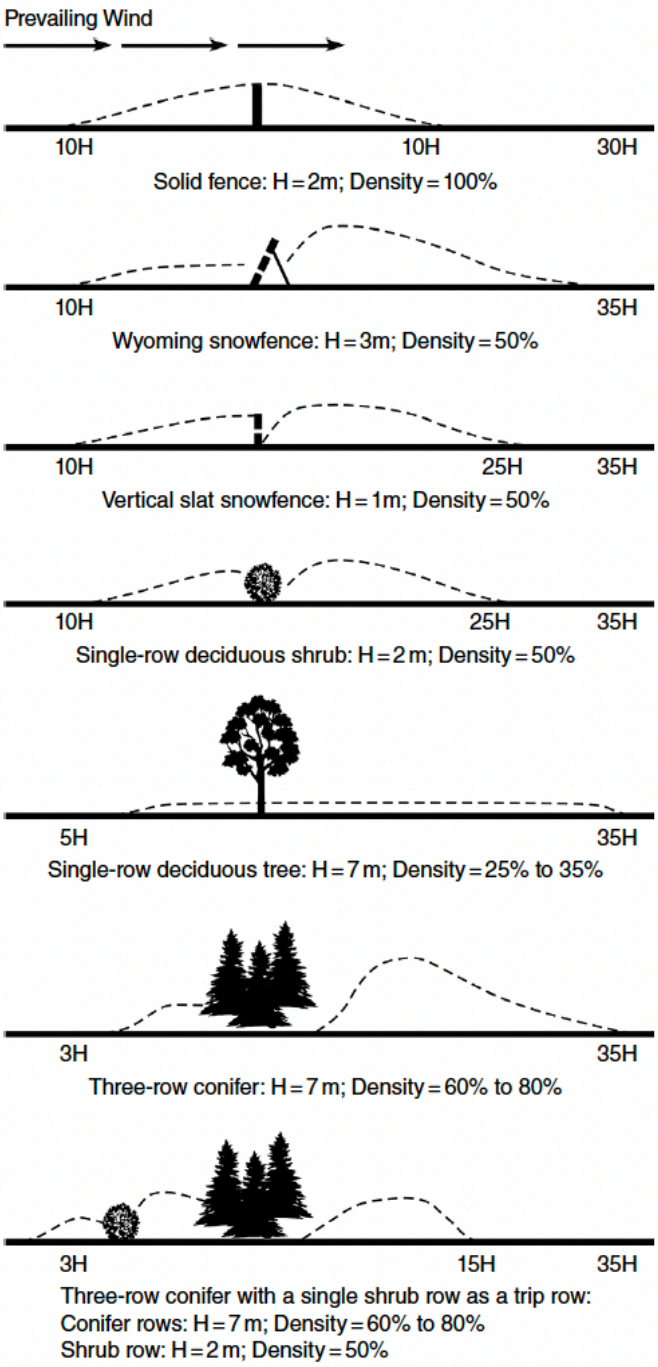


Figure 6. Windbreak designs for snow. (Brandle et al., 2021)

Living snow fences are more cost-effective than structural barriers, can meet many additional objectives, and provide a wide array of benefits beyond snow control.

Design tips

- *To achieve maximum snow accumulation, the windbreak density should range from 60 to 80 percent.*
- *The furthest windward row should be a minimum of 100 feet from the area being protected to prevent inappropriate snowdrifts. This distance will vary (100 to 300 feet) depending on the location and severity of winters.*
- *A trip row of shrubs or dense conifer can be located 50 to 100 feet windward of the main windbreak to create a snow trap.*
- *For protecting roads, allow plenty of room for the leeward drift by locating the windward row of the windbreak 200 to 300 feet from the center of the road.*

The storage capacity of a living snow fence is determined by its height and density (Fig.6).

For more information see Working Trees: Living Snow Fences and Windbreaks for Snow Management.

3) Windbreaks for livestock odor reduction

Windbreaks (or vegetative environmental buffers, VEBs) placed around livestock production facilities can help mitigate the movement of odors and dust generated by these operations. Urban expansion has placed many more people into closer contact with agricultural operations. Large scale livestock confinement production has led to increased concentrations of odor emissions traveling across highly modified landscapes relatively devoid of natural barriers. Windbreaks alone will not prevent these odor problems but can help reduce negative visual perceptions and the detection of smell by neighbors and surrounding communities.

Design tips

- *Windbreaks should consist of at least one to three rows of conifer and deciduous species.*
- *Two to three rows of trees can provide an ideal 60 percent windbreak density (or 40 percent porosity) for odor control.*
- *Shrubs are generally planted in the outside or inside rows, followed by conifers with deciduous hardwoods towards the middle or along the downwind side where they can grow more efficiently.*
- *Tree varieties and placement for the windbreak should be managed to maximize odor interception and dilution of air, and reduce odor leaving the source.*
- *Where site and facility conditions merit and allow, place plantings (not necessarily windbreaks) around*

the entire perimeter of the odor source.

- *Even a site with a windbreak on one side that is strategically placed and designed can make a difference.*

For more information see Windbreaks: A "Fresh" Tool to Mitigate Odors from Livestock Production Facilities.

4) Windbreaks for wildlife benefits

With careful design, windbreaks provide nesting habitat for a wide variety of birds (up to 57 species) and other wildlife. Windbreaks can also produce needed food as well as protective cover when the wildlife forage in adjacent areas. Shelter from predation and escape cover as well as emergency cover from severe weather.

Design tips

- ***Aesthetic appeal*** *- Windbreaks can be given a more natural look and still provide excellent wildlife habitat and wind protection.*
- ***Connecting habitats*** *- Where appropriate, select the windbreak site that connects to a larger habitat block such as a river corridor, woodlot, wetland, woody draw, or similar area.*
- ***Herbaceous cover*** *- Consider planting or leaving herbaceous vegetation such as a mixture of grasses and legumes, standing grain, or crop residues as a border (20 to 50 feet wide) along the edges of the windbreak. If grasses or legumes are used, they should be separated from the new tree planting to avoid competition. This strip of cover can provide nesting, loafing, and foraging cover for a number of species.*
- ***Winter cover*** *- Adding a shrub row 50 to 100 feet windward of the main windbreak as a snow trap results in greater wildlife protection on the leeward side of the main windbreak. Use species that will provide good thermal protection in the winter such as cedar and spruce.*
- ***Food*** *- Select species that may have high food value for a variety of wildlife. Planting food plots or fruit-bearing shrubs on the lee side of windbreaks provides food in an area protected from wind and possibly warmed by the sun, points that are particularly important in cold months.*

For more information see Windbreaks and Wildlife.

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Rejuvenating an 80-year-old windbreak to enhance cattle and crop health in Kansas



At a glance: Established in 2015 at Zumbrunn Farms in Chapman, Kansas, a 640-foot, three-row windbreak featuring eastern red cedar, fragrant sumac, and common ninebark was designed to replace a deteriorating 80-year-old windbreak, providing essential protection for livestock pens on this third-generation family farm. The Zumbrunn's appreciate the benefits their livestock gain from wind protection, particularly during harsh cold weather.

Overview: Kansas is well known for its severe winds, and following the Dust Bowl era, windbreaks became a common feature across the state. These tree barriers were essential for protecting homesteads, livestock, and fields from harsh weather conditions. However, over time, many of these windbreaks deteriorated, losing their effectiveness. Lifelong farmers Cheryl and Dennis Zumbrunn recognized it was time to improve their aging 80-year-old windbreak when it no longer provided the essential wind protection needed for their livestock and homestead. Established in 1928, Zumbrunn Farms is now in its third generation. They manage 1,000 acres of cropland (wheat, soybeans, corn, and milo) and 800 acres of pasture for a 100-head cow-calf operation. Calves are backgrounded to 700-800 pounds and sold locally, while the herd winters near the farmstead and calves in the fall.

Windbreak design: When Zumbrunn Farms decided to replace their aged windbreak, they sought guidance from the Kansas State University (KSU) Forestry Department. This partnership proved invaluable, as the department not only provided a cost-effective plan but also helped secure funding through a financial assistance program. The design process began with a map outlining the planting layout, with species carefully chosen for their resilience and suitability to the local environment.

More than 300 trees and shrubs were planted with white clover seeded between the cedar rows to help with weed suppression and soil health. A row of fragrant sumac (5' spacing) was planted along the north side of the livestock pens. To enhance the old windbreak north of the house, common ninebark (4' spacing) was added to fill gaps and create a lower protective layer. Behind these, two 640' rows of eastern red cedar were planted, with 10' between trees in each row and 15' between the rows.

In addition, elderberry bushes were placed along the lane and near the west end of the cattle pen to provide initial shade. Space between the cedar and elderberry rows was used to grow pumpkins. Straw mulch, adequate rainfall, and fertile soil brought on a bumper crop. This approach offered multiple benefits: the pumpkins suppressed weeds and generated additional income through local sales, while the elderberries provided fruit and flowers for personal use (jelly, syrups, infusions). The clover further contributed by enriching the soil and supporting pollinators.

Establishment: Irrigation and weed control were essential in the early years for tree establishment. The use of poly fabric mulch around trees suppressed weeds and conserved moisture, while white clover between the rows enriched the soil and created a thriving habitat for pollinators. In the early years, maintaining the system demanded a lot of time and effort. Mowing was essential to control grass and weeds, and replanting was necessary to replace seedlings that didn't survive the tough Kansas climate. Hand weeding and occasional spot spraying for pests were also part of the routine. Over time, the need for these labor-intensive practices decreased as the trees grew strong and self-sufficient.

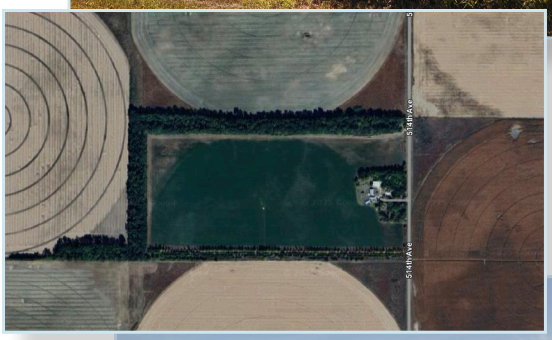
Maintenance: By the tenth year, Zumbrunn Farms transitioned to a much lower-maintenance approach. While irrigation lines and mowing were no longer required, annual pest control, particularly spraying for bagworms, remained a priority to protect the windbreak. Despite the challenges, the family looks back on the project as a rewarding endeavor, one that has transformed their landscape and provided lasting benefits for their cattle and farmstead.



Protecting organic crops with multi-age windbreaks in Nebraska



At a glance: Surrounded by miles of conventional corn-soybean row crop agriculture in Zone 5b, Sht'uh Farm stands out as a certified organic operation with 55-acres of cropland surrounded by windbreaks. Windbreaks play a crucial role in safeguarding the farm's crops, shielding them from pesticide drift and wind erosion, while also providing vital habitat for biodiversity.



Overview: Alexandra McClanahan Shively and her husband John began farming Sht'uh Farm in 2002. Already on site existed an 180' wide windbreak established in the 1930s. In their first eight years on the land, they planted rye, harvesting seed but keeping the straw in the field to improve soil quality. From 2004-2006, the couple invested in establishing a new windbreak along the farm's southern border to further enhance the resilience of their operation. These windbreaks, a combination of nearly 100-year-old historic shelterbelts and newer 20-year-old plantings, serve multiple functions. They protect the farm's organic crops from pesticide drift, reduce wind erosion, and provide critical wildlife habitat. In 2006, the couple began transitioning the farm to certified organic. After rye, Sht'uh Farm produced organic soybeans, wheat, and alfalfa. The couple has since retired and now rents farmland to a young couple who farms organically. They produce and sell alfalfa locally and use a portion for their livestock



Windbreak design: The south windbreak was planted in two phases and includes diverse species for resilience and functionality. In 2004, two rows of green ash, hackberry, and eastern red cedar were planted, spaced 14' apart with 20' between rows. Two years later, three rows of ponderosa pine and Colorado blue spruce were planted with 14' between trees and 24' between rows.

The historic windbreaks on the north and west sides of the farm provide additional protection from wind erosion and habitat for wildlife. These windbreaks are impressively wide, spanning roughly 180'. Originally planted in neat rows, they have since evolved into a thriving non-linear forest ecosystem. The trees now reseed themselves naturally, creating a self-sustaining habitat that serves as a vital refuge for wildlife. In the 1930s, commonly planted species in windbreaks included were green ash, cottonwood, box elder, mulberry, American elm, and black locust. Alexandra and John enhanced the historic windbreaks by adding a row of edible shrubs, including elderberries, plums, and sand cherries, bringing both biodiversity and multifunctionality to the landscape. They also established trails within the windbreaks, creating opportunities for easy access and exploration. These trails have the potential serve as a unique attraction if they or their renters choose to venture into agritourism in the future.

Establishment: Alexandra advises to carefully consider irrigation needs during the windbreak's early stages. Their 2004 planting coincided with a severe drought. To ensure the young trees' survival, they hand-watered each one multiple times throughout the summer using a water wagon.

The windbreaks were established with support from federal financial assistance programs and have proven to be invaluable assets for the farm. Beyond enhancing the property's value, they provide critical environmental benefits, including reducing wind erosion, creating essential wildlife habitat, and serving as buffers against pesticide drift. These functions have greatly supported Sht'uh Farm's ability to gain and maintain organic certification. However, Alexandra points out a modern challenge: the increasing use of volatile pesticides, such as dicamba, which can travel for miles under certain conditions. Despite these challenges, the windbreaks remain a vital feature of the farm, offering resilience and environmental protection in a changing agricultural landscape.

WINDBREAKS REVIEW

1. **What are the specific advantages of windbreaks for crops, soil and cattle?**
2. **How far from the windbreak will crops benefit with increased yields?**
3. **Compare and contrast the uses for single-row and multiple-row windbreaks.**
4. **When deciding between deciduous and coniferous species, what factors will also be used when writing out the management plan?**
5. **Putting in a windbreak will cause a farmer to take acres out of production. How can a farmer justify putting a windbreak?**
6. **A number of features must be analyzed prior to the placement of a windbreak. List four of these features.**

ANSWER KEY

1. Properly designed windbreaks have been shown to increase crop yield for a wide variety of crops. Decreases in wind speed protect downwind crops, decreasing evapotranspiration and increasing water use efficiency. Decreasing wind also speed enhances soil stability and is the primary basis for the installation of windbreaks dating back to the Dust Bowl of the 1930s. Cattle use energy to keep warm in the winter, increasing their feed requirement. Windbreaks moderate winter temperature extremes, reducing cold stress. Windbreaks also improve calving success rates.
2. The rule of thumb is that crop yields are improved out to 10-15H.
3. Single-row deciduous windbreaks are designed to improve snow distribution across a crop field to improve moisture for early season crop growth. They are also used surrounding orchards to still the air and improve pollination and/or speed up crop maturation. They may also be used as a visual screen along roads. Other windbreak applications depend on multiple-rows of deciduous and coniferous trees and shrubs, combined and configured for specific purposes (i.e., crop production, animal protection, snow fences).
4. Both conifers and deciduous trees bring different attributes to the function of the windbreak. Deciduous trees are more porous to wind movement and are less effective in slowing wind speeds. Conversely, deciduous windbreaks reduce wind velocity further downwind. Conifers provide much more wind blockage, critical to protect cattle, roads and buildings from wind and snow.
5. A realistic assessment of the farmers' goals and objectives, coupled with a similar assessment of the entire farm and cropping system, will lead to the diagnosis that may include establishment of windbreaks. Evidence of windblown soil erosion and associated crop damage, need for cattle protection or protection of buildings and roads, may all lead to this diagnosis. Once the diagnosis includes windbreaks, the next step is to explore financial assistance programs that may help to offset establishment costs. Visits to other land stewards that have functioning windbreaks, will be very effective in addressing farmer concerns.
6. Height, density, orientation, length, width, uniformity, cross sectional shape.

Chapter 7: Forest Farming

Chapter Highlights

- Forest farming cultivates non-timber forest products (NTFPs), including medicinal herbs, mushrooms, and decorative plants.
- Canopy modifications create a favorable micro-climate for shade-tolerant crops.
- Forest farming provides income from NTFPs while supporting long-term timber growth, boosting land productivity while promoting sustainable forest management and conservation.
- Biodiversity can be enhanced through forest farming through creation of wildlife habitats for turkeys, deer, and songbirds.
- There is no one way to forest farm. This practice can be implemented through methods like forest gardening, wild-simulated cultivation, and wild harvesting.



Trees are planted with goldenseal, ginseng and other profitable medicinal plants in this photo. Culinary mushrooms grow on logs nearby, demonstrating another product that can be farmed in a forest.

What is Forest Farming?

Forest farming is the intentional and sustainable cultivation of marketable non-timber forest products (NTFPs) in woodlands with suitable shade and site conditions. This agroforestry practice diversifies forest management and enhances associated income opportunities. It also improves forest composition and structure and long-term health, quality, and economic value. Forest farmers actively monitor and manage interactions between trees and understory crops with long-term forest health and productivity in mind. Both timber and nontimber crops can be managed on the same forested land, or non-timber crops can be grown in forests where timber harvesting is not possible or desired. Forest farming operations range from very small (< ½ acre) to very large (> 50 acres).

Advantages

- Enhance forest health
- Improve forest composition
- Diversify income opportunities
- Profit from the rising popularity of forest grown products
- Range of operation sizes possible

Challenges

- Informal or immature markets
- Variable yield
- Limited information available on how to produce crops
- Volatile markets for some products
- Some crops are attractive to poachers

What are Non-Timber Forest Products (NTFPs)?

Forest Farming is defined as the intentional and intensive management of forested lands to produce site-appropriate NTFPs. Forest farmers may intentionally manage shade levels in a forest and among understory plants

to favor cultivation or enhanced growth of NTFPs with viable markets. NTFPs include a broad range of goods harvested from woodlands. Herbal plants such as ginseng and goldenseal, specialty mushrooms like shiitake and reishi, and wild foods such as fiddlehead ferns and miner's lettuce that grow in a forest are termed NTFPs.

Unlike other agroforestry practices where trees are introduced into an agricultural system, forest farming intentionally integrates agricultural techniques into existing or newly established forests to farm NTFPs. While some forest farmers grow NTFPs for personal consumption, many cultivate and harvest with revenue opportunities in mind.

The total value of the NTFP industry is challenging to estimate due to lack of data, and the fact that much of the economic activities associated with NTFPs are considered part of the informal economy, and thus are not reported. Never the less, evidence indicates that the industry contributes significantly to national, regional, and local economies. The value of NTFPs from Federal lands can be estimated using records of issuances of harvest permits, though these data underestimate overall values. From 2004 through 2013, the national forests and Bureau of Land Management generated nearly $80 million from the issuance of harvest permits (Chamberlain et al. 2013). The total estimated wholesale value of NTFPs from federal lands over this period exceeds $9 billion. Since much of the forest land-base in the eastern US is privately held, these figures do not represent the entirety of NTFP economies.

Estimated values of individual products and market segments also indicate significant economic contributions. For example, Chamberlain et al. (2013) estimated the annual market value of wild-harvested American ginseng in 2007 ranged from $18 million - $36 million, depending on price. In 2016, retail sales of black cohosh roots were close to $43 million according to the American Botanical Council. The annual value of maple syrup production exceeds $100 million (Farrell and Chabot 2012). In 2007, the US exported pine nuts valued at about $20 thousand, yet imported more than $54 million of the nuts (Alexander et al. 2011). Each of these figures demonstrates a great capacity for growth of NTFP markets. An example of this growth can be seen in the estimated sales of herbal supplements, which increased $530 million between 2013 and 2016 (Smith et al. 2017). These and other data suggest that NTFPs provide significant economic opportunities for forest dwellers.

Types of NTFPs

Forest farmed NTFPs are generally divided into 4 categories: (1) medicinal, (2) edible, (3) floral, and (4) decorative and craft.

Medicinal NTFPs. People have collected medicinal plants in forests for as long as they have walked in them. Medicinal substances are used in nutraceutical, herbal health, cosmetic, and other products and derived from a variety of sources. This includes wood (e.g., aromatic oils from cedar), bark (e.g., smooth sumac, slippery elm), buds (e.g., cottonwood), leaves (e.g., cat- nip, ginseng, ginkgo), roots (e.g., black cohosh, goldenseal), fruit and flowers (e.g., Echinacea, partridgeberry, skullcap, St. John's Wort), and pollen (e.g., ash, maples, pines). Knowledge about medicinal NTFPs often is informal, but formal information regarding cultivation is increasing.

Edible NTFPs. There is a wide variety of forest-grown edible products. They include fiddlehead ferns, mushrooms, nuts, honey, maple syrup, and the fruit, leaves and/ or roots of many herbaceous plants. Demand for these products is consistent and in some cases increasing. Many types of nuts are farmed throughout Midwest forests, including black walnuts, pecans, hickory nuts and butternuts. Forest farmed food such as shiitake mushrooms and ramps have been highlighted in gourmet magazines and cooking shows. Wild greens are particularly popular right now and include watercress, miner's lettuce, branch lettuce, dandelion, bean salad, and poke sallet. Wild populations of these plants are usually abundant and only need to be tended, not planted. Numerous types of berry species are cultivated and can be used in products ranging from fresh fruit to jams, jellies, syrups, juices and wines.

Floral/decorative NTFPs. Forest farmers can cultivate various decorative plant species to be used individually or in decorative arrangements. Galax is valued for its attractive and durable leaves. Holly is valued for its evergreen leaves (in some species) and bright red berries; and witch hazel, redbud, quince, mountain laurel, and rhododendron for their forced flowers. Pine cones, as well as other seed capsules and pods are used in a variety of craft, potpourri, and seasonal products. These products have consistent markets, command substantial prices, and are sold to floral shops and large retailers or wholesalers. Many plants are valued for landscaping; straw harvested in pine forests is frequently used as landscaping mulch.

Specialty woods NTFPs. A number of species produce specialty woods and materials for use by local artisans in hand crafted products and art. For example, "diamond willow", which is actually a diseased willow with cankered stems, can be carved and polished by craftspeople to create beautiful walking sticks and other items. Smooth sumac, hickory, and aspen saplings are also converted to walking sticks and mass marketed. Burls are carved and turned into bowls. These value-added "art objects" often sell for high prices.

Forest Farming Methods

Management requirements differ according to the NTFP. For example, medicinal herb production often involves cultivating the forest floor and possible canopy management to create appropriate growing conditions. Small diameter hardwoods that are removed for timber stand improvement, for instance, may be used as logs for mushroom production. In general, forest farming methods range from minimal to intensive, which varies depending on what is being produced and often relates to trade-offs between time and money. There are three recognized methods of forest farming: woods grown, wild-simulated, and managed wild populations.

Woods grown is the most intensive and involves comprehensive site preparation and follow-up management. Start-up costs often are high, but the inputs can significantly increase yield.

Wild-simulated is less intensive in terms of site preparation and may involve some canopy management and clearing of the forest floor, but once the plants or seeds are planted, management may be minimal. Compared to woods grown, wild simulated typically renders less volume, but because the inputs are less, the risks are reduced and the returns may be similar. In the case of ginseng, the slower growth and more wild appearance of the roots often command price premiums, resulting in higher returns.

Managing wild populations involves tending an

Forest Farming Method	Management Intensity
Woods Grown	Woods grown, also known as forest gardening, is most intensive. In addition to potential thinning of the forest overstory, it often involves clearing undesirable vegetation in the understory and other practices that are more closely related to agronomy (e.g., tillage, fertilization, weeding, and control of disease, insects, and wildlife). Due to costs associated with input levels, forest farming can be costly and time consuming but can render large NTFP yield.
Wild-Simulated	Wild-simulated is the cultivation of NTFPs in natural growing environments. A natural growing environment can deliver products similar in appearance and quality to plants naturally growing in the wild. Rather than administer intensive agronomic practices, wild simulated forest farmers use minimally invasive techniques to expose the soil, and plant seeds or plants. Fertilizers and pesticides are rarely used. Despite potential decreases in total yields, wild simulated products often have higher priced markets when compared to those that are more intensively cultivated.
Managed Wild Population	Managed wild populations involves working with plants or fungus that already exist. The forest canopy may be modified to favor growth of desirable NTFPs. Understory plants that are competing with the desired species may be removed. Annual harvests might not be possible. Inputs are very low and yields vary depending on the species and how often it is harvested.
Wild-Harvest or Wild-Craft	Wild-harvesting is the harvesting of NTFPs growing naturally in the forest. It is not generally considered forest farming because active management is not involved. There are no inputs and no risks. There are sustainable wild-harvest methods that can be followed to ensure future harvests.

Each forest farming method has advantages as well as potential drawbacks in terms of time and money, which also varies by crop. For example, woods grown ginseng may result in a greater yield when compared to wild-simulated but per weight value may be lower. Successful forest farmers have a good sense of available markets and NTFP prices and match method and product to maximize revenue.

existing population of a plant or fungi. It may involve canopy management, removal of competing understory plants, and thinning of plants to provide for better growing conditions. This method requires few inputs, comes with less risk, and usually does not provide high returns, but may be very desirable for products that have unpredictable markets. Lastly, although not a farming method, a land steward might choose to simply wild-harvest from their forest. If sustainable wild-harvesting methods are used, these plants and fungi should be available for harvest in future years.

Designing a Forest Farming Operation

It is recommended to start small when establishing a forest farm. It often takes multiple years to become familiar with NTFP cultivation. The early years are a time to leverage lessons learned to refine production, increase efficiency, and build on developed markets.

Starting small allows a forest farmer to gain experience and suffer some setbacks without losing large amounts of money. Small areas can be used to test different crops, sites and management practices. Initial operations usually focus on two or three crops, but can include more if markets and labor are not a limiting factor.

Forest farming depends in large part on site conditions that are present and those required by the desired NTFPs. It is necessary to match and maintain appropriate sites to particular NTFPs. For example, if you want to produce floral greens that have a rich, dark green color, optimum conditions may include less shade than what is required for ginseng cultivation. Over time, changes occur in a mature or a developing forest that may necessitate thinning, planting of additional trees, or providing artificial shade to maintain necessary site conditions. Every forest farming operation should contribute to overall forest health and productivity.

Forest Management Considerations

A well-managed forest offers diverse financial opportunities. Managing the understory for NTFPs in addition to other activities such as timber harvesting and habitat improvement can increase revenue and benefit forest health and plant conservation. Success depends on realistic objectives in accordance with time, labor, and site conditions and amendments. Managing site-appropriate species with growth and value potential will help maximize revenue opportunities. While timber harvests are common sources of revenue for woodland land stewards, it is often several years between cuttings. Forest farming of marketable NTFPs can provide owners with intermediate income opportunities while timber and other salable products mature.

Timber Stand Improvement (TSI) is an intermediate practice that removes trees to improve species composition, stand structure, wildlife values, regeneration, and forest health. Crop tree management is one method for managing woodlands according to site conditions. With this technique, the best performing and most marketable trees are identified and their growth favored by thinning other trees to retain a suitable residual density. Both methods can provide woody material for use in NTFP production. For example, logs from thinning may be repurposed as mushroom substrate or used for terracing in hillside forest farms. Management of the forest overstory trees will impact forest farming possibilities regardless of the NTFP crop. In each case, the level of light reaching the forest floor will be altered, the implications of which should be considered by forest farmers.

Summary

Unlike those agroforestry practices that incorporate trees into agricultural systems (e.g., alley cropping and silvopasture), forest farming integrates cultivation and/or stewardship into existing or newly established forests. Benefits include providing intermediate and periodic income from crops while timber matures or where timber harvesting is not possible or desirable. Forest farming practices help diversify forest management and provide important and useful products. Management should

In forest farming, shade levels can be adjusted by one of two methods:

1. If there is not enough shade for the understory, additional planting of trees may be necessary. Shade structures made of wood lath, boughs, or polypropylene shade cloth may be necessary to protect the plants until trees mature and natural shade becomes sufficient.
2. If shade levels are too dense, thinning and/or pruning of trees may help create increase the light levels.

focus on site conditions and . tradeoffs between time and money in terms of method intensity. It also may be necessary to manage shade levels by thinning, pruning, and/ or planting/encouraging trees.

Before beginning an enterprise, forest farmers should:

1. Identify and investigate existing or developing NTFP markets;
2. Select NTFPs of interest from the list of those with viable markets;
3. Obtain site requirements, production, and processing information for selected NTFPs; 4)Decide on a production method and operational investments; and
4. Thoroughly investigate technical resources and engage technical experts.

Markets for forest farmed products vary, but often are direct to consumer and via local stores, cooperatives, or farmers markets. However, in some cases, larger-scale markets are available. For example, shiitake, maitake, morel, and chanterelle mushrooms, as well as truffles, may be sold in small volumes at farmers markets or to gourmet restaurants, or in larger volumes to distributors for resale in regional markets. Markets for decorative products like grape vine wreaths often are in urban areas and may be very seasonal. Decorative products may be sold through cooperatives or to local buyers. Non-local buyers may be reached through the internet. However, by marketing directly to consumers, a grower is more likely to retain a greater share of profits than when a middleman is involved.

A market analysis and business plan can help a beginning forest farmer chart out required inputs and is an essential starting point. This training manual offers a thorough framework for analyzing specialty crop markets and planning successful farming enterprises (see Chapter 10). Carrying out comprehensive and careful planning during and after startup will help minimize problems and increase chances for long term forest farming success.

Forest Farming Coalitions

- Northeast Forest Farmers Coalition
- Appalachian Forest Farmer Coalition
- Appalachian Beginning Forest Farmer Coalition
- Midwest Forest Farming Coalition

Additional Resources

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More than forty years of farming ginseng in Thayer, Missouri





(Top) Lindy pictured with ginseng. (Bottom) Ginseng from Lindy's farm. Photos by Hannah Hemmelgarn.

At a glance: Founded in 1983, Ozark Mountain Ginseng is a wild-simulated and woods-grown ginseng operation located in the Ozarks, spanning five acres with an additional 40 acres leased. With over 30 years of experience, the farm is led by Dennis Lindberg, affectionately known as "Lindy," a passionate grower dedicated to sustainable agriculture and medicinal plants.

Overview: Lindy's journey into ginseng cultivation began after reading *Growing Ginseng in the Woods* by Scott Persons in *Mother Earth News*. In the Ozarks, ginseng harvesting has been a tradition for more than 100 years, where the plant grows wild. However, by the early 1980s, Lindy noticed a significant decline in wild ginseng populations compared to just a decade earlier. Revisiting areas where ginseng once thrived, he often found that overharvesting had left almost none behind.

Recognizing this alarming decline, Lindy wanted to protect ginseng for future generations. He turned to farming American ginseng as a way to ensure its survival, planting seeds on his land to help replenish wild populations. "Farming American ginseng will be the future for this plant," Lindy explains. His work is rooted in a commitment to conservation and sustainable agriculture, ensuring ginseng remains part of the Ozark landscape.

Design and management: Ozark Mountain Ginseng operates as a long-term investment strategy. The farm harvests ginseng sparingly to preserve the crop's sustainability and value. Soil is carefully adjusted, with a focus on calcium and pH levels (5.5), avoiding nitrogen. Lindy emphasizes the benefit of leaf mold in enriching the soil, which provides essential nutrients for ginseng growth. The farm primarily plants on north- or east-facing slopes, as these provide the ideal conditions for ginseng cultivation. The plant naturally grows alongside hickory, oaks, sugar maple, and even pine trees.

Establishment: Ground preparation is important for successful ginseng farming. While naturally loose soil is ideal, Lindy uses a rear-tine tiller to work the ground 4 to 6 inches deep before planting. He scatters the seeds over the worked soil and then rakes them in, mimicking natural seed dispersal. Once established, ginseng requires little maintenance, making it a viable long-term investment.

Farm finances: The farm is self-sustaining, with all loans paid off. Lindy initially took out a few small loans to purchase ginseng seeds, but the land and house are fully owned, making the operation a legacy investment. His son plays an integral role, particularly during planting season. Ginseng roots fetch $600–$700 per pound, and demand is expected to rise as wild ginseng faces the threat of endangerment. With root and herb buyers available in every state, selling ginseng remains a profitable venture. By balancing profitability with conservation efforts, Lindy ensures his work benefits both his family and the environment

Lindy shares his expertise through YouTube videos and upcoming classes. He emphasizes the environmental risks of deforestation and overharvesting and advocates for preserving forest ecosystems to protect ginseng and other native plants. His outreach efforts highlight how farming ginseng can provide a sustainable future for the plant while continuing the Ozarks' rich tradition of ginseng cultivation. His work supports a legacy of education, sustainability, and conservation in the Ozarks.

Examples of Forest Farming Products with Markets

- **Medicinal NTFPs:** Ginseng, goldenseal, black cohosh, bloodroot, mayapple, solomon's seal, wild ginger, Oregon grape, false unicorn (fairywand), ginkgo, skullcap, slippery elm, wild yam, Bethroot, Culver's root (black root), blue cohosh, boneset, lady's slipper, passionflower, partridge berry, hawthorne, pinkroot, spikenard, stargrass (devil's bit), stoneroot, Virginia snakeroot, yellow indigo, and yellow root.
- **Floral/Decorative NTFPs:** Grape vines for wreaths; burls for carving; bark, pine needles, wood splints, kudzu, various stems, and bark for baskets; fall colored leaves and moss for decorations; cuttings from conifers for wreaths, roping, and garlands; salal, pussywillows, ferns, beargrass, and galax for floral greens for use in arrangements; and pine straw for landscaping mulch.
- **Edible NTFPs:** Mushrooms including shiitake, oyster, reishi, morels, maitake, native truffles, and lion's mane; nuts including pecans, black walnuts; fruits and berries including gooseberries and blackberries, crab apples, elderberries, paw paws, and blueberries; vegetables including fiddle heads, ramps, bean salad (rosy twisted stalk), bear grass spiderwort, branch lettuce, burdock, dandelion, dock, miner's lettuce, nettles, poke sallet, sweet salad (Solomon's seal), upland cress (creasy greens), and watercress; syrups including sugar maple and birch; and honey.
- **Woodland Wildflower NTFPs:** Spring ephemerals to be sold as potted plants including celandine poppy, wild geranium, bluebells, Jack-in-the Pulpit, mayapple, and trillium.
- **Specialty Woods NTFPs:** Fine woods for making musical instruments and decorative bowls and plates including curly maple, black walnut, Appalachian red spruce, and eastern red cedar.
- **Biomass Plants:** Willow and poplar grown as short rotation crops; and waste products from timber including sawdust, wood chips, bark, stumps, and branches.
- **Timber Byproducts:** High quality sawlogs, low quality trees, firewood, and woody residues for energy production.



High value medicinal herb markets have been increasing in recent years. Pictured here is black cohosh in bloom.



Fiddlehead fern on display at market.



Pine needles can be harvested into bales and sold for landscaping mulch.

FOREST FARMING REVIEW

1. **Identify the top three farmer objectives related to forest farming.**
2. **What are the four general categories of Non-Timber Forest Products?**
3. **What are the four methods of integrating forest farming with wooded environments? Which are the highest input and cost and which are the lowest?**
4. **Identify three products to be produced from the managed land.**
5. **Identify how the forest farmer can reach their objectives while producing the desired crops.**

ANSWER KEY

1. Typically, the top three farmer objectives related to forest farming include: Alternative income from forested land, Improved forest health, and Improved timber value.
2. The four general categories of non-timber forest products include: medicinal, edible, floral, and decoratives and crafts.
3. The four methods of integrating forest farming with wooded environments are woods grown, wild-simulated, managed wild, and wild-harvested. Woods grown requires the highest inputs and costs while wild-harvested typically requires the lowest.
4. Three products often produced from forest farming include: high-quality timber, shiitake mushrooms, and ginseng, though there are nearly endless options to choose from suited to each site and region
5. First, the forest farmer can identify certain wooded areas that may be more appropriate than others for growing the desired crop. For example, a northerly aspect and well drained site is often well suited for ginseng production. Mushroom cultivation allows for a bit more flexibility, though the ability to access the site regularly is important. It's also important to consider which sites are best for solely producing timber through understandings of soil type, aspect, and slope. Appropriate shade levels for each desired understory crop is also important and should guide tree selection when planting and thinning.


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GROWING SHIITAKE MUSHROOMS

IN AN AGROFORESTRY PRACTICE


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BURGUNDY BLACK TRUFFL CULTIVATIO

IN AN AGROFORESTRY PRACTIC

The Center for Agroforestry has conducted research on specialty mushroom production in previous years. Two technical guides on shiitake and truffle production are available for free download on our website. Find them by scanning the QR code.

Chapter 8: Forest Gardens

Chapter Highlights

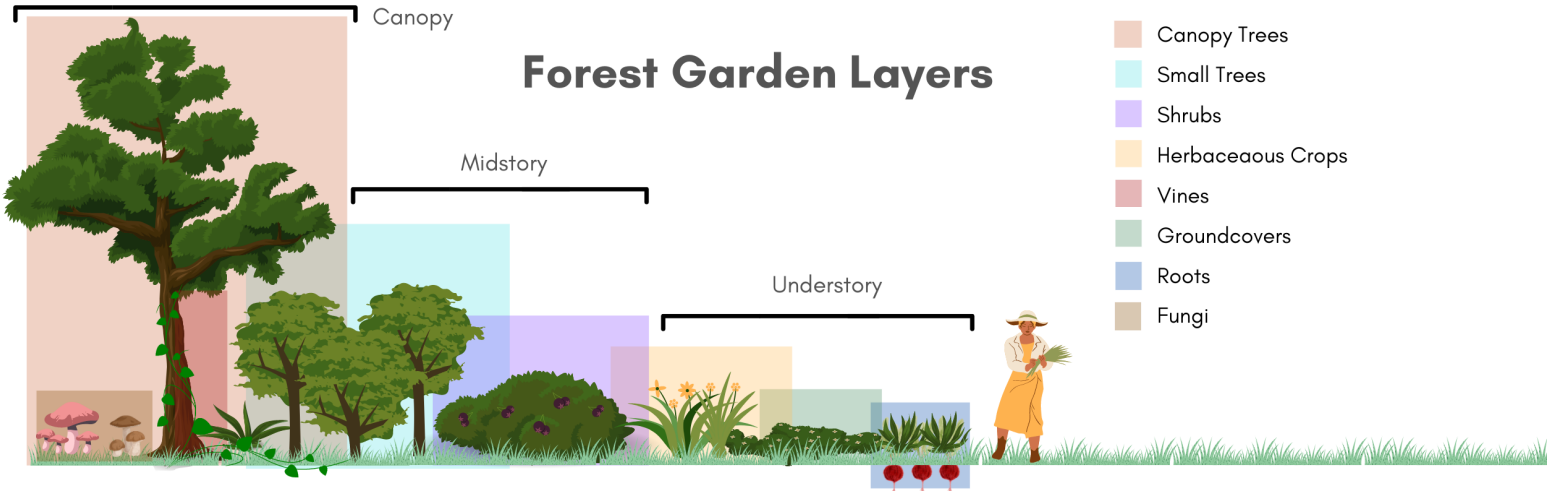
- Forest gardens are multifunctional perennial (woody and herbaceous) polycultures designed and managed to mimic the structure of early successional forests or forest edges, where multiple "layers" of edible, medicinal, or ornamental plants and fungi share a single unit of space.
- Forest gardens are inherently complex, and they often occupy small spaces. Because of this, they can be difficult to mechanize, often relying on hand-labor or small specialized equipment.

Thoughtfully designed agroforestry practices contribute to environmental and economic resilience on farms and ranches. These outcomes can be achieved at a smaller scale by planting forest gardens, also known as food forests, as multi-strata productive growing spaces. Forest gardens can be incorporated into yards, parks, roadsides, or other shared or underutilized spaces suitable for cultivation, allowing growers to maximize space, increase and diversify yields, and create opportunities for social connections and education.

Forest gardens are *multifunctional perennial (woody and herbaceous) polycultures designed and managed to mimic the structure of early successional forests or forest edges, where multiple "layers" of edible, medicinal, or ornamental plants and fungi share a single unit of space*. Unlike conventional rural farms, forest gardens may be planted in relatively small areas. They require careful design to accommodate the challenges and opportunities related to their high levels of diversity and unique site circumstances. We intentionally refer to them as "forest gardens" in this publication to illustrate their ability to provide more than food products and to highlight their parallels to intensively-managed garden spaces.

The practice of forest gardening has become more popular in recent years, but multi-strata perennial gardens have been part of Indigenous land stewardship and subsistence for thousands of years. Research suggests that large parts of the Amazon rainforest, the Pacific Northwest rainforest, and tropical forests around the world are in fact large-scale forest gardens, composed of intentional plantings that have sustained communities through many generations.

Designed like a forest edge or successional transition, forest gardens can contain multiple strata or layers that utilize energy, nutrients, and space in complementary ways both above and below ground. Image credit: Kelsi Stubblefield and Hannah Hemmelgarn.



Today, the role of forest gardens for human and wildlife communities is no less important. They can supplement an individual's or a family's nutritional needs, produce a wide variety of staple crops and medicinal plants, sequester carbon dioxide from the atmosphere, provide critical habitat for wildlife, and offer numerous other social and ecosystem services. When planted in urban areas, forest gardens can also play an important role in regulating micro-climates, mitigating the heat island effect, buffering unpleasant odors, beautifying the built environment, and facilitating community connections.

The long-term success of forest gardens will depend upon planning and design that takes into account not only the unique growing conditions of a site, but also the social dimensions and needs of those who will interact with the space. A fruitful forest garden design will consider both the complex ecological structure of the space, and also the social structure of decision-making, management, and human interactions. This guide is intended as an introduction to the planning process in conjunction with other resources referenced at the end of the document.

Disclaimer: please note that this guide is intended as a primer and is not site-specific nor comprehensive. Refer to the resources listed at the end of this publication for extended information on forest garden planning, design, and management.

Planning a Forest Garden

Forest garden scale and function will vary depending on physical, social, and ecological circumstances, but the process for planning your forest garden can be guided by these basic steps. They can be designed for subsistence, commercial production, education, or recreation; planning decisions will be affected by the unique attributes of the site and the participating community. Start by determining your goals and objectives using these prompts as an initial guide.

Social Considerations

- What is the purpose of the forest garden? Is your primary goal to produce food, to provide a space for community gathering, to serve an educational purpose, or something else?
- Who is the forest garden intended to serve? How will they be involved in the planning process?
- Who will be involved in maintaining the garden, and how much time will they be able to dedicate to taking care of the space?
- How do you envision people interacting with the space? Will it be public or private? How will you facilitate understanding and interpretation of the forest garden?

Environmental Considerations

- What is the current ecological condition of the site, and how do you envision it changing in the next 5, 10, 15, and 20 years?
- What (and how much) do you want to harvest from your site? What, if any, site changes, amendments, or remediation will be required to ensure sustainable and healthy harvests?
- What are your conservation goals? How will the opportunities and constraints of the built and/or natural environment affect and be affected by the garden?
- What level of structural and biological diversity do you aim to achieve?
- What kind of legacy do you hope to create from this effort?

Assess the growing context

Once you have identified your goals and objectives, you can assess your "growing context", which includes the physical and biological features of the land and the ways humans will interact with the space. Consider the following factors and available tools:

- **Climate:** the weather conditions in your area, including season length, temperature, and rainfall.
  - USDA Plant Hardiness Zone
  - First and last frost date estimations
  - Temperature and precipitation (NOAA.gov)
  - Climate and future predictive models (NCICS.org)
- **Topography:** The shape and arrangement of physical features on the land, including elevation and slope.
  - Topographical maps (USGS.gov)
- **Soil structure and fertility**
  - USDA Web Soil Survey

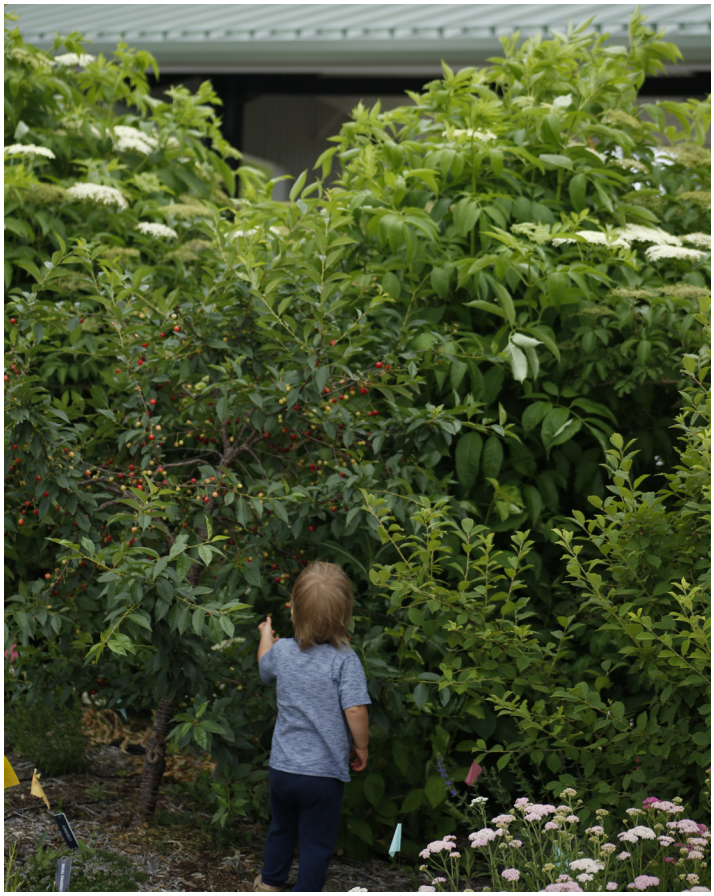
- **Wind direction and intensity**
  - Wind rose maps
- **Sun and shade (over a day and as it changes with the seasons)**
  - Photone App to determine light and shade quality and quantity
- **Observed wildlife, whether wanted or unwanted**
  - LandPKS Software
  - Existing pest issues
- **Existing and historical vegetation** ("weedy" plants and other indicator species' diversity and abundance)
- **Noise, odor, contamination**, or other "problems" in and around your site
- **Built infrastructure**: existing below and above ground utilities
  - 811: the national "Call Before You Dig" hotline
- **Community:**
  - **Engagement:** identify community groups, initiatives, and organizations that could be involved in the forest garden, if desired.
  - **Legal authority over the land:** determine who has legal authority over the use of the land and how that may change over time. An attorney or assessor can assist with this.
  - **Zoning and City Ordinances:** understand what activities are allowed and prohibited in your designated forest garden area.

Inventory your resources

Take stock of the resources you already have access to, as well as the resources you will need to fulfill your goals and objectives. Resources needed for implementation and management, depending on your scale and existing context, may include:

- Financial resources
- Secure access to land
- Crop insurance and/or event insurance
- Access to utilities (water, electricity, septic, trash, etc.)
- Built infrastructure (e.g., storage shed, hoop house, cold frames, etc.)
- Cold storage for produce
- Educational materials (e.g. signage, plant identification labels)
- Tools and equipment
- Organic substrates: soil, mulch, compost
- Plant materials: starts, seedlings, and seeds
- Labor, time
- Knowledge and expertise
- Certifications and licenses
- Business or organization management skills
- Community support

Municipalities often have public mulch sites, "re-stores" with gently used building supplies, and an abundance of recycled materials like cardboard that can be used for



The Columbia Center for Urban Agriculture's (CCUA) community forest garden supports an abundance of edible and medicinal species. Pictured here: American elderberry (used as a visibility screen for the parking lot); sour cherry, nanking cherry, yarrow, and creeping thyme.

suppressing weeds. Communities can also provide resources such as volunteer labor, shared equipment, or other shared resources, including propagated plant materials and space.

Map the site with zones and sectors

Mapping with "zones" and "sectors" is a reference to permaculture design practices that can be a helpful way to spatially assess opportunities and limitations.

Zones refer to the frequency and intensity of human interactions, from "zone 1", an area of interaction multiple times a day, to "zone 5", an area very rarely visited. These spatial boundaries can be fluid, but are generally related to proximity to a central hub, a home, or access points. By pairing the most management-intensive and convenience-oriented elements of your design with areas likely to be more frequented, you will achieve more energy efficient patterns of use.

Sectors describe the physical, biological, and additional "external" elements of the site. This can include sunlight and shade patterns, seasonal wind direction and intensity, precipitation and the movement (or stagnation) of water, and other attributes that require observation and attention over time. This guide includes a set of tools and resources that can help you begin to layer each of these components as part of a holistic site assessment.

These considerations are not exhaustive of the many factors that contribute to a well-designed forest garden. In the sections that follow, we will focus on the ecological components of forest garden planning and design.

Ecological Design

Species selection

Your goals, in combination with the site characteristics, available resources, and contextual limitations, will largely determine what species best fit the garden space. Many plants provide multiple types of harvests and additional benefits simultaneously. In addition to edible and medicinal plants, you may consider selecting species that provide aesthetic value to your site, serve as windbreaks, provide habitat for wildlife, attract pollinators, fix nitrogen and build healthy soil, or do all of the above. Consider your climate, USDA plant hardiness zone, land-use history, and also resident vegetation when deciding what species to plant in your forest garden. When possible, choose native and naturalized plants, or plants bred to have natural disease resilience. Another consideration when selecting species is climate change. Because forest gardens involve



Example of a map drawn with zones and sectors for site planning using permaculture design. Credit: Dana O'Driscoll, The Druids Garden.

planting perennials that will stay in the ground for years to come, select species that are expected to do well in the face of projected temperature and weather extremes.

The layers of a forest garden

Forest gardens are designed to mimic the structure and composition of early successional forests, which are characterized by higher structural complexity (multiple "layers"), higher species diversity, and higher productivity. The "overstory" layer refers to the uppermost layer of growth. The "understory" refers to any lower layer of growth in the forest garden ecosystem. Unlike forests that have reached a more mature stage of succession, in the earliest stages, tree canopies do not dominate the site. Overstory trees and understory trees are spaced widely enough so that light can still penetrate to understory layers, which allows a wide variety of plants to thrive within multiple vertical layers. Following this pattern, forest gardens can include up to eight layers of vegetation that each inhabit a unique niche of light or shade in the space. In each layer, plants can be selected for their multiple functions: as a source of harvestable food, fodder, medicine, or ornamentals (fruit, nuts, foliage, roots, flowers etc.), to attract pollinators and other beneficial insects, to fix nitrogen or accumulate important micronutrients from deeper soil strata, and to serve as structural support and companions for other components of the garden's plant, animal, and fungi community.

Below is a basic list of the distinct vegetation layers most common in forest gardens, though often their attributes overlap. Within each layer, examples of species selections are provided. Please note that these selections are suitable for much of the Midwestern U.S. and may not be appropriate for other regions.

1. The *overstory or canopy layer* is the uppermost layer of foliage. It typically consists of trees that will grow to around 25 - 100 ft (7 - 30 m) in height. This layer regulates the microclimate below by providing the greatest amount of shade. Ex: black walnut, hickory, pecan, mulberry, persimmon.
2. Below the canopy is an *understory tree or midstory tree layer* of smaller trees 7 - 25 ft tall (2 - 8 m). Ex: pawpaw, dwarf fruit trees (apples, pears, peaches, plums, cherries, etc.), hazelnut, serviceberry.
3. A *shrub layer* consists of woody perennial bushes, shrubs, and brambles 3 - 10 ft tall (1 - 3 m). Ex: blackberry, raspberry, aronia, currant, blueberry, gooseberry, nannyberry, spicebush, witch hazel, elderberry.
4. An *herbaceous crop layer* consists of shorter upright plants that will occupy the space below and between woody trees and shrubs, including perennial and annual plants. Both cultivated and volunteer plants can benefit the above- and below-ground living communities. Depending on the density of shade cast by the trees above, these plants need to be well-adapted to shade. Ex: sochan, comfrey, chives and wild onions, asparagus, monarda, lemon balm, yarrow, dittany, wood nettle.
5. The *groundcover layer* consists of low-lying vegetation that can reduce weed pressure and regulate soil moisture. Plants in this layer can include sprawling herbs, mosses, or shade-tolerant low-growing cover crops, fruits and flowers. Ex: strawberries, oregano, clover, purslane, chickweed, dandelion, wild ginger, violets.
6. A *vine layer* of climbing plants can inhabit the vertical infrastructure provided by trees, shrubs, and other strong-stemmed plants, so long as these climbers do not damage or harm their upright host. Ex: groundnut, hardy kiwi, grapes, maypop, pole beans, peas.
7. A *root crop layer* is intended to fill an underground niche where space allows, including both perennial and herbaceous tubers and taproots. In many cases, these plants, like those in other strata of the garden, can inhabit multiple layers at once. Ex: wild leeks, ginseng, goldenseal, perennial onions, sunchoke.
8. Finally, a *fungi layer* can be included as an additional harvest from mulch under the shade of multiple layers of vegetation, or incorporated as log-grown culinary mushrooms in shaded spaces with easy access for harvest. Ex: winecap, oyster, shiitake, maitake, blewit, and others.

When making your selections, consider incorporating native species as much as possible. Native plants are adapted to local conditions and are more likely to thrive in the local environment with fewer inputs. These plants also provide food and habitat for local wildlife such as birds, butterflies, and other insects, promote biodiversity and contribute to resilient and diverse landscapes. In urban areas, where habitat tends to be more limited, this

food and shelter is particularly important. Native plants also support populations of natural insect predators, which contributes to integrated pest management and reduces the need for pesticides. In many states, publicly funded native plant nurseries supply low-cost bare root saplings. Consult with local Extension staff, horticulture and conservation groups to identify nearby reliable nurseries and other sources of needed plant materials.

Spacing and arrangement

Because forest gardens contain multiple layers of vegetation in one unit of space, competition for light, water, and nutrients will occur between species in addition to their potential complementarity and companionship. Careful consideration of spacing will reduce competition and ensure the health of the entire system, allowing all layers of vegetation to thrive. Plant trees and shrubs far enough apart to allow sufficient light to reach the plants below. General guidelines for spacing woody species in a forest garden are as follows:

1. Look up spacing recommendations for each tree species you intend to include; these are typically based on the expected mature canopy diameter of the tree and the space needed to reduce pest and disease pressure. Local Extension professionals and their horticultural guides can be a great starting place for this information. Consider adding 30-50% to the recommended spacing to ensure that tree canopies will not dominate the overstory as they mature. This can be used as a minimum spacing guideline to determine the number of overstory trees your space can accommodate.
2. In spaces where management and equipment will operate best in rows, trees may be planted in a grid-like arrangement, or planted in rows that roughly follow the topography of the land in what is called a "keyline" design. This arrangement encourages the retention and redistribution of water along planted rows perpendicular to the lowest valley.
3. No matter how trees are arranged, it is important to organize plants into groupings that will be complementary to each other spatially and biologically. Make note of the estimated mature plant size and root habits to minimize long-term competition above and below ground.



Educational sign in front of blackberry trellis at CCUA's forest garden site. The native plants selected for this site require lower maintenance while yielding an abundance of fruit and wildlife habitat.

4. Consider the space needed for harvest and care. Where garden users are willing to navigate more complex plantings, spacing can be more condensed, but if the garden is intended for educational purposes or large groups of people, sufficient paths and interpretive signage will be necessary.
5. Add understory shrubs, herbaceous plants, and additional layers between and below the canopy trees with consideration to the long-term changes in light/shade and accessible space. As understory plants propagate themselves (by seed or rhizome), they will self-select over time toward the individuals and spaces best suited to your growing context, which will result in an increasingly productive and resilient system.
6. Remember that any initial plantings may be removed or thinned as the forest garden grows. Ultimately, aim to have every square foot of soil eventually covered with vegetation for maximum production and ecological benefit. A denser initial planting will reduce competition with unwanted volunteer plants while light is less limiting, and can encourage a healthy soil microbiome. Nitrogen-fixing or nutrient-accumulating plants can be particularly helpful to include at the start to support soil health while trees are becoming established.

These basic guidelines are a starting place for designing your planting layout, but close observation and

interaction with the space will allow you to modify your design over time. Refer to your community for input about accessibility and safety.

Grouping with guilds

Light, water, and nutrients are three critical resources that plants need to thrive. Given the multi-layer structure and diversity of forest gardens, it is important to remember that competition will occur between species for these resources. By grouping plants together intentionally, competitive interactions between species can be reduced and synergistic interactions between species can be increased. Intentional groupings of plants designed to maximize beneficial interactions are called "guilds." To reduce competition, think about selecting species that occupy different niches both above- and below-ground. To increase synergistic interactions, think about the complex benefits of each plant (i.e. pollinator habitat, nitrogen fixation, physical support structures such as tall trunks, shelter from wind, protection from heat, leaf litter, nutrient cycling, chemicals that repel certain pests, etc.) and group plants together so that they can benefit from one another.

- *Reducing competition for light*: lower forest garden layers (the herbaceous crop layer, groundcover layer, vine layer, and root layer) will be shaded by overstory trees and shrubs. Therefore, shade-tolerant species should be selected for lower forest garden layers. Alternatively, overstory trees can be spaced to allow light to penetrate to the understory, or tree species with more open canopies can be selected so that more light reaches understory layers. Pruning overstory trees not only benefits tree health, but also increases the amount of light allowed through their canopy.
- *Reducing competition for water and nutrients:* trees and shrubs with large root systems should be planted at sufficient distances from other trees and shrubs in order to avoid below-ground competition for water and nutrients. Combine larger overstory trees and shrubs with plants that have more shallow root systems (some herbaceous crops, groundcovers, vines) in order to avoid competition for below-ground resources. By the same principle, plants have unique nutrient needs, so a "heavy-feeder" like melons or asparagus could be paired with a nitrogen-fixer legume like clover or peas. In general, by following companion planting guidelines, you can select species that spatially and biologically complement each other, rather than competing.

When possible, plant species combinations that provide mutual benefits and promote the overall health of the forest garden system. For example, some plant species require pollination but do not innately attract pollinators themselves, and they may benefit from neighboring plant species that attract pollinators. Some plants, such as onions and the aromatic herb basil, drive pests away from companion crops. Structurally, consider how plants will grow and take up space over time. Eventually, it may be necessary to thin overstory and understory trees to ensure that lower layers receive sufficient light. Alternatively, you may choose to replace sun-loving herbaceous plants with those that thrive in shade.

Installing and Maintaining a Forest Garden

Forest gardens are inherently complex, and they often occupy small spaces. Because of this, they can be difficult to mechanize, often relying on hand-labor or small specialized equipment. Management tasks such as soil preparation, seeding, pest and weed management, pruning, thinning, and harvesting will look different in forest gardens than on larger production farms. Attentive establishment measures and preventative maintenance



Strawberries are planted around young berry shrubs in CCUA's forest garden.

are always preferable to reactive measures, but you can expect management in a forest garden to be relatively intensive.

Spacing and arrangement

When establishing a forest garden in damaged or degraded soils, it is common to plant "nurse" species first, sometimes in the years prior to planting other trees and crops, in order to increase soil fertility by fixing atmospheric nitrogen into soluble nitrogen in the soil. Nurse species are typically hardy, fast-growing native or naturalized species that are adapted to the local environment, and thrive with fewer water and nutrient inputs. They can also quickly increase soil organic matter by producing large amounts of above- and below-ground biomass, including branches, leaf litter, mulch, and root slough. When nurse plants begin to compete with other important forest garden crops, they can be coppiced or removed, as they've done their job of preparing the site for healthy longer-lived trees.

Before planting, be sure that the growing medium (soil, mulch, compost) will support what you intend to grow. Nurse plants, cover crops, and existing vegetation can serve to self-correct nutrient imbalances over time, but additional and ongoing amendments may be required for permanent plantings. Test your soil's pH and available nutrients and amend the site with compost, manure, mulch, organic fertilizers, or topsoil as needed. Imported materials always carry the risk of introducing unknown contaminants to your site, so bring in materials only from trusted sources, and source locally as much as possible.

Remove unwanted biomass and prepare the planting site for establishment. When transferring any species from a container, if the roots have become pot-bound, loosen them manually. The root collar of any woody plant should be just at ground level with space on all sides for backfill soil and compost. Ensure that the soil surrounding the newly established plant allows for roots to penetrate without any air gaps; to do this, step gently around the base of the planted tree to compress these gaps without compacting. Once planted, monitor the health of transplants during this time of stress and transition. Mulch, irrigation, and protection from hungry critters (e.g. tree tubes) is critical in the early years of establishment.

Water considerations

As you plan your forest garden, seasonal precipitation and the movement of water should be mapped as a sector. Consider at the outset of your design process where water is coming from (e.g., large impervious surfaces collecting and directing runoff) and where you need it to go. The management of water can have major implications in your design.

The movement of water on a site is affected by its sources, by soil qualities, and by the topography or slope and elevation. Earthworks can be applied to a site to modify the shape of the landscape and therefore the movement of water. Swales, berms, terraces, and ponds are all examples of earthworks that can be used to slow the flow of water and capture it where desired, reducing the need for irrigation in a forest garden. Perennial plantings can both benefit and be benefited by this type of earthwork; trees planted on berms can help stabilize moved earth and the berms can serve as a space with increased drainage adjacent to higher concentrations of water in the nearby swales.

In most of the US, some irrigation or hand watering will be necessary to establish and maintain a thriving forest garden. Where rainfall is regular, irrigation might only be needed during establishment, or to supplement rainfall during dry months. As weather patterns become less predictable, resilience to both droughts and floods will be important in your structural design and plant selections. Forest gardens are naturally well adapted to catching and storing rainfall in soil and plants, but



An early photo of the CCUA forest garden. Flags indicate planned companion plantings. Cages protect young trees.

additional measures can be taken to further prepare for variable precipitation, including the installation of rain barrels and rain gardens, or, for dry conditions, applying xeriscaping, mulching, and efficient drip irrigation systems.

Because of their structure, many forest gardens can be susceptible to mold issues such as powdery mildew, and excessive moisture can exacerbate this problem. Spacing and design that allows for air flow will reduce this risk, along with avoiding overhead irrigation, which can create moist conditions on plant leaves.

Reducing weed pressure

Unwanted plants can present a challenge in forest gardens, as with any agricultural system. Many of the plants typically considered "weeds" in annual gardens actually play important roles in remediating soil and can provide an abundance of food and medicine. However, the presence and movement of invasive plants can have serious negative consequences. Where time and labor allow, removal of above and below ground invasive plant biomass is an important first step. Seed banks in the soil may persist, however, and the following options for organic weed management can support long-term control:

- *Occultation*, in which dark plastic tarps or landscape fabric is laid down over weeds for 6-8 months.
- *Solarization and biosolarization*, in which clear plastic is sealed over weeds for two weeks to one month.
- *Tillage*, in which weed roots and rhizomes are broken up and killed. In small spaces, this can be done with hand tools.
- *Mulch and compost*, which block sunlight from reaching weeds. Mulch can be obtained for free from tree trimming services in many urban areas.
- *Sheet mulching* in which cardboard and mulch are layered on top of one another to prevent light from reaching weeds.
- *Mowing* with lawn mowers, weed wackers, and other small equipment.
- *Grazing animals* such as chickens, sheep, pigs, if allowed by local ordinances.
- *Cover cropping* with groundcover that smothers and replaces weeds. In forest gardens, edible cover crops such as winter peas, oregano, mint, etc. can be used both as weed control and for harvest.

Pest and disease management

As with any agricultural system, pests, wildlife, and pathogens exist in a forest garden. Integrated pest management (IPM) principles and preventative measures can facilitate organic pest and disease control. Preventative tactics involve annual pruning, avoiding overhead irrigation to reduce the likelihood of mold, planting native and flowering plants to attract beneficial insects, maintaining high levels of plant diversity, frequent sanitizing of tools, and monitoring for early detection of a pest or disease. If an infestation or outbreak does occur, consider attracting beneficial insects, using traps or trap crops, and using organic alternatives such as diatomaceous earth or dormant oil sprays (for insects), hot pepper spray (for other wildlife), or copper sprays (for fungi, bacteria).

Always consult a trained specialist before taking measures that may affect any forest garden inhabitants. University Extension horticulture specialists and USDA technical staff will be able to direct you to resources specific to your needs and circumstances.

Conclusion: Inspiration to Action

Forest gardens can be incorporated into any number of open spaces: backyards, neighborhood parks, schoolyards, spiritual gathering places, small farms, or underutilized lots. Because of their diversity both socially and ecologically, there is no definitive blueprint or design for forest gardening. Opportunities and limitations presented by the environment and its inhabitants often define a forest garden's structure and purpose.

Consider, for instance, land ownership. Whether rural or urban, legal authority over the land may change over time. If the longevity of the forest garden and the long-lived perennial plants established there is of concern, a land trust or long-term lease arrangement can help ensure that goal. Agrarian Land Trust is a prime example of community trusts rooted in land stewardship. For long-term lease guidance, check out the Savanna

Institute's downloadable Long-term Lease Workbook and case studies. Also consider the history of land-use in your area; what natural plant communities will the soil and climate support? How might a changing climate affect the composition of that community? As much as possible, when steps can be taken to proactively anticipate needed changes (fro=m the beginning and throughout the life of the forest garden), these enduring spaces will be more likely to thrive. Ultimately, each of these decisions will contribute to the legacy that grows from these efforts, as perennial harvests and as insights about what is possible when deep roots are nurtured.

The benefits of forest gardens have been documented around the world, from food production that contributes to critical supplies of fresh fruits and vegetables, to mental health and well being for those who interact with the sites, and education that combats "plant blindness". The designs, species, and benefits of forest garden spaces are diverse and plentiful, contributing to the health of ecosystems and communities in innumerable ways.

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FOREST GARDEN REVIEW

1. **Community forest garden design and management requires consideration for the following. Select all that apply.**
    A. The long-term success of forest gardens depends upon planning and design that takes into account not only the unique growing conditions of a site, but also the social dimensions and needs of those who will interact with the space.
    B. Forest gardens are designed to mimic the structure and composition of early successional forests, which are characterized by higher structural complexity (multiple "layers"), higher species diversity, and higher productivity.
    C. Community forest garden planning should avoid involvement of civic organizations in order to reduce risk of potential visibility of ordinance violation
    D. Because forest gardens involve planting perennials that will stay in the ground for years to come, select species that are expected to do well in the face of projected temperature and weather extremes.
    E. Land tenure and potential development pressure are of particular concern for community forest gardens in expanding municipalities. Silvopasture is the deliberate integration of trees and livestock on the same unit of land.
2. **What are some of the benefits of community forest gardens for both for human and wildlife communities?**
3. **Identify a few of the key questions to ask while beginning to organize and plan a community forest garden.**

ANSWER KEY

1. Correct answers include A, B, D, & E.
2. Some of the benefits of community forest gardens include: supplementing an individual's, family's or neighborhood's nutritional needs, producing a wide variety of harvestable crops for food, medicine, and craft, sequestering carbon dioxide from the atmosphere, providing critical habitat for wildlife, helping to regulate micro-climates, mitigating the "heat island" effect, buffering unpleasant odors, beautifying the built environment, and facilitating community connections.
3. A few of the key questions to ask while beginning to organize and plan a community forest garden include: What is the purpose of the forest garden? Who is the forest garden intended to serve? How will decisions be made about the site? Who will be involved in maintaining the garden and how will they safely participate? How will you facilitate understanding and interpretation of the forest garden?

Prioritizing accessibility and education in Columbia's community forest garden



At a glance: The Columbia Center for Urban Agriculture (CCUA), a nonprofit based in Columbia, Missouri, maintains a community forest garden nestled in Columbia's Agriculture Park, a public-private partnership with the City of Columbia that also includes vegetable production fields, a water detention basin with native edible landscaping, and the farmers market pavilion.

Overview: A winding pathway through the forest garden invites people to walk through and learn about the planted species. The primary goal of this diverse demonstration planting is to educate and empower community members to diversify their diets or learn to care for similar species and systems in their own backyards. Over 40 tree and shrub species are featured in the forest garden, such as apple, bush cherry, elderberry, gooseberry, pawpaw, serviceberry, persimmon, currant, aronia, pecan, sugar maple, and hardy kiwi. Non-woody species in the lower strata of the forest garden include sorrels, chives, strawberries, hairy mountain mint, wine cap mushrooms, native wildflowers, and more.

Establishment: When establishing the forest garden, the most prevalent obstacle was the soil. The planting site had a hardened clay pan covered in aggressive Bermuda grass. Following a plan developed by the Kerr Center, CCUA staff chisel plowed to expose Bermuda grass rhizomes to freezing temperatures in the winter, seeded a perennial grass cover crop mix to enhance the soil and mowed it after one year's growth. Then, they lasagna gardened/sheet mulched to create a productive top layer. Bermuda grass and bindweed have continued to pop up in areas of the garden that were planted less densely, so staff continue planting these areas to deter weeds.

Design and management: The CCUA forest garden is divided into approximately 40 plant groupings or "guilds," and several of these were based on templates from *Integrated Forest Gardening* by Ruddock, Halsey, and Weiseman as well as the Missouri Prairie Foundation's Grow Native! landscape plans. A central goal for the garden is to fill all available biological niches in a 7-layer design, meaning the trees, shrubs, and low-lying herbaceous plants were co-planted in a way that utilizes maximum available sunlight, covers the ground, and benefits each plant in the guild. For example, native plants and herbs planted around the trees allow their feeder roots to access the aerated zone close to the soil surface and alliums planted by several fruit trees help with pest deterrence. Matthew, Dolan, CCUA's forest garden manager, says that the garden is an ever-changing system. While all the plants in the food forest currently enjoy full sun, more shade-loving plants will be introduced as the trees grow.

Pests are also a concern, and CCUA staff have experimented with various tactics to combat them. For example, they've applied a concoction of parasitic nematodes, clay, and cow manure to the trunks of stone fruit trees to control a Peachtree borer infestation. They've also coated the bases of Nanking cherry bushes with a plaster, neem, hot pepper blend to deter rabbits from eating the bark, and a kaolin clay, neem oil, and soap spray to brassica plant sto reduce Harlequin beetle damage.





Intensely managed areas of the forest garden utilize a ¼ inch drip line that winds around the plants, though this is typically only used in times of drought or when plants are newly established, as CCUA finds that the sheet mulch layer within the garden is highly effective at retaining moisture.

Labor and maintenance: CCUA credits much of its success to its fundraising campaigns and dedicated volunteer community. Around 2-3 of CCUA's weekly volunteer shifts are dedicated towards maintaining the forest garden. A recent program has also allowed volunteers to 'adopt' specific portions of the food forest, which has shown promise as a method to meet the maintenance needs of the garden while also giving the community a feeling of ownership over the space.

Chapter 9: Agroforestry and Wildlife

Chapter Highlights

- Agroforestry practices such as alley cropping, windbreaks, riparian forest buffers, silvopasture, and forest farming provide opportunities to manage for a diversity of habitats that benefit wildlife.
- Agroforestry can be used to reduce the negative consequences of landscape fragmentation by lessening habitat isolation through the use of plantings that are well thought out and well-connected with other habitats.
- Understanding the plant and wildlife communities that exist on a particular parcel of land, paired with an understanding of the land steward's time and resources available for habitat restoration and maintenance, are essential initial planning steps for any conservation-minded operation.

Wildlife Benefits in Your Agroforestry Operation

Regardless of what a farmer does on their land, including nothing, there are both positive and negative effects on wildlife. Many of our current agricultural practices, particularly those associated with larger farms and the associated increase in size of equipment, has drastically reduced the quality and quantity of available wildlife habitat. Agroforestry practices offer an opportunity to both provide benefits to wildlife as well as quality timber production. Many farmers view wildlife as an important byproduct of their land management activities, particularly wood production. Agroforestry practices' diverse plantings result in structural and spatial diversity. It is this species and structural diversity that is beneficial to wildlife.

The benefits received from wildlife are at least fourfold, including 1) aesthetic, 2) ecological, 3) economic, and 4) recreational benefits. Migratory birds, such as wood ducks and yellow warblers provide ample pleasure to the observer. Bees and flies are important pollinators in agroforestry systems, while foxes and weasels are important predators of seed-eating mice and others. Farmers can also benefit from agricultural tourism by welcoming birders, bicyclists and families that are interested in visiting the farm to teach their children about food onto their land. Another tourism opportunity is a hunting lease, which gives a hunter access to land to pursue wildlife. Ultimately, wildlife provide 1) endless opportunities for the amateur naturalist to learn about the interconnections among plants, animals, and their surroundings, 2) a plethora of photographic opportunities, and 3) entertainment at feeding stations.

What do I need to consider about wildlife and agroforestry?

For wildlife to be present, their basic needs must be met, including food, water, shelter and space. A shortage of any of these elements will severely limit the numbers of a given wildlife species that are able to be supported on a given property. In addition, many wildlife species have complex needs that include 1) the need for multiple habitats during their life cycle, 2) the need for different food items based on their age, 3) the difference in behaviors of the species between the breeding and non-breeding seasons, and 4) an annual migration of many birds, as well as some mammals and insects each year to warmer climates, where someone else is managing their habitat.

Types and amounts of wildlife that will benefit from agroforestry practices are dependent on the size of the agroforestry area, surrounding land uses, types of plantings, configurations of plantings, age of plantings, and the juxtaposition of different habitat types. Some wildlife species are known as area sensitive, needing large, contiguous areas of habitat in which to live. Other wildlife species thrive where there is a lot of edge habitat, the area where two habitat types intersect. Some wildlife species are *specialists*, animals that are reliant on just one or two food sources, for example. Others are *generalists*, animals that can either feed on a large variety of foods, live in a variety of different habitat types, or

Summary of Benefits

- **Aesthetic**: Wildlife provide auditory and visual beauty, and recreational interest.
- **Social**: Wildlife help provide a sense of place that attracts families, photographers, birdwatchers, hikers, hunters and anglers.
- **Ecological**: Wildlife diversity generally indicates high-quality habitat. Some animals provide soil aeration services, such as moles and ants; others disperse seeds and pollinate plants, such as birds and insects.
- **Economic**: Wildlife can provide you with an economic return when you open your land to recreation (e.g. birdwatching, hunting, guiding or agritourism). Indirectly, pollinators provide billions of dollars of pollinating services, and bats provide billions of dollars in insect "pest" control.

both. These characteristics of wildlife will partially determine the feasibility of their management in your agroforestry operation.

Geographic scale, or size, of both agroforestry areas and surrounding land use is an important factor in wildlife habitat management. The scale of agroforestry practices, typically 4-8 ha, is small enough that managing for many wildlife species is impractical. This includes larger-bodied animals and area sensitive species. If your agroforestry practice is embedded in a larger matrix of suitable habitat, it may be possible to benefit many large wildlife species. However, there are many smaller-bodied animals that can be managed within smaller areas.



Agroforestry practices embedded in some habitats can lead to negative impacts on current wildlife populations. The linear and fragmented makeup of many riparian forest sites can lead to a decrease in the different types of small mammals inhabiting an area, as well as birds, reptiles and amphibians. In some cases, the increase in habitat and reproductive success for songbirds can be negated because of an increase in nest predation. Importantly, landscape context matters when managing for wildlife. The wildlife benefit derived from agroforestry is directly related to the surrounding habitat matrix.

Fragmentation, or the isolation of habitats, poses another issue for wildlife. Whenever possible, it is preferable to restore larger fragments or more connected fragments of habitat than to restore many small and isolated fragments. Cowbirds reflect an important example: cowbirds lay their eggs in other birds' nests. Many songbirds are naive to this sort of "parasitic" behavior and will work to raise the larger and louder cowbird chick(s) at the expense of raising their own offspring. The rates at which cowbirds parasitize the nests of forest songbirds typically decline with distance from forest edges. Fragmentation also limits dispersal in amphibians and thereby decreases their opportunities to fully occupy wetlands. For wildlife to thrive, it is important to maintain or recreate habitat connectivity within a larger geographic area. Agroforestry practices can be used to reduce the negative consequences of fragmentation by lessening habitat isolation through the use of plantings that are well thought out and well-connected with other habitats.

A final consideration pertaining to habitat fragmentation and isolation is source and sink population dynamics. When installing agroforestry practices, it may prove to be very inviting to wildlife species, and in fact, be heavily used by wildlife. However, when such practices are isolated from other suitable patches of habitat, they can serve to increase predator use of the area and thus lead to an overall reduction in the prey species. This is because as the prey species disappear from the site, it becomes open and available for others of its kind to move in, thereby further increasing predator use of the area, and leading to another reduction or disappearance of the prey species from the area. This can be compounded when the site is irregularly shaped, which increases the amount of "edge" habitat which makes the prey species more vulnerable to predators.

The potential wildlife benefits that can result from your agroforestry operation are contingent upon your own goals and objectives for your property and the investment that you can and will make to integrate wildlife benefits with your timber and agricultural production. To maximize benefits to wildlife, a producer can slightly modify plantings and select plants that meet the needs of wildlife species with little impact to the production of forest products or field management. With careful selection of trees and shrubs, you can support wildlife while diversifying your returns. However, it is important to note compromise is inherent when you are balancing tree growth, crop production, and wildlife management. A strictly economic cost-benefit analysis is unlikely to result in favoring wildlife-focused land management. However, it's the previously mentioned benefits of wildlife that help to balance the scales. In some instances, discussed later in this chapter, it is also possible to earn some economic return on an investment in supporting wildlife habitat.

What lives here and nearby now?

The first step in constructing a wildlife management plan for your agroforestry area(s) is to conduct an inventory of the wildlife species present on your land. It is advised that you conduct an inventory prior to goal and objective setting, because your goals and objectives should consider the wildlife that is currently on the property. Your interest along with the amount of time and energy you have available to invest, will determine the frequency you go out to observe wildlife and therefore the completeness of your inventory. A good first step in conducting your inventory is to download an aerial map of your property or create your own map of your existing structures, crops, standing timber, and water features. This will be the foundation for your efforts to monitor wildlife. Spending time in the field to identify trees, shrubs and important understory plants will add detail to your map and provide information regarding current food, water and cover resources available to wildlife. Standard methods are available to inventory mammals, birds, amphibians and reptiles on your property. Some insect groups, such as butterflies and moths, are more easily observed and identified than others. Some wildlife species are active when people normally are during the day, and are thus more easily observed than species that are active mainly at night. Some species are year round residents, such as nuthatches and cardinals, while others are only in the area for part of the year such as yellow-rumped warblers and kingbirds. To be able to document the greatest percentage of wildlife that are currently using your property, it is necessary to get out in different seasons and at various times during the day. Citizen science programs and trainings in your area can provide you with the skills, checklists and sometimes even the equipment you need to inventory wildlife on your property. These events will also provide you with opportunities to meet like-minded individuals and the instructors running the trainings, and perhaps garner some assistance in your inventory work. Once you know what plants and wildlife already frequent your property, as well as the time and money you have and are willing to invest in a wildlife management plan, you're ready to define your goals and objectives.

Setting Goals and Objectives

You are more likely to meet with success in increasing wildlife on your property if you have clearly identified goals, and both short and long-term wildlife objectives. Your goals and objectives will guide you in your management activities and subsequent monitoring of wildlife populations on your land to help maximize the return on your investment. The identified end goal of your wildlife management e.g. to harvest deer, will influence the sorts of agroforestry practices you implement to meet your goal. In defining goals and objectives for wildlife, it's important to remember that as your agroforestry areas age and the structure and plant composition of these areas change, the wildlife species composition will also shift over time. As your forests mature, those wildlife species that are dependent on young, or early successional forest habitat will decline while species that are dependent on mature forests will appear and increase in number. For example, in very young stands, we can expect species such as quail and field sparrow to thrive, while in more developed stands, it is more likely that birds such as brown thrashers and northern cardinals with benefit. When the stand reaches maturity (30-60 years), species that are dependent on mast will increase, such as white-tailed deer, whitefooted mice and tree squirrels. The point is to recognize that wildlife species and benefits will change as your plantings mature. Knowing this from the beginning can lead to setting realistic goals and can reduce later disappointment.



> "Rabbits can cause considerable damage in agroforestry. Dugger et al. (2003) found that damage to oaks planted in plots with natural vegetation was greater than in plots that had been planted to redtop grass (85% of the bareroot seedlings clipped and 31% of the bareroot seedlings clipped, respectively)."
>
> **–Millspaugh et al. 2009**

Your wildlife objectives will guide you in your choice of trees to plant, distance between plants, cover crops, and even the configuration of your fields. Some options may be more economically viable than others, while some options may give rise to more wildlife viewing opportunities. Another point regarding the setting of wildlife goals and objectives is to consider some of the potential downsides of managing for wildlife.

Wildlife can and may cause considerable changes perceived as damage. Eastern cottontail rabbits and white-tailed deer routinely feed on tree and crop plantings, as well as ornamental plants and even weeds. While rabbit damage is easily identified by the clean 45° cut made, white-tailed deer damage can be identified by the ragged ends they leave behind. During the summer, rabbit and deer damage to woody vegetation is minimal because of the abundance of green, leafy vegetation available, but they can do considerable damage to seedlings and saplings during the fall and winter. In addition to feeding on woody stems, male deer will rub their antlers on seedlings and saplings, sometimes knocking stems completely out of the ground or leading to misshapen boles and decreased wood value.

There are many methods available to reduce rabbit and deer herbivory in agroforestry plots. These range from fencing, which can be 100% effective but can also be quite costly, to protecting individual stems using plastic mesh tubes or shelter tubes (note that shelter tubes affect the micro-climate within them which is warmer and more humid during the day). Fall mowing may be effective in reducing rabbit herbivory because of the elimination of winter cover. Keep in mind that even a relatively small patch (< 10m2) may contain rabbits.

Agroforestry practices as habitat

Managing a diversity of habitat types will also tend to promote a diversity of wildlife. Agroforestry practices such as alley cropping, windbreaks, forested riparian buffers, silvopasture, and forest farming will provide you with opportunities to manage for a diversity of habitats that may benefit wildlife. Trees and shrubs can enhance wildlife habitat as well as provide additional products on the farm.

Alley cropping

Alley cropping systems are designed to grow an annual crop between rows of high value trees, like oak, pecan or walnut, until the trees are harvested or the alley crops are shaded out. Alley cropping diversifies plant structure for wildlife habitat. Such structure is important for birds, and the matrix of trees and crops provide travel corridors for mammals and reptiles. You can optimize benefits to wildlife by carefully choosing the agricultural crop to be planted and its configuration. Once the trees have matured to the degree that they are shading out the crop, that habitat becomes important for amphibians, which must travel from one activity area to another without drying out. herbaceous wind barriers) create a conservation approach to tolerating wide weather extremes.

Cover crops

A native cover crop mixture that includes native warm season grasses will benefit wildlife. Previous research in such habitat has garnered observations of greater bird abundance, species richness, and reproductive success.

Riparian forest buffers

Riparian buffers consist of streamside plantings of a mixture of grasses, shrubs, forbs and saplings, which are attractive to wildlife. While these buffers can serve as travel corridors for wildlife, they are not necessarily a good place for birds to reproduce, unless other high quality habitat exists nearby. These buffer strips can also be valuable as habitat and travel corridors for amphibians, but need to be about 100 m wide to protect stream amphibians. The tree canopy of buffers reduces water temperature, while roots and fallen leaves provide food and hiding places for wildlife. A potential downfall of streamside buffers for wildlife is that they can lead to reduced nest success in some birds, particularly grassland birds. These areas are most used by generalist birds.

Windbreaks

Windbreaks, plantings of trees perpendicular to prevailing winds, can protect soil, crops, live- stock, buildings and wildlife from harsh winds when properly designed and located. The microclimate that windbreaks create enables native insects to pollinate crops more efficiently. The size of the windbreak is often considered most important to bird diversity. However, it's important to note that birds that benefit the most from windbreaks are forest-edge and generalist species. Windbreaks have been reported to have negative effects on grassland birds due to higher predation and cowbird parasitism rates. Some mammals, such as white-tailed deer and cottontail rabbits benefit from windbreaks because of the mix of food and cover available. Windbreaks are most beneficial to wildlife when they are large and provide a diversity of structure, including both deciduous and coniferous trees, shrubs and a diversity of understory grasses and forbs.

Silvopasture

Silvopastures combine trees, forage and livestock in an intensively managed system. Silvopastures are typically less diverse than a natural forest understory, but incorporating clumps of native grasses and forbs can provide quality habitat for wild turkey and other animals.

Forest farming

High value specialty crops like ginseng and goldenseal can be cultivated under the protection of a forest canopy. This provides a harvestable product for the farmer which is an incentive to keep the land in forest habitat. The diversity created by forest farming attracts a variety of wildlife species.

Restoration of bottomland forests

Bottomland forests can be incredibly beneficial to wildlife because of the availability of mast from oaks and nut-producing trees, fruit from soft mass trees and the variety of structure provided by trees and shrubs. Bottomland forests are important for birds in every stage of development from grassland to mature forest. Recently a number of federal programs have aimed to restore some of the millions of hectares of bottomland forest that were converted to agricultural use in the 19th and 20th centuries. Although trees can be difficult to establish, newer techniques, which includes the use of larger seedlings with well-developed root systems, can increase the likelihood of planting success. Once established, oak species provide mast for waterfowl and deer and are favored foraging areas for spring-migrating and breeding warblers. Faster-growing tree species can also benefit wildlife by providing needed structure to forest songbirds. During the early years of an oak planting, this habitat will be used by a number of grassland species. By planting oaks in combination with fast-growing tree species that promote quick stand development, you can more quickly benefit and attract forest songbirds. The downside to this approach is that the taller trees provide perches for cowbirds, which leads to increased rates of cowbird parasitism on forest songbirds. However, the rates of cowbird parasitism are not only varied at the local level, but are also sensitive to regional and landscape effects such as regional forest cover.

Special applications

Many agroforestry practices have been adapted to help people and communities deal with problems, such as treating wastewater Photo - windbreak (pg. 132) and stormwater with fast growing willows and cottonwood trees. These trees also provide wildlife habitat and may be a future energy source.

Elements of Wildlife Habitat

Disturbance

Historically, fire, floods, wind, ice and wildlife browsing disturbed the land which in turn helped control invasive

species and promote native plant growth. Today, vegetation can be managed by mowing, disking, thinning, prescribed burning and grazing. The extent and timing of disturbances helps create diversity and structure. Timing can also minimize impact to wildlife, such as mowing after nesting is complete.

Vertical and horizontal structure

Different layers of vegetation allow an assortment of wildlife to utilize the same area. Each tier creates a niche in the habitat area. Five or more layers are optimal and include the canopy, understory, shrub layer, herbaceous layer and the floor.

Connectivity

Many species of wildlife need a minimum amount of a particular habitat type; if it gets to be too small they won't use it. Vegetation can be used to connect several small isolated areas within a landscape, thus making it more viable and increasing the usable space for wildlife.

Economic Opportunities Presented by Wildlife

Agritourism and hunting leases are just two of the ways in which you can diversify your farm income with wildlife. Agritourism in its broadest sense involves any agriculturally-based operation or activity that brings visitors to a farm or ranch. In the United States, it includes activities such as picking your own fruit, shopping at farm stands, horseback riding, honey or wine tasting, birdwatching, or learning about cheesemaking. The Whiterock Conservancy, in Coon Rapids, Iowa, provides an example of a working farm enterprise that has embraced agritourism in its mission. Its three-part mission includes: 1) Protect & Preserve the Natural Resources of the Middle Raccoon River Watershed, 2) Demonstrate Sustainable Multipurpose Land Management, and 3) Promote Low Impact Outdoor Recreation & Provide Environmental Education. Their approach to tourism is structured around education and stewardship, which emphasizes the diversity of the landscape managed with diverse methods and used by diverse audiences.

A hunting lease is an agreement between a land steward and a hunter or group of hunters, where the right to trespass and hunt is granted for a particular time and fee. Hunting leases are most popular in areas where little public land is available to hunt and access to private lands is at a premium. Before you delve into the world of hunting leases, it's important to consider what is reasonable to expect. The type and quantity of game animals depends upon not only your land, but that of the surrounding area. As your trees move through different phases of the growth cycle (i.e. seedling, sapling, mature tree), the type and extent of habitat available to game animals will change. The most profitable pay-to-hunt operations usually require the greatest investment in labor and management by the land steward.

Some general considerations when contemplating lease hunting include the following. To be effective and profitable, you need to have willing participants partake of the opportunity. It is therefore, suggested, that providing such opportunities near expanding urban and suburban areas will be advantageous. Another consideration is the "quality" of the hunting experience provided to clients. This includes cost of the lease, distance from the clients' homes, the abundance and variety of game animals, hunter safety, camping or lodging facilities and other amenities.

Finally, you'll need to consider what sorts of leasing opportunities will be available through- out your timber rotation. Early on, it may be that mourning doves provide an opportunity, but once the stand has matured, opportunities for turkey and white-tailed deer hunting will be available, which will require less intensive management on your part. The types of hunting leases are variable. In the past, many land stewards provided non-fee access with an informal verbal permission agreed to by a handshake. This may still be useful for managing nuisance populations, particularly if you don't want to invest the time or energy or simply are not interested in fee hunting. However, these agreements are becoming rare. They are most often still found in rural or rural-small town areas where hunters are more aware of farm-related issues and concerns. Another non-monetary hunting lease is an exchange of services, whereby a farmer allows hunting in exchange for a service such as the monitoring of land for trespassers or helping with farming operations. These arrangements can be either formal or informal.

There are four general categories of fee hunting:

1) daily lease;
2) short-term or season lease;
3) annual or multi-year lease; and
4) broker or outfitter lease.

A daily lease is often used when there is a relatively short hunting season and when a number of hunters can be accommodated on a small parcel of land. Most commonly, game species include pen-reared birds or mourning doves. This sort of lease is intensive for a producer to manage, requiring more interaction with hunters and more intensive wildlife habitat management to assure that game animals are available on the opening day of the season.

Short-term or season leases necessitate much less labor on the part of the producer. This sort of lease works best for species such as turkey or white-tailed deer. Some considerations for short-term leases include the use of equipment, such as blinds. You need to be sure that hunters do not use any kind of screw-in type of tree stand or climbing steps, which may damage the eventual value of the trees that you're growing.

In an annual or multi-year lease, a farmer enters into an agreement with a hunt club or a group of friends willing to share the cost of having long-term access to a hunting spot. An advantage to this sort of arrangement is that be the establishment of a long-term relationship with the land, the hunters may start to develop a sense of stewardship for the property and may ask to help conduct or participate in wildlife habitat management activities.

A broker or outfitter lease involves a middle man that rents all of the hunting rights from a land steward and then subleases to individual hunters by species or season. This alleviates a lot of the work by a land steward, who then only has to interact with one individual on all hunting related issues.

Regardless of the type of hunting arrangement that you enter into, one of the most important concerns for most land stewards has to do with liability. Most farmers fear being sued or held liable for injuries sustained by hunters or others while on the land. The degree of farmer liability differs by the status of the visitor or use, with trespassers being afforded the least protection and invited visitors, the most. A qualified lawyer and an insurance agent should be consulted before you enter into any hunting lease agreement or purchase liability insurance.

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Agroforestry In Action

UNIVERSITY OF MISSOURI CENTER FOR AGROFORESTRY

INTEGRATING AGROFORESTRY PRACTICES FOR WILDLIFE HABITAT

by **Dusty Walter**, *Director, Natural Resources Management, Director, Central Missouri REEC and* **Robert A. Pierce II**, *Associate Extension Professor and State Fisheries and Wildlife Specialist*

Agricultural practices and land-use decisions influence wildlife habitat and use by wildlife. Some actions can enhance habitats, while others negatively impact wildlife. Certain land-use practices have resulted in a decrease in the quality and diversity of available wildlife habitat on the farm. For example, more efficient farming practices, larger field sizes and the loss of field borders, such as those provided by windbreaks and brushy fence rows, have generally had a negative impact on habitat.

The agroforestry practices of forest farming, silvopasture, alley cropping, riparian forest buffers and windbreaks involve the deliberate integration of trees, shrubs and grasses with agricultural practices (crops and/or livestock). Benefits include:

- Opportunities for diversified income from value-added or alternative agricultural products
- Opportunities for long-term income, including timber sales
- Improved soil and water quality; reduction in nonpoint source pollution and erosion
- Enhanced wildlife habitat and biodiversity
- Sustained land resources for future generations

Agroforestry practices can be used to provide many benefits to a farm, such as improved water quality, soil stabilization and income opportunities. Agroforestry also can be used to provide diversity to a farm and enhance the potential to provide habitat for a variety of wildlife species.

When agroforestry is applied, the resulting land uses are often able to accommodate the needs of a variety of wildlife species – as well as offering opportunities for shorthand long-term income and environmental sustainability.

Through integrated combinations of trees, shrubs and grasses, agroforestry practices can provide a means to increase the availability of habitat for certain wildlife without sacrificing the potential to achieve a landowner's agronomic and economic goals and objectives.

The University of Missouri Center for Agroforestry, founded in 1996, works to

develop the science of using combinations of agricultural and forestry practices to achieve a more diverse, sustainable agricultural system. This collaborative effort is uncovering new information about the wildlife benefits of agroforestry practices through the use of alley cropping, windbreaks and riparian forest buffers, in addition to the alternative income opportunities the practices can provi

Wildlife habitat is the combination and environmental factors that requires for survival and reproduc includes the composition and struc vegetation on the land and e seasonal variation to that compo structure.

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Center for Agrofo

Read more about creating habitat for white-tailed deer, waterfowl, quail, wild turkey, and mourning dove in our technical guide on agroforestry and wildlife management.

Scan the QR code below or follow this link.

Floodplain restoration efforts for biodiversity and nutrient-density at the Missouri River Center

At a glance: The Missouri River Center (MRC) is a newly established collaborative conservation project in Huntsdale, Missouri. It's key purpose is to serve as a training and demonstration site for agroforestry practices suitable for big river floodplains and other Midwestern landscapes. In April 2022, Larry and Brenda Potterfield donated the 164-acre site to The Nature Conservancy (TNC) in Missouri. Since then, Preserve Engagement Manager Zack Miller, in partnership with the Center for Agroforestry, has led efforts to return this site to tree cover with plantings of native pecans, black walnuts, and other diverse, multifunctional perennials. The site aims to serve as a hub for collaboration and innovation, exploring how intentional ecological design at scale can simultaneously support food production, biodiversity, and community engagement in working landscapes.







Establishment: In October and November of 2024, Stacked Agroforestry, a local agroforestry contractor, led more than 60 volunteers in planting nearly 2,000 trees at the site. This planting included 30 acres of pecans and black walnuts established in an alley cropping system and a 3-acre riparian buffer. The buffer was planted in two blocks, with species selected for (1) timber production and mushroom log harvests and (2) 'honey flow' species that benefit pollinators with long-flowering, nectar-rich varieties.

Design and management: The site has a significant challenge ahead: to keep invasive Johnsongrass at bay, which Zack hopes to accomplish without the use of agricultural chemicals. Similar to attempts to combat bermuda grass at Columbia's Agriculture Park, he plans to chisel plow the Johnsongrass in winter to expose its rhizomes to frost and reseed with cover crops. The grass will also be shaded out through dense plantings and intensive use of multistrata growing space. Because the site will host many visitors of all ages, including children participating in hands-on field trips, it was important to Zack to create a management plan without chemical use that would be safe and accessible for place-based learning and interaction.

> ***"I think it's really important to remember how generous trees are. And if you plant out a farm, it's going to continue to give back to you. What's a nicer gift to pass on to your kids than mature trees that drop nutrition?"***

Since the site is in a floodplain, Zack has opted to avoid installing permanent irrigation. Should the site encounter drought conditions, Zack plans to individually water trees with water pumped from the river. Trees are mulched for both moisture retention and weed management, and protected from wildlife with tree tubes. Future plans for pest and weed management include livestock grazing, mowing before weeds go to seed, and continued dense plantings.

Financial and technical assistance: Zack works closely with the USDA Natural Resources Conservation Service for financial and technical assistance. The site's tree plantings are also supported by the John Deere Foundation. Equipment has been rented from Soil & Water Conservation Districts. Overyield software by Propagate and technical assistance form the Center for Agroforestry team helped Zack estimate costs, select species and cultivars, and determine tree row spacing and design.

Research and demonstration: Initial data collection for soil health, soil carbon, and bird and bat diversity is in progress at the site. This baseline data will help researchers and site managers monitor changes over time. For demonstration and recreational access, MRC will feature a 2.5-mile public trail connected to the Katy Trail and/or a boat ramp to the Missouri River. The site will also be used as an educational space for local environmental non-profit Missouri River Relief, which aims to (re)connect people with the Missouri River. With regards to plans for future harvests, the script has yet to be written. TNC is considering a variety of options that could benefit nearby communities, including a harvest-centered festival, a 'you-pick' pecan harvest, a perennial-focused restaurant on site, and/or potentially leasing out the land to beginning farmers.

Chapter 10: Marketing Principles

Chapter Highlights

- Markets for many agroforestry products are still developing and not well understood. These specialty crop markets require creative planning and marketing solutions.
- Well-developed marketing strategies are key to a successful agroforestry business. How products will get to customers and for what price, and how the product benefits will be communicated to customers are all key components of a marketing strategy.
- A marketing strategy is complex relationship between customers, product development, costs, physical market space, current market climate, and the business owner's own interests and passions.

Marketing Agroforestry Products

Unlike other types of conservation practices where land is taken out of production, agroforestry is "productive conservation." Agroforestry practices enable farmers to generate income from the production of a wide range of conventional and specialty products while simultaneously protecting and conserving soil, water and other natural resources. Products produced through agroforestry practices, including specialty or non-timber forest products, are produced from trees, within forests, or in a myriad of combinations of trees or shrubs, crops and/or animals. Many of these products have proven economic value but have been ignored by, or are unknown to, agricultural and forest land stewards. In North America such products include: edibles (e.g., mushrooms, chestnuts, pecans, hickories, hazelnuts, persimmon, pawpaw, Asian pears, cornelian cherry, Kiwi fruit, aronia, elderberry, mayhaw, goji berry, other berries); herbal medicinals (e.g., ginseng, goldenseal, witch hazel, elderberry); specialty wood products (e.g., diamond willow canes red cedar closet liners, walnut gunstock blanks); floral and greenery products (e.g., curly and pussy willow), ferns, salal; fiber and mulch (e.g., cedar pet bedding, pine straw); and recreation (e.g., agritourism, fee hunting).

The "black box" of agroforestry enterprises and the need for market research

Agroforestry enterprises often produce niche products for little known markets. All that may be known about a product's market is that it is produced and eventually purchased and consumed. What happens to the product along the value chain between producer and consumer and why the consumer is buying the product is unknown. This is commonly referred to as the "black box" of agroforestry. From a producer's perspective, the list of unanswered questions is long. How do I get into the market? What are my costs and potential returns? Where can I buy what I need for my business and for what price? Is the supply readily available? Who are my customers? How many times does the product change hands before it reaches the final consumer? Who are my competitors, what are they doing? How is this market changing? What strategy should I use in order to be successful in this market? These and many other questions complicate the decision to produce and market niche products. Unlike commodity markets with readily available market information, the challenge for farms and small businesses that engage in agroforestry enterprises is to overcome the lack of information about niche specialty product markets. In order to successfully partake in niche product markets, agroforestry entrepreneurs must perform some market research to open the "black box" and overcome information asymmetry inherent in these niche markets.

Data Collection

The first step in any market research process is data collection. It starts with investigating publicly available data (secondary information sources) and continues with information gathered specifically for the market(s) of interest (primary information sources).

Secondary information sources:

- *Published reports and studies.*
- *Online information sources, such as web- sites, newsgroups, and electronic bulletin boards.*
- *Trade magazines and journals, newspapers, books and literature from competitors.*
- *Business directories.*

Primary information sources:

- *Personal interviews with consumers, producers, and other persons involved in the value chain.*
- *Observations (visiting farmer's markets, retail outlets, production facilities, as well as attending farmer field days, trade shows, and marketing conferences).*
- *Online, mail or phone surveys.*
- *Focus groups*

This list is not complete but should give you an idea of some potential sources for market information that will help with analyzing the business environment and the industry for whatever product you may be interested in selling.

Analyze Your Current Situation: SWOT Analysis

Strengths, weaknesses, opportunities, threats (SWOT) analysis includes an examination of both internal factors (strengths and weaknesses) and external factors (opportunities and threats) that can have an influence on the success of your enterprise.

First, look inside the farm business and identify its strengths and weaknesses. What strengths does the farm/business have that helps you accomplish your goals and makes you competitive? (e.g., the ability to provide quality products, consistent year-round supply, excellent customer service, competitive price, production or marketing skills, good location, reliable workforce, previous experience in the industry, strong financial position). Weaknesses are areas where the farm/business can be vulnerable to competitors. What can create problems in your business? What do your competitors do better than you? (e.g., lack of experience in the industry, insufficient finances, limited access to distribution channels, seasonal product, insufficient workforce). Identified weaknesses (e.g., lack of consistent supply because of the seasonality of the product) can be

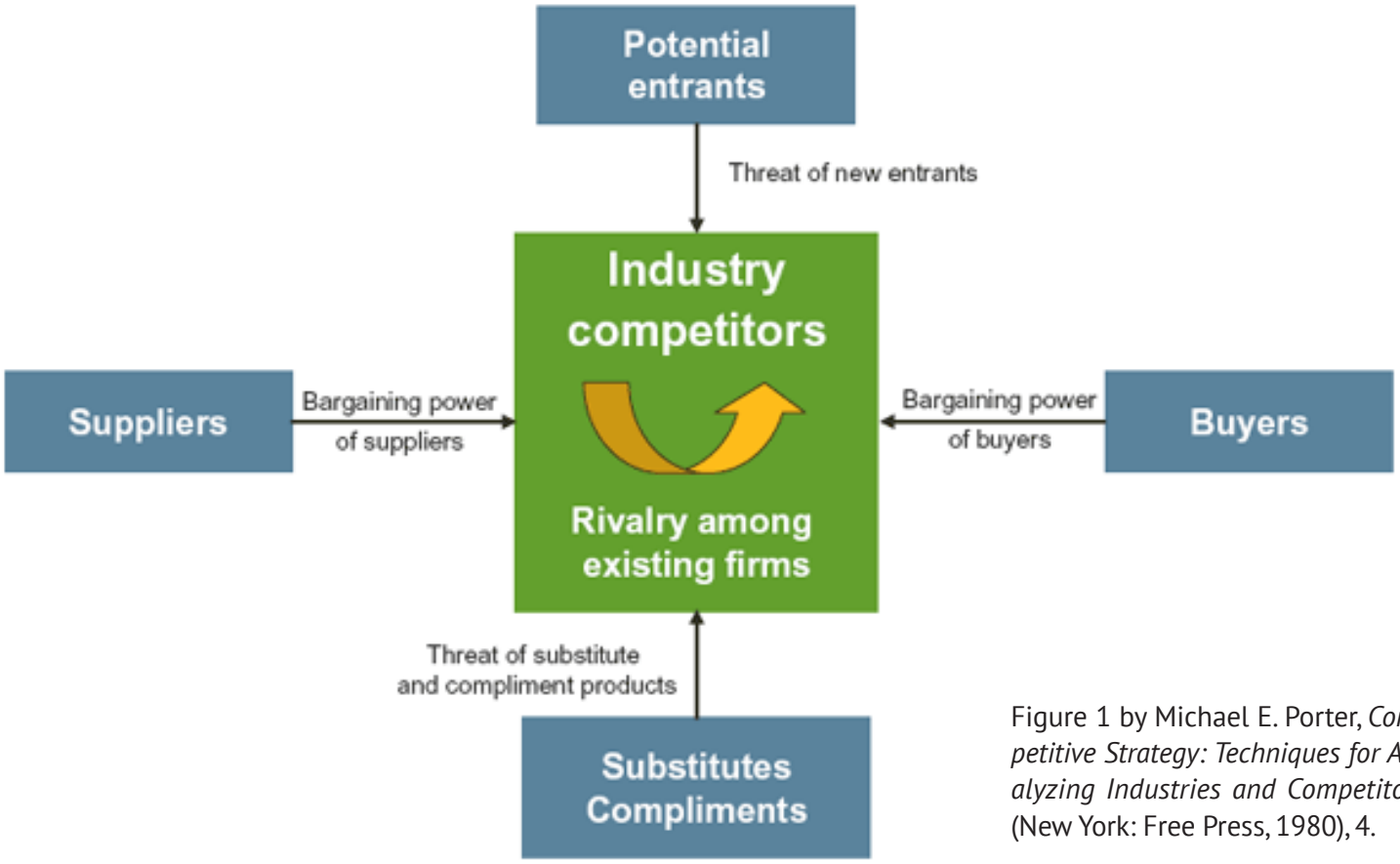


Figure 1 by Michael E. Porter, *Competitive Strategy: Techniques for Analyzing Industries and Competitors* (New York: Free Press, 1980), 4.

transformed into strengths (e.g., building indoor facilities to extend production time). In general, a farm must find ways to minimize the impact of its weaknesses on its business operations.

The second part of the SWOT analysis requires you to look outside your business at issues that you cannot control but can manage and identify opportunities or threats and find ways to influence their impact on your business. Is there anything in the marketing environment related to suppliers, intermediaries, customers, competitors, and public-at-large that can help (opportunity) or affect (threat) your business's ability to produce and sell products? Are there any trends favorable (opportunities) or disadvantageous (threats) for your business?

Examples of opportunities include a farmers market just developing in your area; a grower coop just taking shape close to you; buying property near a large population area that would allow you to direct market your product; increasing interest in locally produced products; increased interest in new, more sustainable agricultural practices; development of new varieties or cultivars.

Examples of threats include changes in federal and state regulations, increased competition from imports, inflation, shortage in raw materials, extreme climate events, fluctuations of markets, seasonal purchasing trends, and high levels of competition.

The process of identifying any strengths, weaknesses, opportunities or threats should help you identify areas where your strengths and opportunities align with a high probability of success as well as combinations of weaknesses and threats that need to be avoided or at least provide for methods to minimize their effects on the farm business. The SWOT analysis helps provide direction and serves as a basis for developing a business plan. It should be repeated at least once a year to review achievements, measure production efficiencies, and evaluate alternatives.

Industry Assessment: Porter's Five Forces Model

An approach proven successful in shedding light on the "black box" is the model developed by Dr. Michael Porter of Harvard University (Porter, 1980) that describes the forces driving industry competition, known as Porter's Five Forces Model (PFFM) (Fig. 1). Porter's strategic forces help evaluate the ease of market entry and exit, buyer and seller power, power of substitute products and competitive rivalry and provide a general view of the industry. With respect to agroforestry, the method is especially useful for farm businesses that plan to enter new markets.

The forces and the questions they help answer:

Potential entrants (barriers to entry)

How difficult is it to enter the market and what resources are needed?

Barriers to entry are advantages that existing firms have relative to new entrants like high start-up costs, proprietary knowledge and a learning curve, and cost advantages for existing firms.

For example, if you want to produce mushrooms, large white button mushroom firms definitely have advantages of scale and cost advantages associated with equity in facilities. Even if you have the necessary information, materials and equipment available, it's tough to break into the white button mushroom industry because of the large capital required to achieve a competitive scale. When supply is limited (like in the case of the elderberry industry), larger, existing firms have better access to the limited supply, leaving new entrants with the need of paying higher prices and/or limiting production. For all agroforestry specialty crops, information about production and marketing is lacking. In a few areas, universities, experienced growers and processors lower this barrier by providing the necessary information to get started. Attention should be given to researching laws and regulations which can facilitate or hinder entry into the industry. As a new firm (entrant), you would like to have easy access to the new industry, but once there, you would like to have some barriers to protect you from new entrants. It is important to know and understand these barriers for an easy entry and for creating protection in the future.

Bargaining power of suppliers

Who can provide the needed supply? Who has more control in the supply chain? Can you choose from a variety of suppliers thus getting competitive prices for the supply you need? If prices get too high can you use another input? If not, can you produce it yourself?

Suppliers are the individuals and businesses that provide the raw materials to be trans- formed into goods. Lack of available supply may increase the cost of production (e.g., limited sources of ginseng seed, import of

elderberry concentrate from Europe) or delay the production start (e.g., need to propagate own elderberry plants or produce and graft own trees).

Bargaining power of buyers

Who is going to buy my product(s)? Would it be better to deliver directly to consumers or to use intermediaries? Who are the intermediaries? How much control does the buyer exert? Who are the final customers and what are their needs? Are you competing against a respected brand name that creates a higher value for its products?

Buyers are the people/organizations who create demand in an industry. When the buyers exert power in an industry, they may impose specific requirements on the quantity and quality of products they buy. These may impose additional costs to sell the products. For small niche specialty products produced in agroforestry settings, there is a challenge to provide large enough quantities to enter distribution channels. Another challenge on the buyers' side is handling perishable products. For example, due to the newness of the industry, there is little knowledge among buyers on how to handle chestnuts. Due to high moisture content, chestnuts need to be kept refrigerated to minimize water loss and decay. Communication and information provided to retailers will ensure that chestnuts will be handled and stored properly and consumers will have a positive experience with the chestnuts they purchase.

Substitutes (substitute products)

Are my products in any way unique or can they be easily substituted by other products with a similar function? If buyers decide your products are too expensive, will they buy another product?

It is very important to distinguish your products and to communicate their unique properties otherwise they will be easily substituted by lower price substitutes. For example, you need to distinguish native pecans from Georgia or Texas pecans if you want to sell them at a premium. Also, you need to communicate and educate the consumer of the various health benefits of elderberry if you want them to choose elderberry juice and not another cheaper or better known juice on the shelf.

Industry competitors (rivalry among existing firms)

Who are the competitors and what are their competitive advantages? What can I do better than them? Are you competing against a respected brand name that creates a higher value for its products?

Rivalry can take many forms, such as price discounting, new product introductions, advertising campaigns, and service improvements. Characteristic for new and small markets like the ones for niche specialty crops, the level of competition is low and existing businesses cooperate to grow the industry. However, to protect your place in the market, you need to start to differentiate from the others and create competitive advantages like quality, customer service and convenience.

Researching and Selecting Target Market

Customers differ in their values, needs, wants, beliefs and incentives to purchase. Product oriented businesses, who find a product they can produce and try to sell it without first looking at customers' needs, risk developing a product that won't sell. Instead, most successful businesses are customer oriented— they design marketing strategies around the needs of their customers.

The process of identifying customers' preferences and dividing the larger market into groups is called segmentation. Markets can be segmented in a variety of ways. The most common ways of segmentation are by





Examples of value-added elderberry products from Missouri elderberry growers: Elder Farms (top) and River Hills Harvest (bottom).

demographic characteristics (e.g., age, sex, race, religion, education, income, household size), geographic location (e.g., counties, states, regions) and psychographic characteristics (e.g., lifestyle characteristics, behavioral patterns, beliefs, values and attitudes).

Creating a customer profile for each segment will help describe who are the customers, what they value, how much they are willing to buy and determine which segment can be the most profitable to target. By identifying and targeting only specific market segments you can develop more effective product, price, distribution and promotion strategies.

Developing Product, Price, Distribution and Promotion Strategies

A marketing strategy is a plan regarding what products to develop, how the products will get to the customers, for what price and how the product benefits will be communicated to customers.

Product strategy

What product will you offer to satisfy the needs of your target customers?

The most common marketing strategy for farmers producing agroforestry products is product differentiation to appeal to a focused group of consumers (the target market). Farmers have the opportunity to implement many creative marketing ideas to differentiate their products and services in response to the needs of their customers. Differentiation equates to adding value to the products. Adding value will allow you to obtain a better price for the same amount of raw material. For small land stewards, adding value to agricultural and non-timber crops can make an enormous difference to the bottom line.

Ideas for Adding Value

Value can be added through processing, packaging and customer service. A few of the more common methods of adding value to your agroforestry products are described below.

- *Many edibles you could produce in an agroforestry practice also have a market in a value added form. Fresh products are usually perishable and only available for short periods. Processing extends the period during which products can be made available, and allows processors to increase potential returns. Examples include: processed fruit products (jams, jellies, fruit leathers, sauces, chutneys, vinegars); frozen products (berries are the most obvious candidates, though mushrooms are sometimes frozen); and dried products (mushrooms, berries).*
- *Value-added decorative and craft products can provide immediate returns. The amount of skill required to produce these products varies. Some products (e.g., wreaths) are fairly easy to produce, while others (e.g., baskets and furniture) may require more time to develop proper skills.*
- *Herbal products offer a number of opportunities for adding value. Medicinal herbs are a good option for marketing at a local level but you must adhere to regulations that govern the sale of these products. Getting into the business of selling 'drugs' to the mass market should not be taken lightly. Herbal teas sold under food regulations may offer a much easier approach.*

Is it worth it? The 'cons' of adding value

Adding value is not always the best option. Ask yourself some hard questions before you embark on the value-added route:

- *Are financial and human resources / expertise available to develop value-added processing?*
- *If not, what will it take to acquire them (e.g., loans, training)?*
- *Do you have the long-term supply of resources to support a value-added strategy?*
- *What are the markets for potential value- added products?*
- *Can you meet the requirements of the marketplace?*
- *How easy will it be to break into those markets?*
- *How long will it take to recoup the costs of any processing equipment involved?*
- *Can you handle the risks sometimes involved in adding value? For example, are you better off taking less for your product but letting a middleman absorb the risk?*

As with any business, you have to do the research, consider your resources and crunch the numbers to see if it's worthwhile. Usually, adding value is smart marketing.



Chinese chestnut, Sleeping Giant, harvested at the MU Horticulture and Agroforestry Research Farm in New Franklin, Mo.

Distribution strategy: Getting products to buyers

There are three aspects to getting your products to buyers:

1. **Distribution**: The sales channel(s) your product will follow.
2. **Location**: Where you sell your product.
3. **Transportation**: How your product will reach the buyer.

Distribution: Sales channels

Your product may be able to take a number of different routes—or sales channels—to the end user. Which sales channel(s) you end up using will depend on a number of factors, such as:

- *Existence of a 'dominant' distribution system for your product*
- *Demand for your product from various levels in the marketing chain*
- *Time you have available and your marketing abilities.*

Using these criteria, among others, you can choose one of the two basic marketing channels that most products follow: Direct marketing is the process of selling a product or service directly to the consumer. Direct marketing is the alternative most suited to agroforestry product producers. Selling direct provides the grower the opportunity to capture a larger share of the consumers' spending and the opportunity to educate the consumer about the farm and its production methods (e.g., about the advantages to buy organic or locally grown products). Direct marketing is growing in popularity because consumers now demand safer and high quality products. Buyers place a value on coming face to-face with the producer and their production location (farm, farmers market, on-farm retail store) and obtaining more information about the products produced.

Intermediary distribution provides other market outlets and include wholesalers, brokers, cooperatives and retailers. One of the challenges in the wholesale marketplace is the need to provide a constant, dependable supply of large quantities of quality goods. Wholesalers may only accept a few weeks' worth of product at any one time, forcing the producer to incur storage and multiple delivery costs. Another challenge is to maintain premium product integrity along the value chain (i.e., maintain freshness or maintain organic integrity at each stage of the product's journey to the market). In general, the closer the producer is to the consumer, the greater the return as well as the workload. Your choice of sales channels may significantly impact your bottom line. You may be tempted to eliminate one or more middlemen in the chain. Remember that if you're being paid outright by a broker/buyer/ wholesaler, that person is also accepting the risk of selling your product to the next level in the sales chain. Before you take over that role yourself, make sure that you are willing to accept the additional risk. Also, some products and markets may allow you to invite bids from different buyers and possibly obtain a better price. Knowing how your product is being distributed could, over time, help you establish 'alternative marketing strategies' to improve your returns. You may find opportunities to sell your products at a higher level and to cut out some of the middlemen. You may also discover potential channels that will provide other business opportunities.

Location

When selling directly to consumers, there is a range of choices as to where you will offer your product. Possible sites for marketing agroforestry products include:

- *Your property (everything from timber to berry jam), if not too remote*
- *Roadside stands (your driveway, highway rest areas, park-and-ride locations)*
- *Farmers markets (in urban areas these can be especially lucrative)*

- *Craft markets*
- *Co-operative marketing with other firms (e.g., renting seasonal space at a plant nursery, Christmas tree lot, supermarket, bed and breakfast).*

Many businesses take orders over the phone, email, or regular mail, and deliver the product (themselves or using a delivery service) directly to customers. For some products, particularly specialty foods and crafts, the Internet can provide easier access to a wider market than traditional mail-order techniques. All 'mail-order' type direct marketing systems require a product that is easily handled and access to reliable transportation for it.

Transportation options

If you are pursuing a sales channel where your customers are not coming to you, it is necessary to consider how your product will get to them. Important factors to consider include: cost to ship to distant markets via various transportation modes, inclusion (or not) of transportation costs in the selling price (i.e., whether you or the buyer pays the freight costs), the reliability and timeliness of various modes of transportation (especially for perishable goods). Negotiating favorable freight terms may be critical to the viability of your business, so do not simply accept the first quote you receive from a shipper. For air cargoes, some freight brokers may be able to offer much better rates than the airlines. Greater volumes may permit price breaks, so partnering with other businesses in assembling loads can be beneficial. Another way to reduce freight costs is to find trucking firms which are seeking 'back-haul' loads (i.e., freight for trucks from regional or provincial distribution centers that would otherwise be returning empty). It is important to compile a list of prospective transport options and their respective costs. In some cases it is simply not profitable to ship a specific product into a particular market.

Pricing strategy: For how much can we sell our products?

Product pricing can be challenging since pricing for niche products produced through agroforestry practices is not regulated as in commodity markets. Producers who sell commodities are normally price takers, sellers that have no market control and must "take" or accept the going market price. For differentiated niche products, one or more pricing strategies can be considered, depending on the target market and product strategy. The basic functions of pricing are to cover costs, make a profit, and encourage customers to buy. You can either price to the market or price to your costs.





Top: chestnuts sold in a local natural foods grocery store. Left: Chef Shelly la Fata of hands out samples of elderberry and hazelnut slaw to promote her restaurant, Pasta La Fata.

Pricing to the market. When you're just starting out, pricing to the market is often the simplest approach. Pricing to the market involves finding out what others are charging for the same products, and then using that information to establish a similar price range. Buyers are also pricing to the market when they tell you what they're willing to pay for your products.

Pricing information on agricultural products can be obtained from a number of sources. If you plan to sell directly to the public, various retail market outlets will provide you with information on the going rate for your product. Buyers will also provide pricing information, but keep in mind that these prices are usually negotiable. The Internet may be another source of pricing information, depending on the market you are seeking to access. Pricing information for agroforestry specialty crops and products can be difficult to obtain, but your

best bet is talking to other producers and the buyers you've identified. The Internet also has limited pricing information for some products, especially for 'finished' or value-added products such as crafts, wreaths, berry jam and the like (these may also be obtained from catalogues from various companies).

Pricing to your costs. Pricing to your costs ensures that what you charge covers all your expenses – not necessarily the case when pricing to the market. Businesses sometimes start out by pricing to the market, and then shift to pricing according to costs once these become clearly identified. If you find that similar products are available for a much lower price than you could charge, you'll have to either adjust your profit margin or differentiate your product so that consumers feel it is worth the higher price. The timing of sales has a strong influence over the price which can be obtained, and the obvious objective is to sell when prices are highest (i.e., demand is high relative to supply). Non-perishable products allow greater flexibility in this choice, as do products processed to allow out-of-season sales. You may also wish to explore different management practices that will enable you to harvest early or late in the season when other supplies may be limited.

What goes into the cost equation?

Production costs, materials, fixed overhead, time/labor and profit. A simple formula for set- ting the price per unit is:

Price per unit = Total costs of production per unit + Desired profit per unit.

Price setter or price taker?

Sometimes you will be able to set prices for your product, other times you won't. A number of factors will influence whether you are a price-setter or a price-taker:

- *The scale of the market; prices for internationally traded commodities (e.g., lumber, wheat) tend to be set far from the place of production. This is also true for many agricultural commodities and agroforestry products (e.g., mushrooms, some floral greens, medicinal herbs) that are traded in international or other extended markets.*
- *Product differentiation; if your product is unique (the opposite of a commodity) you are more likely able to influence the price you receive. 'Niche' market and value-added products usually have superior opportunities for cost-driven pricing.*
- *Your reputation within the industry; sometimes experienced, dependable suppliers are able to get a higher price for their products (a 'premium') because buyers know they will reliably supply a high quality product.*
- *Your negotiating skills; if you have good negotiating skills, your ability to influence the prices you receive for a product will increase greatly.*

In the end, the single most important influence on your pricing decisions will be your customer's ability and willingness to pay the price you are asking. However, keep in mind that you can also influence prices by promoting your products.

Communication (promotion) strategy: How and what will be communicated to buyers and consumers?

Promotion is essential to gain product recognition among customers. The promotion strategy should identify the message, the way of delivery, and costs.

Message: What do I want to communicate about my product? Consumers are often unfamiliar with niche agroforestry products, therefore the more information provided about the products benefits, the more likely people are to try the product. Communicating "freshness" and "local" or "small scale production methods" can be an important part of a promotion strategy.

Tools and delivery: How am I going to communicate this message? Local producers can advertise in newspapers, magazines, flyers and catalogs, radio, TV, billboards, within health food stores, and online. Publicity is more convenient than advertising because it uses non-paid media coverage of the firm and its products. Methods used to generate publicity include participation in festivals and fairs, collaboration with charities, sponsoring community events, and news releases. News releases to the media are a low cost method to get promotion. Offering free samples is a commonly used practice that helps establish local markets. Organizing workshops, giving talks, farm tours, attending farmers markets, collaborating with local Community Supported Agriculture (CSA) groups and word of mouth are ways to raise awareness, inform and educate consumers, and build trust and understanding. For products with health benefits not so known to consumers, fact sheets distributed at farmers markets

and educational on farm displays are very useful.

Costs: How much will all of these cost? If paid advertising media are used, partnering with other farms can reduce individual advertising costs. Brands are created to identify a businesses' product and distinguish it from the competition. While expensive, many niche producers concentrate promotional efforts on image advertising, i.e., promoting the concepts of "heart healthy", "locally grown" or "green" products.

Additional Resources

Building a Sustainable Business. A Guide to Developing a Business Plan for Farms and Rural Businesses. Minnesota Institute for Sustainable Agriculture.

Business Development Resource Page. Agricultural Marking Resource Center.

Break-even Pricing, Revenue and Units, University of Missouri Extension.

Cai, Z., Gold, M. A., Cernusca, M. M. I., & Godsey, L. D. (2021). Agroforestry Product Markets and Marketing. North American Agroforestry, 437-468.

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Cernusca, M. M., Gold, M. A., & Godsey, L. D. (2012). Using the Porter model to analyze the US elderberry industry. Agroforestry systems, 86, 365-377.

Food Safety, Farmers' Market Handbook. Missouri Department of Agriculture.

Fruit and Nut Compass. University of Wisconsin-Madison Center for Integrated Agricultural Systems.

Growing Small Farms. North Carolina Cooperative Extension.

Marketing & Economics Resources. University of Missouri Center for Agroforestry.

Marketing Channels for Locally Raised Foods. University of Missouri Extension.

Marketing Specialty Forest Products. University of Nebraska, Lincoln.

Productive Conservation: Growing Specialty Forest Products in Agroforestry Plantings. University of Nebraska, Lincoln.

Selecting an Appropriate Pricing Strategy, University of Missouri Extension.



Pioneering the "Napa Valley of Elderberries" in the Missouri Ozarks



At a glance: Through his creative marketing solutions and leadership in the elderberry industry, Dave Buehler and his two companies, Elder Farms, LLC and Buehler Organics, LLC, are working toward transforming southwest Missouri into the "Napa Valley of Elderberries".

Overview: Until 2006, the century farm where Dave Buehler was born and raised rowcropped soybeans and corn and operated as a small dairy in Mt Vernon, Missouri. Aware that these practices were declining the health of the land and the sustainability of the farm business, Dave made a leap faith after attending a field day at the University of Missouri Southwest Research, Extension, and Education Center led by long-time specialty crop researcher Andy Thomas. He decided to courageously step into an industry in its infancy: organic elderberry production.

"We provide education on the benefits to both humans and the earth by growing perennials and encourage other farmers to think out of the box and consult on projects that new farmers seek help with."

Products and marketing: Dave continues to push the boundaries of creative marketing, placing Elder Farms and Buehler Organics at the forefront of the industry. Buehler Organics grows 120 acres of elderberry as an alley crop and sells elderberry cuttings and rooted elderberry plants. Elder Farms encompasses 60 acres of organic elderberry and clover alley cropping, 105 acres of organic soybean, 105 acres of organic rye, 40 acres of hay production, 30 acres of sunflowers, and a 4-acre paw paw grove. Elder Farms sources plant material from Buehler Organics as well as from 30 other farms. They utilize the berries, flowers, and even the leaves to create an innovative and wide-ranging product line. Products include consumables like elderberry soda, immunity-boosting shots, and teas as well as herbal and beauty products like lotions, serums, cleansers, and salves. The jack-of-all-trades, Dave and his team also offer agritourism experiences. They host three campsites on HipCamp along a beautiful spring-fed river and rent a shipping-container-converted-Airbnb, complete with a hot tub overlooking the rolling hills of southwest Missouri.



(Top) Employees at Elder Farms, LLC tending to elderberry cuttings. (Bottom) Dave and Ann Buehler at Elder Farms located in Mt. Vernon, Missouri.

Farm finances: The financial realities of operating an organic specialty crop farm are not all sunshine and elderflowers. Farming organically means incurring tremendously more costs compared to conventional methods, so investments are higher and require creative and diverse marketing strategies. Although Elder Farms has utilized a USDA Farm Service Agency program that provided incentive payments to support the transition from row crops to perennial agriculture, they note that while "the opportunities to apply for [federal] grants are abundant [and] the approval is attainable, the funds are fleeting and have yet to appear even with approval." As a result, they have primarily financed their operation independently, driving innovation in the industry through their own efforts.

Product management and software considerations: Dave Buehler and his team oversee the entire elderberry production cycle, from planting to harvesting. They not only cultivate elderberries but aggregate and process elderflowers and elderberries to market their own unique products. Pulling from their innovative spirit and technologies from other industries, Elder Farms has adapted a software program from the cannabis industry called Figgaro to manage the elderberry lifecycle. This program allows them to track each berry from the field to storage, and through to the raw materials used or products created and delivered. It also monitors various aspects of running the farm business, such as employee productivity and chain of custody. This extensive documentation has proven to be an asset during the Organic Certification process.

Diversity is the Spice of Life at Three Creeks Farm + Forest in Ashland, Missouri

At a glance: Three Creeks Farm + Forest consists of a two-acre market garden, a one-acre orchard alley crop, and 10 acres of mixed hardwood forest. Within this highly diversified agroforestry production system, they cultivate over forty species for culinary and floral uses in their orchard, hedgerows, forest understory, and cutting gardens. This multifunctional landscape provides harvestable fruits, herbs, flowers and foliage while also serving as habitat for beneficial insects and pollinators.

Overview: In the heart of mid-Missouri among the rolling Missouri River Hills, Emily Wright and Paul Webber operate the highly diversified Three Creeks Farm + Forest. Inspired in part by an apprenticeship with Spannocchia, a diversified farm in Tuscany with vineyards, orchards, hog silvopasture, forest farming, and more, Emily returned to Missouri following graduate school, ready and eager to start farming. She and Webber teamed up in 2015 and ran their market garden and pastured pigs on a friend's land for five years. Then in 2020, they purchased their own 15 acres and began making significant investments in long-term perennial agriculture. Diversity is truly the name of the game at Three Creeks. In addition to annual vegetables and cut flowers, they cultivate serviceberry, pawpaw, and persimmon in the orchard, along with prickly ash and spicebush in the woodland. Supported by a North Central Sustainable Agriculture Research and Education (NC-SARE) grant, Emily is currently trialing more than 50 species of native perennials as specialty crops for culinary and floral uses. They hope to expand their perennial farming operations over time, eventually phasing out some of their more intensive annual production.



Products and marketing: Almost as diverse as the plants they cultivate and the pollinators they support, Three Creeks employs several marketing strategies. They deliver produce twice weekly to approximately 20 wholesale customers, including restaurants and grocery stores, and have branched out in selling fermented goods. They aggregate specialty crops, such as ramps, from other local producers to sell to their customer base, thus supporting nearby small-scale specialty crop producers. Nearly everything grown is sold within a 30-mile radius. Additionally, the farm is a member of the Missouri Flower Exchange, a flower farmer collective that aggregates from local producers and sells to floral designers and other wholesale buyers. Emily considers one their greatest successes to be the strong relationships they have built with other local businesses that prioritize local sourcing.



Farm finances: Emily and Paul have invested over $10K in tree, shrubs, and other perennials. The return on investment varies considerably from species to species; some can be harvested shortly after planting, while others may take five-plus years to yield returns. They meticulously track all production costs and sales for each crop. They use bookkeeping software that automatically generates invoices and organizes transactions by revenue and expenses. They've utilized the NRCS Environmental Quality Incentive Program (EQIP) to help finance the establishment of many of their woody perennials. Additionally, they have received funding from the University of Missouri Center for Regenerative Agriculture's Climate-Smart Fieldscapes Program, which provides incentive payments to producers for implementing three or more 'climate-smart' production practices. These financial assistance opportunities have allowed Three Creeks to accelerate their perennial plantings and refine their focus on species that are well-suited for culinary and floral specialty crop markets.

"Our farm is embedded in our community. Its success and growth are intertwined with the small businesses that support us by sourcing locally. These relationships are probably our greatest success."

(Top) Echinecea and other perennial flowers at the farm. (Bottom) Emily and Paul harvest basil. Photo by Josh Wright.

Marketing examples for forestry, agroforestry, and natural resources			
Enterprise	**Retail or direct market**	**Wholesale market**	**Niche market**
Firewood	Delivery to homeowner; roadside piles for campers	Broker, garden center, landscape contractors	Convenience store bundles; custom cut/split; select species
Fence posts and/or rails (Black Locust, Cedar or Osage Orange Hedge)	Homeowners	Landscape contractors, garden stores	Nature stores
Wood chips for cooking and smoking (hickory, apple, maple)	Homeowners and businesses	Convenience stores	Fairs and festivals
High-value sawtimber & veneer		Sawmills through traditional sale process	Sell harvested logs directly from log deck to buyers; sell to the export market
Custom sawmilling	Craft artisans, hobbyists	Other sawmills	Cut lumber at land steward's property
Drying lumber	Craft artisans, hobbyists, cabinetmakers	Local lumber store, chain stores, planning mill	Unique species or products such as crotch wood, matching panels
Value-added wood products (hardwood & grapevine baskets, bowls, kitchen utensils, etc.)	Craft fair, tourist sites, Internet and catalog sales	Broker	Custom-shaped and custom-sized baskets; gift basket
Christmas trees	Choose-and-cut or parking lot trees	Garden stores; nonprofit organizations that sell trees for fundraising	Super large trees, tabletop trees, and select species; combine with sleigh ride and other activities
Holiday greenery (wreaths/ roping from pine trees & vines)	Choose-and-cut parking lot sales	Broker; nonprofit organizations that sell greenery for fundraising	Decorated greenery at holiday crafts fair
Native vegetation collection for floral & food markets on a sustainable basis (moss, ferns, colored twigs, mushrooms, etc.)	Florist shops, craft artisans, fairs	Brokers for floral markets and edibles, stores, restaurants	
Shiitake, oyster, and other mushrooms	Farmers market	Broker, specialty stores, restaurants	Dried mushrooms and other unique products
Ginseng / Goldenseal		Broker	Ginseng jams or other products at specialty stores
Walnut, pecan, hazelnut, or other nut production	Farmers market, Internet or catalog sales	Broker	Specialty stores
Recreational natural resource events (logging, heritage, wildlife, harvest festivals; forestry skill competitions)	Individuals, organizations, and groups		Combine with value-added forestry products and many other unique offerings

Marketing examples for forestry, agroforestry, and natural resources (con't)			
Enterprise	**Retail or direct market**	**Wholesale market**	**Niche market**
Hunting lease	Hunting clubs and groups	Forester or other outlets to act as your broker	Combining hunting lease with cabin rentals
Vacation cabin	Individuals, families, hunting clubs	Broker	Combine with fee hunting, campground or other recreational access enterprises
Recreational trails (bird watching, hiking, cross-country skiing, horseback riding)	Individuals, nature and conservation groups, church and school groups	Broker	Special arrangements
Hayride or sleigh ride with bonfire combinations	Individuals, nature and conservation groups, church and school groups	Broker	Special holiday programs and promotions (e.g. Halloween, Thanksgiving, Christmas)
Nature-based bed and breakfast	Individuals, couples, small groups	Broker	Special program offering
All-terrain-vehicle (ATV) and mountain- biking access	Individuals, groups	Broker	Special races, events, and promotions
Hay	Farmers, small- farm owners, horse owners	Auction	Special hay mixes for specific livestock
Vegetables	Farmers markets, roadside stands, pick-your-own, CSAs*	Broker, auction, cooperative, restaurants	Ethnic markets, organic
Field crops (corn, soybeans, small grains, etc.)	Livestock farmers	Elevator, cooperative	Popcorn, edible soybeans, fuel for heating stove, organic
Wine and table grapes	Wine and table grapes Farmers markets, CSAs*	Stores, wineries, restaurants	Organic, special and heirloom varieties for wineries
Bramble fruit crops (raspberries, blackberries, currants, gooseberries)	Farmers markets, roadside stands, pick-your-own, CSAs*	Stores	Organic, heirloom varieties
Fruit trees (apples, pears, peaches, etc.)	Farmers markets, roadside stands, pick-your-own, CSAs*	Broker, stores, restaurants	Unique and heirloom varieties and species, special sizes and quality
Honey	Individuals, roadside stands, farmers markets	Stores, restaurants, cooperative	Stores, restaurants, organic, honeycomb
Sheep and goats (milk, meat and fiber)	Farmers, 4-H groups, other individuals and groups	Auction	Ethnic meat markets, organic markets
Exotic livestock (emu, fallow deer, ostrich, etc.)	Farmers, 4-H groups, other individuals and groups	Auction	Ethnic meat markets, restaurants
Value-added food processing	Farmers markets, roadside stands, fairs and festivals	Specialty stores, restaurants, broker	Organic, specialty products

Marketing examples for forestry, agroforestry, and natural resources (con't)			
Enterprise	**Retail or direct market**	**Wholesale market**	**Niche market**
Herbs (Echinacea, basil, etc.)	Farmers markets, roadside stands	Broker, stores, restaurants	Organic, medicinal, special product combinations, heirloom varieties
Native plant nursery	Homeowners, local businesses	Landscape contractors doing residential and restoration work, garden centers	Specific in-demand species that are difficult to grow
Greenhouse	Homeowners, local businesses	Garden centers, brokers	Specialty plants for a specific market
Recreational agriculture (harvest festivals, corn mazes, petting zoos)	Individuals, organizations and groups		Combine with value-added, roadside stand, and many other unique offerings

*CSA: Community Supported Agriculture

MARKETING REVIEW

1. **According to Michael Porter, there are five forces that influence how an industry is structured. What are they?**

2. **What are the main marketing strategies that you need to develop for each target market?**

ANSWER KEY

1. According to Michael Porter, the five forces that influence how an industry is structured include: (1) barriers to entry, (2) bargaining power of suppliers, (3) bargaining power of buyers, (4) threat of substitute products, and (5) rivalry among existing firms.
2. The main marketing strategies to develop for each target market include:
    - Product – the right products to satisfy the needs of your target customers
    - Price – for what price can we sell our products?
    - Distribution – how are we getting the products in the hands of our customers?
    - Promotion – how are we letting people know what we have for sale?

Chapter 11: Economic Considerations

Chapter Highlights

- Financial and technical assistance for agroforestry is typically available from at least three major sources: federal, state, and private conservation programs.
- One of the most common mistakes that many land stewards make is failing to account for their own personal time. Remember to count personal time spent as a variable cost.
- Because of the impact of long establishment periods for tree crops to produce marketable crops, it's important for agroforestry producers to think carefully about the time horizon of each enterprise on their land. Creativity in stacking multiple enterprises (e.g. growing annual crops in alleys while trees mature) may be useful, especially in the operation's early years.

Agroforestry Economics Overview

Agroforestry should not be thought of as a set of practices that take land out of production. Instead, agroforestry is a set of practices that responsibly weaves together production and land stewardship. There are many economic benefits to incorporating agroforestry practices into agricultural landscapes. The five practices of agroforestry provide opportunities for generating income from a wide array of alternative products, ranging from edible nut and berry crops to diverse woody floral crops. Additionally, agroforestry practices provide valuable environmental services for producers, such as soil and stream protection, wildlife habitat, and aesthetics at a low cost.

Monitoring the economic costs and benefits from an agroforestry practice is essential for analyzing its economic success or failure. Economic budgeting provides a method for systematically tracking costs and revenues that are incurred on any productive enterprise.

For most agroforestry practices, there are numerous incentive programs available that can help offset establishment costs. Federal income tax laws can also provide incentives in the form of increased deductions from taxable income and lower tax rates on certain types of income. This chapter will briefly discuss agroforestry from an economic perspective.

Budgeting, funding incentives, and tax incentives are three of the most important economic considerations when analyzing an agroforestry practice. Even if the goals of the land steward do not include managing the agroforestry practice for income, the land steward should be aware of ways to minimize the costs associated with establishing and maintaining that practice.

Economic budgeting

Economic budgeting is a decision making tool used to: *report, monitor, analyze, and forecast the financial performance of an economic enterprise.*

Budgets can be highly detailed standardized forms or roughly delineated estimates on the back of an envelope. The quality of the economic analysis and thus the quality of the decisions made based on the analysis depend on the time and effort put into the budget. There are several methods for budgeting, depending on the type of analysis being conducted. For agroforestry economic analysis, two main types of budgets are used: enterprise budgets and cash flow budgets.

Enterprise budget

This is a detailed list of all cost and revenues for a single enterprise, such as corn or livestock, typically for a single planning period.

Cash flow budget

This is a detailed schedule of the amount and timing of costs and revenues. Cash flow budgets can identify possible risks, predict cash needs over a period of time, and provide a basis for comparison with other alternatives. A cash flow budget can combine several enterprise

budgets to identify areas where losses from one enterprise can be offset by revenues from another enterprise.

Costs

Costs can be grouped into two categories: fixed and variable. Within these two categories, costs are separated even further into cash and non-cash costs. Cash costs are those costs that require out-of-pocket cash payments. Non-cash costs are often called economic costs or opportunity costs. Understanding each of these categories of costs will help organize data into economic information.

Fixed costs

Fixed costs are typically those costs that are attributed to resource ownership. In other words, fixed costs occur regardless of any productive activity being attempted. Fixed cash costs are out-of-pocket expenses that are not dependent on production level or commodity. Examples of fixed cash costs include property taxes and insurance. Fixed non-cash costs are accounting costs that do not require a cash outlay. Although these costs are incurred regardless of production, they are influenced by production activities. For example, depreciation is a non-cash fixed cost that accrues regardless of whether the capital is used for production or not. A tractor will depreciate in value even if it is parked in a barn and never used. The amount and type of capital that depreciates will depend on the production activities. A crop enterprise may have depreciation from specialized equipment such as a combine and a planter, but a livestock enterprise will not have this type of depreciation.

Variable costs

Variable costs are those costs attributed to the productive use of resources. Variable cash costs include all input costs, such as seed, chemicals, fuel, hired labor, and maintenance. Variable cash costs for agroforestry practices can be broken down even farther into four main cost areas: establishment, maintenance, harvesting, and marketing. One of the most common mistakes that many land stewards make is failing to account for their own personal time. Although many land stewards enjoy the time they spend working with trees and nature in general, there is still an economic cost to the time that is spent establishing, managing, harvesting, and marketing products from agroforestry practices. Remember to count personal time spent as a variable cost.

Revenues

Typical revenues from conventional forestry can come from things such as nuts, timber, and seedlings. In agriculture, revenues are typically based on monoculture crops or livestock enterprises. However, by combining agriculture and forestry, more income opportunities can be realized from the same natural resource base. Revenues in agroforestry are limited only by the creative resources of the decision maker.

Many agroforestry practices require significant investment during establishment years, followed by a period of several years before the trees start to generate a return on that investment. This may be a strong disincentive to the adoption of these practices, even if long-run estimates indicate that the practice will be more profitable. Because of this characteristic of agroforestry, farmers should be encouraged to seek out additional incentives for agroforestry.

Incentives for Agroforestry

Agroforestry incentives can come from many different sources. The fact that the practice improves the environmental quality of a farmer's property may be all the incentive needed to convince that farmer to adopt that practice. However, for some producers to adopt agroforestry practices requires a significant financial incentive. Programs designed to minimize or offset the initial establishment cost burden are the most common type of funding incentive available to land stewards interested in agroforestry.

Funding incentives can come from at least three major sources: (1) federal, state, and private conservation programs.

Federal conservation programs are those initiated by major legislation, such as the Farm Bill. Examples of federally funded agroforestry incentives would include programs such as:

- *Conservation Reserve Program (CRP)*
- *Environmental Quality Incentive Program (EQIP)*
- Conservation Stewardship Program (CSP)
- *Sustainable Agriculture Research and Education Program (SARE)*
- *Partners for Fish and Wildlife (PFW)*

These programs offer cost share payments, land

easement payments, and other incentive payments to farmers who adopt environ- mentally responsible land-use practices. One downside to many of these programs is the fact that the producer often foregos design flexibility and alternative product market income for the guaranteed program payments.

State funding programs are very similar to the federal programs. In 1990, the State of Missouri passed an innovative program called the Missouri Agroforestry Program which was part of the Missouri Economic Diversification and Afforestation Act. Although this program has had limited funding, the concept is unique in the fact that it encourages farmers to seek income opportunities from alternative products grown or harvested from land that is managed primarily for conservation benefits. The Missouri Department of Conservation was given the responsibility of overseeing this program along with a cost share program that promotes conservation practices. Other sources of funding in Missouri include the Missouri Department of Agriculture and the Missouri Department of Natural Resources.

Private funding sources with application for agroforestry often center on organizations that promote game animals or forestry. Private sources include groups such as Pheasants Forever, Ducks Unlimited, Quail Unlimited, and the National Wild Turkey Federation. These organizations offer cost-share programs and land easement payments to producers who manage their land in a way that improves the habitat of the game animal they represent.

Tax incentives

Another incentive for agroforestry adoption may be the income tax benefits that a producer could receive.

There are three basic ways to substantially reduce your tax burden: (1) increased deductions, (2) reduced tax rate, and (3) tax credits.

The current Internal Revenue Code (IRC) offers tax benefits for reforestation, conservation, business investment, and capital gains.

Section 194 of the IRC describes the reforestation deduction and amortizable basis deduction. This deduction allows a producer to deduct the first $10,000 of reforestation expenses from taxable income and then amortize and deduct the remaining expense over an 84-month period.

Section 175 describes the conservation deduction that allows a producer to deduct certain conservation expenses up to 25% of the gross income earned from the farming business. These conservation expenses must be incurred in accordance with a plan approved by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), or a similar agency.

Section 126 details how to exclude cost- share payments received from approved federal or state conservation programs from taxable income.

Section 179 allows a producer who is managing the agroforestry practice as an active business to deduct a large amount of expenses incurred for personal property used more than 50% in the business.

Summary

Agroforestry is a set of land-use practices that interlaces production and stewardship. From an economic standpoint, agroforestry can increase production diversity by integrating a wide range of commodity and alternative products. In order to monitor and analyze the economic parameters of an agroforestry practice, land stewards may need to adopt some form of economic budgeting. Because of the impact of long establishment periods and long periods where no economic returns are generated, a combination of enterprise budgeting and cash flow budgeting is recommended in order to fully capture the short- and long-term revenue potentials. Some agroforestry practices may have substantial costs during an establishment period and not generate revenue to offset those costs until several years later. Because of this, farmers may wish to seek funding incentives to help ease the establishment cost burden. Federal, state and private conservation programs offer land easements and cost-share payments for establishing agroforestry practices or related land use practices.



In addition to these programs, the IRC offers some substantial tax benefits for those who invest in reforestation, conservation, or some form of business that relies on the management of the natural resource base.

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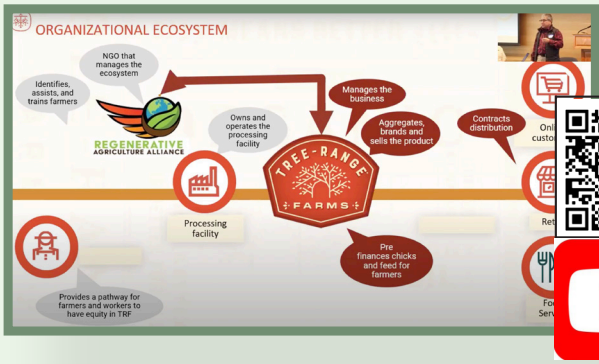
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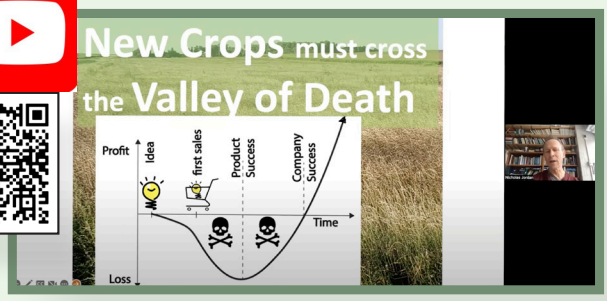
Explore more agroforestry marketing lectures and how-to videos on our Mizzou Agroforestry YouTube Channel!



Growing and Marketing Pawpaw in Missouri with Patrick Byers, horticulture field specialist with MU Extension.



Expert Panel: The Real Impacts of Silvopasture, featuring insights on marketing regenerative poultry products from Reginaldo Haslett-Marroquin of Tree Range® Farms.



One Theory of Scaling for Perennial Crops with Dr. Nick Jordan, co-director of the UMN Forever Green Initiative.

Scaling pecan production at Shepherd Farms in Clifton Hill, Missouri



At a glance: Dan Shepherd's family has been growing pecans in Missouri since 1971. Today, Dan farms around 300 acres of pecans, which were established 20 acres at a time over the years. Pecan trees need nearly a decade of growth before providing steady income to a farmer, and Dan embarked on a variety of successful agriculture endeavors while his trees matured. His family raised buffaloes for 42 years and spent 30 years in the eastern gamma grass seed business. They also sold direct to consumers at their farm store from 1990 to 2023.

Design and management: Dan's pecans are grafted with eight varieties. He grows bluegrass in between tree rows. This shallow rooted grass was selected because it doesn't take much water away from the pecan trees and creates a good mat to pick up pecans. He opted to forgo drip irrigation, relying on rainfall for moisture, and due to the large scale of his operation, he has chosen not to install fencing or other wildlife protection. Dan also raises cattle, but has decided to keep them in a separate portion of his farm to avoid food safety issues and potential harvest complications, as well as to prevent livestock from damaging trees. As for pecan processing, all cracking, air separating, and bagging of the nuts happens on the farm with the help of two employees.



Operational scale: Dan has invested in all the necessary specialized equipment to process and sell pecans. A challenge Dan notes from the early years is the problem of scaling the orchard. Small-scale growers often cannot justify investing in harvesting and processing equipment, but may eventually have too much orchard ground to cover to continue harvesting by hand. To mitigate this issue, collective equipment sharing among neighbors or formalized cooperative agreements can be useful. Nearby pecan farmers pay Dan by the pound to shell their pecans at his facility, with a 3,000-pound minimum required. These farmers sell their pecans to local farmers markets and bakeries in the area. Dan focuses more on wholesale markets spanning the Midwest and Southern U.S. for his pecans. These buyers receive shipments of 45,000 pounds per truck load.



Dan's advice to other agroforestry farmers is to stick with it. For pecans, it takes about 8-10 years to see a profit get turned. He says it takes stamina and strong will to say in it when the times are bad, but developing a solid marketing plan from establishment onward will help agroforestry farmers to one day enjoy the fruits of their labor.

(Top) Collecting scionwood for pecan grafts. (Middle) Pecan processing equipment at Shepherd Farm. (Bottom) An aerial shot of the Shepherd's orchards.

"My dad always had a saying; you stand to make a little money doing what everyone else does but you stand to make a lot of money doing what no one else does."

ECONOMIC CONSIDERATIONS REVIEW

1. **Variable cash costs can be grouped into four categories. What are they?**

2. **Two types of budgets are recommended for the economic analysis of agroforestry practices. What are they?**

3. **What are the four sections of the Internal Revenue Code (IRC) that can affect agroforestry adopters?**

4. **What is the difference between a variable cost and a fixed cost?**

ANSWER KEY

1. Variable cash costs are grouped into the following four categories: establishment, maintenance, harvesting, and marketing
2. The two types of budgets recommended for the economic analysis of agroforestry practices include: enterprise budgets and cash flow budgets.
3. The four sections of the Internal Revenue Code (IRC) that can affect agroforestry adopters include:
    - Section 194: Reforestation deduction and amortizable basis deduction
    - Section 175: Conservation deduction
    - Section 126: Cost-share exclusion
    - Section 179: Business investment deduction
4. A fixed cost is a cost that is associated with the ownership of resources. Fixed costs must be paid regardless of what activity is conducted on the property. Variable costs are costs associated with the productive use of resources. Variable costs are the costs that are used when comparing the economics of competing resource-use options.

APPENDICES

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Appendix I: Financial Decision Support Tools for Agroforestry

Excel-based financial decision support tools can help potential growers better understand the economics behind various management practices for some of the most common temperate agroforestry crops. The University of Missouri Center for Agroforestry has developed four model-based tools, including:

The Eastern Black Walnut Financial Decision Support Tool (timber production); the Black Walnut Financial Model (nut production); the Chestnut Decision Support Tool (nut production); the Pawpaw Financial Decision Support Tool and the Elderberry Financial Decision Support Tool (berry production). These tools are publicly available, free to use, and can be found at the www.CenterForAgroforestry.org.

The following Chestnut Decision Support Tool example illustrates how these models can be used. The tool asks users a series of questions designed for inputting data about the user's orchard, and outputs financial results based on those inputs. These instructions are designed to help you answer the user input questions after you've opened the spreadsheet to begin data entry. Please read these instructions before you begin using the Financial Model.

The Chestnut Decision Support Tool spreadsheet consists of six tabs: (1) Management Input, (2) Cost Budgets (3) Financial Analysis, (4) Input Tables, (5) Chemical Costs, (6) Growth Models, and (7) Inputs.

Users can select and enter their own information in the Management Input, Financial Analysis, Input Tables, and Chemical Costs tabs. The Cost Budgets and Growth Models tabs are for calculation purposes and cannot be edited by users.

The Management Input tab consists of four sections: Establishment Decisions, Management Decisions, Harvesting and Marketing Decisions, and Financial Results. Blocks highlighted in yellow indicate areas where users should enter their own decision information.

Once data is entered for each of the "Decisions" sections, financial results will automatically be calculated and will appear in the "Financial Results" sections. Establishment decisions include: site prep, spacing, layout/design, site quality, planting stock, graft technique, fertilization, tree staking, and irrigation system.

Each establishment decision offers a drop down option list to chose from (except for spacing). Choose one option for each decision that best reflects your establishment plan. For example, "site prep" has tree options: herbicide only, herbicide with discing, and user defined.

For "user defined", you may enter your own cost per acre for site prep into cells B5 (cost per acre) and C5 (cost per tree). "Estimated Cost per Acre" equals "Estimated Cost per Tree" multiplied by the "Initial Number of Trees per Acre", where the spacing indicated determines "Trees per Acre". The same procedure should be followed when entering any user-defined decision.

Inputs

The Management Decisions tab consists of options for thinning, fertilizing, pruning, weed control, pest control, disease control, and deer control. In order to provide the necessary input for "thinning", enter a number between 0 and 1 indicating percentage of trees removed at each

thinning. For example, if the grower chooses to thin one-third of the trees at each thinning, enter .33 or 33% in the blank. Other questions in this tab should include both quantity and occurrence of the corresponding management decisions. For example, after selecting a fertilization method from the drop down menu, go to the Input Tables tab and enter the frequency of fertilization in cell G35, and the starting and ending years of application in cells G36 and J35. Costs will vary depending on frequency and duration of management activities.

Further, if users want to specify the chemical application rate and calculate their own costs, use the detailed information in the Chemical Costs tab. Enter your own application rates (Low App Rate/ac in cell B2, or Hi App Rate/ac in cell C2). Be sure to select the correct unit from the options in cell E2.

Harvesting and Marketing Decisions includes four categories: harvest method, expected rate of return, expected price per lb for nuts, and number of acres. Enter a discount rate (expected rate of return on investment) in this section. For example, if a grower would like to earn 5% from their investment, they should enter .05 or 5% in the blank.



	A	B	C	D	E	F	G
1	Site Prep	Estimated Cost/ac	Cost per Tree				Occurrence
2	Discing only	$ 100.00	$ 2.07	1			
3	Herbicide only (1 qt/ac.)	$ 120.00	$ 2.48	1			
4	Herbicide with Discing	$ 150.00	$ 3.10	1			
5	User Defined	$ -	$ -				
6							
7	Layout/Design	Estimated Cost/ac	Cost per Tree				Occurrence
8	Diamond						
9	Hexagonal				No Cost		
10	Rectangular/Square						
11							
12	Planting Stock	Estimated Cost/ac	Cost per Tree				Occurrence
13	Grafted Seedlings	$ 968.00	$ 20.00	1			
14	Seed	$ 169.40	$ 3.50	1			
15	Seedlings (bare root)	$ 193.60	$ 4.00	1			
16	Seedlings (RPM™)	$ 847.00	$ 17.50	1			
17	User Defined	$ -	$ -	1			
18							
19	Fertilization (initial)	Estimated Cost/ac	Cost per Tree				Occurrence
20	Good early growth (> 8")	$ 49.37	$ 1.02	1			
21	Slow early growth (< 8")	$ -	$ -	1			
22	User Defined	$ -	$ -	1			
23							
24	Thinning	Estimated Cost/ac	Cost per TC				Occurrence
25	33%	$ -	$ 0.04				As per model
26							
27	Tree Staking	Estimated Cost/ac	Cost per Tree				Occurrence
28	Re-Bar	$ 67.28	$ 1.39	1			
29	Steel conduit pipe	$ 96.80	$ 2.00	1			
30	T-posts	$ 338.80	$ 7.00	1			
31	User Defined	$ -	$ -	1			
32	Wooden stakes	$ 19.36	$ 0.40				
33							
34	Fertilization (maintenance)	Estimated Cost/ac	Cost per Tree				Occurrence
35	Bearing trees (33% N)	$ 90.00	$ 1.86		Fertilizer applied every		1
36	Bearing trees (46% N)	$ 90.00	$ 1.86		First Year of Application		2

Management Input | Cost Budgets | Financial Analysis | Input Tables | Chemical costs | Growth mod

Figure 1. Input Tables; enter values in each yellow cell.

Outputs

The Chestnut Decision Support Tool outputs indicate the financial performance of the orchard over a 60-year period. The Chestnut Decision Support Tool, among other agroforestry models, also provides an enterprise budget. Go to the Cost Budgets tab for a printable budget with costs. A cash flow diagram is available on the Financial Analysis tab, which shows Total Revenues, Total Costs, and Net Revenues for each year.

Six financial indicators are provided to better understand the economics of growing black walnuts. These indicators include:

- *Present Value of Revenues (PV of Revenues)*
- *Present Value of Costs (PV of Costs)*
- *Net Present Value per acre (NPV)*
- *Rate of Return / Modified Internal Rate of Return (MIRR)*
- *Annual Equivalent Value (AEV), and*
- *Years to Break Even*

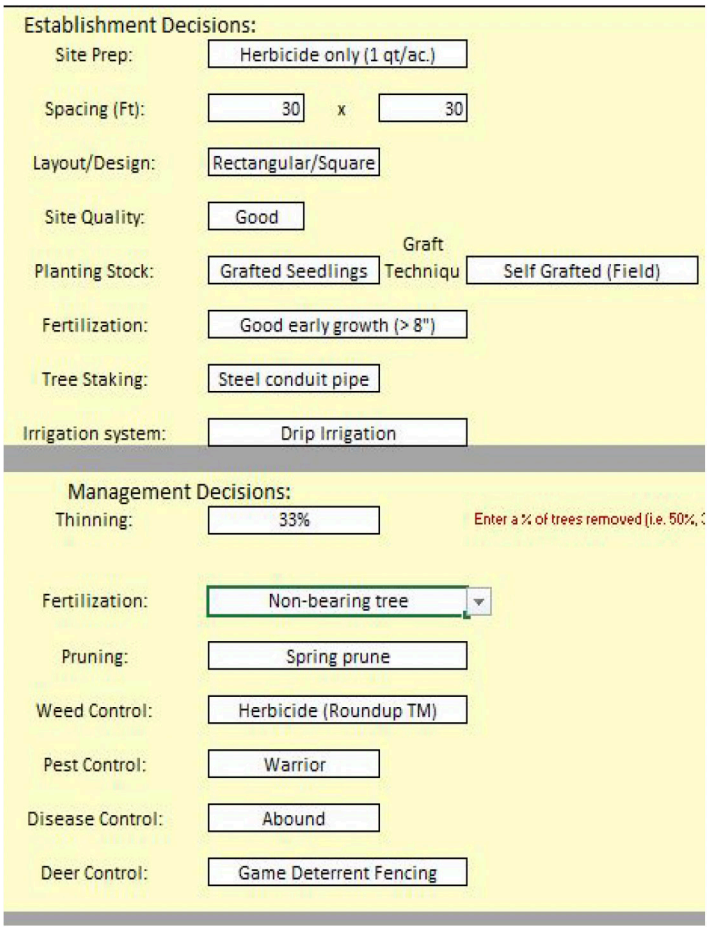


Figure 2. Establishment and Management Decisions; select from a list of drop-down menu options for each management decision.

For information about the interpretation of and calculations used for these indicators, see our *Economic Budgeting for Agroforestry Practices* Technical Guide.

Advanced options

Most of the agroforestry Financial Decision Support Tool programs have been locked to prevent keystroke errors by users. However, different costs can be manually applied to the model by "unprotecting" the Input Tables. To unprotect the spreadsheet, click *Review* and then click *Unprotect Sheet*.

Model limitations

The Financial Decision Support Tools are simplified decision models, and thus have limitations. The models are based on the best information available at this time for each of the factors accounted for. For instance, nut production can be impacted by different management decisions (e.g. tree spacing, thinning); however, due to the limited field data on nut production over time, a simple linear regression model simulates nut production over 60 years in the Chestnut Decision Support Tool model. The predicted revenues and other financial values are estimates; thus these models are intended as a guide, not a crystal ball. The purpose of the models is to identify how varying establishment, management, harvesting, and marketing decisions affect the financial outcome of the system. While the models cannot provide a promised level of income, they are accurate in predicting whether or not a decision will increase or decrease returns.

All Financial Decision Support Tools can be downloaded from the University of Missouri Center for Agroforestry resource library by searching for "Excel worksheet" in the format dropdown menu.

Appendix II: What makes a tree appropriate for agroforestry?

Agroforestry combines trees, shrubs, forages, grasses, livestock, and crops in innovative, flexible combinations tailored to a land manager's needs. The *trees and shrubs* within the system serve as the foundation for the agroforestry enterprise. They occupy land for many years and take longer to produce marketable crops than other agricultural crops. Thus, they require careful thought before planting and long-term care. Through deliberate integration with farm practices, long lasting production and conservation benefits can occur simultaneously.

So what makes a tree appropriate for an agroforestry system? The answer is not always the same for any given situation, and will likely vary according to each land steward's specific interest. That said, many trees and shrubs can be planted in configurations and/or densities that can meet several objectives.

Selecting the proper trees and shrubs for your site

When selecting a tree species, begin by matching the species with the site. The selected species should be capable of providing the products and services desired by the land steward. Depending on the practice selected, additional considerations might include: species suitability to the site's soil, topography, and growing zone; compatibility with other trees/shrubs/crops in the system (i.e. competition for moisture or nutrients through root interactions); economic value and rate of growth (i.e. fast growing with low value? slow growing with high value?); drought tolerance; shade characteristics throughout growth cycles; existing species on the site; and/or marketability of various products derived from the species selected.

The management requirements of each species should also influence species selection and planting design. The design and management of an agroforestry practice depends on existing site conditions and the goals of the land steward (you may also refer to the section on each specific practice for more information on design considerations). Trees can be planted in single or multiple rows, on contours, or in groups. Always consider the products you wish to produce, any conservation or wildlife benefits desired, on-farm equipment and the needs of companion crops when planning the planting

design. Some important management considerations include the following.

- **Weed control** is most important for young trees. Weed control can reduce competition for moisture, nutrients and, in some cases, for light. Options for weed control include the use of herbicides, mulches (including living mulches such as many clovers, and fabric mulches) and cultivation. To gain the best growth from newly established trees, weed control should be maintained for a minimum of 3 years, and often for as many as 5 years.
- **Fertilization** regimens depend on the species selected and the producer's objectives. Timely fertilization may be necessary for high-yielding fruit and nut production. In fruit and nut production, having certain nutrients available to the tree at the appropriate time of year is often essential for flower and nut set. For timber production, the cost of fertilization is usually not recovered over the time it takes for a timber tree to reach maturity.
- **Pruning** is a must for timber production and is also recommended for fruit and nut production. Pruning allows room for equipment to pass below the branches and can be used to promote the production of desired products such as timber. Through proper pruning of fruit and nut trees, the shape of the crown and its density can be managed to facilitate and improve productivity.
- **Thinning** is critical to maintaining tree growth. Timely thinnings reduce competition for water, light and nutrients. As trees mature they grow to occupy more of the space where they are being managed. As crowns of adjacent trees begin to touch or overlap, this is also a general indicator that their root systems are overlapping. When trees touch or overlap, competition for light, moisture and nutrients between adjacent trees may become a factor limiting tree growth. At this point, thinning can be beneficial.
- **Grafting** primarily applies to fruit and nut production. By grafting scion wood to a tree you are assured that the fruit or nut produced has the potential to exhibit the exact same characteristics as the adult tree from which the scion came. However, this does not always occur, since moisture, nutrients and management also play a significant role in fruit and nut development. Still, it is considered the best way to ensure success. Spread planting over several years to limit the number of trees that will require grafting in a single year.

In the following pages, additional information is provided on tree/shrub species suitable for agroforestry practices in Missouri. This list is not exhaustive, but rather a starting point. All species listed for a given region may not be suited to all sites in that region, and species not generally recommended for a given region may have appropriate applications on individual sites. For more specific information on trees and shrubs for a particular site, contact the area Missouri Department of Conservation Forester or Private Lands Specialist.

Additional Resources

USDA NRCS Plant Database

Plant Database of Trees, Shrubs and Vines. University of Connecticut.

Grow Native! Missouri Prairie Foundation.

Silvics of North American Trees

Missouri Flora Database

Arkansas Home and Garden Plant Database

Native Prairie Plants of Iowa

Kansas Wildflowers and Grasses

Trees and Shrubs for Agroforestry Practices in Missouri (page 1 of 5)

Common Name *Scientific Name*	Region	Agroforestry Application	Markets	Site	Soil Moisture	Growth Rate	Height	Light Preference	Rooting	Notes
American basswood *Tilia americana*	1 - 8	RB, FF	HV, LV, E	B-U	M	F	75-130'	● - ◗	S-L	Missouri native Sprouting habit
American cranberrybush *Viburnum trilobum*	6, 8	D	W		M-W, X	F-I	8-12'	❍ - ◗		
American elm *Ulmus americana*	3, 4, 7	RB	LV	B	M, X	I	100'		S-L, D-T	Dutch elm disease
American holly *Ilex opaca*	1, 3 - 7	WB	NT, W	B	W-M, X	S	40-50'	◗		High tolerance to flooding Missouri native
American plum *Prunus americana*	1 - 8	RB, WB, FF	W, F	B	M		<15'	❍	S-L	Thicket forming Missouri native
American sycamore *Platanus occidentalis*	1 - 8	RB	LV, W	B	M-W	F	100'+	❍ - ◗	S	Coppice regeneration Missouri native Disease prone
Arrowwood *Viburnum dentatum*	1 - 4, 6, 8	D	W			I-F	<8'			
Austrian pine *Pinus nigra*	1 - 6, 8	WB	O, NT	B	M, X	F-I	70-120'		D-L	Diseases: foliar fungus/blight
Baldcypress *Taxodium distichum*	1 - 8	WB	O, W	B-U	W-M	S-I	100'+	❍ - ◗	S	Missouri native
Black cherry *Prunus serotina*	2, 3, 5, 7, 8	RB	LV, HV		D-M	I	80-100'	❍ - ◗	S	Missouri native
Black locust *Robinia pseudiacacia*	1 - 8	RB, AC, SP, WB	LV	U	M-D	F	40-60'	❍	S	On MDC noxious plant list Missouri native Nitrogen fixing
Black oak *Quercus velutina*	1 - 8	AC, WB	LV, W	U	D-M	I	50-60'	◗	D-T	Missouri native
Black walnut *Juglans nigra*	1 - 8	RB, AC, SP, WB	HV, LV, F	B	M	I	70-90'+	❍	D-T+L	Very site sensitive Missouri native Allelopathic (chemical growth inhibitor)
Black willow *Salix nigra*	1 - 8	RB	LV, E, W	B	M-W	V	30-60'	❍	S	Missouri native
Blackberry, raspberry *Rubus* spp.	1 - 3, 8	AC, RB, WB	W, F		D-M	F	6-10'	❍ - ◗		Thicket former Missouri native
Blackgum *Nyssa sylvatica*	7, 8	RB	LV	B-U	W-D, X	I	50-100'	● - ◗		Missouri native
Blackhaw *Viburnum prunifolium*	1 - 8	D	W	B-U	M-D	F	12'	◗		Missouri native
Blue spruce *Picea pungens*	1 - 6, 8	WB	O, W		M-W, D	I	70-100'	◗ - ❍		Disease & insect problems

Region: see UMCA Region map // **Agroforestry Application:** AC-alley cropping, SP-silvopasture, WB-windbreak, RB-riparian forest buffer, FF-forest farming, D-to add diversity // **Markets:** HV-high value wood products, LV-low value wood products, NT-non-timber forest products, F-fruit, W-wildlife food or shelter, O-ornamental or Christmas trees, E-environmental // **Site:** B-bottomland, U-upland // **Soil Moisture:** W-wet, M-moist, D-dry, X-well-drained // **Growth Rate:** V-very fast, F-fast, I-intermediate, S-slow // **Height:** maximum range in feet under optimal site conditions // **Light Preference:** ❍-full sun, ◗-partial shade/sun, ●-full shade // **Rooting:** S-shallow, D-deep, T-taproot, L-lateral (may be used in combination; i.e., D-T=deep taproot)

Trees and Shrubs for Agroforestry Practices in Missouri (page 2 of 5)

Common Name *Scientific Name*	Region	Agroforestry Application	Markets	Site	Soil Moisture	Growth Rate	Height	Light Preference	Rooting	Notes
Buckthorn *Rhamnus cathartica*	5	RB, WB, D	W	B-U	M-D	F	10-20'		L	
Bur oak *Quercus macrocarpa*	2 - 8	RB, AC, SP, WB	LV, HV, W	B-U	M-D, X	S	70-80'		D-T	Commonly used in CRP Missouri native
Buttonbush *Cephalanthus occidentalis*	1 - 8	RB	W, E	B	W-D	F	6-10'	❍		Wetland invasive problem Missouri native
Cherrybark oak *Quercus pagoda*	6 - 8	AC, RB	HV, W, O	B	M, X	I-F	100'+	◗ - ❍	D	Excellent market Missouri native
Chinkapin oak *Quercus muehlenbergii*	1 - 5, 7, 8	WB	LV, HV, W	U	D-M	S	60-80'	◗	D	Lumped with white oak for sale Missouri native
Common chokecherry *Prunus virginiana*	1 - 8	RB, D	W, F, E	B	M	F	3-20'	❍	S-L	Foliage toxic to livestock Natural wetland species Missouri native
Common elderberry *Sambucus canadensis*	2, 5	RB, D	W, F	B-U	M-W	F	<10'	❍ - ●		
Common hackberry *Celtis occidentalis*	1 - 8	RB, WB	LV, NT	B-U	W-D	S-F	100'			Can be hard to sell Missouri native
Coralberry (Buckbrush) *Symphorocarpus orbiculatus*	1, 3 ,5, 8	D	W	U	M-D		4-10'	❍ - ◗		Holds berries late in the season Missouri native
Cornelian cherry dogwood *Cornus mas*	1, 4, 8	D	W, O	U	M, X	I	10-20'	❍ - ◗		
Deciduous holly *Ilex decidua*	1 - 8	D	W, O	B-U	M-W		<20'	● - ◗		Adaptable to varying site conditions
Eastern cottonwood *Populus deltoides*	1 - 8	RB, AC, SP, WB	W, LV	B	M-D	V	80-100'	❍	S	Missouri native
Eastern redbud *Cercis canadensis*	1 - 8	WB	W, O, NT	U	M	I	<45'	● - ❍		Easily transplanted Missouri native
Eastern redcedar *Juniperus virginiana*	1 - 8	WB	W, LV, HV	U	D-M	S	<50'	❍		Some disease and insect problems Spreads/naturalizes easily Missouri native
Eastern white pine *Pinus strobus*	1 - 8	WB, AC	O, NT	U	D-W, X	I-F	<80'	◗	D, T	Disease and insect problems Preferred deer browse
Flowering dogwood *Cornus florida*	2 - 8	D	W, O	U	M, X	I-F	10-30'	◗ - ●	S	Problem with Armillaria root rot Invader or pest species Missouri native
Fragrant sumac *Rhus aromatica*	1 - 8	D	W	U	D	F-I	<10'	◗ - ●	S	Missouri native
Gray dogwood *Cornus racemosa*	1 - 8	D	W, O		W	I-F	10-15'	●	S	Thicket forming Can be invasive
Green ash *Fraxinus pennsylvanica*	1 - 8	RB, AC, SP, WB, FF	LV, NT	B-U	W-M, D	I	30-50'	❍ - ◗	S	Commonly used in CRP Subject to borers & anthracnose Missouri native

Region: see UMCA Region map // **Agroforestry Application:** AC-alley cropping, SP-silvopasture, WB-windbreak, RB-riparian forest buffer, FF-forest farming, D-to add diversity // **Markets:** HV-high value wood products, LV-low value wood products, NT-non-timber forest products, F-fruit, W-wildlife food or shelter, O-ornamental or Christmas trees, E-environmental // **Site:** B-bottomland, U-upland // **Soil Moisture:** W-wet, M-moist, D-dry, X-well-drained // **Growth Rate:** V-very fast, F-fast, I-intermediate, S-slow // **Height:** maximum range in feet under optimal site conditions // **Light Preference:** ❍-full sun, ◗-partial shade/sun, ●-full shade // **Rooting:** S-shallow, D-deep, T-taproot, L-lateral (may be used in combination; i.e., D-T=deep taproot)

Trees and Shrubs for Agroforestry Practices in Missouri (page 3 of 5)

Common Name ***Scientific Name***	Region	Agroforestry Application	Markets	Site	Soil Moisture	Growth Rate	Height	Light Preference	Rooting	Notes
Green haw *Crataegus virdis*	2	D	W		W	I	20'			
Gooseberry *Ribes spp.*	1 - 3, 8	AC, RB, D	W, F							Thicket forming Missouri native
Hazelnut *Corylus americana*	1 - 38	AC, FF, RB	W, F, O				7-15'	❍ - ◗		Difficult to establish from seed Missouri native
Honeylocust (thornless) *Gleditsia triacanthos* var. *inermis*	1 - , 8	AC, SP, WB	LV	B-U	M-D	F	70-80'	❍	D	Only thornless varieties recommended Pods can be used for cattle feed Missouri native
Ironwood (Hophornbeam) *Ostrya virginiana*	1, 3, 8	D		U	M-D	S	<30'	●	S	Very hard wood Missouri native
Kentucky coffeetree *Gymnocladus dioicus*	1 - 8	RB, AC, SP, WB	LV, HV, O	B	M		100'			Ring shake can be a problem Missouri native
Loblolly pine *Pinus taeda*	3 - 8	SP, AC	NT, LV, O	B-U	W-D	F-V	90-110'		L	Does not produce seed this far north Susceptible to ice damage
Nannyberry viburnum *Viburnum lentago*	1 - 6, 8	D	W				10-15'		S	Thicket forming
Ninebark *Physocarpus opulifolius*	1 - 8	RB	W, E		W-D	F	10'	❍ - ●		Missouri native
Northern red oak *Quercus rubra*	1 - 8	AC, SP, WB, FF	HV, LV	U	M-D, X	I-S	60-80'	◗ - ❍	D-L	Susceptible to oak wilt & chlorosis Missouri native
Northern white-cedar *Thuja occidentalis*	1, 4, 5, 7	WB	O	U	D-W	S-I	40-50'	◗	S-L	
Norway spruce *Picea abies*	1 - 8	WB	O			I-F				Good WB substitute for other conifers Disease & insect problems
Nuttall oak *Quercus texana*	8	RB	LV, HV, W	B	W-M	F	100'	◗ - ❍		Self prunes better than pin oak High flood tolerance
Osage-orange *Maclura pomifera*	1 - 3	WB	LV, HV, W	B-U				❍ - ◗		Sometimes a pest tree
Overcup oak *Quercus lyrata*	8	RB	LV, W	B	W	S	100'			High flood tolerance Missouri native
Pawpaw *Asimina triloba*	3	FF	W	B	M		20-30'	◗ - ●		Site specific Missouri native
Pecan *Carya illinoensis*	1 - 8	AC, RB, SP	W, LV, HV, F	B	M, X	I-F	110-140'	◗ - ❍		Use proper cultivars for nut production. Missouri native
Persimmon *Diospyros virginiana*	1 - 8	AC, SP, WB, FF	W, F, LV, HV	U-B	D-M		30-50'	● - ❍	D	Missouri native
Pin oak *Quercus palustris*	1 - 8	AC, RB	LV, W, O	B-U	W-M	I-S	70-80'	❍	S	Not tolerant of growing season floods Susceptible to oak wilt & chlorosis Missouri native

Region: see UMCA Region map // **Agroforestry Application:** AC-alley cropping, SP-silvopasture, WB-windbreak, RB-riparian forest buffer, FF-forest farming, D-to add diversity // **Markets:** HV-high value wood products, LV-low value wood products, NT-non-timber forest products, F-fruit, W-wildlife food or shelter, O-ornamental or Christmas trees, E-environmental // **Site:** B-bottomland, U-upland // **Soil Moisture:** W-wet, M-moist, D-dry, X-well-drained // **Growth Rate:** V-very fast, F-fast, I-intermediate, S-slow // **Height:** maximum range in feet under optimal site conditions // **Light Preference:** ❍-full sun, ◗-partial shade/sun, ●-full shade // **Rooting:** S-shallow, D-deep, T-taproot, L-lateral (may be used in combination; i.e., D-T=deep taproot)

Trees and Shrubs for Agroforestry Practices in Missouri (page 4 of 5)

Common Name *Scientific Name*	Region	Agroforestry Application	Markets	Site	Soil Moisture	Growth Rate	Height	Light Preference	Rooting	Notes
Pussy willow *Salix discolor*	1, 3 - 7	RB, D	W, NT			I	<15'			
Red (slippery) elm *Ulmus rubra*	3, 4	RB	LV	B	M-D		60-70'			Missouri native
Red maple *Acer rubrum*	1 - 8	RB, AC, WB, FF	LV, O	B-U	W-D	F	50-70'	◗	S	Missouri native
Red mulberry *Morus rubrum*	3, 5	RB	F	B	M, X	I	40-50'			Missouri native
Red pine *Pinus resinosa*	1 - 5, 8	WB	W, NT, O	U	M-D, X	S	<50'	◗ - ❍		Short-lived
Redosier dogwood *Cornus stolonifera*	1, 3 - 6, 8	RB, WB	W, O, NT	B	M	I	6-10'	◗ - ❍	S	Thicket forming
River birch *Betula nigra*	1, 3, 8	RB	LV, O, E	B	M		50'			Missouri native
Rusty blackhaw *Viburnum rufidulum*	3, 7	D	W	B-U	M-D			◗ - ●		Missouri native
Sassafras *Sassafras albidum*	2 - 4, 8	D	W, NT	U	D-M, X	I	30-50'	❍	S	Missouri native
Scarlet oak *Quercus coccinea*	3, 5, 7, 8	AC, SP, WB, FF	LV, HV	U	D-M	I-F	70-80'	❍		Fastest growing oak Missouri native
Scotch (Scot's) pine *Pinus sylvestris*	7	WB, AC	O			S				Many disease and insect problems Short-lived
Serviceberry *Amelanchier spp.*	3, 7, 8	FF	W, O	U	M-D	I-F	<30'	◗		Missouri native
Shagbark hickory *Carya ovata*	1 - 8	RB, WB	W, LV, F	U-B	D-M	S	70-80'	◗ - ●	D-T	Missouri native
Shellbark hickory *Carya laciniosa*	1, 3, 8	RB	W, LV, F	B	W-M	S	80-100'	● - ◗		Missouri native
Shingle oak *Quercus imbricaria*	1 - 8	WB	LV, HV, W	U-B	M-D	S	50-60'	❍ - ◗	D	Susceptible to oak wilt & insects Missouri native
Shortleaf pine *Pinus echinata*	2 - 8	WB, SP, AC	HV, LV, W, NT	U	D-M, X	F-I				Missouri native
Shrub lespedeza *Lespedeza bicolor*	3	RB, SP, WB	W, E		M-D	F	4-6'			
Shumard oak *Quercus shumardii*	3, 7	AC, SP	LV, HV	B-U	M, X	I	100'	❍	S	Susceptible to oak wilt & insects Missouri native
Silky dogwood *Cornus amomum*	1 - 4, 6	WB, RB	W, NT, O, E	B-U	M	F-I	6-10'	●		Thicket forming Missouri native
Silver maple *Acer saccharinum*	1 - 8	RB, WB	LV, O	B	W-M, D	F-V	60-80'	◗ - ❍	S	Prone to ice and wind damage Missouri native
Sugar maple *Acer saccharum*	1, 3	FF	NT, LV	U	M, X	F	60-80'	● - ❍	S to D	Syrup ration - 80:1 Missouri native

Region: see UMCA Region map // **Agroforestry Application:** AC-alley cropping, SP-silvopasture, WB-windbreak, RB-riparian forest buffer, FF-forest farming, D-to add diversity // **Markets:** HV-high value wood products, LV-low value wood products, NT-non-timber forest products, F-fruit, W-wildlife food or shelter, O-ornamental or Christmas trees, E-environmental // **Site:** B-bottomland, U-upland // **Soil Moisture:** W-wet, M-moist, D-dry, X-well-drained // **Growth Rate:** V-very fast, F-fast, I-intermediate, S-slow // **Height:** maximum range in feet under optimal site conditions // **Light Preference:** ❍-full sun, ◗-partial shade/sun, ●-full shade // **Rooting:** S-shallow, D-deep, T-taproot, L-lateral (may be used in combination; i.e., D-T=deep taproot)

Trees and Shrubs for Agroforestry Practices in Missouri (page 5 of 5)

Common Name ***Scientific Name***	Region	Agroforestry Application	Markets	Site	Soil Moisture	Growth Rate	Height	Light Preference	Rooting	Notes
Swamp chestnut oak *Quercus michauxii*	7, 8	AC, RB	LV, HV, O	B	M-W, X	S	60-80'			Best white oak for bottom areas Missouri native
Swamp white oak *Quercus bicolor*	1 - 6, 8	AC, RB	LV, HV, W, NT	B	W-M	S	60-70'			Common in CRP Missouri native
Sweetgum *Liquidambar styraciflua*	1 - 8	RB, WB	LV, HV, O, NT	B-U	M, X	I	80-120'	❍	S-L	Recommended for more southern areas Missouri native
Tulip-poplar *Liriodendron tulipifera*	2 - 8	AC, WB	LV, HV, O	B	W-M	F	100'	❍	D-L	Site-sensitive Suffers some wind damage Missouri native
Virginia pine *Pinus virginiana*	2 - 8	WB, SP	W, O		M, X	I	40'	❍	S	
Wahoo *Euonymus atropropureus*	1 - 8	D	W	B-U	M		<25'			Susceptible to foliar diseases Missouri native
Washington hawthorn *Crataegus phaenopyrum*	1 - 8	D	W, O	U		I-S	15-25'			Susceptible to rust diseases Thorns
Water oak *Quercus nigra*	1, 4, 7	RB, WB	LV	B-U	M-W	I	60-70'			Poorer quality than other red oaks Missouri native
White ash *Fraxinus americana*	1, 3, 4 7	AC, RB, WB	LV	U-B	M, X	I	70-100'	◗ - ❍	S to D	Disease problems Missouri native
White oak *Quercus alba*	1 - 8	AC, SP, WB, FF	HV, W, LV	B-U	D-M	S	80-100'	◗ - ❍	D	Can be hard to regenerate/establish Missouri native
White spruce *Picea glauca*	1 - 5, 8	WB	O, W	B	M-W	S				Not drought tolerant
Willow oak *Quercus phellos*	3, 7, 8	AC, SP, RB	O, LV, HV	B-U	M	S	80'			Missouri native
Winged sumac *Rhus copallina*	5, 7, 8	D	W, O	U	D-M	F	5-10'	❍	S-L	Missouri native
Witch-hazel *Hamamelis virginiana*	1, 3, 8	AC, FF, WB, D	W, NT	B-U	M-D		5-15'			Can be hard to establish Missouri native

Notes

Region: see UMCA Region map // **Agroforestry Application:** AC-alley cropping, SP-silvopasture, WB-windbreak, RB-riparian forest buffer, FF-forest farming, D-to add diversity // **Markets:** HV-high value wood products, LV-low value wood products, NT-non-timber forest products, F-fruit, W-wildlife food or shelter, O-ornamental or Christmas trees, E-environmental // **Site:** B-bottomland, U-upland // **Soil Moisture:** W-wet, M-moist, D-dry, X-well-drained // **Growth Rate:** V-very fast, F-fast, I-intermediate, S-slow // **Height:** maximum range in feet under optimal site conditions // **Light Preference:** ❍-full sun, ◗-partial shade/sun, ●-full shade // **Rooting:** S-shallow, D-deep, T-taproot, L-lateral (may be used in combination; i.e., D-T=deep taproot)

Appendix III: Grasses and Forages for Agroforestry

Agroforestry combines trees, shrubs, forages, grasses, livestock and crops in innovative, flexible combinations tailored to the land steward's needs. Through their integration with farm practices, production and conservation benefits can occur simultaneously. However, because the same resources are often used by all the plants in a given area, competition can pose some challenges to productivity.

As a component of a farm system, the properly designed and implemented agroforestry practice will help:

- *Increase crop production*
- *Diversify products and farm income*
- *Improve soil quality and reduce erosion*
- *Improve water quality and reduce damage*
- *due to flooding*
- *Enhance wildlife habitat and improve biodiversity*
- *Reduce pest management inputs*

These goals are important to keep in mind when selecting the appropriate forage/grass for an agroforestry system.

What makes a forage/grass appropriate?

The answer will likely vary according to each land steward's specific interest and goals. That said, many trees and shrubs can be planted in configurations or densities that will also enhance the production of select forages and/or grasses. In fact, the Center for Agroforestry has researched and identified many cool season grasses and legumes that produce better or the same under 50% shade as compared to full sun.

Design and management

Planting design and management of an agroforestry practice depends on existing site conditions and the goals of the land steward. (You may also refer to the section on each specific practice for more information on design considerations). Many forages/grasses will do quite well under partially shaded conditions. The following table outlines some of the forages/grasses that the Center for Agroforestry has identified for use in partially shaded environments, including expected productivity outcomes. In all cases, consider the products you wish to produce, any conservation or wildlife benefits desired, on-farm equipment and the needs of companion crops when planning the planting design.

When you decide on the appropriate forage/grass for your agroforestry practice, you should then seek out specific information on how to manage or establish that specific forage/grass species. Some considerations that will have a significant influence on the success of the forage/grass of choice include:

- *Soil pH*
- *Time of seeding*
- *Use of companion or nurse crops*
- *Use of herbicides to control undesirable or competing species*
- *Seeding method (broadcast vs. drilling)*
- *Seeding rates*
- *Need for inoculation*
- *Seed bed preparation*
- *Soil fertility*

Each of the above mentioned establishment and management considerations can have a significant impact on both the growth and productivity of a forage/grass stand. For more on establishing forages and seeding of a variety of forages common to Missouri, please reference: *A Guide to the Common Forages and Weeds of Pastures,* MU Extension, Publication No. M169, https://extension.missouri.edu/publications/m169.

Selecting forages and grasses

When selecting a forage/grass species, consider compatibility with the site. The selected species should be capable of providing the products and services desired by the land steward. Depending on the agroforestry practice selected, other forage/grass considerations may include:

- *level of shade tolerance*
- *season of production , i.e. warm vs. cool season*
- *productivity capacity for the site, i.e. drought-tolerance vs. capability to grow on a wet site*
- *compatibility with end use, i.e. is the forage for livestock or is the grass intended for erosion control?*
- *existing vegetation, i.e. can a natural forage/grass stand be enhanced?*

Included in the following table are recommendations on practice applicability, potential uses and general site recommendations. Forages and grasses are listed in alphabetical order by common name. Consult with your regional agronomy specialist, or check with your

University Extension personnel, to identify specifics on the appropriateness of a forage or grass to your region Please note that the following list is not exhaustive, but rather a starting point. All species listed may not be suited to all sites or regions within the State.

Additional Resources

Missouri

For a number of publications on specific forages and grasses suitable to Missouri, visit MU Extension's publication directory and search "forage".

Grow Native!, Missouri Prairie Foundation

Henning, J.C. and Wheaton, H.N. (1996) *Establishing Forages*. MU Extension.

Missouri Flora Database

Roberts, C. and Gerrish, J. (2001). *Seeding Rates, Dates and Depths for Common Missouri Forages*. MU Extension.

Other regions/states

Please note that many states not listed here have similar databases.

Arkansas Plant Database

Kansas Wildflowers and Grasses

Native Prairie Plants of Iowa

University of Connecticut Plant Database

National

USDA NRCS Plant Database

Silvics of North American Trees

Notes

Common Grass and Legume Forages for Agroforestry Practices in Missouri (page 1 of 5)

Common Name *Scientific Name*	Agroforestry Application	Valued for...	Growth Characteristics	Site Requirements	Notes
Alfalfa *Medicago sativa*	• Alley cropping • Silvopasture	• Hay	• Perennial • Cool-season • Legume • Persists 5-8 years • Flood intolerant	• Best on well drained soils • Does best in full sun • Soil pH above 6.0	• Excellent hay • High maintenance • Low-to-moderate tree competition
Alsike clover *Trifolium hybridum*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control	• Perennial • Cool-season • Legume	• Low, wet areas on a variety of soil types • Higher tolerance to soil acidity than Alfalfa	• Sometimes utilized for forage and hay production • Often in mixtures with red clover and grasses
Annual lespedeza *Kummerowia stipulacea* or *striata*	• Alley cropping • Silvopasture	• Wildlife benefits	• Annual • Warm-season • Legume • Tolerates lower pH than other legumes • Tolerates high temperature	• Productive on shallow, infertile soils • Best growth on well-drained soils	• Allow to reseed in late-summer • Best used in pastures and most effective when grown in grass sod
Annual ryegrass *Lolium multiflorum*	• Silvopasture	• Forage	• Annual • Cool-season	• Best under high fertility	• Winter Annual
Bermudagrass *Cynodon dactylon*	• Alley cropping • Silvopasture	• Erosion control	• Perennial • Warm-season • Not shade tolerant	• Prefers deep, sandy loam or medium textured soils • Will grow on poorer soils with management	• Grazing tolerant • May winter kill particularly in Northern Missouri
Big bluestem *Andropogon gerardii*	• Alley cropping • Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control • Hay	• Perennial • Warm-season • Not shade tolerant	• Prefers deep, well-drained soils • Intolerant of continuously wet soils	• If burned, care must be taken to protect trees • Native
Birdsfoot trefoil *Lotus corniculatus*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control	• Perennial • Cool-season • Legume	• Tolerates poorly-drained, droughty, infertile and acidic • soils better than Alfalfa	• Allow stand to naturally reseed every 2-3 years

Common Grass and Legume Forages for Agroforestry Practices in Missouri (page 2 of 5)

Common Name *Scientific Name*	Agroforestry Application	Valued for...	Growth Characteristics	Site Requirements	Notes
Buffalograss *Buchloe dactyloides*	• Silvopasture	• Erosion control	• Perennial • Warm-season • Drought resistant • Sod forming	• Avoid sandy soils	• Withstands heavy grazing
Canada wildrye *Elymus canadensis*	• Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control	• Perennial • Cool-season	• Grows in wet shaded areas	• Native
Caucasian bluestem *Andropogon caucasia*	• Alley cropping • Silvopasture • Riparian Buffer	• Erosion control	• Perennial • Warm-season • Not shade tolerant • Long active growth period	• Needs good drainage	• Grazing tolerant • Don't need to burn
Creeping red fescue *Festuca rubra*	• Silvopasture • Riparian Buffer	• Erosion control	• Perennial • Cool-season	• Grows best in well drained, infertile and droughty soils	• Shade tolerant • Usually used for turf
Crownvetch *Coronilla varia*	• Alley cropping • Riparian buffer	• Erosion control	• Perennial • Deep taproot • Spreads vegetatively • Legume	• Best adapted to well-drained, fertile soils with pH 6.0 or greater	• Does not tolerate grazing
Eastern gamagrass *Tripsacum dactyloides*	• Alley cropping • Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control • Hay	• Perennial • Warm-season • Slow to establish • Tolerates temporary flooding • Stiff upright stems • Forms large clumps or mounds • Not tolerant of shade	• Deep soils in low areas	• Excellent forage • Native
Golden feather grass *Sorghastrum nutans*	• Alley cropping • Silvopasture • Riparian buffer	• Wildlife benefits Erosion control	• Perennial • Warm-season • Not shade tolerant • grows 4-6 ft tall • 2-3 years to establish	• Deep, moist soils	• Native • If burned care must be taken to protect trees

Common Grass and Legume Forages for Agroforestry Practices in Missouri (page 3 of 5)

Common Name *Scientific Name*	Agroforestry Application	Valued for...	Growth Characteristics	Site Requirements	Notes
Hop clover *Trifolium agrarium*	• Silvopasture		• Annual • Cool-season • Legume	• Tolerates poorly-drained, droughty and infertile soils	• Used mainly in Southern Missouri
Illinois bundleflower *Desmanthus illinoensis*	• Alley cropping • Silvopasture	• Wildlife benefits	• Warm-season • Legume	• Grows well on clay or limestone soils	• Sometimes used in mix with warm-season grasses • Native
Kentucky bluegrass *Poa pratensis*	• Silvopasture • Riparian buffer	• Erosion control • Weed • suppression	• Perennial • Cool-season	• Grows on a variety of soil types	• Usually used in mixes for grazing
Little bluestem *Schizachyrium scoparium*	• Alley cropping • Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control	• Perennial • Warm-season	• Droughty sites • Grows on a variety of soil types	• Mix with warm-season grasses • Native
Orchardgrass *Dactylis glomerata*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay	• Perennial • Cool-season • Shade tolerant • Short lived • Not tolerant of overuse • Bunch grass	• Tolerates moderately poor drained soils, yet is intolerant to flooding	• Mixes well with legumes (alfalfa, ladino clover) • Matures yearly • Moderate - tree competition • Disease problems under some conditions
Red clover *Trifolium pratense*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay	• Perennial • Cool-season • Short lived • Legume • Easy to establish	• Prefers fertile, well-drained medium to heavy textured soils	• Requires reseeding • Best in grass/legume mixture • Common in pastures • Can crowd out grass in seeding year if planted too thick
Redtop *Agrostis gigantea*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Cover crop in orchards	• Perennial • Cool-season • Long-lived • Sod forming	• Will grow at lower pH and in wetter soils • Adapted to a wide range of soil conditions	• Moderate - competition with trees • Use smooth bromegrass, • Redtop, alsike clover and ladino clover in filter strips

Common Grass and Legume Forages for Agroforestry Practices in Missouri (page 4 of 5)

Common Name *Scientific Name*	Agroforestry Application	Valued for...	Growth Characteristics	Site Requirements	Notes
Reed canarygrass *Phalaris arundinacea*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay	• Perennial • Cool-season • Grows up to 6 ft tall • Tolerant of wet & drought • Mat forming - dense • Hard to establish	• Grows well in wet or dry soil • Wet areas	• Recommend low alkaloid variety • Too competitive with trees • Invasive in wet areas
Sideoats grama *Bouteloua curtipendula*	• Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control	• Perennial • Warm-season	• Droughty sites • Grows on a wide variety of well-drained soils	• Mix with other native warm- season grasses • Native
Smooth *bromegrass* *Bromus inermis*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay	• Perennial • Cool-season • Sod former with good fertility • Winter hardy	• Best growth on deep, fertile soils	• Weeds or companion crops may retard establishment from spring sowing
Sorghum-sudangrass *Sorghum hybrids*	• Alley cropping • Silvopasture	• Hay	• Annual • Warm-season	• Requires high fertility and moisture	• Tall growing, competitive
Sudangrass *Sorghum bicolor*	• Alley cropping • Silvopasture	• Hay	• Annual • Warm-season	• Requires high fertility and moisture	• Tall growing, competitive
Sweetclover *Melilotus sp.*	• Alley cropping • Silvopasture	• Soil • improvement	• Annual/Biennial • Legume • Drought tolerant • Winter hardy • Deep taproot	• Not tolerant of acid soils	• Improperly cured hay can contain the poison Dicoumarol
Switchgrass *Panicum virgatum*	• Alley cropping • Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control • Hay	• Perennial • Warm-season • Long lived • Grows 4-6 ft tall • Flood & herbicide tolerant • Good deep root filtering • Slow to establish (2-3 years)	• Performs well in wet areas • Will grow where many grasses will not • Prefers fertile, well-drained sites	• Plant thick to avoid weed competition • If burned, care must be taken to protect trees • Native

Common Grass and Legume Forages for Agroforestry Practices in Missouri (page 5 of 5)

Common Name *Scientific Name*	Agroforestry Application	Valued for...	Growth Characteristics	Site Requirements	Notes
Tall fescue *Festuca arundinacea*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay • Seed	• Perennial • Cool-season • Drought tolerant • Hardy	• Tolerates many soil conditions	• May be too competitive with trees • Endophyte free/friendly endophyte varieties recommended • Grazing tolerant • Good fall pasture
Timothy *Phleum pratense*	• Alley cropping • Silvopasture • Riparian buffer	• Erosion control • Hay	• Perennial • Cool-season • Winter hardy • Short lived • Bunch grass	• Prefers well-drained, moist soils • Not tolerant of droughty sites	• Intolerant of overgrazing • Use in a mixture with other cool season grasses and legumes • Low competition with trees
Virginia wildrye *Elymus virginicus*	• Riparian Buffer • Silvopasture	• Wildlife benefits • Erosion control	• Cool season • Perennial • Slow to get started	• Grows in moist sandy soils • Prefers medium textured soils	• Should be used in • conjunction with other grasses
Western wheat grass *Pascopyrum smithii*	• Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control	• Perennial • Cool-season	• Grows well on low, heavy soils	• Produces an open but uniform sod
White/Ladino clover *Trifolium repens*	• Silvopasture • Riparian buffer	• Wildlife benefits • Erosion control	• Perennial • Cool-season • Legume • Not drought tolerant	• Does best in wet soils and seasons • Performs poorly on shallow, droughty soils	• Use in combination with grasses

General note: **Warm season grasses may need prescribed fire for management which may not be compatible with agroforestry.*

Appendix IV: The Basics of Selling Timber

Selling timber can be a rewarding experience for some forest land stewards while a traumatic experience for others. Land stewards who do a thorough job of planning and marketing are usually satisfied with a timber harvest; those who did not prepare for a timber sale are likely to be dissatisfied. Many people receive a fraction of their timber's true value because they do not know what they have or do not know how to sell it. This article presents guidelines to assist individuals in selling timber from their woodlands.

Define your objectives

A successful timber harvest begins with identifying your objectives. This can best be done with a written Forest Management Plan that identifies your objectives, including steps to achieving them and realistic timelines. The plan should also identify the type of harvest to be conducted and steps to be taken for reforestation after the harvest.

You need to tell the log buyer exactly what you expect from the timber sale. This is best done through provisions written into a timber sale contract. For example, if one of your objectives is maintaining water quality, a provision in the contract should state that Best Management Practices (BMPs) will be followed during road building, stream crossing, and harvesting. For a list of voluntary BMPs, contact a Missouri Department of Conservation (MDC) forester.

Why sell timber?

Other than simply for financial gain, timber harvesting is a tool for accomplishing objectives that you may have identified in your forest management plan. Such objectives may include:

- *improving the overall health and vigor of the forest*
- *promoting seedling regeneration*
- *creating wildlife habitat*
- *reducing the density of the forest (if overcrowded)*
- *establishing planting areas*
- *creating vistas and trails*
- *developing certain types of recreational activities*
- *salvaging damaged trees*

Steps in selling timber

When selling timber these steps should be followed:

1. *Know what you have to sell.*
2. *Determine what your timber is worth.*
3. *Determine what method you will use to sell your timber.*
4. *Determine a method of payment.*
5. *Advertise your sale.*
6. *Develop a written contract with the buyer.*
7. *Supervise and inspect the harvest.*
8. *Practice good forestry.*

Sources of Forestry Advice

Land stewards who have little experience in forestry should contact a professional forester to assist in managing their woodlands. There are private and public foresters available to help you with your management plan.

Private sources

A consultant is a professional forester whose services are available on a contract or fee basis, with the fee paid by the client. Consultants can perform a variety of work including forest inventories, timber sales and land appraisal. Consultants may also serve as the main contractor in carrying out a Forest Management Plan on your land. A list of consulting foresters is available from the Missouri Department of Conservation.

Public sources

The Missouri Department of Conservation can help private landowners become good stewards of their forest land by providing technical forestry assistance. A forester can provide a variety of services to help you meet your land management goals. These services are free-of-charge and will be as in-depth as you need, depending on your commitment to the long-term management of your forest lands. A forester can answer your questions over the telephone or may provide on-site assistance. A brochure entitled "Forest Management Assistance for Missouri Landowners" is available from

MDC foresters and describes the services offered. Additional resources are available on the MDC website: or by contacting the Missouri "Call Before You Cut" line at (877) 564-7483.

Know what you have to sell

Before advertising a timber sale, you first need to determine what you have to sell. This involves selecting the trees to be harvested and determining what volumes and products are present in those trees. Make sure the trees are, in fact, on your property. Settle any boundary disputes with your neighbors before you sell any timber. Clearly mark the trees to be harvested so the logger can easily see them. Mark each tree with a spot of paint about chest high (bright blue or orange works best) on the same side of the tree so they are visible from a main trail or road. A second spot of paint should be placed at the ground line. This paint spot will remain after logging to serve as a check to make certain that only marked trees were harvested.

After selecting the trees to be harvested, estimate the wood volume or the number of products that will be cut by species. Timber volumes are estimated by measuring individual trees. For more details read the University Extension guide *How to Measure Trees and Logs* which is available from a MDC forester or the county Extension Service agent.

Some common products that may be produced from trees include sawlogs, stave bolts (to make barrels), veneer logs, firewood, pulpwood (to make paper), posts and poles. These products are determined by the species, size and quality of your timber and can vary greatly in price. There may not be a market for all these products within any given area. Local mills will determine the specifications for each product they purchase. For current market conditions, Timber Price Reports are available from a MDC forester.

Determine what your timber is worth

The price paid for standing trees before they are harvested (called stumpage) has no set value. Your timber is worth whatever you and the buyer agree to. Many factors influence the price of standing trees. These include:

- **Tree species:** wood from some species is more valuable than wood from other species.
- **Tree size:** large trees will have more volume and clear wood than smaller trees.
- **Tree quality:** trees with fewer defects (e.g., branch scars, decay, embedded wire) have higher quality, more valuable wood.
- **Volume of sale:** Large volume sales will bring a higher per unit price than small volume sales.
- **Distance to the mill:** the closer a woodlot is to the mill, the lower the hauling costs.
- **Site accessibility:** the ease with which the forest land can be reached affects costs.
- **Logging difficulty:** steepness of terrain and soil moisture conditions affect the equipment that can be used and speed of harvesting.
- **Market conditions:** poor markets mean lower timber prices. Buyers often pay more for logs when their inventories are low to ensure continued mill operation.
- **Your restrictions on harvesting and skidding techniques:** restrictions set forth in your timber sale contract, such as seeding skid trails after harvest, will increase logging costs.

Different buyers may offer substantially different prices for the same timber, depending on their own particular costs and markets. The only way to actually determine what your timber is worth is to offer it for sale on the open market and contact as many potential buyers as possible.

Determine a selling method

Selecting the appropriate selling method for marketing your timber is the key to having a successful timber sale. The two methods commonly used in Missouri are sealed bid and negotiation.

The ***sealed bid*** sale is recommended most often for private woodland owners. This process informs potential buyers about the timber sale. These buyers are allowed a length of time (usu- ally 4 to 6 weeks) to inspect the sale and sub- mit bids. Each bidder is allowed to make only one bid and late bids are always rejected. Bids are then opened at a specified time and place, and the successful buyer is selected. If no bids meet your minimum requirements, you have the right to refuse all bids. No further price negotiations should take place after a buyer has been selected and unsuccessful bidders

notified that the timber was sold. A blank Bid Solicitation is available from a MDC forester.

A ***negotiated sale*** involves face-to-face negotiations between the seller and a single buyer. This procedure often results in a price well below what the timber is worth because the buyer has no competition and the seller is often uninformed about the timber's value. For that reason, do not be too anxious to accept the first offer for your timber. A negotiated sale, however, may be the best method if:

- You have a small amount of timber or poor quality timber to sell.
- Markets for the species and products for sale are so poor that few buyers would be interested.
- You want to work with a particular buyer that you know and trust.
- You are marketing certain specialty products.

Method of Payment

There are two methods of payment available to woodland owners who sell timber.

In a ***lump sum*** sale you receive a single payment for the trees to be sold before the harvest begins. Splitting payments for each cutting area may be necessary for large sales. Payment is based on the amount of timber volume estimated and not the actual volume harvested.

Lump sum sales, therefore, depend heavily on the accuracy of your estimate of the volume and quality of timber for sale. An advantage of a lump sum sale is simplicity. The landowner is relieved of the burden of keeping track of the volume of timber being harvested and income is provided before harvesting begins. A disadvantage is that the seller receives bids that are based on an estimate of the volume to be harvested, which may be different from the amount actually harvested.

In a ***yield sale*** the landowner is paid a certain amount for each unit of product cut. This requires that someone (usually at the mill) scale the volume of products after harvest. An advantage of a yield sale is that the landowner is being paid for the timber that is actually being harvested. The disadvantage is that problems can arise in obtaining an accurate tally since tracking the logs is difficult once they leave your property.

Advertising Your Sale

There are several steps to follow in preparing a timber sale notice. You must have accurate, reliable information and you need to send it to as many prospective bidders as possible. An up- to-date Log Buyers List is available from a MDC forester. A timber sale notice should include the basic information that will later become part of the timber sale contract including:

- **Your name, address and telephone number.**
- **Location of the timber for sale.** Include a map, legal description and directions.
- **Description of the trees or logs to be sold.** Include volume by species, number of trees, diameter classes and sawlog grades if appropriate. Describe how the trees and sale boundaries will be marked.
- **Type of bid you are expecting: lump sum or yield sale.**
- **Times when potential buyers can visit and inspect the timber.**
- **Date, time and place written bids will be opened.** Include how the successful bidder will be selected and notified.
- **Whether or not a down payment is required to bind the offer when the contract is signed.** An amount of 5 to 10 percent of the bid price is normally required.
- **Any limitations or special ownership considerations on the sale.** Such considerations include harvesting deadline, restrictions on access, conditions when loggers cannot operate (such as wet conditions), streamside management zones or buffers, etc.
- **Requirements for a performance bond.** A performance deposit is an amount of money above the sale price (usually 10 percent of sale price) posted by the buyer when the contract is signed and held in escrow by the seller. The bond's purpose is to ensure that the buyer abides by the terms set forth in the contract. The performance deposit should be refunded immediately after the sale is completed and contract requirements are met.

- **Statement whether the logger must carry insurance and liability.** Insurance will avoid possible legal complications if a logger is injured on your property and liability insurance will cover any damage to your property or adjoining lands caused by the logger.
- **Statement indicating your right to reject any or all bids.**

Timber Sale Contract

The purpose of a timber sale contract is to protect the interests of buyer and seller and must be signed by both parties. You should meet with the logger or buyer to discuss the items to be included in the contract; this will reduce the possibility of misunderstandings.

The written contract does not need to be a complex document, but it should reflect what you and the logger have agreed to with respect to the sale. Timber buyers will frequently provide their own standard contract. Such contracts may not adequately represent your interest as a seller. A blank Timber Sale Contract is available from a MDC forester. You may want to have a lawyer draft or review your contract. It is critical that you include the provisions that you feel are important regarding the harvest on your property.

Supervise the Timber Harvest

One of the most important things you can do during the harvest is to inspect it periodically. Before harvesting begins, review the timber sale contract with the logger and point out sale boundaries. If possible, walk the site to be harvested with the logger. This will accomplish two objectives; 1) it will give you an opportunity to get to know the logger, and 2) it will give you a chance to explain your objectives of harvesting timber. A logger that is familiar with you personally and aware of your objectives will likely do a better job on the site.

Once timber harvesting begins, visit the area frequently. When you visit the site make sure that logging meets the terms of the contract. Questions that arise should be discussed with the logger. Unless you discover a flagrant violation of the contract, a simple suggestion to the logger in charge of the operation will usually solve the problem. After the harvest is completed and all provisions of the contract have been fulfilled, write a letter releasing the buyer from the contract and return the performance deposit.

Practice Good Forestry

Improper logging practices can have adverse effects on water quality, wildlife and forest regeneration. To ensure that you are satisfied with the end result of the timber harvest, it is important that good forestry practices are applied during and after the logging operation. Following BMPs and having a reforestation plan are two important considerations for harvesting timber on your property.

Notes

Sample Solicitation of Bid for Timber

You are invited to bid on timber located as follows: in the NW 1/4, Section 23, Township 25 North, Range 14 West, Timber County, Missouri. The timber is located five miles south of Oak Grove on Route AB.

For additional information or for directions on how to see the timber, contact: Forrest Farmer, Oak Grove, Missouri; telephone 573/555-1234.

DESCRIPTION:

Approximately 160 acres of mixed oak timber. The trees to be cut are marked with a fresh orange paint spot at breast height and on the stump. About 1,600 trees are marked. Bids are to be made on a lump sum basis.

BID INSTRUCTIONS:

After the bid is completed, return it to:

Forrest Farmer, Route 1
Oak Grove, MO 61234

on or before: ***1:00 PM THURS 21 MARCH 2024***

Please mark "TIMBER BID" on the envelope.

The owner reserves the right to reject any or all bids.

BIDDER INFORMATION:

TELEPHONE:

EMAIL:

ADDRESS:

SIGNATURE:

AMOUNT OF BID:

Sample Timber Sale Contract (page 1 of 2)

Joe Logger of Big Cedar, Missouri, herein after called the Purchaser, agrees to purchase from Forrest Farmer of Oak Grove, Missouri, herein after called the Seller, the designated timber specified below:

WITNESSETH:

ARTICLE I. The Seller hereby agrees to sell to the Purchaser, subject to the terms listed below, all of the timber specified below, on a certain tract owned by the Seller, located in NW 1/4, Section 23, Town- ship 25 North, Range 14 West, County of Timber, State of Missouri, located on 160 acres, more or less.

ARTICLE II. The Purchaser agrees:

1. To cut only those trees marked with a fresh orange paint spot. Trees marked with an "X" may be cut if desired.
2. Trees other than those specified above may be cut only for access on areas used for roads and landings.
3. To pay the Seller a lump price of $12,000.00 when the contract is signed to pay for the trees designated for cutting.
4. To pay three times the stumpage value per tree, a penalty rate, for each tree that is cut which is not designated for cutting.
5. To keep fields, fences, roads, and streams free from tree tops and other logging debris at all times. He also agrees to remove all oil and gasoline cans and other debris accumulated during cutting.
6. And understands that the Seller is not responsible or liable in any manner for injury or damage resulting from the cutting and removing of these trees.
7. That this contract cannot be transferred to another party without the written permission of the Seller.

ARTICLE IV. The Seller agrees to the following conditions:

1. To guarantee title to the forest products covered by this agreement and to defend it against all claims at his expense.
2. To grant or secure necessary entry and right-of-way to the Purchaser and his employees on and across the area covered by this agreement, and also other privileges usually extended to purchasers.

ARTICLE V. It is mutually understood and agreed by and between the parties hereto as follows:

1. All timber included in this agreement shall remain the property of the Seller, and shall not be removed until paid for in full.
2. In case of a dispute over the terms of this contract, we agree to accept the decision of an arbitration board of three selected persons as final. Each of the contracting parties will select one person and the third will be the State Forester or his chosen representative.

Signed in duplicate this _____ day of _____ , 20 _____.

(Witness) (Purchaser)

(Witness) (Seller)

(Witness) (Seller)

Sample Timber Sale Contract (page 2 of 2)

ACKNOWLEDGMENT

STATE OF _____

COUNTY OF _____

On this _____ day of _____, 20 _____ before me personally appeared _____to be known to be the person(s) described in and who executed the foregoing instrument and acknowledged that _____ executed same as _____ free act and deed.

In Testimony Whereof, I have hereunto set my hand and affixed my official seal, at my office in _____, the day and year first above written.

My Commission as Notary Public Expires _____.

. .

_____

NOTARY PUBLIC

NOTES

Agroforestry in Action Technical Guides

The following guides are available for free download on our website:

Specialty crop guides

- *Growing Pecans in Missouri*
- *Growing Shiitake in an Agroforestry Practice*
- *Burgundy Black Truffle Cultivation in an Agroforestry Practice*
- *Growing and Marketing Elderberries in Missouri*
- *Growing Black Walnut for Nut Production: Orchard Establishment and Early Management*
- *Growing Black Walnut for Nut Production: Bearing Years Management*
- *Growing and Marketing Chinese Chestnuts*
- *Establishing & Managing a Forest Garden*

Conservation guides

- *Integrating Agroforestry Practices for Wildlife Habitat*
- *Establishing and Managing Riparian Forest Buffers*
- *Succession Planning for Woodland Owners*

Agroforestry economic guides

- *Using NRCS Assistance for Agroforestry and Woody Crop Establishment*
- *Understanding Casualty Loss of Timber*
- *Economic Budgeting for Agroforestry Practices*
- *Tax Considerations for the Establishment of Agroforestry Practices*



Mechanized nut harvest demo at the MU Horticulture and Agroforestry Research Farm in New Franklin, MO.

Looking for more agroforestry information, conversation, and connection? Join us at one of our upcoming events!

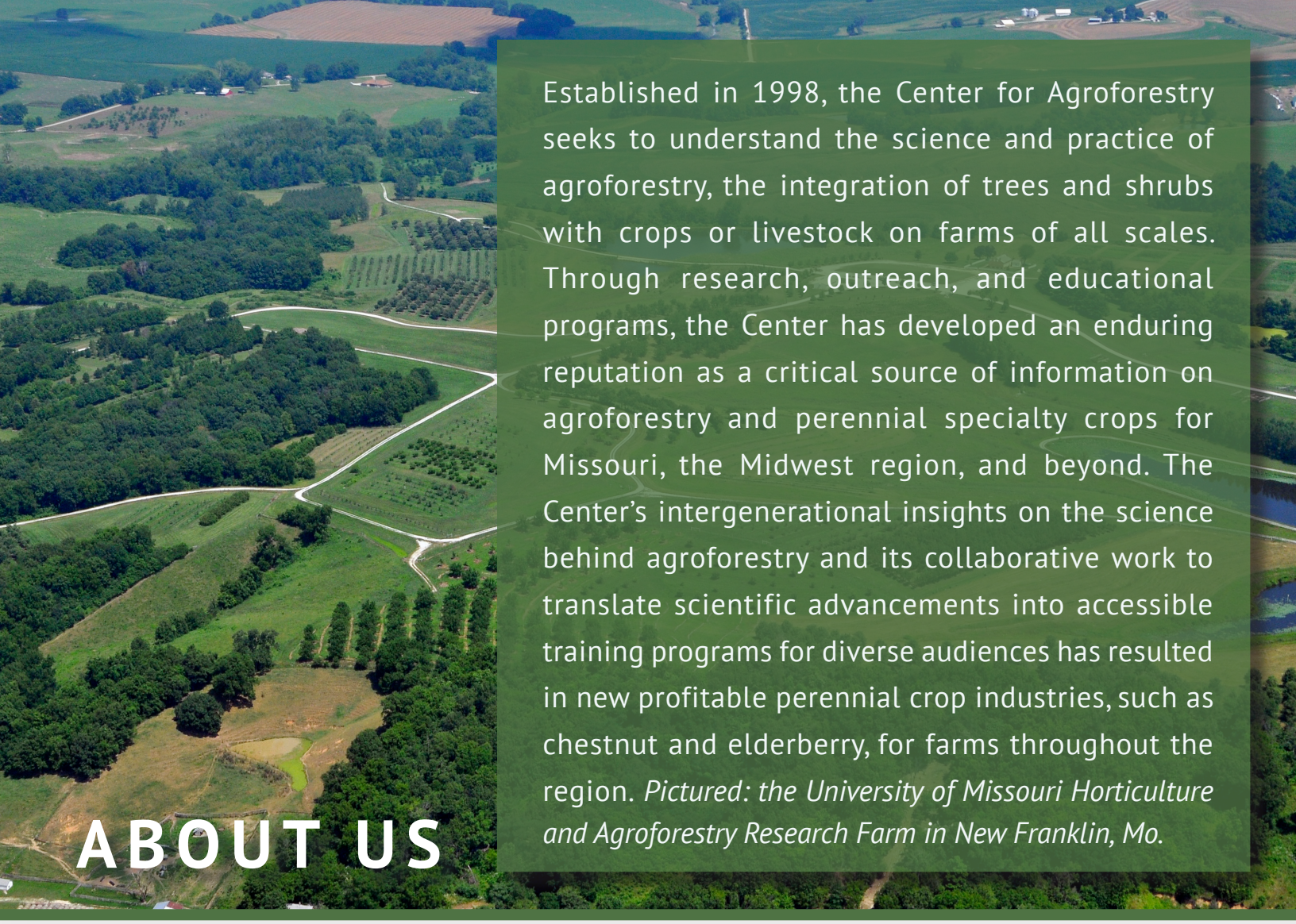
Find our full calendar on our website: https://centerforagroforestry.org/farmers/events/

The Agroforestry Symposium: Typically held in January, the Symposium offers both virtual and in-person programming that seeks to explore the interdisciplinary nature of agroforestry science. Recordings of previous Symposia can be found on the Mizzou Agroforestry YouTube Channel.

Agroforestry Training Academy: The Center for Agroforestry's Training Academy is an intensive educational program designed for natural resources professionals and farmers to gain an in-depth understanding of agroforestry practices, design concepts, species selection and management, economics and marketing, and more. The virtual program occurs every spring with an optional, in-person field experience every summer. Learn more on our website: https://centerforagroforestry.org/farmers/the-agroforestry-academy/

Annual field events and workshops: From tree planting demos to grafting workshops to the Missouri Chestnut Roast Festival and mushroom cultivation sessions, our team offers a variety of programming in the field every year. See our event calendar linked above for upcoming offerings.

Conferences: Whether hosting, exhibiting, or attending, you can find our team at a variety of conferences every year, including: the North American Agroforestry Conference, the Perennial Farm Gathering, the Short Rotation Woody Crops International Conference, Lincoln University Forest Farming Workshops, the Midwest Elderberry Conference, Missouri Natural Resources Conference, Missouri Organic Association Conference, and more.



ABOUT US

Established in 1998, the Center for Agroforestry seeks to understand the science and practice of agroforestry, the integration of trees and shrubs with crops or livestock on farms of all scales. Through research, outreach, and educational programs, the Center has developed an enduring reputation as a critical source of information on agroforestry and perennial specialty crops for Missouri, the Midwest region, and beyond. The Center's intergenerational insights on the science behind agroforestry and its collaborative work to translate scientific advancements into accessible training programs for diverse audiences has resulted in new profitable perennial crop industries, such as chestnut and elderberry, for farms throughout the region. *Pictured: the University of Missouri Horticulture and Agroforestry Research Farm in New Franklin, Mo.*

RESEARCH

We are an experienced leader in temperate agroforestry research, both basic and applied, including on-farm applications, tree crop improvement, silvopasture, the impact of perennial buffers on soil and water quality, the economics and marketing of agroforestry products, phytoremediation, human health, and more. We put the science behind the practices of agroforestry.

EDUCATION

We host the only comprehensive agroforestry graduate degree program in the United States, offering graduate certificate and online and on-campus M.S. programs. Students may also pursue a Ph.D. in the University of Missouri School of Natural Resources focused on agroforestry. Our students are a source of inspired commitment to the next generation of agroforestry science.

OUTREACH

We facilitate the exchange of insights and information among scholars, researchers, farmers, ranchers, foresters, land stewards, business owners, technical assistance providers, and educators. Our team hosts an annual online and in-person Agroforestry Training Academy and Agroforestry Symposium, as well as countless workshops, presentations, field days, and learning circles.

Center for Agroforestry
University of Missouri