# Chapter 6
# Agroforestry Resources

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Agroforestry has potential to serve as a climate change management option for building resilient and profitable agricultural operations and landscapes. Realizing this potential requires identifying the opportunities and tradeoffs that exist in each situation and designing an agroforestry practice that achieves the desired balance among them. The decisionmaking process must incorporate many considerations, not only at the field scale but also at the larger scales of farm, landscape, and watershed, while taking into account climate variability and change.

Resources for planning, designing, and implementing agroforestry systems can provide assistance in this process. Important resources for these tasks include decision-support tools and conservation programs that provide technical and financial assistance to interested landowners. This chapter presents available resources in both of these categories and identifies gaps in the suite of tools.

## Decision-Support Tools

The application of agroforestry can be greatly enhanced through the use of decision-support tools, which are any technology or resource that can be used to help integrate diverse sets of information (Ellis et al. 2004). Information gathering and analysis tools already exist at the farm ownership level, the most notable being precision agriculture systems (Mulla 2013). The focus of this section is on decision-support tools that assist implementation rather than tools that aid research in agroforestry science. Crucial differences exist between research tools and planning-and-design tools. Researchers generally seek answers to "Why?" whereas practitioners and landowners need answers to "What?" "Where?" and "How?" Useful decision-support tools for implementation should—

1. Minimize expenses.
2. Reduce dead ends.
3. Reduce anxiety of landowners and practitioners.
4. Accelerate necessary decisionmaking.

Agroforestry systems in the United States are applied in diverse geographic, environmental, and institutional contexts. In addition, each landowner has a unique set of conditions that will dictate different questions that the decision-support tools need to answer (Arbuckle et al. 2009). In light of each unique situation, practitioners and landowners will need to rely on a suite of tools throughout the planning and implementation process (Ellis et al. 2004).

Table 6.1 lists a broad cross-section of tools to support planning, design, and management of agroforestry systems. Although not an all-encompassing list, it illustrates the range and type of tools that are available. Some of these tools are specifically developed for agroforestry systems and others come from different disciplines but can be used effectively in agroforestry applications. Not every tool has a climate change focus, but most can help the user address the potential impacts of a changing climate and possible responses.

**Table 6.1.** Examples of decision-support tools to support planning, design, and management of agroforestry systems.

| Decision-support tool | Tool type | Focus | Description | End user | Reference/link |
|---|---|---|---|---|---|
| Agroforestree Database | Database | Biophysical | Provides information on the management, use, and ecology of tree and shrub species used in agroforestry. | Practitioners, landowners, researchers | Orwa et al. (2009) http://www.worldagroforestry.org/resources/databases/agroforestree |
| Agroforestry Species Switchboard 1.0 | Database | Biophysical | Documents the presence of more than 22,000 plant species in 13 Web-based databases and, when available, provides hyperlinks to information on the selected species. | Practitioners, landowners, researchers | Kindt et al. (2013) http://www.worldagroforestry.org/products/switchboard/ |

**Table 6.1.** Examples of decision-support tools to support planning, design, and management of agroforestry systems (continued).

| Decision-support tool | Tool type | Focus | Description | End user | Reference/link |
|---|---|---|---|---|---|
| Forestry Compendium | Database | Biophysical, economic, social | Offers a compilation of knowledge on forestry, agroforestry, and tree plantations, including decisionmaking information for tree management. | Practitioners, researchers | http://www.cabi.org/fc/ |
| Agroforestry Suitability Assessments | GIS | Biophysical, economic | Provides instruction for developing GIS-based suitability assessments for agroforestry. | Practitioners | Bentrup and Leininger (2002) |
| Target Regions for Silvoarable Agroforestry in Europe | GIS | Biophysical | Identifies regions where productive growth of trees in agroforestry systems could be expected and where these systems could reduce soil erosion and nitrate leaching and increase landscape diversity. | Practitioners, researchers, policymakers | Reisner et al. (2007) |
| Agroforestry Development Production Tool | Model | Biophysical, economic, social | Helps assess many levels of new agroforestry endeavors, including environmental, social, and economic considerations; labor; and cashflow planning. | Practitioners, landowners | http://agroforestry.ubcfarm.ubc.ca/agroforestry-production-development-tool/ |
| COMET-Farm™ | Model | Biophysical | Enables farmers and ranchers to estimate carbon sequestration and GHG emissions related to crop and livestock production and on-farm energy use. | Practitioners, landowners | http://comet-farm.com |
| HOLOS Farm Greenhouse Gas Calculator | Model | Biophysical | Estimates GHG emissions based on information entered for individual farms (calibrated for Canada) using whole-farm modeling software program. | Practitioners, landowners | http://www.agr.gc.ca/holos-ghg |
| FALLOW (Forest, Agroforest, Low-Value Landscape or Wasteland) | Model and GIS | Biophysical | Evaluates impacts of shifting cultivation and fallow rotations at a landscape scale, evaluating transitions in soil fertility, crop productivity, biodiversity, and carbon stocks. | Practitioners, researchers | http://worldagroforestrycentre.org/regions/southeast_asia/resources/fallow-forest-agroforest-low-value-landscape-or-wasteland |
| AgBufferBuilder | Hybrid GIS and model | Biophysical | Designs buffers around agricultural fields using terrain analysis to account for spatially nonuniform runoff. | Practitioners, researchers | http://nac.unl.edu/tools/AgBufferBuilder.htm |
| Water Erosion Prediction Project (WEPP) | Model | Biophysical | Predicts soil erosion and the effects of conservation practices on soil erosion. | Practitioners, researchers | http://www.ars.usda.gov/Research/docs.htm?docid=10621 |
| Riparian Restoration to Promote Climate Change Resilience Tool | Hybrid GIS and model | Biophysical | Identifies areas in the riparian zone that would benefit most from increased shading produced by planting trees. | Practitioners, landowners | http://applcc.org/plan-design/gis-planning/gis-tools-resources/riparian-restoration-decision-support-tool-1 |
| Economic Budgeting for Agroforestry Practices | Model | Economic | Provides guidance for developing agroforestry enterprise budgets. | Practitioners, landowners | http://www.centerforagroforestry.org/pubs/economichandbook.pdf |
| Simulation Tool to Assess Economic Impacts of Agroforestry Practices | Model (Excel based) | Economic | Evaluates the economic impacts of installing riparian forest buffers and windbreaks for crop, building, and road protection. | Practitioners, landowners | http://www.wbvecan.ca/anglais/coutspdf.html |
| Farm-SAFE | Model (Excel based) | Economic | Compares arable, forestry and silvoarable systems across four areas of a farm in order to determine the feasibility of silvoarable systems. | Practitioners, landowners, researchers | Graves et al. (2011) https://www.agforward.eu/index.php/en/web-application-of-yield-safe-and-farm-safe-models.html |
| Elderberry Financial Decision Support Tool | Model (Excel based) | Economic | Assists with establishment and management decisions. | Practitioners, landowners | http://www.centerforagroforestry.org/profit/elderberryfinance.php |
| Black Walnut Financial Model | Model (Excel based) | Economic | Assists with establishment and management decisions. | Practitioners, landowners | http://www.centerforagroforestry.org/profit/walnutfinancialmodel.php |
| Windbreak Economic Model | Model (Excel based) | Economic | Estimates long-term financial benefits of windbreaks on crop yields. | Practitioners, landowners | http://www.centerforagroforestry.org/profit/#budget |

**Table 6.1.** Examples of decision-support tools to support planning, design, and management of agroforestry systems (continued).

| Decision-support tool | Tool type | Focus | Description | End user | Reference/link |
|---|---|---|---|---|---|
| Midwest Hazelnut Enterprise Budget Tool | Model (Excel based) | Economic | Assists with establishment and management decisions. | Practitioners, landowners | http://midwesthazelnuts.org/ |
| Buffer$ | Model (Excel based) | Economic | Analyzes cost-benefits of implementing buffers compared with traditional crops. | Practitioners, landowners | http://nac.unl.edu/tools/buffer$.htm |
| Snow Fence Cost-Benefit Web Tool | Model | Economic | Calculates what transportation agencies can pay landowners to establish a living snow fence to reduce snow and blowing snow to highways. | Practitioners, landowners | http://snowcontroltools.umn.edu/#!/calculator |
| CanVis 3.0 Visual Simulation Kit | Model | Social | Simulates agroforestry practices with 2-D image-editing tool. | Practitioners, landowners | http://nac.unl.edu/simulation/index.htm |
| Agroecological Knowledge Toolkit (AKT5) | KBS | Biophysical, economic, social | Stores, manipulates, and analyzes a variety of information and knowledge on agroforestry agroecological systems. | Practitioners, researchers | http://akt.bangor.ac.uk/ |
| *Handbook for Agroforestry Planning and Design* | Other: handbook | Biophysical, economic, social | Assist in the planning and design of agroforestry practices. | Practitioners, landowners | http://www.centerforagroforestry.org/pubs/training/HandbookP&D13.pdf |
| *Agroforestry Tech Notes* | Other: technical note series | Biophysical, economic, social | Provides agroforestry information in a useful "how to" format. | Practitioners, landowners | http://nac.unl.edu/publications/agroforestrynotes.htm |
| *Conservation Buffers Handbook* | Other: handbook | Biophysical, economic, social | Provides design guidelines for buffers and other linear vegetative practices based on a synthesis of more than 1,400 research publications. | Practitioners, landowners | http://nac.unl.edu/buffers/index.html |
| *Silvopasture: Establishment and Management Principles for Pine Forests in the Southeastern United States* | Other: handbook | Biophysical, economic, social | Assist in managing pine silvopasture system in the Southeastern United States. | Practitioners, landowners | http://www.silvopasture.org/ |
| *Profitable Farms and Woodlands: A Practical Guide in Agroforestry* | Other: handbook | Biophysical, economic, social | Depicts step-by-step methods and principles on developing agroforestry practices for farmers and woodland owners. | Practitioners, landowners | http://nac.unl.edu/documents/morepublications/profitable_farms.pdf |
| USDA PLANTS | Other: Web site (online database) | Biophysical, economic | Provides botanical information, images, and links on plants in the United States, including crops and invasive species. | Practitioners, landowners | http://plants.usda.gov/java/ |
| Forest Farming eXtension Community of Practice | Other: Web site | Biophysical, economic, social | Consolidates resources on forest farming and offers a portal for landowners to ask questions of experts. | Practitioners, landowners | http://www.extension.org/forest_farming |
| CropScape | Other: Web site | Biophysical, economic | Provides a view of the USDA Cropland Data Layer for checking the type of crop grown in each field across the contiguous United States from 1997 to the present and a sequence of views that show how the distribution of crops has shifted over time. | Practitioners, landowners, researchers | http://nassgeodata.gmu.edu/CropScape/ |
| ClimateData.us | Other: Web site | Biophysical, economic, social | Provides comparisons of projected changes in temperature and precipitation and of conditions by decade under a mitigation scenario (reduced emissions) and a high-emissions scenario. | Practitioners, landowners, researchers | http://climatedata.us/ |

GHG = greenhouse gas. GIS = Geographic Information System. KBS = Knowledge-based system. USDA = U.S. Department of Agriculture.

Databases: Organize and facilitate the management and querying of large quantities of data and information.

GISs: Add a geographic or spatial component to a database; manage, manipulate, and analyze spatial data.

Models (mathematical): Represent real-world processes and predict outcomes based on input scenarios.

KBSs: Adopt artificial intelligence in the form of organizing, manipulating, and obtaining solutions, using knowledge in the form qualitative statements, expert rules (i.e., rules of thumb), and a computer language representation system for storing and manipulating knowledge.

Hybrid systems: Integrate two or more of the computer-based technologies listed in the table (e.g., GISs, KBSs, models) for more versatile, efficient, and comprehensive decision-support tools.

Other: Includes information resources such as Web sites and planning-and-design manuals.

Source: Adapted and updated from Ellis et al. (2004).

## Conservation Programs

Voluntary conservation-based programs at the Federal, State, and local levels provide technical and financial assistance to landowners to develop conservation plans and install conservation practices. These programs address a number of farming- and ranching-related conservation issues, including drinking-water protection, agricultural-waste management, soil health improvement, enhancement of fish and wildlife habitat, and better forest management and wetland restoration. Because agroforestry can help solve these issues, conservation programs are used as a resource for implementing agroforestry practices, particularly riparian forest buffers and windbreaks.

Federal assistance for agroforestry is primarily administered through U.S. Department of Agriculture (USDA) agencies, such as the Farm Service Agency (FSA), Natural Resources Conservation Service (NRCS), Forest Service, and National Institute of Food and Agriculture (table 6.2). The USDA programs are authorized through farm bill legislation; the programs in table 6.2 are based on the 2014 Farm Bill and may be subject to change as the details of that policy are refined during the next few years. Other Federal assistance and funding for agroforestry are available through the USDI's Fish and Wildlife Service.

Depending on the details in each program, financial assistance for landowners can come in the form of cost sharing implementation costs, incentive and maintenance payments, and land use or rental payments. In return, landowners must commit to maintaining the practice for the length of the contract period. Within these Federal programs, resource professionals with NRCS, the Forest Service, State agencies, conservation districts, universities, and technical service providers provide technical assistance for planning and designing tree-based practices. These assistance programs collectively have been an important resource in implementing agroforestry on farms and ranches. Table 6.3 summarizes agroforestry practices applied using FSA and NRCS programs. Data from the other Federal programs are not tracked in a way to easily quantify the agroforestry practices implemented.

**Table 6.3.** Agroforestry practices applied during FY 2012 to FY 2015 using all FSA and NRCS conservation programs.

| Agroforestry practice applied | Unit | FY 2012–FY 2015 |
|---|---|---|
| Windbreaks | Kilometers | 6,520 |
| Riparian forest buffers | Hectares | 30,950 |
| Alley cropping | Hectares | 110 |
| Forest farming | Hectares | 12,475 |
| Silvopasture | Hectares | 595 |

FSA = Farm Service Agency. FY = fiscal year. NRCS = Natural Resources Conservation Service.

Note: This table does not include agroforestry practices installed with other Federal or State programs or practices installed without assistance programs.

Source: USDA-NRCS (2016).

**Table 6.2.** Primary Federal conservation programs used for implementing agroforestry.

| Conservation program | Agency | Description | Eligible agroforestry practices |
|---|---|---|---|
| Conservation Technical Assistance (CTA) | USDA NRCS | Technical assistance to clients to address opportunities, concerns, and problems related to the use of natural resources. | Alley cropping, riparian forest buffer, windbreak, silvopasture, forest farming |
| Environmental Quality Incentives Program (EQIP) | USDA NRCS | Financial assistance to promote agricultural production, forest management, and environmental quality as compatible goals. | Alley cropping, riparian forest buffer, windbreak, silvopasture, forest farming[a] |
| Conservation Stewardship Program (CSP) | USDA NRCS | Financial assistance to encourage producers to undertake additional conservation activities or to improve, maintain, and manage existing conservation activities. | Alley cropping, riparian forest buffer, windbreak, silvopasture, forest farming |
| Conservation Reserve Program (CRP) | USDA FSA | Financial assistance to help agricultural producers safeguard environmentally sensitive land and to convert marginal cropland to long-term conservation cover, either grass or trees. The land is bid into the program on a competitive basis and ranked based on environmental benefits and cost. | Tree planting that can be used to support future agroforestry practices after contract period has expired |
| Conservation Reserve Enhancement Program (CREP) | USDA FSA | Special financial initiative within CRP to address agricultural resource problems, targeting priority environmental needs and providing additional incentives for conservation. | Riparian forest buffer, windbreak |
| Forest Stewardship Program (FSP) | USDA Forest Service | Technical assistance to nonindustrial private forest landowners to develop comprehensive, multiresource conservation plans for their forests. | Alley cropping, riparian forest buffer, windbreak, silvopasture, forest farming |
| Sustainable Agriculture Research and Education (SARE) Program | USDA NIFA | Competitive producer grants for landowners and practitioners who want to try new agroforestry enterprise concepts. | Alley cropping, riparian forest buffer, windbreak, silvopasture, forest farming, system research |
| Partners for Fish and Wildlife (PFW) | USFWS | Financial and technical assistance to help conserve, protect, and enhance fish, wildlife, and plants and their habitats on private lands. | Riparian forest buffer, tree planting |

FSA = Farm Service Agency. NIFA = National Institute of Food and Agriculture. NRCS = Natural Resources Conservation Service. USDA = U.S. Department of Agriculture. USFWS = U.S. Fish and Wildlife Service.

[a] Practice availability will vary from State to State, depending on each State's practice policies.

### States

Many States also have agency-supported programs that may be used to establish agroforestry practices, even if the program objectives do not have an explicit agroforestry focus. These programs are tailored to each State's conservation priorities and are too numerous to describe in this chapter. These programs, however, can be a resource for implementation because agroforestry can be used to support some State conservation goals. Although not a totally State-run program, the State of Washington Conservation Reserve Enhancement Program (CREP) is a joint Federal- and State-funded effort that restores riparian habitat for salmon. Since 1999, more than 445 hectares (1,100 acres) of riparian forest buffers and other restoration measures have been implemented on the Tucannon River with CREP. This action has reduced summer mean water temperatures by about 5.5 $^{o}$C, a valuable effect under a warming climate (Smith 2012). Young Chinook salmon (*Oncorhynchus tshawytscha*) are now using areas of the river that were previously too warm for them; the number of returning Chinook adults rebounded from a low of 54 fish in 1995 to 1,239 in 2012 (Gallinat and Ross 2013).

### Private or Other Nongovernmental Organizations

Numerous private organizations indirectly support agroforestry by offering grants, cost share, and equipment on loan for landowners who are improving wildlife habitat with timber stand improvement or by planting shrubs, trees, and forages. Examples of these private organizations are the National Fish and Wildlife Foundation (NFWF), the National Wild Turkey Federation, Quail Forever, Ducks Unlimited, and Pheasants Forever. For instance, NFWF is planning to invest $12.9 million in the Chesapeake Bay watershed between 2013 and 2025 to install 2400 kilometers (1,500 miles) of riparian forest buffers for water-quality and wildlife habitat improvement (NFWF 2012).

## Challenges and Opportunities

Although tools are available for implementing agroforestry, challenges and needs persist as we improve existing tools and develop new ones to add to the suite of tools. These broad challenges include:

- Analytical capacity.
- Scalability.
- Comparison of alternatives.
- Usability.

### Analytical Capacity

Unlike the extensive datasets that exist for agronomy and forestry in the United States, agroforestry has a less robust collection of data on which to develop decision-support tools and models (Ellis et al. 2004). The inherent flexibility of designing an agroforestry system or practice, although a highly desirable feature, can result in a number of potential agroforestry systems and combinations of plantings. The multiple possible combinations can create challenges for building tools and models capable of handling the diversity of options. As a consequence, basic models are often used to predict outcomes from agroforestry practices although these models can have high uncertainty and risk, especially due to our limited understanding of the impacts of climate change on agroforestry. Whereas climate change impacts on monoculture crops or simple livestock production systems can be reasonably predicted with process-based models, robust models for multifaceted agroforestry systems are not yet available (Luedeling et al. 2014). The challenge will be to enhance the analytical capacity of agroforestry tools for present-day decisionmaking and to refine those tools as additional information becomes available (see chapter 9).

### Scalability

In the United States, agroforestry practices are implemented at the site scale by individual landowners who make decisions based on the benefits they desire, such as income diversification and soil protection. Among the agroforestry community, the expectation is that these individual agroforestry actions by numerous landowners will collectively lead to the benefits that society values, such as water-quality protection and food security, at a magnitude that will have impact. Many agroforestry decision-support tools have focused on the landowner scale (site, field, farm) because farmers and ranchers hold the key to agroforestry adoption and implementation. Tools at landscape and watershed scales, however, are also needed to help inform placement of agroforestry practices to more effectively achieve societal benefits (Tomer et al. 2009). Targeting tools that identify areas in the landscape where agroforestry practices can achieve multiple benefits simultaneously will be valuable in accomplishing landowner and societal goals (Reisner et al. 2007). The challenge is to collect data at the appropriate scales and to build tools that can work across those scales.

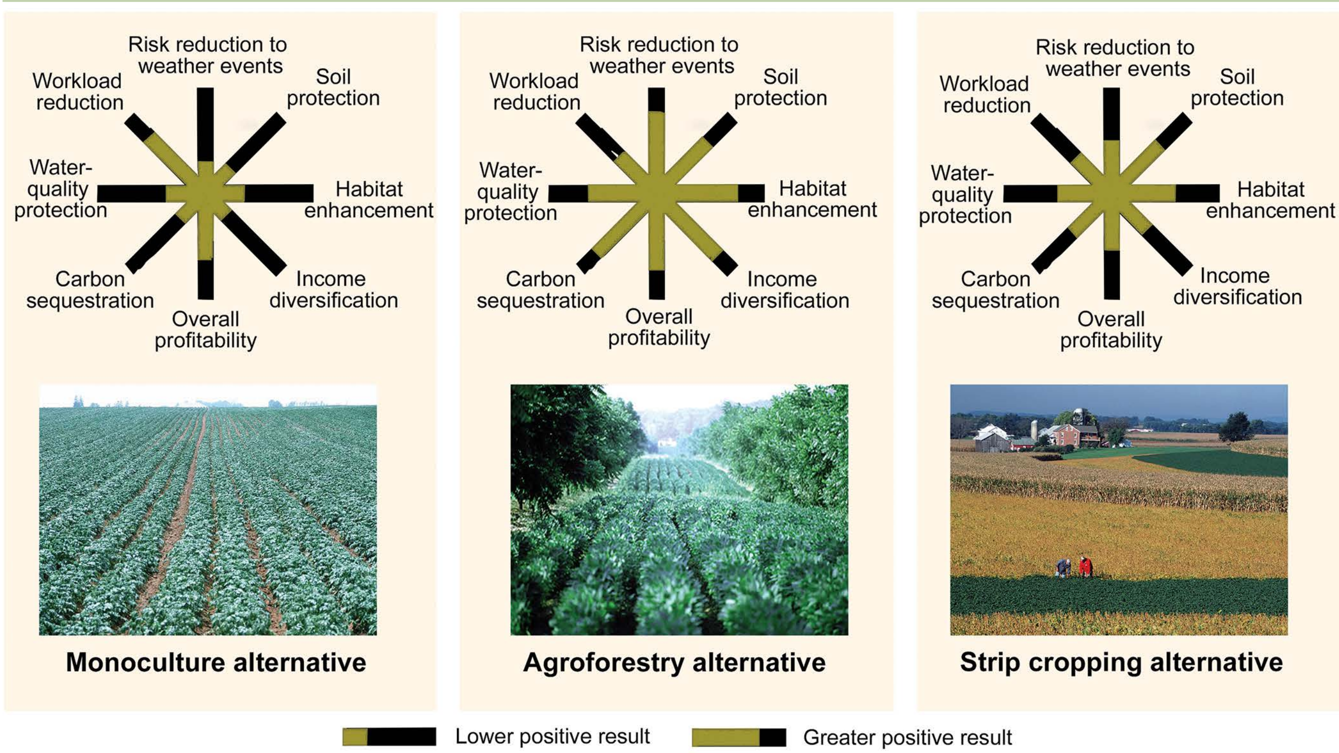
## Comparison of Alternatives

Decisionmakers often compare tradeoffs between alternative courses of action; therefore, effective decision-support tools need the capability to present the differences between the options (Ellis et al. 2004). By design, agroforestry can have numerous ecological, economic, and social effects, so the ability to compare these effects during decisionmaking is important. Placed within a larger context, agroforestry is just one option of many for transitioning to climate-smart agriculture (e.g., Delgado et al. 2011, FAO 2013). Many tools currently available for climate-smart agriculture focus on a single approach and do not facilitate cross-comparison among options (FAO 2013). Hence, the challenge is to develop tools that can compare tradeoffs among various climate-smart agricultural options at the scale of the decisionmaker (fig. 6.1).

## Usability

The usability of a decision-support tool by end users may be the most important challenge to address because, if the tool is not used, the time and cost of developing the tool is generally wasted and the scientific information underlying the tool will not aid in decisionmaking (McCown 2002). To enhance the adoption and use of agroforestry tools, end users should be consulted in tool development from start to finish, ensuring the tools match their needs and capabilities (McIntosh et al. 2011). If end users are not involved in the process of developing these tools, the resulting tools may be too complicated, too narrowly focused, and too difficult to apply in many situations (Ellis et al. 2004). Another usability consideration, particularly with erratic weather and climate change, is accommodating users with different comfort levels regarding uncertainty and risk (Willows et al. 2003). Agroforestry tools will need to incorporate innovative ways to help users evaluate risk and uncertainty in a manner that fits their decisionmaking style (see Kujala et al. 2013, Peterson et al. 2003; see appendix B).

**Figure 6.1.** A conceptual framework for comparing climate-smart agriculture options for decisionmaking. This diagram illustrates the need for decision-support tools that enable comparison of options across a variety of ecological, economic, and social considerations. This framework ideally would allow for quantitative comparisons. The longer the buff-colored bar, the greater the positive result for that resource issue. (Basic scheme from Foley et al. 2005).



## Opportunities

Decision-support tools are rarely standalone components but are used most effectively in a planning-and-design process to identify needs, develop plans, and compare tradeoffs. Technical assistance offered through conservation programs often provides a structured process in which to use decision-support tools to implement agroforestry. Among the opportunities to improve the delivery of this important service (Dosskey et al. 2012), one of the greatest is to increase awareness of these conservation programs for implementing agroforestry through promotional materials, train-the-trainer programs, and agroforestry demonstration sites (Lassoie et al. 2000).

Another opportunity is to use the planning-and-design processes provided by conservation programs as a tool to assist in adaptive management. Adaptive management is a structured, iterative process of decisionmaking in the face of uncertainty, with the goal of reducing uncertainty over time via system monitoring (Howden et al. 2007). Adaptive management has the potential to reduce the risks of climate change in agriculture by improving planning, preventing maladaptation, and informing investment and resource management (Walthall et al. 2012). By tracking the successes and failures of different adaptation actions using agroforestry and other climate-smart agriculture strategies, effective, efficient, and equitable policies and measures can be identified that can lead to more robust adaptation strategies over time (Preston et al. 2011).

## Key Findings

- The multifaceted nature of agroforestry practices and the diversity of landowner considerations require a suite of decision-support tools.
- A variety of decision-support tools addressing biophysical, economic, and social considerations are available for applying agroforestry.
- Financial and technical assistance from Federal and State conservation programs and private organizations has proven valuable in implementing agroforestry practices.

## Key Information Needs

- Strengthen the analytical capacity of decision-support tools for agroforestry.
- Continue developing targeting tools that identify locations for implementing agroforestry practices that concurrently achieve landowner and societal goals.
- Develop decision-support tools that enable comparisons of tradeoffs among climate-smart agriculture options at the scale of the decisionmaker.
- Involve end users in the development of the decision-support tools to ensure the tools match their needs and capabilities.

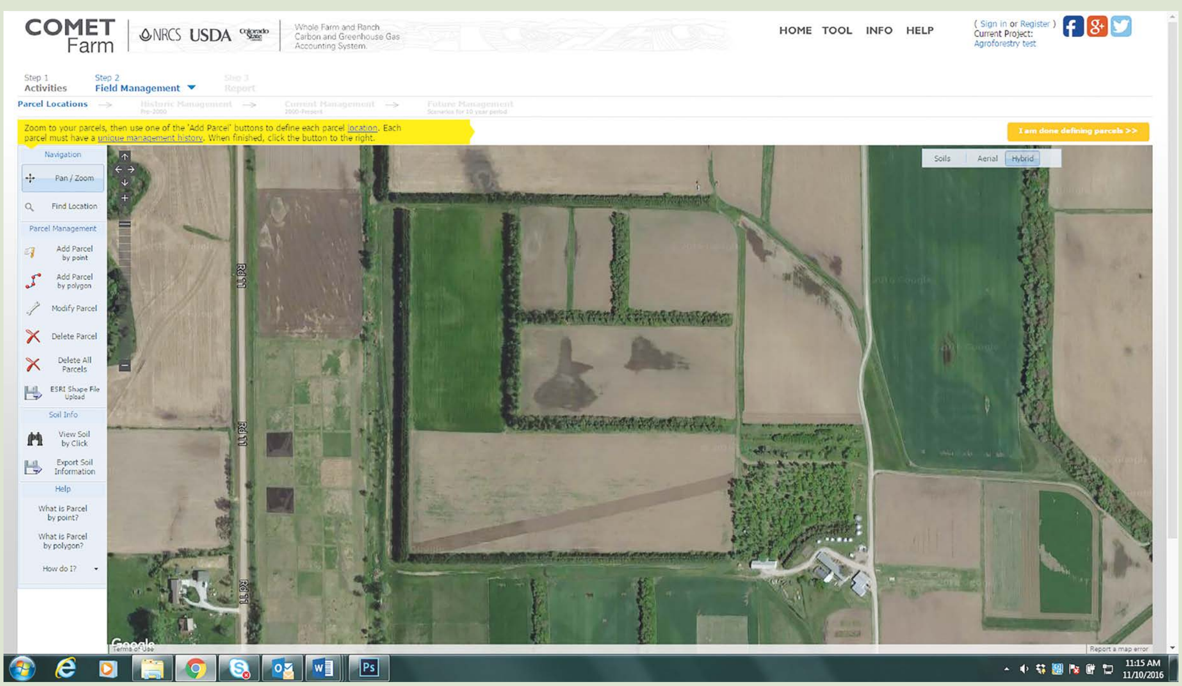
## **Box 6.1.** COMET-Farm™

COMET-Farm is a Web-based tool enabling farmers, ranchers, resource professionals, and others to assess the greenhouse gas (GHG) balance of land use and management. The tool allows for assessments of the GHG emissions and potential for carbon sequestration in farming, ranching, agroforestry, other livestock operations, and on-farm/ranch energy use. COMET-Farm estimates the GHG footprint for all or part of a user's farm/ranch operation and enables the user to evaluate the GHG benefits of conservation practices. General guidance is provided about potential changes to management practices that are likely to sequester carbon and reduce GHG emissions.

Because the tool uses detailed spatially explicit data on climate and soil conditions for a user's location and allows users to enter detailed information for field and livestock operations, it is able to produce an accurate estimate tailored to a user's specific situations. No previous training is required to run the tool, and embedded Help functions are provided. The tool guides the user through describing farm and ranch management practices, including alternative future management scenarios. After this setup process is complete, the tool generates a report comparing the carbon changes and GHG emissions between current management practices and future, alternative scenarios.

Agroforestry assessments conducted in COMET-Farm use a stock-change method. This tool enables a user to describe agroforestry practices according to the number of trees in his or her system and the sizes (diameters) of those trees; from this information, the tool calculates the biomass carbon stock now and at 10-year intervals for 50 years in the future and a yearly average. Biomass carbon stocks and change rates are calculated based on growth equations developed from the Forest Inventory and Analysis database of the U.S. Department of Agriculture (USDA), Forest Service.

COMET-Planner is another tool available within the COMET-Farm suite of tools that can be used to provide a quick and broad estimate of GHG potentials of implementing USDA Natural Resources Conservation Service conservation practice standards, including agroforestry practices. This tool considers impacts on GHG including woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide from lower synthetic fertilizer application due to the implementation of an agroforestry practice. Users need only enter location data, select the practices, and select the acreage under these practices to generate a yearly estimate of the GHG emission reductions. Both tools are available for use at http://www.comet-farm.com.




*The COMET-Farm tool enables landowners to use spatially explicit data on climate and soils for their location and to input information on their field and livestock operations to produce an estimate of GHG emissions and potential for carbon sequestration. COMET-Farm is funded by grants from the USDA Natural Resources Conservation Service and the USDA Office of the Chief Economist.*

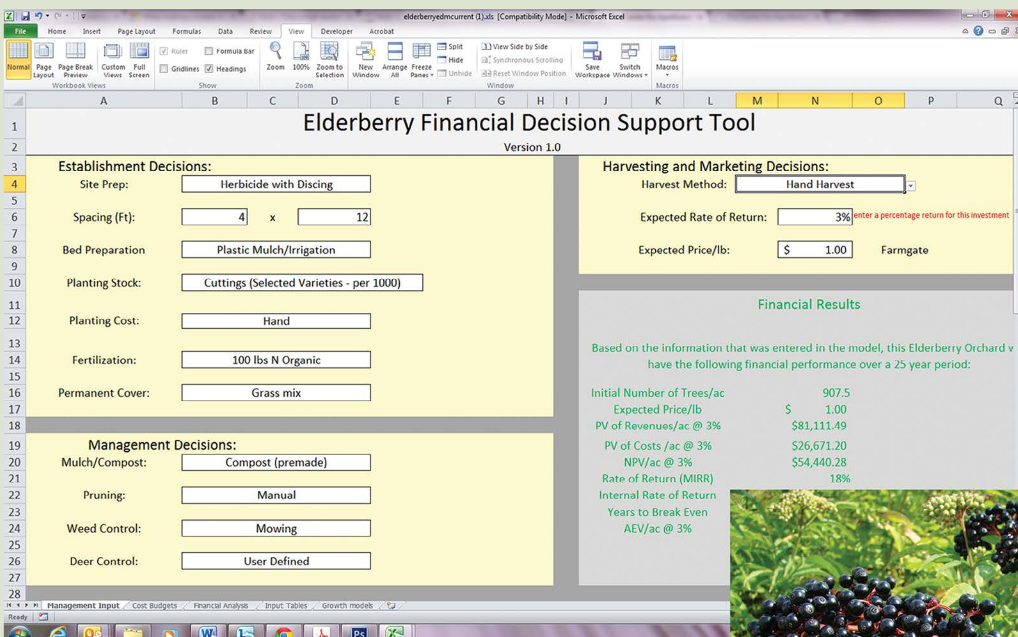
## **Box 6.2.** Economic Tools

Some of the most pressing questions for landowners wanting to know about incorporating agroforestry into their operations center on financial concerns, including costs, returns, risk, and uncertainty. Recognizing this need, the Center for Agroforestry at the University of Missouri (UMCA) developed several financial tools to help landowners explore those questions.

Agroforestry poses some unique economic budgeting challenges because it involves multiple enterprises with varying production cycles, such as trees, row crops, forages, and livestock. To help navigate these challenges, a step-by-step guide, *Economic Budgeting for Agroforestry Practices* (Godsey 2010), provides a flexible process that can be applied to any agroforestry enterprise for estimating financial needs and feasibility, highlighting tradeoffs, and monitoring economic efficiency. This tool enables landowners to develop enterprise budgets and combine these budgets into annual cashflow plans for evaluation.

Several Microsoft™ Excel-based economic tools are available from UMCA. The Windbreak Economic Model is a practice-based tool for estimating long-term financial benefits of windbreaks on crop yield. More detailed tools are available to evaluate the economic potential of black walnut (*Juglans nigra*) for nut and timber production and American elderberry (*Sambucus canadensis*) for fruit production. The Black Walnut Financial Model is a simplified model for assisting potential growers with making decisions about tree spacing, nut harvesting, and using improved (grafted) or unimproved trees.

The *Elderberry Financial Decision Support Tool* is designed to assist with elderberry establishment and management decisions. This model enables users to select options from a list of common establishment, management, harvesting, and marketing techniques to determine the mix of options that will generate the best economic returns. Each tool includes a random variable to simulate uncertainty in production due to annual weather conditions and other unpredictable events. Additional plant-specific tools are under development and soon will be released. The available tools and other financial resources are available at http://www.centerforagroforestry.org/profit/#budget.



*Elderberry is a hardy, multipurpose shrub that is suitable for many agroforestry practices. The fruit and flowers are edible and can be used for making wines, jams, syrups, and health tonics. The plant has other attributes, including attracting and benefiting birds, pollinators, and other wildlife; tolerating wet or poor soil conditions; and producing extensive root systems that can help reduce soil erosion. Photo: http://commons.wikimedia.org/wiki/File:Sambucus-berries.jpg.*

## Literature Cited


Arbuckle, J.G., Jr.; Valdivia, C.; Raedeke, A. [et al.]. 2009. Non-operator landowner interest in agroforestry practices in two Missouri watersheds. Agroforestry Systems. 75(1): 73–82.

Bentrup, G.; Leininger, T. 2002. Agroforestry: mapping the way with GIS. Journal of Soil and Water Conservation. 57(6): 148A–153A.

Delgado, J.A.; Groffman, P.M.; Nearing, M.A. [et al.]. 2011. Conservation practices to mitigate and adapt to climate change. Journal of Soil and Water Conservation. 66(4): 118A–129A.

Dosskey, M.; Wells, G.; Bentrup, G. [et al.]. 2012. Enhancing ecosystem services: designing for multifunctionality. Journal of Soil and Water Conservation. 67(2): 37A–41A.

Ellis, E.A.; Bentrup, G.; Schoeneberger, M.M. 2004. Computer-based tools for decision support in agroforestry: current state and future needs. Agroforestry Systems. 61–62(1–3): 401–421.

Foley, J.A.; DeFries, R.; Asner, G.P. [et al.]. 2005. Global consequences of land use. Science. 309(5734): 570–574.

Food and Agriculture Organization of the United Nations (FAO). 2013. Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations. 557 p.

Gallinat, M.P.; Ross, L.A. 2013. Tucannon River spring Chinook salmon hatchery evaluation program: 2012 annual report. FPA 13-03. Olympia, WA: Washington Department of Fish and Wildlife, Fish Program Science Division. 102 p.

Godsey, L.D., 2010. Economic budgeting for agroforestry practices. University of Missouri Extension publication AF 1006. Columbia, MO: University of Missouri.12 p.

Graves, A.R.; Burgess, P.; Liagre, F. [et al.]. 2011. Farm-SAFE: the process of developing a plot- and farm-scale model of arable, forestry, and silvoarable economics. Agroforestry Systems. 81(2): 93–108.

Howden, S.M.; Soussana, J.F.; Tubiello, F.N. [et al.]. 2007. Adapting agriculture to climate change. Proceedings of the National Academy of Sciences. 104(50): 19691–19696.

Kindt, R.; Ordonez, J.; Smith, E. [et al.]. 2013. ICRAF Species Switchboard [Database]. Version 1.0. Nairobi, Kenya: World Agroforestry Centre.

Kujala, H.; Burgman, M.A.; Moilanen, A. 2013. Treatment of uncertainty in conservation under climate change. Conservation Letters. 6(2): 73–85.

Lassoie, J.P.; Buck, L.E.; Current, D. 2000. Development of agroforestry as an integrated land use management strategy. In: Garrett, H.E., ed. North American agroforestry: an integrated science and practice. Madison, WI: American Society of Agronomy: 1–29.

Luedeling, E.; Kindt, R.; Huth, N.I. [et al.]. 2014. Agroforestry systems in a changing climate: challenges in projecting future performance. Current Opinion in Environmental Sustainability. 6(February 2014): 1–7.

McCown, R.L. 2002. Changing systems for supporting farmers' decisions: problems, paradigms, and prospects. Agricultural Systems. 74(1): 179–220.

McIntosh, B.S.; Ascough, J.C., II; Twery, M. [et al.]. 2011. Environmental decision support systems (EDSS) development: challenges and best practices. Environmental Modelling & Software. 26(12): 1389–1402.

Mulla, D.J. 2013. Twenty five years of remote sensing in precision agriculture: key advances and remaining knowledge gaps. Biosystems Engineering. 114(4): 358–371.

National Fish and Wildlife Foundation (NFWF). 2012. Business plan for the Chesapeake Bay stewardship fund. Washington, DC: National Fish and Wildlife Foundation. 12 p. http://www.nfwf.org/chesapeake/Documents/chesapeake-business-plan.pdf. (4 November 2016).

Orwa, C.; Mutua, A.; Kindt, R. [et al.]. 2009. Agroforestree database: a tree reference and selection guide. Version 4.0. Nairobi, Kenya: World Agroforestry Centre.

Peterson, G.D.; Cumming, G.S.; Carpenter, S.R. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology. 17(2): 358–366.

Preston, B.L.; Westaway, R.M.; Yuen, E.J. 2011. Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. Mitigation and Adaptation Strategies for Global Change. 16(4): 407–438.

Reisner, Y.; De Filippi, R.; Herzog, F. [et al.]. 2007. Target regions for silvoarable agroforestry in Europe. Ecological Engineering. 29(4): 401–418.

Smith, C. 2012. The Washington State Conservation Reserve Enhancement Program: 2011 accomplishments and cumulative program benefits for Salmon recovery. Olympia, WA: Washington State Conservation Commission. 36 p.

Tomer, M.D.; Dosskey, M.G.; Burkart, M.R. [et al.]. 2009. Methods to prioritize placement of riparian buffers for improved water quality. Agroforestry Systems. 75(1): 17–25.

U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). 2016. Integrated Data for Enterprise Analysis (IDEA). Washington, DC: U.S. Department of Agriculture. https://idea.sc.egov.usda.gov/IDEA/Home.aspx. (1 November 2016).

Walthall, C.J.; Hatfield, J.; Backlund, P. [et al.]. 2012. Climate change and agriculture in the United States: effects and adaptation. Tech. Bull. 1935. Washington, DC: U.S. Department of Agriculture. 186 p.

Willows, R.; Reynard, N.; Meadowcroft, I. [et al.]. 2003. Climate adaptation: risk, uncertainty and decision-making. UKCIP technical report. Oxford, United Kingdom: UK Climate Impacts Programme. 154 p.