# Agroforestry: Mapping the way with GIS

By Gary Bentrup and Tim Leininger

**The advent of agricultural monocultures in the United States has not only contributed to the decline in water and soil quality, wildlife habitat, and other natural resources, it's also reduced profit margins for many farmers and ranchers (NRC, 1993). Marketing uncertainties, increasing fuel and fertilizer costs, high interest rates, and climate variations are forcing farmers to rethink traditional agricultural approaches. Agroforestry offers a solution. It not only helps landowners reduce soil erosion, improve water quality, and enhance wildlife habitat but it also allows them to diversify farming operations by sustainably harvesting agroforestry specialty products.**

Agroforestry combines agriculture and forestry technologies to create diverse, profitable, and sustainable land-use systems (Rietveld, 1995). Agroforestry practices include alley cropping, forest farming, riparian forest buffers, silvopasture, and windbreaks-each of which meets environmental, social, and economic needs (Gold et al., 2000). Environmentally, agroforestry practices can reduce erosion, improve water infiltration and quality, moderate microclimates, enhance nutrient cycling, and provide wildlife habitat (Allen, 1995; Sanchez, 1995). Socially, partnerships that implement publicly owned agroforestry projects like community shelterbelts may revitalize communities (Josiah et al., 1999). And Rattan Lal of Ohio State University (2000) recently cited agroforestry as one of the future technological innovations needed to meet food demands for a growing global population.

Economically, agroforestry practices reduce production costs by lowering the need for chemical, water, energy, and labor inputs while potentially increasing overall agricultural output (Lassoie and Buck, 2000; Olson et al., 2000). One of the strongest financial incentives for landowners is growing and selling specialty products (Rietveld and Francis, 2000) like ginseng, mushrooms, and black walnut for lumber, nuts, and hulls. Species used in agroforestry applications allow landowners to diversify the marketable products derived from a given tract of land, improving overall profitability and economic stability. Through careful management, growers can sustainably harvest edible foods like berries and nuts, medicinal products like goldenseal and ginkgo, and horticultural materials like evergreens for floral wreaths, Christmas trees, or colorful woody stems (see sidebar list of possible products) (Hill and Buck, 2000). Landowners can maximize benefits by combining several agroforestry products into a synergistic system, for example:

- goldenseal + walnuts + black walnut veneer logs
- ginseng + mushrooms + decorative ferns
- Christmas trees + serviceberries + beargrass

## Suitability assessments

To help landowners adopt agroforestry, resource planners need to be able to determine the best locations for growing agroforestry specialty products. Suitability assessments match potential products with ideal growing conditions. A suitability assessment makes a match by overlaying data maps (McHarg, 1995) with information like soil type and climate factors garnered from geographic information systems (GIS). Each map, or "layer," is ranked based on suitability for a particular crop (see Figure 1 for an illustration of the process). Resource planners have used suitability assessments for decades to site landfills, wildlife reserves, and aggregate mining (McHarg, 1995). Agroforesters, however, have yet to use these technologies extensively (Ellis et al., 2000).

## Applying suitability assessment to agroforestry

How do sustainability assessments work? Two examples from Nebraska's Nehama watershed (as shown in Figure 2), illustrate the assessment process. Funding from the USDA National Agroforestry Center and the University of Missouri Center for Agroforestry (under cooperative agreements AG-02100251 with the Agricultural Research Service and CR-826704-01-0 with the US Environmental Protection Agency) made these assessments possible. The first example evaluated the multi-county watershed for a single species, while the second example offers a finer resolution analysis identifying where several species can be grown together in a sub-watershed.

## Single species assessment

The single-species assessment looked at willow species and cultivars, such as corkscrew willow (*Salix matsudana* "Tortuosa") known for its curly stems, the French pussy willow (*Salix caprea*) with red stems and flowers, and the black pussy willow (*Salix melanostachys*) with black flowers; all are used in the decorative floral industry (Dirr, 1983; Yoder and Moser, 1993). The industry's demand for these unique stems and flowers in floral arrangements, wreaths, and baskets has been increasing. Estimates suggest that floral products grown in riparian agroforestry buffers can offer potential returns of up to $5,650/acre, or $13,590/hectare (Miller et al. ,1994).

Decorative willow species tolerate most soil and climate conditions found in the study area so these riparian species primarily require the presence of seasonally flooded or moist soils (Dirr, 1983) (see Table 1 for assessment factors used to identify appropriate growing locations). Although the willows will grow on dry soils with irrigation, the assessment focused on areas

**FIGURE 1** **Basic suitability assessment procedure**

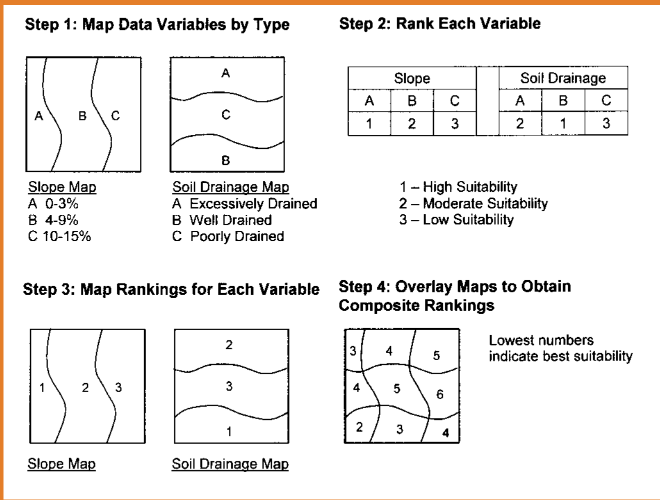


**FIGURE 2** **Location map for suitability assessment examples**


**FIGURE 3** **Willow suitability assessment for Nemaha Watershed**


requiring no additional inputs. Using Natural Resources Conservation Service's (NRCS) State Soil Geographic Soil Database (STATSGO), the assessment selected soils with occasional to high frequency of annual flooding or with shallow water tables of less than 6 feet. The assessment also incorporated land use and cover data, rating developed areas as unfavorable but agricultural lands as suitable since they could easily be converted to willow production. The grey areas in Figure 3 illustrate the concurrence of suitable land uses with required soils, or, the best places to cultivate willow.

## Multi-species assessment

From florals to medicinal herbs to edible fungi, growing high-value specialty products under an existing forest canopy can benefit landowners. Product diversity provides some protection from market vagaries and can help spread out production and harvesting tasks over the course of a year (Hill and Buck, 2000). Ginseng, shiitake mushrooms, and decorative ferns exemplify a multi-species agroforestry system cultivated under a forest canopy since they require similar environmental conditions.

For centuries, roots of American ginseng (*Panax quinquefolius*) have been used for medicinal purposes; today, an established international market buys ginseng (Hill and Buck, 2000). Growers can cultivate ginseng under artificial shade, but the most valuable roots grow under a forest canopy (Hankins, 1999). In a multi-species agroforestry system, landowners can also cultivate edible, exotic mushrooms like the shiitake (*Lentinula edodes*) on forest logs and sell them to grocers and restaurants. Decorative ferns like sword ferns (*Polystichum* spp.) and shield ferns (*Dryopteris* spp.) can be marketed to nurseries and floral shops (Hill and Buck, 2000; Hoshizaki and Moran, 2001). Unlike with ginseng, mushrooms and ferns will grow under artificial shade without reducing their market value; however, using existing forest cover minimizes start-up costs and improves landowner profitability.

Deciduous forest cover is the primary sustainability factor for these species, since they all thrive under dense shade trees in high soil organic matter (Hill and Buck, 2000; Hoshizaki and Moran, 2001). Table 2 lists the assessment factors in analyzing appropriate locations. The first step in the assessment was to extract deciduous forest from a 30-meter resolution land use/cover map of the Nebraska study area; forest cover becomes one "layer" of the assessment map. Evaluators ranked any other type of land cover or uses as unfavorable. Next, the assessment found information on slope and aspect layers from a 30-meter digital elevation model (DEM) in ArcView software. For the ginseng/shiitake/fern agroforestry system, slopes with 5 to 20 percent grade facilitate necessary air and water drainage. Slopes below 5 percent allow undesirable ponding while slopes over 20 percent strongly restrict cultivation opportunities (Beyfuss, 1999), so they were ranked unsuitable. Avoiding southwest, west, and southern aspects further ensures the selection of moist, protected microclimates (Beyfuss, 1999). Because the three species are generally intolerant of flooding, evaluators used the NRCS's Soil Survey Geographic Database (SSURGO), which maps individual soil units, to select non-flood prone soils (Hill and Buck, 2000; Hoshizaki and Moran, 2001).

Adding each successive layer of required growing conditions ultimately honed potential sites down to a few areas in southeastern Nebraska, represented by the grey areas in Figure 4. The major factor limiting suitable sites was the lack of existing forest cover; promoting woodlot plantings could provide future forest cover for growing specialty products.

## Suitability assessments and public policy

For agroforestry to achieve its full potential in the United States, a shift in policy needs to provide adequate financial, institutional, and technical support for its development (Garrett and Buck, 1997). Depending on the scale of analysis, suitability assessments can serve in the promotion, adoption, planning, and design of

**FIGURE 4 Multi-species suitability assessment for Nebraska City Sub-watershed**

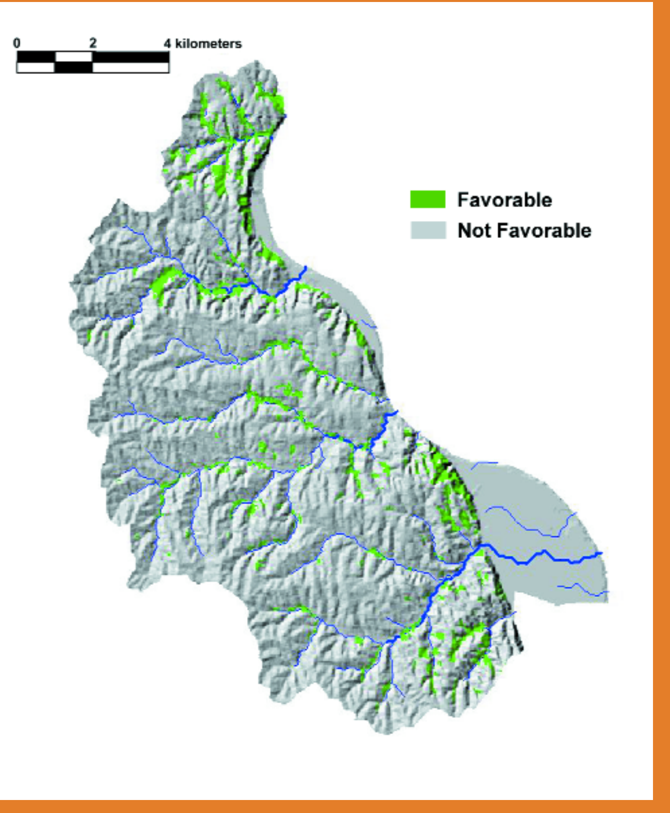


**TABLE 1 Single-species assessment factors: decorative willows**

| FACTOR | FAVORABLE | UNFAVORABLE |
|---|---|---|
| Flood Prone Soils | Occasional (5-50%)<br>High (> 50%) | Low (0-5%)<br>None |
| Shallow Water Table | ≤ 6 feet | > 6 feet |
| Land Use-Cover | Cropland | Commercial and Residential |

**TABLE 2 Multi-species assessment factors: ginseng, ferns, and shitake mushrooms**

| FACTOR | FAVORABLE | UNFAVORABLE |
|---|---|---|
| Non-Flood Prone Soils | Occasional (0-5%)<br>None | Occasional (5-50%)<br>High (> 50%) |
| Slope | 5-20% | 0-4 and > 20% |
| Aspect | N, NE, E, NW, SE | SW, W, S |
| Land Use-Cover | Deciduous Forest | All other land use-cover |

## Potential Agroforestry Products for Landowners

### FOOD PRODUCTS

Walnuts, pecans, pine nuts, hazelnuts, chestnuts
Blueberries, other berries
Edible mushrooms
Maple, boxelder syrup
Wildflower and plum honey

### BOTANICALS

Saw-palmetto
Ginseng
Goldenseal
Ginkgo
Elder flowers
Purple coneflower
Witch hazel

### DECORATIVES

Salal, beargrass, ferns
Spanish moss, other mosses
Wild grape, vine maple
Decorative willows and dogwoods
American bittersweet

### HANDICRAFTS

Wormy chestnut, cedar veneer, mesquite
Conifer boughs
Holly branches and berries

### OTHER

Cedar bedding
Cedar and pine aromatic oils
Poplar, switchgrass biomass fuels

agroforestry systems. Assessments conducted at a multi-state or national scale can help influence federal policymakers to incorporate agroforestry into programs such as the Farm Bill or Forest Stewardship Act (Kurtz, 2000). Suitability assessment can illustrate a range of alternative products that can be grown in a region, providing a case for cost-share and other assistance programs designed to encourage crop diversification and integration. The industry can generate support for assistance programs by demonstrating how agroforestry helps landowners with problems like highly erodible lands.

State or even multi-county level analyses help in developing technology transfer programs such as publications and landowner workshops on agroforestry. They are also helpful in deciding whether it's feasible to establish processing facilities or co-ops to market and distribute specialty products. Finally, results from suitability assessments may direct university and institute research dedicated to finding viable alternatives for agricultural producers.

## Assessment strategies

These single species and multi-species assessment examples illustrate just the basics in the suitability assessment process. Other resources offer details on specific GIS methodologies; refer to *The GIS Book* or *GIS Solutions in Natural Resources Management*. The examples' rankings of environmental variables are also not definitive, and the USDA PLANTS database (http://plants.usda.gov/) can help identify additional environmental variables to incorporate into any assessment. Broader suitability assessments could effectively include potential market variables like proximity to urban areas or processing facilities. Combining suitability assessments with other resource evaluations can help promote better land stewardship while meeting production goals.

Agroforestry suitability analysis will only improve as spatial data and computer resources become more accessible. Many states are already assembling internet-accessible GIS data clearinghouses to facilitate the use of spatial information. With detailed data, assessments can guide landowners and resource planners in selecting an appropriate suite of species for a given parcel of land. Suitability assessment has the power to identify the range of agroforestry specialty products for any given tract of land, giving landowners the power to integrate the best species into farming operations.

**Gary Bentrup** is a research landscape planner and **Tim Leininger** is a GIS specialist for the U.S. Department of Agriculture National Agroforestry Center in Lincoln, Nebraska.

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