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Agroforestry as a sustainable ancient agriculture practice: potential for small-scale farmers and ranchers in dry regions

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Introduction

Human activities have contributed to climate change in many ways, including unsustainable agriculture activities such as monocropping and intensive use of chemicals, which contributes to greenhouse gas emissions and climate change. The problems caused by these conventional systems have led to the search for more sustainable and regenerative agricultural practices that will support our ecosystems without compromising future food security. This is especially critical in areas such as the southwestern United States (U.S.), with its arid conditions and climate extremes. This bulletin summarizes the main agroforestry practices, their importance, practical applications, and implementation challenges for small-scale farmers and ranchers in the southwestern U.S.

Agroforestry concept and aim

Agroforestry is an ancient agricultural system that deliberately combines trees with shrubs, crops, and livestock in a single system (Figure 1). Agroforestry helps to produce food, support biodiversity, build soil health and water reserves, control pests, and sequester carbon from the atmosphere (Schoeneberger et al., 2017). The United States Department of Agriculture (USDA) National Agroforestry Center defines agroforestry as "the intentional combination of agriculture and forestry to create productive and sustainable land use practices, which take advantage of the interactive benefits from growing trees and shrubs together with crops and/or livestock" (Figure 1). Although agroforestry has been practiced for hundreds, if not thousands, of years in the tropics, it has gained considerably greater attention in temperate regions only in the last several decades (USDA).

A central goal of agroforestry practitioners is to find an alternative to conventional agriculture using low-cost practices through integrated land management to achieve greater ecological diversity with productive outputs. The agroforestry concept seeks to provide a green economy through promoting sustainable long-term renewable forest management, especially for small-scale producers, but with reduced human impact on land resources (Schoeneberger et al., 2017; Gold, 2017).

While agroforestry is a modern concept, which emerged in the early 20th century, the integration of woody

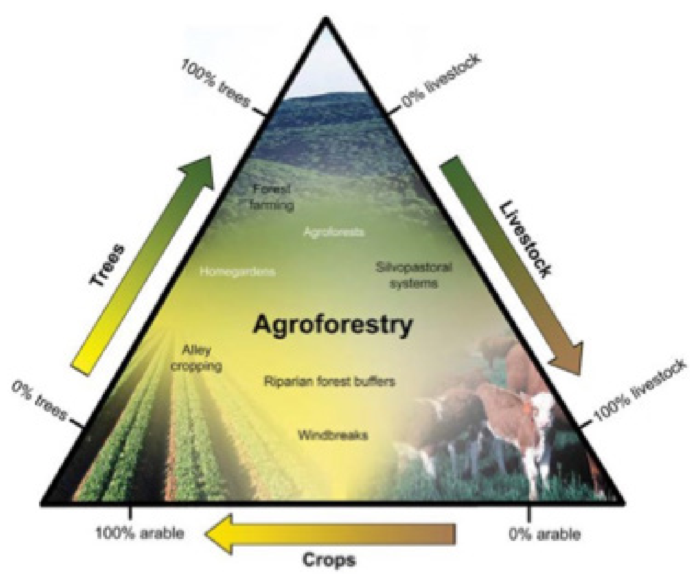

Figure 1: Agroforestry practice with three major components (trees, livestock and crops) and their levels of interaction that create the various agroforestry systems. (Figure from Schoeneberger et al., 2017 who adapted from Herder et al. 2015).

perennials in agricultural systems is an ancient practice dating at least to Roman times. Agroforestry is a common practice in the tropical regions. In 2004, the World Bank estimated that agroforestry practices were used by 1.2 billion people (Gold, 2017). In the U. S., it is promoted by the National Agroforestry Center through the United States Department of Agriculture (USDA). In our region, the Southwest Agroforestry Action Network (SWAAN), which includes Arizona, Colorado, New Mexico, and Utah (USDA) is leading the educational promotion efforts.

Types of agroforestry practices

There are different implementation practices of agroforestry, depending on the objective of the farmer or rancher, the climate, the ecological zone, and other factors. They include riparian forest buffers, silvopasture, alley cropping, windbreaks, and forest farming as discussed below with their benefits.

Riparian forest and land buffer: This type of agroforestry employs combinations of perennial plants, trees, and shrubs to filter runoff into a stream, lake, or wetland (Figure 2a). The area is managed for conservation and food benefits such as filtering nutrients, pesticides, and animal waste from agricultural land runoff; stabilizing eroding banks; filtering sediment from runoff water; providing shade, shelter, and food for fish and other aquatic organisms; providing wildlife habitat and corridors for terrestrial organisms; protecting cropland and downstream communities from flood damage; producing income from farmland that is frequently flooded or has poor yields; providing space for recreation; and diversifying landowner income. The riparian practice (Figure 2a) can be installed on agricultural, range, urban, and suburban lands (UDSA).

In planning a riparian buffer, many factors must be considered.

a. Know your market and implement the product that will sell well in your design.
b. Know the interest of the public to help you serve them better with the right product. Don't give them fruits and nuts when they are interested in recreation and conservation.
c. Understand the site conditions such as nearby agricultural practices and crop types, stream size, slopes, and soils.
d. Know the landscape conditions such as position in the watershed, nearby land practices, and buffer continuity.

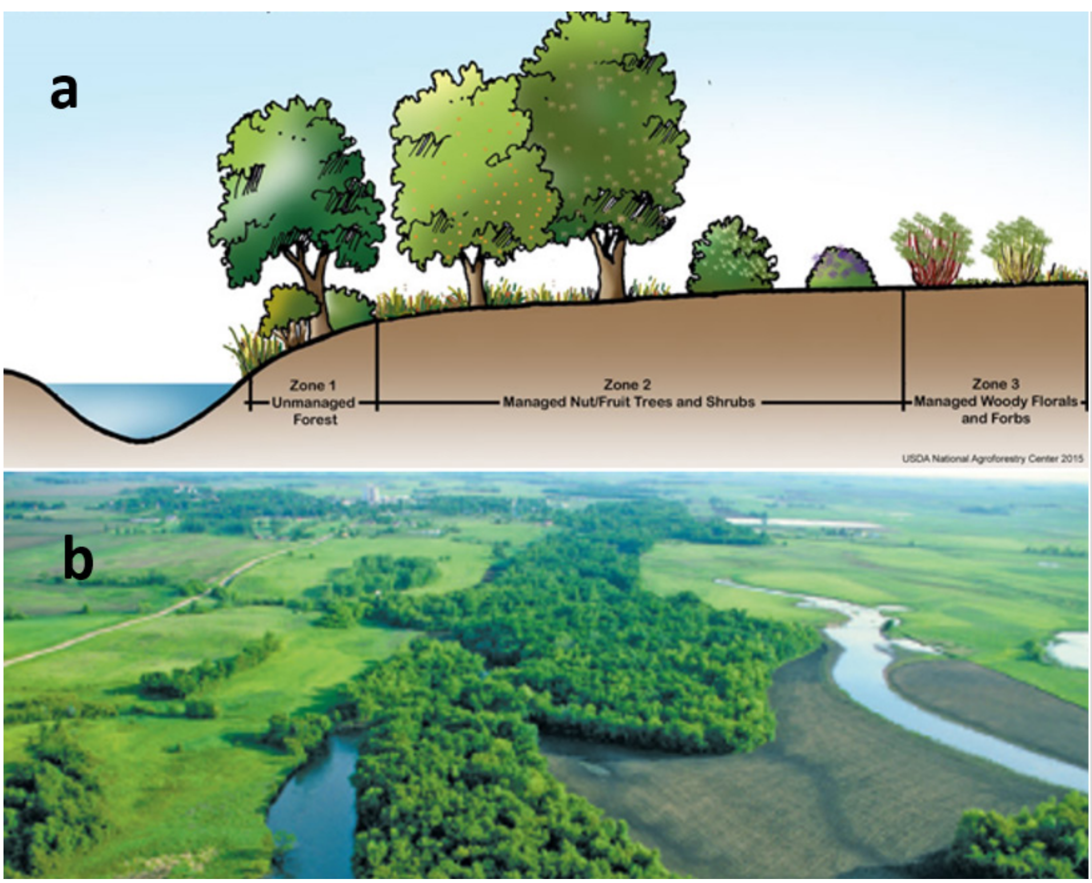

Figure 2: Riparian forest buffers, management option for timber forest (Photo a by USDA National Agroforestry Center), and an aerial view of a riparian buffer field (Photo b by Natural Resources Conservation Service).

Windbreaks: In this agroforestry practice, trees or shrubs are linearly planted as barriers to slow wind speed across a crop or livestock field (Figure 3). Windbreaks have economic, environmental, and community benefits, which are related to the improvement in soil fertility and health, crop yield, livestock productivity, and people's livelihood. Other benefits include aesthetic views, field borders and buffers, reduced wind speed which could increase effectiveness of sprinkler irrigation and pesticide spray application, improved food and fuel production, and supplemental income from trees. Environmental benefits include a reduction in soil erosion due to slower wind speed, noise, and odor from fields (USDA). Factors such as location, orientation to the wind, height, width, and density of the windbreak, and species selection must be critically analyzed and planned to garner the full benefits that the windbreak will provide based on a specific objective.

In arid areas like Arizona, selecting native or arid adapted trees, shrubs, and crops with high water use efficiency will support water conservation. In riparian areas where water is not limiting, cottonwood, willow, sycamore, pecan and walnut trees grow tall enough for effective windbreaks. At higher elevations, evergreen trees such as Arizona cypress, red cedar, junipers, pines (ponderosa, elderica, or italian stone pine) and oak trees provide a buffer to slow wind. Mesquite, desert willow, Texas ebony, Arizona rosewood, and some fruit trees are also suitable in windbreaks. Evergreen trees will provide the greatest barrier while deciduous trees will be less effective when they do not have leaves. Knowing the time of year when the strongest winds can be expected will aid in the proper species selection of trees and shrubs.

Figure 3: Windbreak (photo adapted from USDA Forest Service & Natural Resources Conservation Service)

Figure 4: A simple alley cropping system with pecans trees and cotton (Photo by Jim Robinson, USDA Natural Resources Conservation Service).

Alley cropping: In this agroforestry practice, trees are planted in multiple rows combined with crops growing in the alleyways between tree rows. It is mostly practiced by small-scale farmers who cultivate multiple crops and want to improve their total farm yield. The alley cropping systems could vary from simple (annual grain crop rotation between fruit and nut tree species as in Figure 4) to complex systems (systems with multilayer crops to produce diversified agricultural products and benefits). The complex system requires high-level management of light, water, and nutrients as the trees and shrubs grow bigger and change the crop canopy microclimate permanently. These evolving ecosystem interactions differentiate the alley cropping agroforestry practice from other practices (USDA). Figure 4 with pecans and cotton is a classic example that fits very well in the southwest agroforestry. There could be modifications with other crops and trees that are well adapted in the region. Evaluating yields and other benefits of the annual and perennial crop is necessary to gauge the economic viability of such a system.

Silvopasture: In this agroforestry practice, trees are intentionally combined with forage pasture and livestock production on the same piece of land (Figure 5a & b). This practice involves intensive management to harness the full potential of forest, forage, and livestock production for both short- and long-term benefits, which is worth the investment. The intensive management includes agronomic principles that make good use of native pasture grasses, and soil fertility management utilizes nitrogen-fixing legumes and rotational grazing that optimizes plant biomass production and harvest (USDA). Some benefits of silvopasture include increased wildlife diversity, improved water quality, reduced water and wind erosion, increased soil organic matter, shade for livestock and wildlife, and an aesthetically pleasing landscape.

Potential livestock for silvopasture systems include cattle, bison, sheep, goats, horses, turkeys, chickens, ostriches, and game animals such as deer or elk, depending on the project goals, climate, and available resources. Other silvopasture systems combine growing fruit or nut trees such as pecans or apples with water-efficient cereals such

Figure 5: Silvopasture agroforestry systems animation with cattle (a. photo by Jim Robinson, USDA Natural Resources Conversation Service) and (b. Rhode Island Red hens under hazelnuts and maize; photo by Main Street Project).

as barley, pearl millet, or sorghum and chickens. In this case, the poultry will feed on the fallen grains, control pests and weeds by feeding on them, provide manure to the fields while thriving in the shade of the trees (Figure 5b). The farmers have three potential sources of income from cereals, poultry, and fruit or nut trees on the same piece of land.

Potential food safety issue with zoonotic pathogens (diseases that can be transferred between animals and human) must be considered in the planning stages to ensure livestock will not contaminate crops that are destined for human consumption. Therefore, vegetables and fruits with edible parts having direct contact with the soil should not be included in a silvopasture system because the animal droppings can contaminate them with zoonotic diseases.

Forest farming: This is also called multistory cropping and is the cultivation of high-value specialty crops such as mushrooms or ginseng under the protection of a forest overstory that provides a desirable microclimate (Figure 6). For a well-structured and functional forest farm, the goals must align with the market availability, and site conditions that support the complexity of the design. Management activities range from planning, site preparation, soil amendments, seeding, thinning competing plants, harvesting, pest control, and possible fencing to keep out animals.

Forest farming is an excellent source of timber and non-timber products, which both serve as potential supplemental family income. Also, it is a good place to grow both medicinal and native shade loving plant species.

Food forests: Also known by names such as forest gardens, food forests are multi-layered plantings of mostly perennial plant species (Figure 7). They may include as many as seven layers, including overstory and midstory fruit and nut trees along with shrubs, herbaceous species,

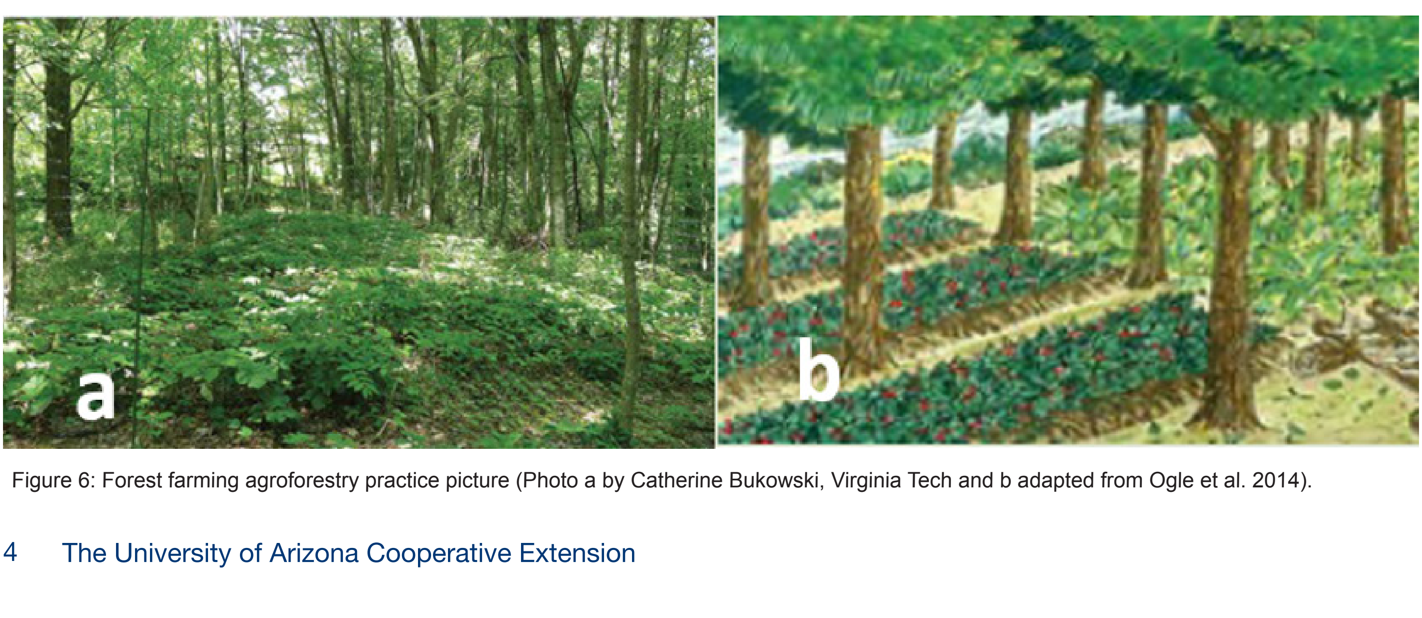

Figure 6: Forest farming agroforestry practice picture (Photo a by Catherine Bukowski, Virginia Tech and b adapted from Ogle et al. 2014).


Figure 7: Food forest at the Central Rocky Mountain Permaculture Institute near Basalt, Colorado (Picture by James Allen, Northern Arizona University)

ground covers, root crops and vines (Jacke and Toensmeier, 2005). Although they are established primarily for food production, food forests typically provide several other desired goods and services, such as medicinal plants, wood, soil fertility enhancement, biodiversity protection, carbon sequestration, and education. Until relatively recently food forests were mainly associated with the tropics and have not been considered as one of the five main temperate agroforestry practices. However, they are receiving increasing attention in temperate regions and are growing in number in North America and Europe. In temperate regions, many food forests are found in urban or suburban settings (Bukowski & Munsell, 2018).

Summary of agroforestry benefits

Table 1: Summary of agroforestry benefits based on the agroforestry practices (Adopted from Bentrup et al., 2017)

Agroforestry practices	Benefits
1. Riparian forest buffers	• Reduce nonpoint source pollution from adjacent land uses. • Stabilize streambanks. • Enhance aquatic and terrestrial habitats. • Increase carbon storage in plant biomass and soils. • Diversify income through added plant production or recreational fees.
2. Windbreaks (shelterbelts)	• Control wind erosion. • Protect wind-sensitive crops. • Enhance crop yields. • Reduce animal stress and mortality. • Serve as a barrier to dust, odor, and pesticide drift. • Conserve energy. • Manage snow dispersal to keep roads open or to harvest moisture.
3. Alley cropping (tree-based intercropping)	• Produce annual and high value perennial crops. • Enhance microclimate conditions to improve yield or forage quality and quantity. • Reduce surface water runoff and erosion. • Improve soil quality by increasing the utilization and cycling of nutrients. • Enhance habitat for wildlife and beneficial insects. • Decrease offsite movement of nutrients or chemicals.
4. Silvopasture	• Produce diversification of livestock and plant products in time and space. • Produce annual and higher value long-term products. • Reduce nutrient loss.
5. Forest farming (multistory cropping)	• Improve crop diversity by growing mixed but compatible crops with different heights in the same area. • Improve soil quality by increasing the utilization and cycling of nutrients. • Increase carbon storage in plant biomass and soil.
6. Food forests	• Increase diversity of crops for commercial use and local consumption • Improve food security at the household level • Mitigate the heat island effect in urban areas • Improve aesthetics • Increase local biodiversity and serve as a focal point for community building

Challenges of practicing agroforestry on small-scale farms in dry regions

Water is the most critical issue in dry regions such as in the southwest, which includes Arizona, California, New Mexico, and Nevada. Most crops need irrigation water to complete their life cycle and to produce economically viable yields. Limited water availability is a challenge for the adoption of agroforestry practices in the region. However, there are alternative sources of water that could be explored for agroforestry. Rainwater harvesting (Figure 7a, b, and c), and gray water can augment existing irrigation water sources (Lancaster 2019 a, b). Integrated approaches to water management using irrigation technology, drought tolerant crop plants, and best management practices such as conservation agriculture (Mpanga et. al., 2020) can help maximize water supplies for agroforestry. Some of these practices could improve ecosystem resilience to adverse climate conditions by establishing a microclimate that is more conducive for plant production.

Operating a combination of crops and possibly livestock requires different equipment than growing a single crop or managing a conventional livestock system. Economically viable yields to offset required investments and potentially higher management costs need to be weighed for the different alternatives. Careful evaluation of crop needs such as light, water, soil and nutrient requirements need to be studied to ensure a balanced system.

The future of agroforestry practices in the USA and for small scale farmers

The potential benefits of agroforestry are huge, ranging from improved biodiversity, soil health, resilience to climate change, water, and air quality, which translates into added economic value, improved livelihood and health, and better food security. Areas such as the southwest, which includes parts of Arizona with a high population of small-scale farms, could benefit if more research-based information and resources related to agroforestry are made available to farmers and landowners.

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Figure 8: Rainwater harvesting options include passive collection through soil works and active collection in storage tanks. (a-rain garden, b-bioswale). (Photo a from NEXT.CC and b adopted from Natural Resources Conservation Service, and c-from Cypress Creek in Texas).

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