Agroforestry 101: An Introduction to Integrated Agricultural Land Management Systems

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EXECUTIVE SUMMARY

Agroforestry is a dynamic system that uses principles of agricultural science, forestry, husbandry, ecological conservation, economics, and policy to sustainably manage crops through the combination of annuals, perennials, trees, and livestock. By integrating trees, perennials or livestock into a conventional annual cropping agricultural system, agroforestry promotes the efficient use of sunlight, moisture, plant nutrients, and other ecological services for increased ecological, economic and social benefits. The integration of perennial crops, livestock and tree species has implications for sustainable agricultural practices, improved product diversification, improved human nutrition, reduced system risk and instability, labor equity and increased use of renewable resources. The ecological benefits of successful agroforestry systems include improved soil health, reduced microclimate extremes and increased rates of biodiversity. This land management system aims to reduce risk and increase total productivity while also providing specialized socioeconomic services to individual farmers and their communities.

Local farmers and landowners, governments and international institutions contribute to the implementation of agroforestry techniques. Diagnosis and Design (D&D) methodology pioneered in the late 1980s provides a system to evaluate agroforestry techniques by analyzing their ecological and economic productivity on a geographic basis. Although agroforestry is primarily known as a system aimed at promoting socioeconomic values alongside agricultural processes, it is also a scientific and technical methodology that requires specific knowledge of land management practices and biophysical sciences.

While agroforestry has roots in agricultural practices originating as early as 1000 B.C., its contemporary use in temperate and tropical ecosystems is extensive. Commonly practiced temperate zone agroforestry techniques include silvopasture, alley cropping, forest farming, windbreaks, and riparian buffers. Humid tropical zone agroforestry techniques include home gardens, living fences, silvopasture and shifting cultivation.

This report defines agroforestry, analyzes its components and actors, and examines its projected environmental, economic and social impacts throughout the world. It briefly discusses the history and evolution of agroforestry from a small-scale agricultural experiment to its potential as a broadly applied high-yield land management system. Information about activities in the United States as well as examples from Ecuador, China, and France demonstrate how agroforestry programs are implemented and evaluated around the globe and highlight governmental, organizational and private partners involved as well as their respective agroforestry-related economic, social and environmental impacts.

INTRODUCTION TO AGROFORESTRY

Agroforestry is a land management system that combines perennials (including trees, shrubs and palms) with annual agricultural crops and/or livestock to increase total production while providing economic, social and environmental benefits. The goal is to reduce risk and increase total productivity in an agricultural system while simultaneously providing regular income and increased cash flow.[1] By integrating trees, perennials and/or livestock into a conventional agricultural system, agroforestry promotes the efficient use of sunlight, moisture, plant nutrients and other ecological services.

Globally, it is estimated that about half of agricultural lands contain at least 10 percent tree cover (Buttoud, 2013). Although agroforestry is a relatively newly defined system, the integration of trees and agriculture has been practiced throughout history. Indian scriptures from as early as 1000 B.C. mention multipurpose tree species being used as fodder, and Roman era writers offered detailed accounts of mixed livestock and tree systems. During the Middle Ages, Europeans and Asians began pioneering the method of shifting cultivation, in which certain trees are retained during forest clearing because of their use as canopy for exposed soil (Conklin, 1957). During this same time period individuals in Central America were attempting to recreate the layered structure of mixed tropical forests by growing dozens of crops on plots smaller than one-tenth of a hectare (Wilken, 1997).

Figure 1: "Harvesting Acorn to Feed Swine" 1310-1312 AD

Source: Queen Mary Psalter, British Library

During the mid-19th century, foresters and other land use planners began researching methods to create a forest system that would be capable of surviving competition from other agricultural species while also ecologically benefitting from them. Increasing concerns about soil erosion during this time spurred countries including France to plant trees on overgrazed slopes to protect against erosion (King, 1987).

In the years since, many factors have led to the development of agroforestry as an alternative land management system. In the 1960s and 70s major institutions like the World Bank and the Food and Agricultural Organization (FAO) began to re-examine existing alternative agricultural strategies. As food and nutrition concerns in the developing world emerged and agricultural inputs such as fertilizer became limited, the International Development Research Center of Canada funded a major research milestone in the field of agroforestry. Their influential 1975 report led to the creation of the International Council for Research in Agroforestry that specializes in agroforestry issues in the developing world (Bene, 1977).

[1] In this report, "productivity" refers to a system's ability to diversify agricultural yields and reduce the cost of production inputs.

Since then, various countries in temperate, mid-humid, and tropical humid environments have implemented their own agroforestry experiments aimed at solving complex problems related to economic inequality, crop yield failure and resource limitations. Recently, the U.S. Department of Agriculture (USDA) released an Agroforestry Strategic Framework for Fiscal Year 2011-2016[2] that has guided increased support and awareness of agroforestry, promoted on-the-ground applications of agroforestry practices and systems, and identified important areas of agroforestry research, development and technology transfer. The USDA's Agroforestry Strategic Framework depicts the United States' ongoing dedication to incorporating agroforestry into federal programs, policies and activities in order to further highlight its use as an effective sustainable land management system that seeks to balance agricultural production and natural resource conservation.

AGROFORESTRY SUB-SYSTEMS & GEOGRAPHIC TECHNIQUES

Agroforestry can be separated into three sub-system classifications - agrisilviculture, silvopastoral and agrosilvopastoral (WeiWei, 2014).

- *Agrisilviculture* combines annual and perennial crops with woody perennials (trees, shrubs, vines),
- *Silvopastoral* combines trees with pastures and animals, and
- *Agrosilvopastoral* combines crops, pastures, animals and trees.

Defining the three sub-systems of agroforestry aids in evaluating productivity and developing management plans for each respective system.

The specific use and effect of each agroforestry sub-system differs along geographic lines that can be simplified into two categories - the temperate zone and the humid tropics zone. According to the USDA, the five most widely recognized types of agroforestry techniques in the U.S. and much of the planet's temperate zone are silvopasture, alley cropping, forest farming, windbreaks and riparian forest buffers.[3] Some of the most common agroforestry techniques in the humid tropical zone are home gardens (a mixed cropping of annual and perennial crops), silvopasture, living fences and shade trees, and shifting cultivation (Table 1).

Table 1. Common Agroforestry Techniques in Temperate and Humid Tropic Zones

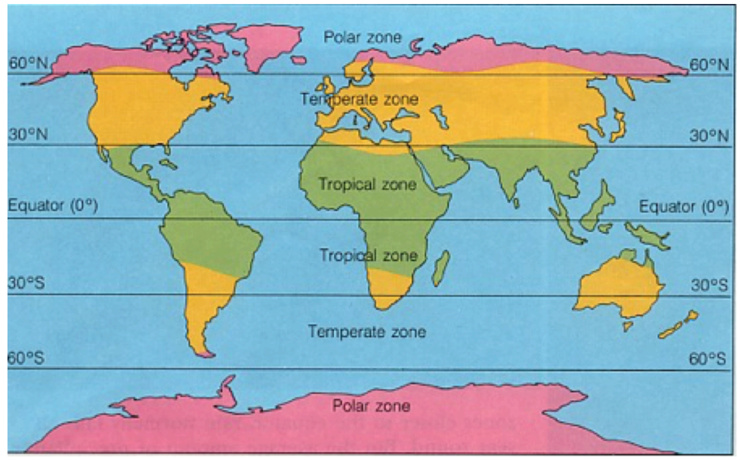
Temperate Agroforestry Techniques	Humid Tropic Agroforestry Techniques
Silvopasture	Silvopasture
Alley Cropping	Home Gardens
Forest Farming	Shifting Cultivation
Windbreaks, Shelterbelts, Living Fences	Living Fences and Shade Trees
Riparian Forest Buffers	

[2] http://www.usda.gov/documents/AFStratFrame_FINAL-lr_6-3-11.pdf
[3] http://www.usda.gov/wps/portal/usda/usdahome?navid=agroforestry

MAJOR AGROFORESTRY TECHNIQUES IN THE TEMPERATE ZONE

Much of the developed world exists within the temperate zone (Figure 2) and contains a significant percentage of the world's agricultural land. The agroforestry techniques practiced in this part of the world are uniquely suited to its weather conditions, species and biological structure unique to mid-temperature-dry climates.[4] Commonly practiced Temperate Zone agroforestry techniques include silvopasture; alley cropping; forest farming; windbreaks, shelterbelts and living fences; and riparian buffers.

Figure 2: Map of World Climate Zones



Source: Webquest Hawaii Education

Silvopasture

Silvopasture is a system in which forests are managed for timber production along with domesticated animals being raised on the same plot of land (King, 1979). This system utilizes several agronomic principles such as fertilization, native pasture grasses, and rotational grazing systems with short grazing periods that maximize plant growth and harvest while avoiding damage to the tree crop (Brantly, 2013).[5] Silvopasture is a highly intensive agroforestry method that requires grazing and timber management that can involve tree pruning, grazing, haying, fertilization and more. There are several benefits of silvopasture, which have led to its increased use. Silvopasture systems reduce economic risk by producing multiple crops and products, create shorter timber rotations (due to forage fertilization), enhance tree growth (due to the ability of grazing animals to control competition for moisture, nutrients and sunlight), provide a cooler environment for livestock and allow for control of weeds and brush without herbicide applications. It can also create high value timber products (resulting from pruning and tree management) that lead to higher diversification of income for farmers and increased income opportunities. While considerable scientific research depicting beneficial animal/tree interactions has been conducted, the issue of soil compaction and animal/soil interactions in silvopastures has not been scientifically evaluated to a great extent (Sharrow, 2007). This is an area where additional research could prove beneficial.

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[4] The Association for Temperate Agroforestry (AFTA) defines agroforestry as "an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock."

[5] Foresters are often concerned about the risk of tree damage in silvopasture system. Well-designed and properly managed systems include significant consideration of tree damage prevention, and this is essential to ensuring the maximized benefits of this type of agroforestry practice. Examples of approaches to addressing this consideration are included in the recent review of silvopasturing in the Southeastern United States, see: *Silvopasture: Establishment & management principles for pine forests in the Southeastern United States* prepared by Jim Hamilton, Ph.D. and the USDA National Agroforestry Center and available at: http://www.silvopasture.org/pdf_content/silvopasture_handbook.pdf

Alley Cropping

Alley cropping is an agroforestry practice wherein rows of trees or shrubs are planted at a spacing that provides an "alley" where perennial and annual agricultural crops are then grown. Agricultural crops within an alley cropping system are often referred to as intercrops. In this system, special care must be taken to ensure that crops and trees are compatible with one another as well as local climatic and geologic conditions. Alley cropping requires careful maintenance and pruning to limit the lateral spread of tree branches and to ensure that trees will provide the desired level of shade. The typical intercrops for this agroforestry system are row crops (corn, wheat, barley), forage crops (bluegrass, clover, alfalfa), specialty crops (dogwood, Christmas trees) and biomass crops (willows, birches) (Hodge, 1999). According to the USDA, alley cropping can be used for short-rotation woody crops or fast-growing woody plants that are then combined with forage to produce fuelwood and fodder. Alley cropping improves crop health through the creation of tree canopies that protect against wind damage and pests and also aid in pollination activities. It also improves soil health in areas prone to erosion, adds carbon to improve soil health, and enhances nutrient recycling. As with most other agroforestry techniques, alley cropping diversifies income for landowners who are able to harvest trees and other crops at different times throughout the year (Wotjkowski, 2006).

Figure 3: Alley Cropping Technique

Source: USDA National Agroforestry Centre

Forest Farming

Forest farming, or multistory cropping, refers to the cultivation of specialty crops under the canopy of trees that provide a specific shade level. This agroforestry technique often involves thinning existing woodland to leave desired canopy trees. The remaining trees are used to create appropriate conditions for understory crops while also providing the potential for timber production. The most common type of forest farming is done for specialty crops such as mushrooms and maple syrup, but can also be used for ginseng and ferns used for culinary, medicinal or ornamental applications. Other examples of forest farming crops include fruits (blackberry, huckleberry), nuts (walnut, hazelnut, beechnut), medicinal herbs (mayapple, bloodroot), moss and pinecones. Forest farming provides income from specialty crops while also creating revenue from high-quality trees that can be grown for wood products.

Windbreaks, Shelterbelts and Living Fences

Windbreaks are linear clusters of trees or shrubs maintained to alter wind flow and regulate climate, thereby protecting people, property and livestock while benefitting soil health and improving water conservation. The main types of windbreaks are *field windbreaks, livestock windbreaks* and, *living fences*. Windbreaks are also referred to as shelterbelts. Field windbreaks protect crops from wind, reduce soil erosion and increase pollination activities, whereas livestock windbreaks are designed to help reduce animal mortality and manage feed consumption. Living fences reduce wind and snow on roads and can also spread snow uniformly across a field to ensure even soil moisture. In addition, windbreaks have the potential to protect communities and individual farmsteads from cold winds, drifting snow, odor from animals, dust and chemical drift. Windbreaks improve soil quality by preventing wind erosion, enhance air/water quality through the trapping of airborne pollutants, and reduce wind speed to decrease soil evaporation rates. The U.S. has a long history with windbreaks, including the planting of more than 100 million trees in response to the Dust Bowl conditions in the 1930s.[6]

Windbreaks can reduce energy costs around homes, maintain livestock health and wellbeing, produce specialty products, and improve crop yields. Thoughtful vegetation selection in a windbreak and its continued maintenance greatly influence associated benefits to people, livestock, wildlife, or pollinators. Windbreak systems are also useful for creating wildlife corridors and can provide carbon storage benefits. According to the National Agroforestry Center, planting 2.5 percent of tillable land in the American Great Plains with windbreaks could remove up to 80 million metric tons of carbon dioxide from the atmosphere over a period of twenty years (Wright, 2002).

Figure 4: Windbreak System

Source: USDA, National Agroforestry Center

Riparian Buffers

Riparian buffers are either natural or rehabilitated forests and native plant communities along waterways that provide water quality protection as well as the potential for diverse benefits such as crop production, flood control, wildlife habitat, and recreation opportunities. Riparian buffers protect aquatic resources from the impacts of agricultural sediment and pesticide and nutrient runoff. Forest stands planted along waterways can also regulate waterway temperature and decrease eutrophication rates by maintaining shade over the water (National Agroforestry Center, 2012). Woody plants and trees reduce shoreline erosion by absorbing energy from strong waves and keeping roots and soils in place. These buffers also foster habitat diversity and reduce the risk of floods while protecting water quality. The economic incentive of diversified income also makes riparian buffers a popular type of agroforestry technique within the temperate zone. This agroforestry technique requires intensive management to determine soil types, appropriate vegetation types and relative shoreline stability where riparian buffers will be placed.

MAJOR AGROFORESTRY TECHNIQUES IN THE HUMID TROPICAL ZONE

The world's tropical zone is characterized by high amounts of rainfall and consists of a variety of environments from tropical rainforests to deserts. Due to the low nutrient content of some tropical soils, slash-and-burn techniques have traditionally characterized the agricultural approach in these regions (Vitousek, 1986). A rising demand for wood products and specialty crops has led to increased interest in the implementation of sustainable

[6] http://www.npr.org/2013/09/10/220725737/dust-bowl-worries-swirl-up-as-shelterbelt-buckles

agriculture and forestry management in recent years, including agroforestry systems. Commonly practiced humid tropical zone agroforestry techniques include home gardens, living fences and shade trees, silvopasture and shifting cultivation. In recent years, agroforestry techniques in the humid tropical zone have encompassed new intercropping and silvopasture systems that attempt to overcome issues with land and capital requirements for raising animals on cropland (Macdicken and Vergara, 1990).

Home Gardens

Home gardens (also called Kitchen Gardens) are characterized by the intensive use of trees, shrubs, crops and animals on the same plot of land and on a much smaller scale than traditional agrisilvicultural systems (Figure 5). Natural rainforest strata influence home gardens in the tropical zone. For example, trees, fodder and fruit are concentrated in the *upper* story; coffee, fruit, or cacao are concentrated in the *middle* story; and beans, root crops or legumes for fodder are concentrated in the *understory*. An important benefit of the home garden system is that it provides farmers with multipurpose crops and perennials. Planted trees reduce temperatures and wind speeds for understory crops, and provide shade and privacy for sensitive crops (MacDicken and Vergara, 1990).

Figure 5. Thai Home Garden

Features diverse crops and rainwater storage for household use or watering

Source: Marten & Suutari, 2006

Living Fences and Shade Trees

Living fences, or hedgerows, are trees that are planted on agricultural land in order to provide protection from wind and intense sunlight while reducing erosion. In addition, they produce valuable wood resources, fruits and medicinal plants. Living fences function similarly to windbreaks used in the temperate zone. They differ from temperate zone windbreaks in the type of tree or shrub that is used. Today, some of the most common perennials in tropical living fences are g*liricidia sepium, erythrina berteroana, hibiscus* and *ipomoea*.

Effective shading practices in the tropical zone involve thinning natural forests and interplanting shade trees on crop plantations. The most common trees used for shading are *albizia, cordia* and *ficus*. These practices are similar to the temperate zone forest farming technique. Multipurpose trees (MPTs) are frequently referenced in agroforestry resources and refer to the "trees and shrubs that are deliberately kept and managed for more than one preferred use" (Ramachandran, 1993). For example, leguminous trees are often used to provide the additional benefit of fixing nitrogen in the soils. The plantings may also serve as a trellis or support system for higher valued climbing plants, including black pepper and vanilla. Hedgerows may also be periodically pruned or pollarded to provide fodder or energy crops (Muschler, 1993).

Tropical Zone Silvopasture

Livestock production in the humid tropical zone is less common than it is in the temperate zone due to climatic differences and the abilities of small-scale farmers to manage animal grazing. Introducing livestock into the traditional agrisilvicultural model in the tropical zone allows for meat and milk production and enhanced nutrient transfer from forage to soil (Payne, 1976). In addition, animals can eat plants with little commercial value such as weeds and excess fruits, nuts and leaves. Another advantage of silvopasture in the tropics is that animals provide farmers with an alternative income source and can stabilize livelihoods and provide economic resiliency.

Shifting Cultivation

The shifting cultivation technique of agroforestry, also known as swidden agriculture, involves rotational farming in which forested land is selectively cleared for cultivation. Cleared land is left fallow for a period of time followed by planting of agricultural crops. This process involves selectively removing some trees from a given system while leaving the most valuable ones and using the remaining understory to grow crops. The system provides wood products such as fuelwood and timber while also allowing cropped lands to recover from intensive annual agricultural plantings and harvests.[7]

AGROFORESTRY HEALTH AND PRODUCTIVITY

The health of an agroforestry system can be described by analyzing how productive, sustainable and adaptive it is. The success of the agroforestry model is based on both direct goods and indirect services, including the production of goods such as food, fodder, fuel or industrial products, and services such as soil and water conservation, species protection, and microclimate management. In the late 1980s, an agroforestry evaluation methodology known as Diagnosis and Design, also referred to as "D&D," was developed by the International Centre for Research in Agroforestry (ICRAF – known since 2002 as the World Agroforestry Centre). This methodology measures the productivity and potential of agroforestry systems. D&D evaluation is adapted to the specific conditions of each agroforestry model. In this way, landowners, researchers, and other stakeholders can avoid generalizations about the productivity of systems by first analyzing the ecological and economic productivity of the system in its respective geographic location. It provides a systematic method for supporting successful agroforestry systems and is utilized for informing agroforestry research design. The D&D methodology is used to 1) describe and analyze existing land use systems; 2) design agroforestry technologies; and 3) design research work. The analysis of the existing land use system can occur at various scales – from macro (i.e., country-wide) to micro (i.e., sub-ecozone).[8]

AGROFORESTRY PARTNERS

Agriculture is the main source of income and employment for 70 percent of the world's poor who live in rural areas (World Bank, 2015). Agroforestry provides opportunities to improve sustainable agriculture practices and

[7] Global concern about land use change associated with "slash and burn" agriculture has led to skepticism of shifting cultivation system. As with other land use systems, the proper design and management of this type of agroforestry system is essential to ensuring maximized benefits and long-term sustainability.

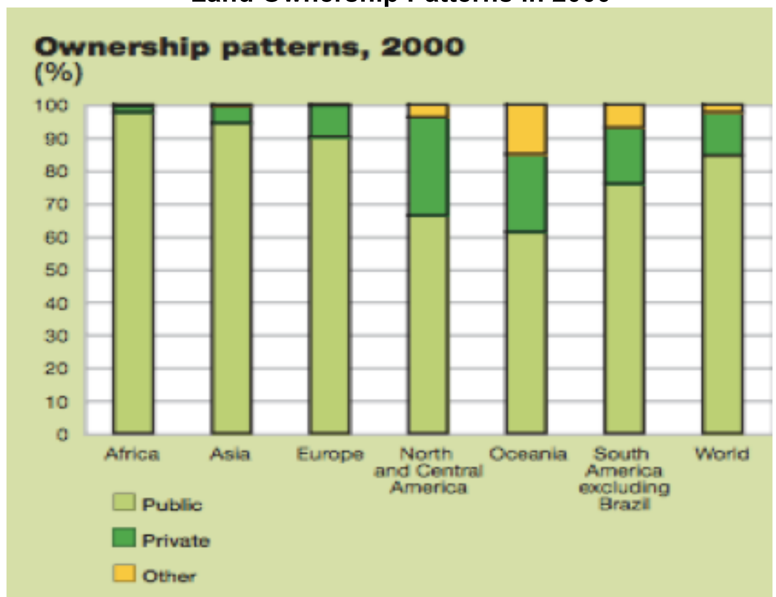
[8] For more information about the D&D methodology, see: www.fao.org/wairdocs/ILRI/x5546E/x5546e07.htm

rural livelihoods. The current distribution and adoption of agroforestry practices globally has relied upon the efforts of various partners including governments, international organizations, researchers, and private interests.

Governments

Much of the world's natural resources are government owned and remain under the jurisdiction of country-specific government institutions that specialize in land tenure, agriculture and forestry (Figure 6). Regulation and control of land tenure rights can either encourage or restrict agroforestry. Permitting procedures for the harvesting of wood, timber, perennial crops and food are highly regulated and nuanced. In addition, many state governments control natural resource production with the involvement of foreign investors that do not directly engage with rural farmers. The government bodies engaged in land management and land rights often do not specifically deal with agroforestry. Although several agricultural policies acknowledge agroforestry as a technical solution to ecological and social problems within their respective countries, many government-regulated agricultural policies favor conventional annual crop cultivation. Although government policies can be a roadblock in the adoption of agroforestry and the distribution of benefits to rural farmers, there have been several attempts to explore different approaches. For example, the government of Kenya enacted a regulation in 2009 that required ten percent of all farms to be under tree cover and allocated extra funding to farmers to ensure that this regulation was being met. In addition, some local government systems fiscally supplement training programs to instruct rural farmers on how to implement sustainable and ecologically beneficial planting systems.

Figure 6: Global Public and Private Land Ownership Patterns in 2000



Source: Global Forest Resource Assessment, 2005 (FAO)

International Organizations and Researchers

Agroforestry is internationally recognized as a viable solution to income inequality, resource depletion and irresponsible land use. After the Rio Convention of 1992 that inspired a rise in global environmental governance, many international initiatives such as the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD), Committee on World Food Security (CWFS) and others began to pledge their support to fostering successful agroforestry worldwide. For example, the World Agroforestry Centre sponsors research about food security, funds projects aimed at fostering agroforestry implementation throughout the world, and operates five programs through a regional network with locations in Eastern and Southern Africa, Latin America, South Asia, Southeast Asia, East and Central Asia and West and Central Africa. Besides sponsoring research and identifying new innovations in agroforestry, some agroforestry institutions are involved in the support of policy initiatives concerning the role of state governments in farmer land tenure, the regulation of market transfers and the assignment of land permits (Voluntary Guidelines on the Responsible Governance of Tenure, 2012). Most recently, reports by the Intergovernmental Panel on Climate Change (IPCC) have strongly endorsed the potential of land dedicated to agroforestry to serve as a carbon sink and contribute to increased socioeconomic benefits for the world's rural poor (Swallow, 2006).

There are a number of domestic and international research organizations addressing agroforestry opportunities. Many countries have their own regional body overseeing agroforestry policy and research. In the U.S. such organizations include the USDA National Agroforestry Center in Lincoln, Nebraska and the Association for Temperate Agroforestry located at the University of Missouri in Columbia, Missouri. The Center for Agroforestry was established at the University of Missouri in 1998 and has been leading research on diverse crops such as chestnuts, pecans, black walnuts, pawpaws, grapes, apples and alternative cropping systems such as alley cropping and silvopasture. The North American Agroforestry Conference, most recently hosted by the Leopold Center for Sustainable Agriculture at Iowa State University, is held every two years and provides an opportunity to share findings and highlight research needs.

Private Companies

Private companies involved in managing agroforestry are often focused on maximizing the outputs of a system. Although private companies have been criticized for failing to provide appropriate payment to local farmers, they have also been known to make reforestation much more practical on severely degraded lands (Whitmore and Burwell, 1986). By implementing agroforestry systems, private companies can include reforestation costs within their operations. Some private companies have attempted to create productive systems that provide high-quality crops without damaging the ecology of the land. In recent years, the concept of "zero deforestation" emerged from the 2014 New York Declaration on Forests and as a result there have been various commitments by global private and public sector interests which present an important opportunity for balancing land uses to provide economic, social, and ecological benefits.[9]

AGROFORESTRY EXAMPLES: ECUADOR, FRANCE & CHINA

Following are examples of various agroforestry systems, techniques and operations, the partners involved, and their associated environmental, economic and social impacts.

Tropical Agroforestry in Amazonian Ecuador

Traditional agroforestry systems in the humid tropics have been practiced by indigenous communities through the form of home gardens and shifting cultivation for a long time, but the influence of uncertain land tenure and lack of technological support has forced many indigenous groups to turn to other forms of agriculture. In an effort to encourage sustainable agroforestry practices among small producers, the Ecuadorian government implemented the Coca Agroforestry Project with funding from the U.S. Agency for International Development (Anderson, 1990). The government encouraged the use of three forms of agroforestry: shifting cultivation or

[9] For more information, see: http://blog.cifor.org/27203/zero-deforestation-pledges-palm-oil-conversation?fnl=en

chacra, modification of coffee plantations, and the addition of partial tree cover to cattle pastures. Chacra is similar to shifting agriculture in that both systems involve removing some trees while leaving the most valuable ones and using the understory to grow perennial crops. However, the difference is that a chacra is continuously managed rather than being periodical left fallow (Anderson, 1990). The Coca Agroforestry Project was implemented in 1987 through on-farm demonstrations that provided direct training and assistance to Ecuadorian farmers with a goal of increasing productivity. A legume was designated as the choice cover crop and cattle feed. Lechero, or *euphorbia cotinifolia* was planted around trees to prevent cattle from eating the leaves. Living hedges were also installed to divide pastures into smaller units. Overall, the Coca Agroforestry Project proved that one of the biggest obstacles to successful agroforestry was the lack of available labor and expertise. When these factors were addressed through the hiring of local people and region-specific training, a successful agroforestry model for small producers was established. Within the project, almost 200 on-farm demonstrations were completed and the Ecuadorian government oversaw the creation of a nursery that made planting stock and seeds available to the public. The farmer training was completed at local agronomy programs within universities and led by people who had been raised on farms and had practical knowledge of local crops and management strategies.

Temperate Agroforestry in Europe

In 2001, a Europe-wide intercropping system was approved with support from the Common Agricultural Policy of the European Union. Three years later, the European Commission launched Article 44 (also known as Measure 222) for support of agroforestry, which was approved on a limited regional and national level by several countries. One of the countries that approved Article 44 was France in 2010, which gave access to subsidies for agroforestry plots that included 30 to 200 trees per hectare. Under Article 44, growing trees on cropland was considered a factor of production and therefore was eligible for subsidies. Since the adoption of Article 44 in France, the country has recognized the economic and ecological benefits of agroforestry and adopted tax and funding advantages for farmers who transition to this system.

Figure 7: Agroforestry in Southern France

Source: Malignier et. al (2014, Agforward

Figure 8: Chinese Farmer Assessing New Tree Species in Grain for Green Program

Source: World Agroforestry Center

Agroforestry and the Economy in China: Grain for Green Program

The Chinese government instituted the “Grain for Green” program in 1999 in order to reduce soil degradation and erosion and sponsor economic growth in rural areas. Under the policy, the government distributed grain, saplings or subsidies to rural farmers to encourage them to convert their degraded cropland into forests and grassland.

The Grain for Green program attempted to isolate the economic factors that prevented farmers from adopting agroforestry techniques by subsidizing local governments to sponsor training programs, transportation and more. The response to the program by farmers led to the spread of fruit tree intercropping across the countryside (Liu, 2010). Eleven years after the program was initiated, more than 15 million hectares of cropland were converted into forest or grassland in almost twenty distinct Chinese provinces (Buttoud, 2013).

AGROFORESTRY CRITIQUES

Modern criticism of agroforestry has focused on its socioeconomic and biological constraints. Individual farmer needs, support infrastructure, skill levels, and land tenure complicate the socioeconomic benefits that agroforestry can provide. Agroforestry's emphasis on long-term land management requires not only a shift in philosophy but also significant financial capital, training and technical knowledge. This has resulted in a global uncertainty about the true potential of agroforestry to provide economic support for farmers in rural and often impoverished areas. In addition, agroforestry techniques are oftentimes difficult to adopt for farmers who have already developed their own agricultural processes. The lack of an extensive research base adds to its perceived complexity.

Farmers who express hesitation to adopt agroforestry note that the system relies on variable environmental conditions that are outside of their control. The issue of competitiveness among plants presents a potential problem when native plants do not survive alongside introduced species. Overstory shading can also lead to understory plant mortality or reduced growth and productivity. Mechanical damage from harvesting can negatively impact crops and livestock can also significantly hinder crop health if grazing is not carefully managed. The introduction of new plant species may also introduce new pests or disease risks. A productive agroforestry system must consider the relative health of new trees, shade tolerant species or other specialty plants that are introduced.

The agroforestry system has also been critiqued for being labor and time intensive because of the diversity of management activities and production outputs. As research on plant and animal interactions is still developing, the lack of sufficient research continues to be a problem for farmers who are considering implementing agroforestry techniques on their land.

THE BOTTOM LINE

Agroforestry is a dynamic system that uses principles of agricultural science, forestry, husbandry, ecological conservation, economics, and policy to sustainably manage crops through the combination of annuals, perennials, trees, and livestock on agricultural lands. By integrating trees, perennials or livestock into a conventional annual cropping agricultural system, agroforestry promotes the efficient use of sunlight, moisture, plant nutrients, and other ecological services for increased ecological, economic and social benefits. This land management system aims to reduce risk and increase total productivity while also providing specialized socioeconomic services to individual farmers and their communities. Worldwide, agroforestry is known for strengthening the social and economic climate of rural communities while bolstering sustainable agricultural practices. Although agroforestry is primarily known as a system aimed at promoting socioeconomic values alongside agricultural processes, it is also a scientific and technical methodology that requires specific knowledge of land management practices and biophysical sciences. The breadth of goods, services and benefits that agroforestry provides is indicative of its potential for improving ecological, social and economic structures throughout the world.

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