Agroforestry

Basic knowledge

This module provides an overview of agroforestry systems; it also describes how to identify the most appropriate agroforestry system and to design, adapt, establish and manage it. A section on the "enabling environment" is targeted primarily at policymakers, including national and local authorities.

Agroforestry is the collective term for land-use systems and technologies in which woody perennials (e.g. trees, shrubs, palms or bamboos) and agricultural crops or animals are used deliberately on the same parcel of land in some form of spatial and temporal arrangement. Agroforestry can also be defined as a dynamic, ecologically based natural resource management system that, through the integration of trees on farms and in agricultural landscapes or through the production of agricultural products in forests, diversifies and sustains production for increased economic, social and environmental benefits for land users.

Agroforestry has been practised for a very long time in many parts of the world. Its forms vary considerably from landscape to landscape, country to country, and region to region, depending on human needs and capabilities and the prevailing environmental, cultural and socioeconomic conditions. Among the agroforestry systems used worldwide are improved fallows; taungya; homegardens; alley cropping; growing multipurpose trees and shrubs in farmlands; boundary planting; farm woodlots; orchards and tree gardens; tree plantations; shelterbelts; windbreaks; conservation hedges; fodder banks; live fences; silvopastoral systems; and apiculture with trees.

Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural and environmental benefits. Agroforestry can be particularly important for smallholder farmers because it generates diverse products and services on a limited land area. Agroforestry systems also have limitations, and a careful analysis should be carried out before their introduction.

Economic benefits

Most agroforestry systems aim to increase or maintain the production and productivity of farming systems; reduce agricultural inputs and thus production costs; and diversify production by the use of trees or other woody perennials to produce, for example, food, fodder, lumber, building materials and woodfuel. Agroforestry systems may also create opportunities for small-scale forest-based enterprises. Agroforestry can help reduce rural poverty by increasing on-farm production and household income and by providing employment opportunities, and it can reduce the risk of economic failure by increasing the diversity of production within farming systems.

Social benefits

An increase in production, productivity and product diversity through agroforestry can help improve the health and nutrition of the rural poor. The on-farm production of fuel, fodder and other tree products, otherwise collected from off-farm sources, can reduce the time and effort needed to obtain them (often lessening the burden on women) or save money if the products would otherwise be purchased. When the

supply of labour changes at the household or community level (e.g. due to the seasonal out-migration of men), agroforestry offers options for maximizing output per labour input. The perpetuation of traditional agroforestry practices can help maintain social bonds established through mutual-help arrangements (e.g. in the case of shifting cultivation).

Environmental benefits

Agroforestry systems can provide a range of environmental services. For example, they can improve soil fertility, protect crops and livestock from wind, restore degraded lands, improve water conservation, limit pests and prevent soil erosion. If properly designed and managed, agroforestry systems can contribute to biodiversity conservation and climate-change adaptation and mitigation. If deployed inadequately, however, they may lead to decreases in production because of competition among trees and crops.

The adoption and appropriate implementation of agroforestry systems require a good understanding of those systems and a way of building knowledge in the light of experience. The dissemination of agroforestry practices and the provision of support for farmers are essential for the effective uptake of agroforestry. The development and up-scaling of traditional and improved agroforestry systems also requires an enabling environment, such as clear land and tree tenure, a robust legal framework, support for agroforestry product value chains, and coordination among the various sectors involved.

Agroforestry contributes to SDGs:

Related modules

- Climate change adaptation and mitigation
- Dryland forests & agrosilvopastoral systems
- Forest inventory
- Forest management planning
- Forest policy
- Land-use planning
- Mountain forests
- Urban and peri-urban forestry
- Watershed management

In more depth

Agroforestry outcomes may differ considerably depending on the system deployed and the conditions under which it is put into effect. Guidance is particularly important during the process of deciding which agroforestry system to use in light of prevailing economic, social and environmental conditions.

Establishing and managing agroforestry systems

The following steps should be taken in the adoption of an agroforestry system.

Identifying appropriate agroforestry options

The first thing to determine is whether agroforestry is already practised in an area and if there is potential for the adaptation or wider adoption of local systems. If agroforestry is not practised, the question is whether it is an appropriate land-use option in the area. Agroforestry systems are more complex than monocultures and may need considerable effort, time and expertise for their successful uptake. It is important, therefore, to consider the costs and benefits of agroforestry.

The suitability of an agroforestry system for a particular site depends on the needs of the family or community and the potential benefits of the system. Reasons for agroforestry adoption include: increasing farm production or income; diversifying production, such as of food, fibre, fodder, fruit, construction materials, medicine, honey, dyes, resins and gums; and providing environmental services that help increase food security and improve household livelihoods.

Agroforestry can be an efficient land use that is capable of producing more goods on a given area of land than other systems; for example, the several vegetation layers in agroforestry systems can use sunlight, water and nutrients more efficiently than the single layers of monocultural crops. The land-equivalent ratio (that is, the area of land under sole cropping needed to yield an equal amount under an agroforestry system at the same management level) is usually higher than 1, indicating that agroforestry systems are more productive than simpler agricultural systems.

Agroforestry systems can also produce more environmental services that other systems with fewer inputs and lower costs. For example, nitrogen-fixing woody species can reduce fertilizer use and improve soil fertility.

Agroforestry does have limitations. Trees may compete with food crops for space, sunlight, moisture and nutrients, thereby reducing crop yields. Food crops may be damaged during tree-harvesting. Trees that form part of agroforestry systems may be hosts of insects and birds that can damage crops. Finally, the rapid regeneration of trees may displace food crops and even take over entire fields.

If it is considered that agroforestry can help meet the needs of land users, the next step is to determine which agroforestry system is most suitable in the prevailing economic, social and environmental conditions. Three key elements to be considered in this decision-making process are:

- **Land characteristics**, such as topography, soil fertility and drainage, and water resources, and **climate and other environmental conditions**, such as precipitation, temperature and seasonal variations.
- **The needs and priorities** of landowners, such as products for their own consumption and to sell in the market, and environmental services. Needs may vary by scale (e.g. smallholders versus big landowners) and conditions (e.g. ownership regime and management system). Participatory rural assessments, other means of collecting information on stakeholders, and market analyses can help in identifying household needs and the opportunities for agroforestry in an area (for further learning on such tools see Participatory Approaches and Tools in Forestry).
- **The availability of resources** such as land, labour, technology and capital.

Decision-making tools and simulation models can help in determining which agroforestry systems are most suitable in a given area. Researchers, extension agents and community-based organizations may have knowledge of the agroforestry systems practised in the area and what is and is not appropriate in the local context, so they can provide advice to farmers. It is difficult for outside parties to identify all the factors that affect the uptake of agroforestry; it is essential, therefore, that farmers and other land users are involved at an early stage in identifying what is most appropriate for their needs and resources.

Improving, adapting and designing agroforestry systems

In many areas, agroforestry has been a traditional land use for a long time. Surveys of local knowledge and practices, including the agroforestry species (both native and exotic) used in an area, are highly recommended and will help decision-making on the adoption of agroforestry. Information can be gathered through field observations, questionnaires and consultations with local residents. Survey results

can be used to evaluate existing practices, explore possible improvements, and help design agroforestry systems.

Where an agroforestry system already exists, it may be most appropriate to look to improve that system rather than to introduce an entirely new system. Traditional systems will be well-adapted to local circumstances, although it may be possible to make them more efficient, and local farmers are likely to be more willing to modify an existing system than to introduce an unfamiliar one.

The adaptation or design of an agroforestry system is the process of choosing and arranging components spatially and temporally. Common **components** of an agroforestry system are:

· **Trees or other woody perennials** – trees can provide fruit, fodder, woodfuel, timber and other products, as well as environmental services such as soil fertility replenishment, erosion control and carbon sequestration. Trees normally remain in a landscape for many years, with rotation lengths depending on species and desired end-products.

· **Crops or forage** such as grains, tubers, roots, vegetables and even flowers. The rotation for crops is generally much shorter than for trees.

· **Animals** – animals for dairy, meat and egg production, as well as fish, snails and other edible organisms.

The most common agroforestry systems are:

· *Agrosilvicultural systems* (crops – e.g. annual crops and vines – plus trees)

- improved fallow
- taungya
- alley cropping
- multilayer tree gardens
- multipurpose trees in croplands
- plantation–crop combinations
- homegardens
- trees for soil conservation and reclamation
- shelterbelts, windbreaks and live hedges
- woodfuel production.

· *Silvopastoral systems* (trees plus pasture and animals)

- Trees or shrubs on rangelands or pastures
- Protein banks (blocks or lines of trees or shrubs established and managed for fodder production)
- Plantation crops with pastures and animals

· *Agrosilvopastoral systems* (trees plus crops plus pasture and animals)

- homegardens involving animals
- multipurpose woody hedgerows
- apiculture with trees
- aquaforestry

- multipurpose woodlots.

The choice of species of trees and other woody perennials should be based on:

· the goals and objectives of the farmer;

· the potential products/functions (e.g. fruits, nuts and nitrogen fixation);

· the environmental suitability of species for the site;

· the tree/shrub characteristics that influence their interactions with other components of the agroforestry system (e.g. growth rate, crown shape and rooting pattern); and

· the origin (native/exotic) and availability of planting material.

For example, if food production is the top priority, fruit or nut trees suitable for the local environment and markets could be included. Domesticated wild plant or animal species used by local people may be particularly well suited for locally adapted agroforestry systems.

Factors to be considered in the selection of crop and forage plants include their water and fertilizer needs, local dietary requirements, livestock needs (in the case of fodder), market potential, shade tolerance, competition with trees or other woody perennials, and the quality, price and availability of seed.

If animals are to be a component of the agroforestry system, factors to be considered in choosing the kinds (and quantities) of animal include potential markets, desired products (e.g. meat and milk), interactions with other components of the system, price, and availability.

The spatial and temporal arrangements of the various components of an agroforestry system (i.e. trees, crops and animals) are critical for its success; the aim is to minimize the competition for land, sunlight, water and nutrients among those components and to maximize their complementarity. Spatial arrangements refer to how system components are arranged in a landscape – such as the distance between trees in plots, and the configuration of such plots in relation to agricultural crops. Temporal arrangements may comprise the rotation lengths of trees and the seasonality of annual crops.

It is highly recommended that any proposed agroforestry system is tested first at a small scale, and a cost–benefit analysis conducted.

Several factors need to be considered in the design of an agroforestry system:

· **Land ownership** affects the feasibility of agroforestry designs and the motivation for adopting an agroforestry system. For example, farmers are more likely to invest in the planting and management of fruit trees and lumber trees, and to plan a succession of annual and perennial understorey crops, if their tenure to the land is secure.

· The **size of plots available for agroforestry** can vary significantly, from less than one hectare to many hectares. Some agroforestry systems may not be practical (or economically feasible) below a certain size; for example, very small plots may be unable to sustain livestock.

· The **location** of a plot – in terms of access, slope, and possibilities for future land-use change – can also affect agroforestry design.

· **Environmental factors** such as climate, soil, drainage, sunlight and precipitation will help determine the trees, agricultural crops and livestock that can be grown or raised in a given area.

· Design principles differ according to the planned **duration** of the agroforestry system. For example, one system may be introduced to address an immediate problem, such as soil erosion, to be replaced when the problem has been resolved by a (possibly more profitable) system.

Establishing and managing an agroforestry system

The establishment of an agroforestry system involves, among other things, site preparation, plant and animal material selection, planting, and marketing. The availability of suitable materials and adequate financial and technical inputs is crucial.

The nature of **site preparation** varies according to the land type and agroforestry system. It may be minimal (e.g. preparing holes for planting seedlings, or weeding around and protecting naturally regenerated seedlings), or it may involve extensive works, such as land clearing, terracing, fencing, irrigation and fertilization. Such works require appropriate machinery and tools, which can be shared among farmers and communities as a way of reducing (and sharing) costs.

The selection of plant and animal material is an important element in the success of agroforestry establishment.

1. Tree seedlings can be purchased from commercial nurseries or produced by the land owners/managers themselves, depending on needs and situations. Smallholders may be able to purchase tree seedlings at competitive rates from local nurseries. In some cases it may be possible to transplant seedlings from nearby natural forests (where this is legal), although survival rates may be relatively low because of the stresses imposed on the seedlings by the transplanting process. High-quality seedlings should be selected to ensure high tree survival rates. The establishment of a community forestry nursery – in which community members share costs and provide inputs – could be an efficient way of producing low-cost seedlings. Individual enterprises may consider producing tree seedlings in their own nurseries, as described below.

- *Nursery establishment* is a long-term investment and requires good planning. The production target will determine the size of the nursery; the choice of location should be based on the distance to planting areas and the extent to which it matches site conditions.
- *Seed collection and handling* usually includes the following activities:

- selection of seed provenance

- selection of mother trees

- seed collection

- seed extraction (e.g. from pods, cones or fruits)

- seed storage

- recordkeeping

- pre-sowing treatment

- inoculation.

2. *Trees* can be propagated in different ways. E.g.:

- collection of wildings

- direct seed sowing in the field

- farmer-managed natural regeneration

- cuttings

- budding and grafting

- grafting.

3. Crop seeds may be purchased in local markets or obtained from self-production. High-quality crop seeds should be chosen (this may be indicated, for example, by parameters such as size and colour); experienced local farmers are likely to be good sources of information. Trials should be conducted to test the quality and survival rate of seeds.

4. Animals can be bought in markets or from neighbours; only healthy animals should be purchased, and they should be provided with adequate shelter and food to ensure their continued growth and good health. In any given agroforestry system, it should be clear who has primary responsibility for the care and security of the animals and for obtaining animal products such as milk, eggs and fibre.

The planting of trees and crops may involve special machinery or tools and requires adequate knowledge. If prospective agroforesters lack knowledge on tree-planting, they should obtain assistance from someone who is experienced and technically competent – such as an

early adopter in the area or a governmental or non-governmental extension service. The planting of trees and annual crops should be timed to coincide with favourable climatic conditions (e.g. the onset of the rainy season). A detailed workplan should be prepared to ensure that planting proceeds efficiently and that any follow-up work, such as weeding, is carried out effectively.

Marketing is another essential element of agroforestry, in which the products generated by the system are converted into actual income. It involves the following steps:

- selecting target markets;
- adding value to products;
- getting products to prospective buyers;
- setting the price; and
- promoting the products.

Maintaining and monitoring an agroforestry system

Maintenance is needed to ensure that an agroforestry system functions effectively. Common maintenance practices include:

- seedling protection
- weed control
- pest control
- animal browsing
- fertilization
- irrigation
- thinning
- pruning
- coppicing
- harvesting
- post-harvesting operations.

Agroforestry systems are dynamic; their performance, and the impacts of outside factors, should be monitored. The management plan should be adapted to changing circumstances and in achieving production goals. Management changes may be required when, for example:

- trees start competing with crops for space, sunlight and nutrients;
- markets for products change; and
- there are changes in labour requirements or availability.

Effective monitoring requires good baseline information and a set of relevant and measurable criteria.

Please refer to further learning

Disseminating and scaling up agroforestry systems

Self-learning and knowledge-sharing are critical for scaling up good agroforestry practices, bringing in new knowledge and planting materials, testing new methods and designing agroforestry experiments. Knowledge can be shared in various ways, such as through farmer-to-farmer and scientist–farmer exchanges, farmer field schools, demonstration farms, and extension services.

Creating and reinforcing the enabling environment

Although there is substantial evidence of the positive contributions of agroforestry systems to improving and diversifying agricultural production, many barriers to their adoption remain. Some of the main **challenges** for agroforestry development are:

- a lack of secure land and tree tenure;
- adverse regulations;
- a lack of coordination among sectors and producers;
- the time between an investment in agroforestry and the financial return on it;
- limited knowledge;
- the continued emphasis on commercial agriculture;
- weak marketing; and
- lack of public involvement.

Public policy actions should be viewed as tools for creating favourable conditions for the development of agroforestry. This can be achieved by:

- **Providing secure tenure over land and trees.** Conducive land-use policies and regulations may involve creating a secure framework for tenure rights, linking tree tenure with land tenure, developing legal standards to protect farmers, and using community-based rules for land and tree resource management.
- **Adjusting the context.** Reforms may be available to remove unfavourable regulations (e.g. that inhibit tree-cutting), laws and financial barriers.
- **Organizing and synergizing.** Greater intersectoral coordination is likely to produce greater policy coherence and synergies; it can be achieved through strategies to foster collaboration among departments and stakeholders (e.g. through multistakeholder forums) and the application of stakeholder-based participatory approaches to decision-making, such as in land-use planning.
- **Providing incentives.** The environmental services generated by agroforestry can be rewarded through, for example, grants, tax exemptions, cost-sharing programmes, microcredit or delivery in kind, the environmental certification of wood products and other sustainably produced commodities, and better integration with carbon markets. Other long-term, predictable and consistent agroforestry support mechanisms could be established.
- **Transferring know-how.** The information available to agroforestry practitioners could be increased through extension services and farmer field schools, which could be provided by local organizations (such as farmer associations), and through the provision of e-learning, toolkits, plot demonstrations and farmer–farmer exchanges.
- **Using innovative approaches.** Agricultural policies could be revised to acknowledge the role of trees in rural development and entrench the concept of agroforestry as an integral part of sustainable agricultural development, especially for the multiple social and environmental functions and services agroforestry can perform.
- **Developing markets.** Access to markets for tree products could be strengthened through the development of local markets for smallholder farmers, the provision of market information (e.g. production versus demand), and the creation of fair and open competitive markets.
- **Involving stakeholders.** Policy development should use participatory approaches to ensure that outcomes are based on the needs and rights of local people. Community-based institutional mechanisms can be effective in involving local stakeholders in policymaking and decision-making processes.

Gender and agroforestry

Women are attracted to agroforestry because of the substantial benefits it provides, particularly in times of need, in terms of food, fuelwood, fodder and other products and services. Women are often responsible for managing trees and, as with other types of agriculture, they do most of the work, especially during the initial stages when the trees are becoming established, such as planting, weeding and watering.

Women play important roles in small enterprises such as processing indigenous fruits and vegetable (e.g. *Vitellaria paradoxa,* or shea, and *Gnetum africanum,* a vine often eaten as a vegetable). Indigenous fruits can provide a significant source of income. For example, in Tanzania women earn money by processing and selling jam, wine and juice. Women also earn income by processing fodder shrubs and mulch, which require few inputs and less effort thus saving their time for other productive activities.

Agroforestry practices are also attractive to women farmers because they replenish the soil's fertility, increase yields and reduce weeds.

Men and women often have different objectives when they plant trees: men are more interested in trees for commercial purposes, and reserve higher value products for themselves while women usually use tree products for their families' livelihood. Often, in fact, women's rights are limited to the less valuable products (with little or no commercial value).

How can women increase their participation in agroforestry?

1. Technological interventions

- Domesticate agroforestry species
- Develop appropriate storage and processing methods

2. Policy interventions

- Increase women's access to extension services
- Support women's access to market information
- Improve women's access to finance from microcredit institutions

3. Institutional interventions

- Strengthen local institutions and women farmers' organizations.
- Develop new, diverse, high-value products such as oil, soap, juice, body lotion, wine and leaf meal. Many of these products can be made from the same raw materials.

Further Learning

Alao, J.S. & Shuaibu, R.B. 2013. Agroforestry practices and concepts in sustainable land use systems in Nigeria. Journal of Horticulture and Forestry, 5(10): 156–159.

Amonum, J.I., Babalola, F.D. & Agera, S.I.N. 2009. Agroforestry systems in Nigeria: review of concepts and practices. Journal of Research in Forestry, Wildlife and Environment, 1(1): 18–30.

Elevitch, C.R. 2000. *Agroforestry guides for Pacific Islands.* Permanent Agriculture Resources.

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: 401–421.

FAO. 2005. Realizing the economic benefits of agroforestry: experiences, lessons and challenges. Rome.

Garrity, D., de Foresta, H., & Michon, G. 1996. *Agroforests examples from Indonesia - Creating profitable and sustainable multi-purpose forests in the agricultural lands of the humid tropics*. ICRAF, CIRAD, ORSTOM and the The Ford Foudation.

Iiyama, M., Neufeldt, H., Dobie, P., Njenga, M., Ndegwa, G., & Jamnadass, R. 2014. The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability*, 6, 138–147.

Mbow, C., Smith, P., Skole, D., Duguma, L. & Bustamante, M. 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*, 6, 8–14.

Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P.A. & Kowero, G. 2014. Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, 6, 61–67.

Montagnini, F. et al. 1992. Sistemas agroforestales: principios y aplicaciones en los trópicos. 2da. ed. rev. y aum. Organización para Estudios Tropicales, San José, Costa Rica. 622 pp.

Montagnini, F., Somarriba, E., Murgueitio, E., Fassola, H. & Eibl, B., eds. 2015. *Sistemas agroforestales: funciones productivas, socioeconómicas y ambientales.* Serie Técnica Informe Técnico 402, CATIE, Turrialba, Costa Rica. Fundación CIPAV. Cali, Colombia. 454 pp.

Nair, P.K.R. 1993. *An introduction to agroforestry*.

Rao, K.P.C., Verchot, L.V. & Laarman, J. 2007. Adaptation to climate change through sustainable management and development of agroforestry systems. *Journal of SAT Agricultural Research*, 4(1): 1–30.

Smith, J. 2010. *Agroforestry: reconciling production with protection of the environment.*

Verheij, E. 2003. *Agroforestry. Agromisa Foundation, Wageningen.*

Web links

http://people.umass.edu/psoil370/Syllabus-files/Agroforestry_Principles.pdf Agroforestry principles. Last accessed 22.07.2015.

http://www.silvopasture.org/ E-learning: silvopasture management online course. Last accessed 22.07.2015.

Credits

This module was developed with the kind collaboration of the following people and/or institutions:

Initiator(s): Simone Borelli, Yujuan Chen - FAO, Forestry Department

Contributor(s): Susan Braatz - FAO, Forestry Department

Reviewer(s): Guillermo Detlefsen - CATIE; Hans Vellema - Tropenbos International; Florencia Montagnini - Yale University

This module was revised in 2018 to strengthen gender considerations.

Initiator(s): Gender Team in Forestry

Reviewer(s): Simone Borelli - FAO, Forestry Department