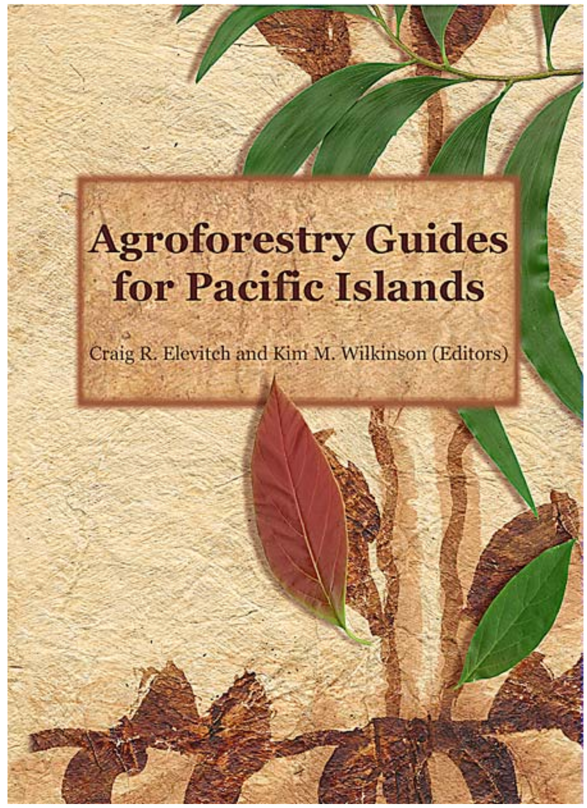
For Educators, Gardeners, Farmers, Foresters, and Landscapers

Agroforestry Guides for Pacific Islands



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Agroforestry Guides for Pacific Islands
edited by Craig R. Elevitch and Kim M. Wilkinson

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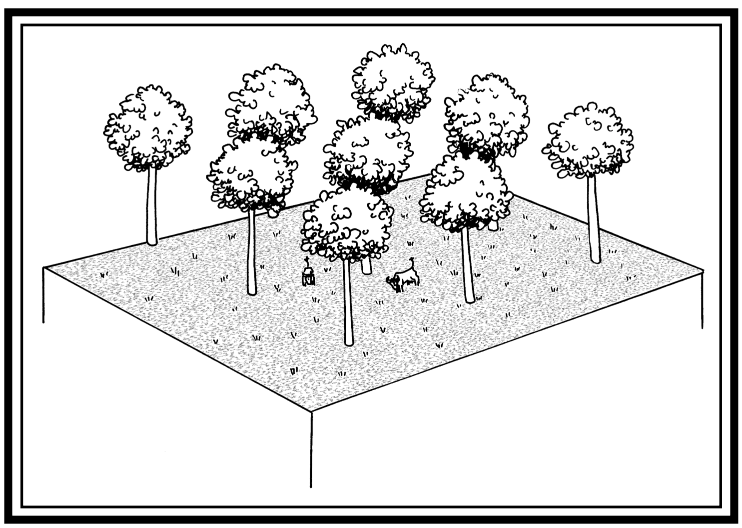
Agroforestry Guides for Pacific Islands #5

Introduction to Integrating Trees into Pacific Island Farm Systems

by Craig R. Elevitch and Kim M. Wilkinson



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Introduction to Integrating Trees into Pacific Island Farm Systems

Abstract: Integrating trees into farm systems can diversify products, optimize use of space, conserve soil and water, reduce the need for off-farm inputs, and broaden opportunities for rural enterprises.

This guide introduces eight agroforestry practices: silvopastoral systems (trees and livestock), windbreaks, live fences/border plantings, hedgerow intercropping, improved fallow and land rehabilitation, woodlots, sequential cropping systems, and dispersed trees/understory cropping. Potential products and benefits, as well as important design considerations, are summarized for each practice.

Keywords: agroforestry, silvopasture, windbreak, shelterbelt, live fences, hedgerow intercropping, contour hedgerows, alley cropping, nitrogen-fixing trees, multipurpose trees, improved fallow, dispersed trees, land rehabilitation, reforestation, woodlots, farm forestry, understory crops, sequential cropping, Pacific Islands, self-sufficiency, low-input agriculture

Contents

Authors: Craig R. Elevitch and Kim M. Wilkinson, **Illustrator:** Christi A. Sobel

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Introduction

Integrating trees with other crops and/or animals a traditional approach to agricultural land use in the Pacific Islands and elsewhere in the tropics. Agroforestry is a modern name for this practice, defined as:

> A dynamic, ecologically based natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increase social, economic, and environmental benefits for land users at all levels. (ICRAF 1997)

This guide introduces eight agroforestry practices. Each practice represents a different way to integrate trees into farm systems. Potential products and benefits, some tips on appropriate species, and important design considerations are included, along with a concept illustration for the practice. The systems introduced in this guide are summarized in the table below.

Agroforestry practices introduced in this guide

Agroforestry Practice	Tree Connections	Potential benefits	Potential tree products
Silvopastoral systems	forage, livestock	shelter/shade for livestock and forage pasture	timber, fruit, or other wood products
Windbreaks	crops, buildings, or animals	protection from wind, erosion, salt spray, pesticide drift; improve crop quality and yield	timber, fruit, or other products
Live fences/border plantings	animals and people, to control movements	affordable and long-lasting protection of crops and animals with fencing	Fence posts and/or fence materials; also potential for fruit, fodder, mulch, or medicinal products
Hedgerow intercropping and contour hedgerows	crops (annual or orchard crops)	replace purchased mulch and nitrogen fertilizers with on-site source and, if planted on contour, can control erosion.	mulch, nitrogen fertilizer, and/or supplemental animal fodder.
Improved fallow and land rehabilitation	soil, soil microorganisms, and future crops	improve fertility and conditions for future production on the site	timber or other wood products, mulch, animal fodder
Woodlots	poor, difficult, or hard-to-access farm land	make productive use of marginal land, land rehabilitation	timber, poles, firewood, animal fodder
Sequential cropping systems	annual or short-term crops	overlap long-term tree products with short-term crops for more efficient use of land	Timber, fruit, or other tree crop products
Dispersed trees/ understory cropping	shade-tolerant understory crops	diversified yields, efficient use of microclimate	Timber, fruit, or other tree crop products

Some of farmer benefits of integrating trees on farms may include:

- Diversified products and yields (financial risk management).
- Reduced need for purchasing off-farm inputs.
- Broader opportunities for rural enterprises.
- Opportunities for year-round production, or to combine short-term crops with long-term crops.

- Local creation of resources like firewood, animal fodder, construction materials, etc.

Some ecological benefits of integrating trees on farms include:

- More efficient use of land to provide for human needs, allowing more land to be left to nature.
- Decreased use of manufactured fertilizers, insecticides, fuels, etc.
- Increased protection of the land from wind and erosion.
- Enhanced biodiversity/wildlife habitat on farms.
- Support for a diversity of soil microlife.
- Long-term carbon storage in trees (to help counter carbon dioxide pollution/greenhouse effects).
- Improved water and watershed management.

The Importance of Advanced Planning for Agroforestry

As with any farm practice, growers should understand the potential limitations of a practice before installation. Agroforestry systems involve two or more species, managed for multiple products and/or environmental services. Agroforestry systems also tend to be dynamic, evolving and changing over time. Therefore, they are usually more complex than single-species (monocultural) plantings.

Agroforestry design strives to maximize positive interactions between trees and other elements (crops, animals, etc.), and minimize negative interactions. This is achieved through appropriate species selection, spacing, and management practices. Tree-crop interactions are beneficial when the total production of the system is greater than that obtained by growing the crops separately, usually due to more efficient resource capture and utilization (Young 1997). One of the best-documented cases of this comes from West and East Africa, where crops grown under the tree *Faidherbia albida* regularly have higher yields than crops grown without the trees (Young 1997). Trees may also have a neutral effect, co-existing with crops (usually by exploiting, at least partially, different environmental niches) without significantly affecting growth or yields. Negative interactions come from competition for water or nutrients which can be minimized by extending the space between the trees and crops. In some cases where interactions are negative, economic or other benefits of the trees may compensate for a limited loss in crop production (Young 1997).

Economic as well as technical considerations are part of successfully planning an agroforestry system. For example, mixed cropping systems often involve some trade-offs in production: e.g., timber production combined with understory crops usually involves fewer timber trees per acre, but the system as a whole is managed so the economic benefits of additional crops exceeds the reduction in timber yields.

Careful advanced planning is important to minimize risks and maximize benefits of agroforestry practices.

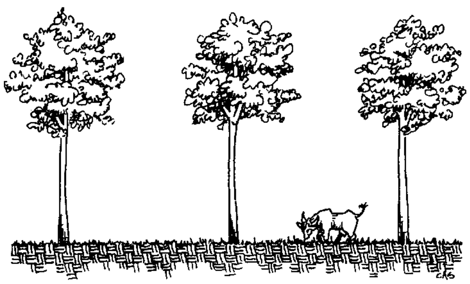
Silvopastoral systems (trees and livestock)

When trees are integrated with pasture forage and livestock production, it is called silvopasture. In silvopasture, the interactions among timber trees, forage and livestock are managed to simultaneously produce timber commodities, a high quality forage resource and efficient livestock production (Klopfenstein et al 1997).

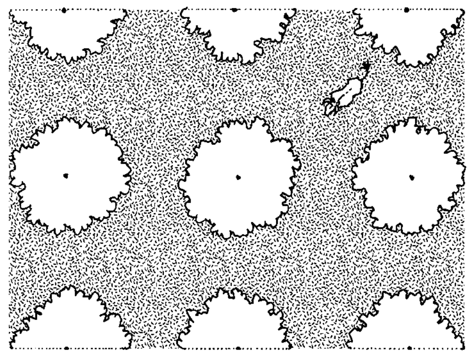
Connections: Trees, Forage, and Livestock

For silvopastoral systems, timber tree species are usually spaced wider than standard to optimize healthy pasture forage underneath. Trees can be evenly distributed over the area to optimize growing space and light for both trees and forage. Alternatively, grouping trees into rows or clusters concentrates their shade and root effects while providing open spaces for pasture production. Trees are typically pruned to increase light penetration and develop high-quality saw logs.

The trees benefit the livestock by providing shelter and shade. For example, most cattle breeds do better in cooler conditions, and their productivity and health declines in the heat (AIS 1993). The livestock in silvopastoral systems play two roles. First, the animals are a source of income. Second, the livestock can be managed to maintain the understory of the forest, thus reducing the need for mowing, herbicides or other weed control.



Silvopasture (section view)



Silvopasture (plan view)

Advantages of Practice

Silvopastures can provide economic returns while creating a sustainable system with many environmental benefits. Potential advantages of silvopastoral practices include:

- Comprehensive land utilization.
- A relatively constant income from livestock sale and selective sale of trees and timber products.
- Reduced economic risk because the system produces multiple products.
- Reduced production costs because management costs are distributed between timber and livestock components.
- Enhanced tree growth because grazing controls can control grass competition for moisture, nutrients and sunlight.
- Grazing provides economical control of weeds and brush without herbicides.
- Livestock manure recycles nutrients to trees and forage.
- Trees provide shade and shelter to increase livestock productivity and well-being (Klopfenstein et al 1997).

Examples of Practice

In the Pacific Islands, the grazing of cattle under commercial timber species has been practiced in many settings. In Papua New Guinea, cattle have been used to control weeds and reduce fire danger under plantations of Caribbean pine (*Pinus caribaea*), hoop pine (*Araucaria spp.*) and *Eucalyptus* species. In Vanuatu, cattle have been grazed under *Cordia alliodora* as well as under *Pinus caribaea* plantations. In the Solomon Islands, cattle have been grazed under *Eucalyptus deglupta* plantations. The most widespread silvopasture system found in Pacific Islands is the grazing of cattle under coconut plantations, which has been practiced since colonial times throughout the Islands including the Solomon Islands, Tonga, Niue, Vanuatu, and Fiji (Clarke and Thaman 1993).

Example Species Used

Animals in silvopastoral systems are commonly cattle or sheep, although potential livestock choices for also include goats, horses, turkeys, geese, chickens, and other grazing animals.

Tree species selected for silvopasture systems should have large crowns above livestock reach, and should not be poisonous to livestock. A thin canopy that allows light to enter for the pasture is also desirable. The trees used must also tolerate the impacts of livestock. Some native Pacific Island trees, for example Hawaiian koa (*Acacia koa*), have sensitive root systems that are easily damaged by the presence of cattle, and may not be appropriate for this practice. However, there are many species that are suitable for silvopasture. Timber species include pines (*Pinus* spp.), laurel (*Cordia alliodora*), and *Eucalyptus* species. Other kinds of tree crops may also be used in silvopastures, including rubber, tamarind, mango, cocoa, and cashew. Some tree species, such as *Leucaena* spp. and *Paulownia* spp., can also be managed to provide nutritious animal fodder as part of the system (Gutteridge and Shelton 1994).

Design Considerations

A successful silvopasture requires an understanding of forage growth characteristics, tree characteristics, and livestock needs. The implications of combining forestry and livestock production should be considered carefully when planning a silvopastoral system, so that the trees, livestock, and forage are compatible and can benefit each other. In most cases, cattle must be kept away from newly planted areas until the trees are several years old, so they will not damage young seedlings. The forage component should be a perennial crop that is suitable for livestock grazing and productive under partial shade and moisture stress.

Silvopasture Resources

Agroforestry in Australia and New Zealand

Authors: R. Reid and G. Wilson, 1985

Publisher: Goodard and Dobson, Victoria, Australia

ISBN: 0-949200-00-X

Scientifically based practical information on how to productively integrate trees into farming systems.

Pasture/Livestock Production Under Coconuts (FACT Sheet)

Authors: various

Publisher: FACT Net, Winrock International, Morrilton, Arkansas

For a concise summary of information about a multipurpose tree or shrub species, see the appropriate FACT Sheet at http://www.winrock.org/forestry/factpub/factsh.htm or order hard copies from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-5417; E-mail: forestry@winrock.org; Web site: http://www.winrock.org/forestry/factnet.htm

Forage Tree Legumes in Tropical Agriculture

Editors: R. Gutteridge and M. Shelton, 1994 (republished 1998)

Publisher: The Tropical Grassland Society of Australia, St Lucia, Queensland, Australia (previously published by CAB International, Wallingford, UK)

ISBN: 0-9585677-1-9

Covers a number of multipurpose tree legumes that can serve as ruminant forage in silvopastoral agroforestry systems. Download the text or order at: http://193.43.36.7/waicent/faoinfo/agricult/agp/agpc/doc/publicat/Gutt-shel/x5556e00.htm

An Introduction to Agroforestry

Author: P.K.R. Nair, 1993

Publisher: Kluwer Academic Publishers, Dordrecht, The Netherlands

ISBN: 0-7923-2134-0

A widely used comprehensive textbook on agroforestry which is both practical and theoretical, covering many agroforestry practices and species. Highly recommended.

Nitrogen Fixing Trees for Fodder Production—A Field Manual

Publisher: FACT Net, 1998

Available from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-5417; E-mail: forestry@winrock.org; Web site: http://www.winrock.org/forestry/factnet.htm

Plantation Forestry in the Tropics

Author: J. Evans, 1992 (2nd edition)

Publisher: Oxford University Press, New York, NY

ISBN: 0-19-854257-7

This comprehensive text covers plantation, community, and social forestry, tree planting to control erosion, and agroforestry.

Silvopasture: An Agroforestry Practice

The Biology of Silvopastoralism

Trees and Pastures: 40 Years of Agrosilvopastoral Experience in Western Oregon

Publisher: National Agroforestry Center (NAC), Lincoln, NE

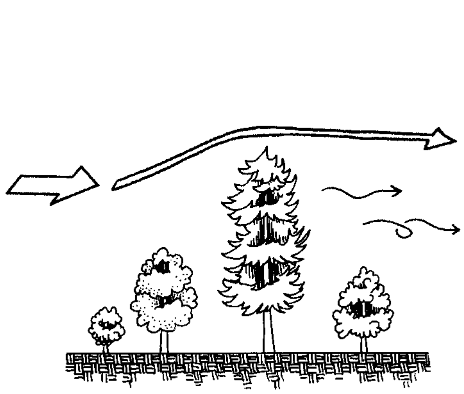
Available from: USDA Forest Service/Natural Resources Conservation Service, East Campus–UNL, Lincoln, Nebraska 68583-0822, USA; Tel: 402-437-5178; Fax: 402-437-5712; Web site: http://www.unl.edu/nac/

Windbreaks

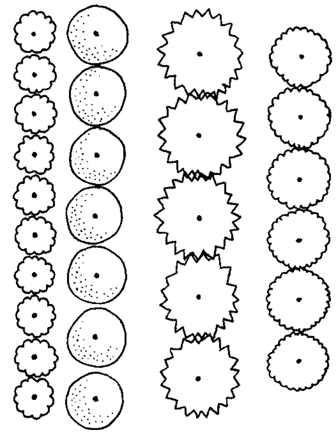
Windbreaks (also known as shelterbelts) are rows of vegetation, usually trees, strategically placed to protect an area from wind damage. A windbreak slows the wind that enters the protected area. Depending on the site conditions, windbreaks may consist of single or multiple rows. They may be oriented to protect from winds coming from one direction, or they may be planted in a pattern that protects an area from variable or shifting winds.

Connections: windbreaks, crops, and animals

Well-designed and managed windbreaks have in many cases been shown to significantly improve the health, productivity, and quality of the crops or livestock they protect. In areas affected by seasonal or constant winds, windbreaks reduce stress on plants and animals, conserve moisture, and protect an area from salt spray or pesticide drift from neighboring properties. Pollinators such as bees are also more active in sheltered areas, which can mean improved pollination and yields for the many orchard and vegetable crops that rely on pollinators. Windbreaks may also be planned and managed to provide additional economic or farm products such as timber, animal fodder, or fruits.



Windbreak (section view)



Windbreak (plan view)

Advantages of Practice

The primary benefits of windbreaks include:

- Improving crop quality by protecting crops from wind damage.
- Increasing crop yield (by 5-50%), due to healthier plants, reduced stress, and improved pollination.
- Conserving moisture by reducing evaporation and transpiration.
- Protecting from extremes of salt spray or hot, dry winds and dust.
- Improving animal health and productivity by reducing stress.
- Enhancing the aesthetic value, property value, and/or recreational value of the property.

Depending on the species used and the design, windbreaks may also provide additional farm or economic products such as timber, fire wood, fodder, or food.

Examples of Practice

Windbreaks are common on many Pacific Islands, and numerous species and planting patterns are used. While there is tremendous variation, three examples are: A three-row windbreak of dwarf Brazilian banana (*Musa balbisiana*) on staggered 2.5 X 2.5 m (8 X 8 ft) spacing (Guam); a two-row windbreak of the timber trees narra (*Pterocarpus indicus*) and sissoo rosewood (*Dalbergia sissoo*) and staggered 2.5 X 5 m (8 X 15 ft) spacing (Guam) (Lawrence 1999); and a two-row windbreak of Dunn's white gum (*Eucalyptus dunnii*) and a *Podocarpus* species on staggered spacing (Hawaii). A single-row windbreak can also be effective if composed of a very wind-strong species with uniform branches to the ground. In single-species windbreaks, one of the most commonly used species is ironwood (*Casuarina* spp.).

Examples of Species Used

Species selected for windbreaks should be wind-strong, long-lived, and adapted to the conditions of the site. Species may also be selected to provide additional products such as timber, food, or fodder. In Pacific Island settings, many kinds of trees have been used as windbreaks. Some native and Polynesian species make good windbreak components; for example in Hawaii milo (*Thespesia populnea*); false kamani (*Terminalia catappa*), hau (*Hibiscus tiliaceus*); and kamani (*Calophyllum inophyllum*) are used (Shigeura and McCall 1979). A few examples of food-producing windbreak trees include dwarf Brazilian banana (*Musa balbisiana*), tamarind (*Tamarindus indica*) and jackfruit (*Artocarpus heterophyllus*). Timber producing-windbreak species include *Eucalyptus* species, mahogany (*Swietenia macrophylla*), narra (*Pterocarpus indicus*), and neem (*Azadirachta* *indica*). There are numerous other native and exotic species that are good windbreak trees (see Windbreak Resources).

Design Considerations

A windbreak has to form a physical structure that will slow and filter wind. The essential physical factors to consider include orientation, spacing, density, height, length, and number of rows. Appropriate species selection is also a key factor in creating an effective windbreak.

Advance planning of a windbreak is necessary to optimize its effectiveness and avoid future problems. For example, a windbreak which is installed or managed incorrectly could increase wind damage rather than preventing it. Issues of potential competition or shading of crops by the windbreak must also be considered. Good planning can prevent these factors from becoming problematic.

Windbreak Resources

Agroforestry in Dryland Africa

Authors: D. Rocheleau, F. Weber, and A. Field-Juma, 1988

Publisher: ICRAF, Nairobi, Kenya

ISBN: 92-9059-049-1

This book is especially useful for field workers, researchers, and extension agents, providing guidelines for evaluating and planning agroforestry projects with community involvement. Also details a wide range of traditional and adaptive agroforestry practices in drier environments in Africa.

Multipurpose Windbreaks: Design and Species for Pacific Islands

Authors: K.M. Wilkinson and C.R. Elevitch, 2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

Agroforestry for the Pacific: Fact Sheets

- Windbreaks for Pacific Islands

Authors: various

Publisher: FACTNet, Winrock International, Morrilton, Arkansas

This brochures outlines the design and maintenance of windbreaks for Pacific Islands. Order from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-5417; E-mail: forestry@winrock.org; or download from
http://www.winrock.org/forestry/FACTPUB/AIS_list.html

Windbreaks in Sustainable Agricultural Systems
Windbreak Establishment
Windbreaks for Rural Living
Windbreaks and Wildlife
Windbreak Systems (Field, Livestock, Farmstead)

Publisher: National Agroforestry Center (NAC), Lincoln, NE

Available from: USDA Forest Service/Natural Resources Conservation Service, East Campus–UNL, Lincoln, Nebraska 68583-0822, USA; Tel: 402-437-5178; Fax: 402-437-5712; Web site: http://www.unl.edu/nac/windbrks.htm

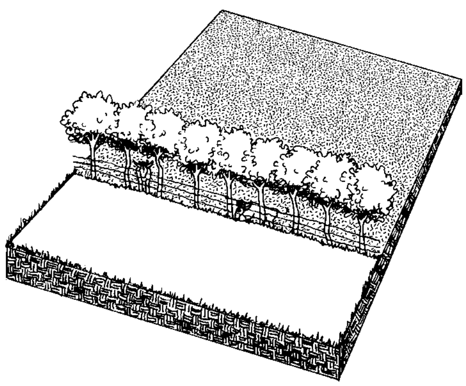
Live Fences/Border Plantings

(Cherry and Fernandes 1998)

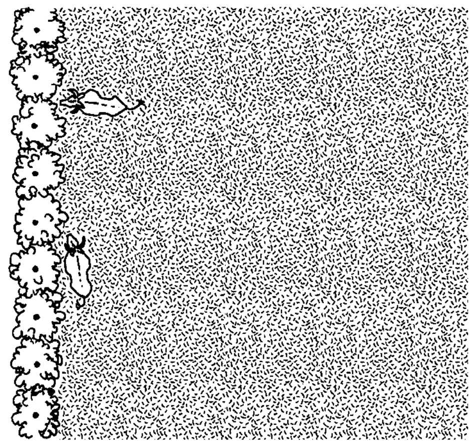
Trees can be used to define boundaries or to control the movements of animals and/or people. When trees form a boundary, it is called a live fence. Live fences can be divided into two basic categories: live fence posts and live barriers or hedges. Live fence posts are widely spaced, single lines of woody plants that are used instead of metal or wooden posts for supporting barbed wire, bamboo or other fence materials. Hedges and live barriers are thicker, more densely spaced fences that may include a number of different species and usually do not support other fencing materials.

Connections

The primary purpose of live fences is to control the movement of animals and people. Live fences can also provide fuelwood, fodder and food, act as a windbreak, or enrich the soil, depending on the species used and the design.



Live Fence (oblique view)



Live Fence (plan view)

Advantages of Practice

Benefits of live fences may include:

- Live fences may be more affordable to install and maintain than conventional fencing for some farmers, as some or all of the fencing materials can be grown rather than purchased.
- The trees acting as live fence posts are far more durable than traditional wooden posts, as they are more resistant to attack by termites and decay by fungi.
- Live fencing can provide a range of products and services, such as fodder, food, fuelwood, or flowers. Farmers may also be able to market seeds and cuttings for future fence materials.

Examples of Practice

Live Fence Posts

Live fence posts are commonly found in conventional barbed wire fences. Farmers may plant stakes of easy-to-root species such as *Gliricidia sepium*, *Erythrina* spp., *Spondias* spp., and *Bursera simarouba*. When grazing or browsing animals are already present, the only way to establish live fence posts and eventually a living fence, is to start with a conventional wire fence supported by conventional non-living fence posts and to gradually establish live fence posts to substitute for the decaying posts. *Gliricidia sepium* is the most common live fence post species in Central America and in other tropical areas because of the ease with which large stem cuttings root and its multiple uses such as forage, green manure and its properties as a rat poison.

Live Barriers/Hedges

As an alternative to purchasing barbed wire or electric fence, some farmers use a number of different tree and shrub species to establish dense, often thorny, hedges to protect their crops. If well established and maintained, these natural barriers can deter both animal and human trespassers from entering into the farm.

Examples of Species Used

The most common live fence-post species are *Gliricidia sepium* and *Erythrina* species. Species used to form live barriers and hedges include thorny species such as Natal plum (*Carissa grandiflora*), kiawe (*Prosopis pallida*), and Manila tamarind (*Pithecellobium dulce*). Other good live fence species are sisal (*Agave americana*) and various bamboos. There are also a number of tropical fruit trees that have been incorporated into live fencing systems either as fence posts or within live fence hedgerows including guava, citrus, bush plum (*Canarium* sp.), *Inga edulis*, *Spondias mombin*, *Moringa oleifera*, and a variety of palm species. Certain plants with medicinal properties (*Prunus africana*, *Columbrina* spp., *Comiphora* spp. and neem *Azadirachta indica*) are also used for live fences.

Design Considerations

The species used for live fence posts must have the ability to rapidly form a callus and cover over the point of attachment of the wire to the post. The callus protects the wood from attack by decay fungi and wood-boring insects. Tree or shrub species that have a resin or sap that is corrosive to metal should be avoided. Otherwise, the wire breaks a few months after being attached to the live fence post.

Live barriers and hedges must usually contain some thorny species if they are to exclude animals and people effectively, which may make working with them unpleasant. Also, the fence must be established and maintained to avoid gaps. Even so, live barriers may not effectively exclude all kinds of undesirable animals.

Live Fence/Border Resources

Live Fences

Authors: S.D. Cherry and E.C.M Fernandes, 1998

Publisher: Cornell University, Ithaca, NY

The full version of the above discussion on live fences can be viewed at: http://ppathw3.cals.cornell.edu/mba_project/livefence.html

Live Fence Video

Authors: S.D. Cherry and E.C.M Fernandes, 1998

A three-part video concerning live fencing presents the perspectives and management practices of small-scale farmers in Cameroon, West Africa. The video is available through ECHO, 17430 Durrance Rd., N. Ft. Myers, FL 33917, USA; Tel: 941-543-3246; Fax: 941-543-5317; E-mail: echo@echonet.org; Web site: http://www.echonet.org/

Multipurpose Trees for Agroforestry in the Pacific Islands

Authors: R.R. Thaman, C.R. Elevitch, and K.M. Wilkinson, 2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Contains a species table denoting tradition Pacific Island species suitable for live fences. Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

The Living Fence: Its role on the small farm

Author: F.W. Martin, 1999

Publisher: Educational Concerns for Hunger Organization (ECHO), N. Ft. Myers, FL

This helpful article can be viewed at: http://www.echonet.org/LivingFence.html

Outdoor Living Barn: A Specialized Windbreak

Publisher: National Agroforestry Center (NAC), Lincoln, NE

Available from: USDA Forest Service/Natural Resources Conservation Service, East Campus–UNL, Lincoln, Nebraska 68583-0822, USA; Tel: 402-437-5178; Fax: 402-437-5712; Web site: http://www.unl.edu/nac/pubs/afnotes/afnwb2.htm

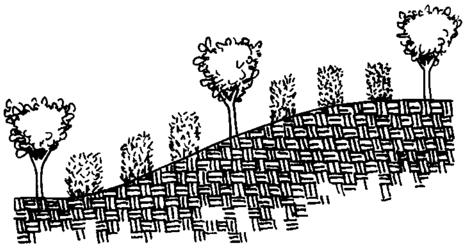
Hedgerow Intercropping and Contour Hedgerows

Hedgerow intercropping (also known as “alley cropping”) is a practice that can increase farm self-sufficiency by reducing or eliminating the need to purchase mulch and most nitrogen fertilizers from off-farm. Nutrient-rich mulch is supplied by a system of hedgerows of nitrogen fixing trees (NFTs). Crops are cultivated between the hedgerows or “alleys.” The nitrogen fixing trees are pruned, and their leaves and green stems provide an on-site, renewable source of fertility and mulch for crops. This management strategy seeks to maximize tree service roles of nitrogen fixation, soil and water conservation, weed control, and nutrient cycling. Hedgerow intercropping can lead to soil and micro-environmental improvements directly affecting associated crops. On sloping land, the hedgerows can be densely planted (5-10 cm within rows) along the contours to form a barrier against soil erosion.

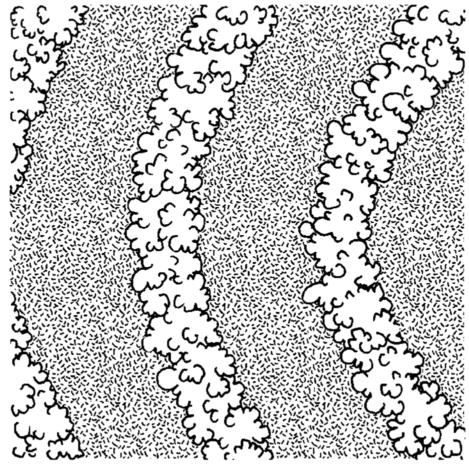
Connections

NFTs used in hedgerow intercropping can accumulate nitrogen from the air into their leaves and tissues. This fertility becomes directly available to other plants through the cycling of organic matter from the NFTs. In alley cropping, the NFT hedgerows must be cut back periodically and the prunings applied to the soil as mulch in adjacent crops.

Aside from the nutrient contribution of the prunings, alley cropping can be adapted to provide other benefits, such as a favorable microclimate and wind protection for crops. When planted on the contour of sloping land, the hedgerows can also can serve to significantly reduce erosion.



Hedgerow (section view)



Hedgerow (plan view)

Advantages of Practice

Hedgerow intercropping can benefit farmers by:

- Increasing self-sufficiency by providing an on-site source of nutrient-rich mulch and fertility.
- Making use of natural nitrogen cycle to provide fertility.
- Reducing use of expensive and environmentally harmful soluble fertilizers.
- Conserving water and fostering beneficial soil microorganisms through the use of mulch.
- Controlling erosion (if hedgerows planted on contour).

Examples of Practice

Alley cropping has been used and researched for several decades, and has received recognition for its potential as a sustainable technique for producing annual food crops such as rice, soybean, and corn. Studies in many tropical areas have shown improved of soil levels of nitrogen (N) and potassium (K), as well as the addition of minor nutrients like calcium (Ca) and magnesium (Mg) from the use of this technique (Nair 1993). Favorable effects on soil temperature and moisture conservation have also been reported (Nair 1993). An on-farm study of alley cropping in an orchard took place in a tropical fruit orchard in Holualoa, Island of Hawaii, that showed similar improvements: in two year's time, with no fertilizer inputs except for the mulch from the hedgerows, data showed a significant increase in total nitrogen and in potassium in the soil, as well as in improvement in soil pH (more neutral) (Elevitch and Wilkinson 1998).

Examples of Species Used

Species used for hedgerow intercropping must be fast-growing, able to regenerate easily after pruning, and, usually, nitrogen-fixing. Common hedgerow species include *Leucaena leucocephala, Acacia angustissima, Calliandra calothyrsus, Gliricidia sepium, Senna siamea* (not an NFT), and *Sesbania sesban*.

Design Considerations

Hedgerow intercropping systems require a substantial up-front investment in time to plan and install. The potential competition from the hedgerows with the crops for water, and nutrients must be minimized with careful planning and layout. In very dry areas, this practice is not recommended due to competition problems. If hedgerows will be planted on the contour, it is important that they follow the contour closely and do not contain gaps, as these may contribute to erosion rather than prevent it. Finally, this practice, while it reduces farm dependence on outside sources of fertilizer, is labor intensive. If labor is in shorter supply than cash, the practice may not be appropriate. Otherwise, good planning, installation, and management will optimize the benefits of this practice while reducing competition between the hedgerows and the crops.

Hedgerow Intercropping Resources

Agroforestry for the Pacific: Fact Sheets

- Hedgerow Intercropping for Upland Root Crop Systems
- Managing Organic Matter: Composting and Mulching
- Nitrogen Fixing Trees as Atoll Soil Builders
- Selecting and Testing Nitrogen Fixing Trees for Acid Soils

Authors: various

Publisher: FACTNet, Winrock International, Morrilton, Arkansas

These brochures presents a wide range of valuable information related to hedgerow intercropping. Order from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-5417; E-mail: forestry@winrock.org; or download from http://www.winrock.org/forestry/FACTPUB/AIS_list.html

Agroforestry for Soil Management

Author: A. Young, 1997

Publisher: CAB International, New York, New York and ICRAF, Nairobi, Kenya

ISBN: 0-85199-189-0

This book presents a synthesis of evidence from agriculture, forestry, and soil science, drawing on over 700 published sources dating largely from the 1990's. Very well written and accessible to practitioners and academics. Highly recommended.

Agroforestry Technology Information Kit (ATIK)

Author: Various authors, 1990

Publisher: International Institute of Rural Reconstruction (IIRR), Cavite, Philippines

ISBN: 0-942717-31-7

This practical agroforestry guide details nursery techniques, seed collection, seed treatment, soil and water conservation strategies, animal systems, and more. Available from IIRR Bookstore and several other sources. Highly recommended.

Multipurpose Trees for Agroforestry in the Pacific Islands
A Guide to Orchard Alley Cropping
Nitrogen Fixing Tree Start-Up Guide

Authors: various, 1998–2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

Improved Fallow/Land Rehabilitation

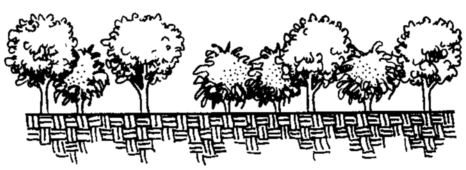
Traditionally, farmers have used the practice of "fallow" to allow crop land to rest and be rejuvenated naturally. When the fallow is enriched with fast-growing trees, shrubs or vines, the practice is called "improved fallow." Improved fallow strategies (sometimes called managed tree fallows) are used to rehabilitate land that has been overexploited, overgrazed, or otherwise depleted of nutrients and organic matter essential for crop growth.

The purpose of improved fallow is to increase the future potential for agriculture on the site. Improved fallow systems normally reduce the amount of time required to restore soil productivity. The trees and shrubs are planted or seeded, and left to occupy land that will not be cropped for several months or several years. If the land has been severely degraded, the fallow may be a long-term land rehabilitation practice. Normally nitrogen-fixing trees and shrubs are used, because of their ability to assimilate atmospheric nitrogen, and because their deep root systems enable them to take up and recycle nutrients. Improved fallow systems gradually increase soil productivity, add organic matter, and accumulate nutrients, while suppressing the growth of undesirable weeds.

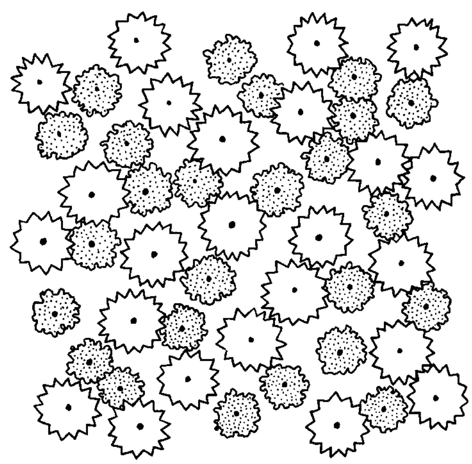
Connections

Improved fallow can be used in any part of the farm that is not under cultivation. In addition to improving the future productivity of the site, improved fallow systems may also yield products such as fuelwood or poles for sale or farm use when the trees in the fallow are removed.

The trees and shrubs in the fallow provide another important service to the farmer: they impede the establishment of undesirable weeds. Many kinds of invasive and problematic weeds prefer open, sunny conditions on vacant land, and will not spread into areas that are cooler and shadier. The trees that are part of the improved fallow create conditions that are unfavorable to many problematic weeds, making the subsequent establishment of crops easier.



Improved Fallow (section view)



Improved Fallow (plan view)

Examples of Practice

Improved fallow has its origins in shifting cultivation in the tropics, where farmers scatter seeds of fast-growing trees in order to shorten the length of the fallow period (Nair 1993). However, the practice has been adapted to many parts of the world. In Costa Rica, for example, improved fallow on degraded land with *Acacia mangium* has helped to control erosion and improved nutrient reserves, while supplying a timber product (FACT Net 1999). In Zambia, maize production has been improved with the introduction of improved fallow systems with *Sesbania sesban* and *Tephrosia vogelii* (Rocheleau et al 1988).

Examples of Species Used

Species used in improved fallow systems have some common characteristics. They should be nitrogen-fixing and/or able produce large amounts of litter with high nutrient content, and they should have deep root systems. They should be hardy, tolerant of drought, poor soils, and neglect. In addition, unless the fallow species will be permanently integrated with future crops, it is important that species used in improved fallow be short-lived or removable, and not invasive, so the land can be returned to crops. Ideally, improved fallow species should also be able to produce useful by-products such as firewood, poles, edible seeds, etc. Species used for this purpose include *Inga edulis* (food, fodder, firewood), *Cajanus cajan* (edible leaves and pods, mulch, fodder), *Crotalaria* sp., *Sesbania sesban* (fodder, mulch, food, firewood), *Albizia saman* (timber, firewood, pods for fodder), *Gliricidia sepium* (mulch, fodder, firewood), *Erythrina poeppigiana* (firewood, mulch), and *Senna siamea* (timber, organic matter).

Advantages of Practice

Using trees in an improved fallow or land rehabilitation practice can have the following benefits:

- Control of undesirable weeds while land is not under cultivation.
- Improved soil fertility.
- Accumulation of nutrients and organic matter.
- Break up of physical barriers to extensive root growth (rock, hard soil, and hard pan).
- Regulation of temperatures (less extremes of hot/cold).
- Protection from winds and erosion.
- Encouraged or sustained populations of beneficial soil microorganisms.
- Reduced time required to restore soil fertility and productivity.

Design Considerations

The effectiveness of the fallow in improving the subsequent productivity of the land depends on a number of factors. These include the length of time the land is kept in improved fallow, which should be long enough for the conditions to improve significantly. Severely degraded land will need more time than healthier land. The effectiveness of the species used is also an important factor, as their productivity, growth rate, and ability to accumulate nutrients is key to improving the productivity of the land. In most cases it is also important that the species used are removable (can be cut down and not grow back), so the land can be returned to other crops. Some species of nitrogen-fixing trees (such as *Leucaena* species) regrow vigorously after repeated cutting, and therefore would not be suitable in most cases. Shorter-lived species or those less tolerant of coppicing, for example *Sesbania* species, are much easier to remove if necessary.

Improve Fallow Resources:

Agroforestry for the Pacific: Fact Sheets

- Hedgerow Intercropping for Upland Root Crop Systems
- Managing Organic Matter: Composting and Mulching
- Nitrogen Fixing Trees as Atoll Soil Builders
- Selecting and Testing Nitrogen Fixing Trees for Acid Soils
- Trees and Shrubs for Agroforestry on Atolls

Authors: various

Publisher: FACTNet, Winrock International, Morrilton, Arkansas

These brochures presents a wide range of valuable information related to improved fallows. Order from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-

5417; E-mail: forestry@winrock.org; or download from http://www.winrock.org/forestry/FACTPUB/AIS_list.html

Agroforestry for Soil Management

Author: A. Young, 1997 (2nd edition)

Publisher: CAB International, New York, New York and ICRAF, Nairobi, Kenya

ISBN: 0-85199-189-0

This book presents a synthesis of evidence from agriculture, forestry, and soil science, drawing on over 700 published sources dating largely from the 1990's. Very well written and accessible to practitioners and academics. Highly recommended.

An Introduction to Agroforestry

Author: P.K.R. Nair, 1993

Publisher: Kluwer Academic Publishers, Dordrecht, The Netherlands

ISBN: 0-7923-2134-0

A widely used comprehensive textbook on agroforestry which is both practical and theoretical, covering many agroforestry practices and species. Highly recommended.

Nitrogen Fixing Tree Start-Up Guide

Authors: C.R. Elevitch and K.M. Wilkinson, 1998

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

Selection and Management of Nitrogen-Fixing Trees

Author: K.G. MacDicken, 1994

Publisher: Winrock International, Morrilton, Arkansas

ISBN: 0-933595-86-7

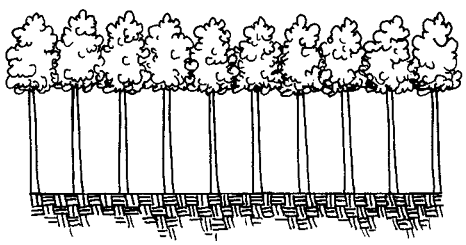
A very useful reference for agroforestry uses of nitrogen fixing trees, including species selection, plant inoculation, growth characteristics, and potential uses.

Woodlots (Timber, Firewood, Fodder Banks)

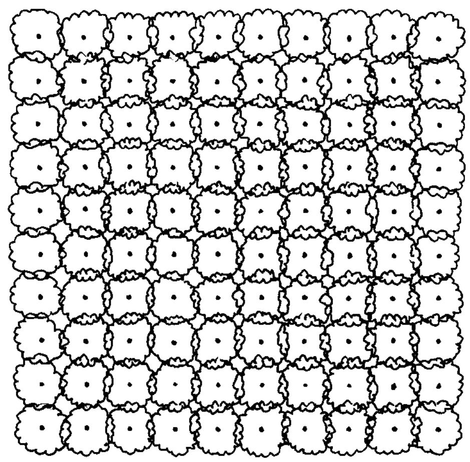
Sometimes farmers devote parts of the farm to solid stands of trees, called woodlots. Woodlots can be a productive use of difficult or hard-to-access farmland, such as steep slopes, river banks, borders, exposed ridges, etc. Depending on the design and the species used, woodlots are managed to provide products such as poles, firewood, or timber. When nitrogen-fixing trees are used, woodlots may also be effective in land rehabilitation (see Improved Fallow), or as a cut-and-carry source of mulch for crops or fodder for animals.

Connections

Woodlots usually consist of trees planted close together and uniformly spaced. Although woodlots can be large, they often occupy small parcels of land, e.g., in Kenya some lots are only 5 X 5m (15 X 15 ft) (FACT Net 1999). Woodlots are often harvested on a rotational basis providing a constant supply of fuelwood, poles, and other products, or they can be managed for the long-term for timber products.



Woodlot (section view)



Woodlot (plan view)

Advantages of Practice

Some of the potential benefits of installing a woodlot include:

- Providing economic products such as timber or firewood
- Making productive use of marginal or difficult-to-access land
- Providing farm products such as poles, stakes, or fodder
- Enhancing wildlife habitat on the farm

Examples of Practice

In Tanzania, woodlots for fuel and construction are composed of pheasantwood (*Senna siamea*), Tibet tree (*Albizia lebbeck*), or *Eucalyptus* species. (Otsyina et al 1996). On the islands of Nukuhiva and Uapou in the Marquesas, stands of *Leucaena* grow in areas surrounding the villages, providing the main source of lowland fodder for horses, and also firewood (Clarke and Thaman 1993).

Examples of Species Used

Desirable species for woodlots are fast-growing and provide useful products. If the woodlot is harvested rotationally, the species should also coppice, resprout, or otherwise regenerate easily. Important nitrogen-fixing genera for woodlots are

Acacia (particularly Australian species), *Albizia*, *Calliandra*, *Casuarina*, *Gliricidia*, and *Leucaena*. Hardy timber-producing species such as sissoo rosewood (*Dalbergia sissoo*), brown salwood (*Acacia mangium*), Tibet tree (*Albizia lebbeck*), neem (*Azadirachta indica*), pheasantwood (*Senna siamea*), teak (*Tectona grandis*), and *Eucalyptus* species are also used in woodlots (Otsyina et all 1996).

Design Considerations

Species choice is a key factor in the success of the woodlot. If the woodlot is planted on marginal or difficult-to-access land, species must be tolerant of poor site conditions and neglect. Species choice is also important for providing the products that are needed by the farmer, such as firewood, fodder, or mulch. Proper species selection, spacing, and management are particularly important if quality timber is a desired product.

Woodlot Resources:

Economics of Farm Forestry: Financial Evaluation for Landowners
Choosing Timber Species for Pacific Island Agroforestry

Authors: various, 2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

Forest Production for Tropical America

Agriculture Handbook 710

Author: F.H. Wadsworth, 1997

Publisher: USDA Forest Service, Washington, DC, USA.

A very useful text on tropical forestry. Includes extensive species data for about 150 forestry species, including wood uses. Order from: International Institute for Tropical Forestry, Publications, USDA Forest Service, P.O. Box 5000, Rio Piedras, Puerto Rico 00928-5000; Web site:
http://www.fs.fed.us/global/iitf/welcome.html

Agroforestry for the Pacific: Fact Sheets

- Fodder Bank Establishment and Management
- Fuelwood Production in the South Pacific

Authors: various

Publisher: FACTNet, Winrock International, Morrilton, Arkansas

Order from FACT Net, Winrock International, 38 Winrock Drive, Morrilton, Arkansas 72110-9370, USA; Tel: 501-727-5435; Fax: 501-727-5417; E-mail: forestry@winrock.org; or download from
http://www.winrock.org/forestry/FACTPUB/AIS_list.html

Plantation Forestry in the Tropics

Author: J. Evans, 1992 (2nd edition)

Publisher: Oxford University Press, New York, NY

ISBN: 0-19-854257-7

This comprehensive text covers plantation, community, and social forestry, tree planting to control erosion, and agroforestry.

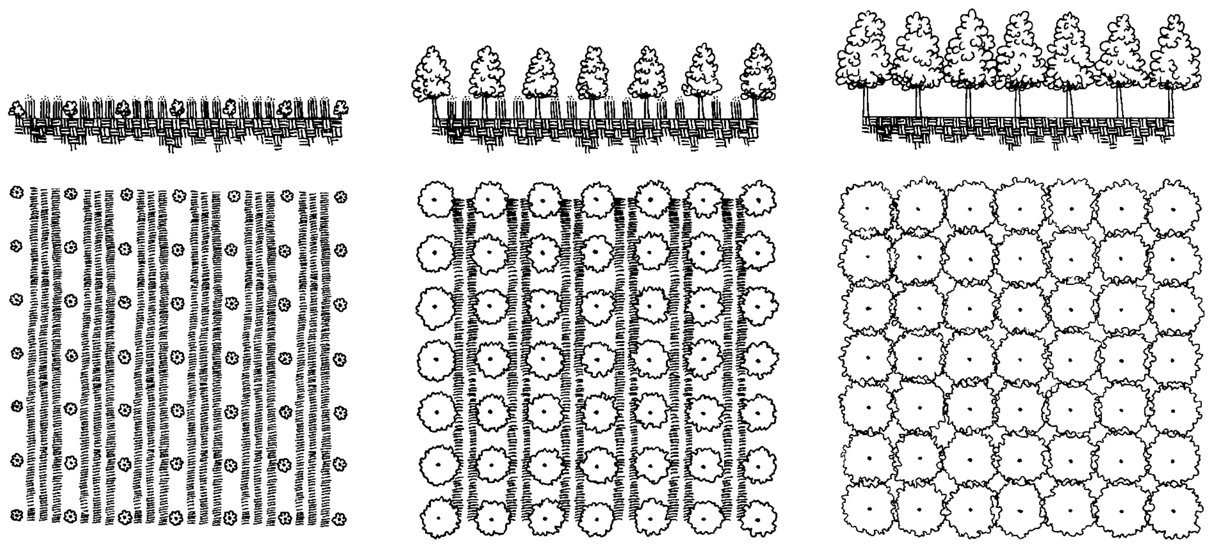
Sequential cropping systems

Sequential cropping is a practice wherein short-term crops are planted with and eventually replaced by long-term trees. The long-term tree crops can include either fruit/nut or timber species. Sequential cropping may be used during the establishment phase of a forestry or orchard project, or in other cases where annual or short-term crops are being replaced by long-term tree crops. For either purpose, sequential cropping enables farmers to harvest short-term crops while waiting for the tree crops to become productive.

Connections

Most tree crops require a long-term investment of land, labor, and other scarce farm resources. Fruit and nut trees can take two to fifteen years to bear, and timber trees usually need to grow fifteen or more years before they can be harvested. Some farmers prefer not to devote their land entirely to a crop that will not yield for many years. Sequential cropping systems provide a short-term source of income until the tree crops mature.

Sequential cropping systems also may save on maintenance costs. In conventional tree crop systems, the area between the trees must be weeded, sprayed, mowed, or otherwise maintained during the establishment phase. With sequential cropping systems, the costs of weed control and maintenance are shared with annual crops that also provide products during the first few years of tree growth.



Sequential Cropping Year 1 (section and plan view) **Sequential Cropping Year 3 (section and plan view)** **Sequential Cropping Year 5 (section and plan view)**

Advantages of Practice

Some advantages of sequential cropping systems include:

- Long-term investment made economically viable by the addition short-term yields.
- Greater efficiency in land use (less land area is unproductive while tree crops mature).
- Increased efficiency in labor (because tree and crop maintenance can overlap).
- Diversified farm products.

Examples of Practice

Sequential Planting in a Multistoried System: Cavite, Philippines

A classic example of sequential planting with fruit trees comes from farmers in Cavite, The Philippines, who have devised ways to subsist and profit off the land while permanent tree crops become established. There are many local variations, but the basic model results in a rice paddy slowly being converted permanently into coffee, fruit trees, and other perennials.

Year 1: Rice is planted. Pineapple and papaya are interplanted with the rice. Rice is harvested, phased out.

Year 2: Papayas are harvested. Coffee and fruit trees are planted.

Year 3: Pineapples and papayas are harvested.

Year 4: Pineapples and papayas are harvested, phased out. Coffee and fruit trees begin to bear.

Some of the variations of this model increase short and long-term profits even more, by incorporating bananas, corn, and other crops. This kind of system gives farmers a return from their land while they invest in long-term perennial tree crops such as fruits or timber (Capistrano and Moeliono 1990).

Sequential Planting in a Forestry System: Pentecost, Vanuatu

In Vanuatu, cash crops are grown between the line plantings of *Cordia alliodora* (laurel, an important commercial hardwood). Crops have included sweet potatoes, cassava, yam, kava, coffee, and cardamom. Subsistence gardens have also been established in *Cordia alliodora* plantings by local landowners and forest workers (Clarke and Thaman 1993).

Example Species for This Practice

Because the trees in sequential cropping systems will eventually overtake the crops, the trees are usually selected based on their promise as a long-term investment. However, certain characteristics of the trees are desirable. Trees should not be excessively fast-growing or competitive with the crops, and of course species with known allelopathic (inhibitory or suppressant) effects on crops should be avoided. Although there will be some overlap of tree and crop root systems (due to lateral roots of trees), it is ideal if the young trees exploit, at least partially, different soil horizons than the understory crops (Young 1997). Additionally, it is important to choose tree species that will not be damaged by the cultivation or harvest of surrounding crops.

There are many kinds of trees that are established in conjunction with sequential cropping systems. Teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*), neem (*Azadirachta indica*), and laurel (*Cordia alliodora*) are a few examples of timber trees successfully used in sequential cropping (Evans 1992). Other trees used as the long-term tree component in sequential cropping include coconuts, bananas, peach palm (*Bactris gasipaes*), and rubber (*Hevea brasiliensis*) (Nair 1993).

Design Considerations

Careful planning is necessary to ensure that a sequential planting system will be successful. The system design assumes that eventually the trees will overtake the crops. In the interim it may be difficult to predict and manage the crop-timber interactions and their consequences. Planning and advanced study is necessary to help determine how long the short-term crop can be expected to bear until the long-term crop takes over by competition. Growth and rooting habits should be understood so plants are compatible and not overly competitive for nutrients and water in the short-term. Also, marketing of the different crops as they change from year to year may require extra effort on the grower's part.

Sequential Planting Resources

Agro-Forestry in the Pacific Islands: Systems for Sustainability

Editors: W.C. Clark and R.R. Thaman, 1993

Publisher: United Nations University Press, Tokyo

ISBN: 92-808-0824-9

Very thorough treatment of agroforestry practices in the Pacific. Includes tables and descriptions of many traditional agroforestry species.

Agroforestry Technology Information Kit (ATIK)

Author: Various authors, 1990

Publisher: International Institute of Rural Reconstruction (IIRR), Cavite, Philippines

ISBN: 0-942717-31-7

This practical agroforestry guide details nursery techniques, seed collection, seed treatment, soil and water conservation strategies, animal systems, and more. Available from IIRR Bookstore and several other sources. Highly recommended.

Integrating Understory Crops with Tree Crops: An Introductory Guide for Pacific Islands

Authors: K.M. Wilkinson and C.R. Elevitch, 2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, HI 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

An Introduction to Agroforestry

Author: P.K.R. Nair, 1993

Publisher: Kluwer Academic Publishers, Dordrecht, The Netherlands

ISBN: 0-7923-2134-0

A widely used comprehensive textbook on agroforestry which is both practical and theoretical, covering many agroforestry practices and species. Highly recommended.

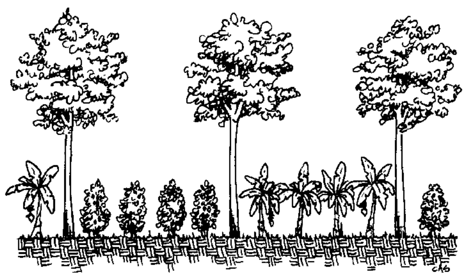
Dispersed Trees/Understory Crops

Understory cropping combines trees and shade-tolerant crops in a permanent arrangement. The practice can be integrated during the design of a forestry, orchard, or other tree-crop system, or may be used to increase economic returns from a native forest or conservation area. Some farmers may add overstory trees to provide shade for existing crops. There are many valuable cash and subsistence crops that thrive in the shady climate under trees. When cultivated in combination with tree or forest crops, understory crops enable farmers and foresters to diversify their yields, reap earlier returns, and make more efficient use of land.

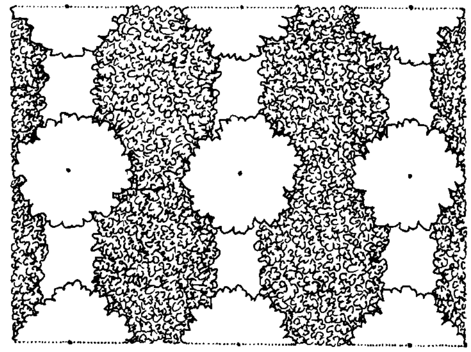
Connections

Plantings that take advantage of the understory range from simple systems consisting of one species in the overstory and one in the understory, to complex systems with many layers of trees, shrubs, and herbaceous plants stacked together as appropriate for their needs. The understory is a unique environment, involving more than just shade. The shade brings about a whole complex of environmental changes, affecting not just available light but also air temperature, humidity, soil temperature, soil moisture content, wind movement, and more. These factors impact plants, and some the effect can be beneficial to certain kinds of crops.

Unlike sequential cropping systems, understory crops are installed and managed to produce for many years as the trees mature. Usually the number of trees per acre is 25-75% less then when timber or fruit trees are planted alone, to make space for the understory crops.



Dispersed Trees/ Understory (section view)



Dispersed Trees/ Understory (plan view)

Advantages of Practice

Some advantages of understory cropping systems include:

- Greater efficiency in land use (more environmental niches are exploited).
- Increased efficiency in labor (because tree and crop maintenance can overlap).
- Diversified farm products.
- Greater stability, both environmental and economic.
- Short-term yields combined with long-term investment in trees.

Examples of Practice

Integrating trees and understory crops is practiced in many parts of the tropics. In the Pacific Islands, it is common to find taro, kava, or pasture under coconut plantations. In Central America, coffee and cocoa (cacao) or often grown under long-term timber trees such as laurel (*Cordia alliodora*), plus nitrogen-fixing trees for mulch an managed shade such as *Gliricidia sepium* or *Erythrina* spp. In Indonesia, patchouli (an essential oil crop) is cultivated in the understory of teak (*Tectona grandis*) plantations.

Another important example is the cultivation of crops under the canopy of a natural forest. In Hawaii, a variety of culturally valuable plants such as kava, herbaceous medicinals, and vines for garlands are cultivated in the understory of native forests.

Example Species for This Practice

Desirable characteristics for trees integrated with understory crops are similar to those for sequential cropping (see above), with root systems that partially exploit different soil horizons and are not overly competitive with the crops. Species such as *Eucalyptus globulus* are known to have very competitive surface-feeding roots that make them unsuitable for intercropping (Macmillan 1991). Naturally, trees with allelopathic or toxic effects on the crops should also be avoided. For example, ironwood (*Casuarina* spp.) has been reported to have suppressive effects on sorghum, sunflower, and cowpea (Nair 1993). The tree canopy should allow acceptable light penetration to crops. Additionally, it is important to choose tree species that will not be damaged by the cultivation or harvest of surrounding crops.

Intercropping understory crops with coconut palms is one of the most common agroforestry practices of the Pacific Islands. However, there are many other trees and tree-like species that are suitable for understory intercropping systems. Examples of timber trees regularly used with certain understory crops include teak (*Tectona grandis*), laurel (*Cordia alliodora*), and pheasantwood (*Senna siamea*). Examples of nitrogen-fixing trees include *Erythrina* spp., *Inga* spp. (ice cream bean), *Sesbania* spp., and *Gliricidia sepium*.

Suitable understory crops include a diverse array of economic crops. These include essential oil crops such as vetiver, lemon grass, and patchouli; spices such as black pepper, ginger, and vanilla; fruits including pineapple, *Annona* species, and guava; and numerous root crops, herbs, and vegetables. Understory crops may also include medicinal or culinary plants such as kava, betel vine, cocoa, coffee, tea, and gourmet or medicinal mushrooms.

Design Considerations

The conditions in the understory will be determined by the kinds of trees that form the canopy above. Some trees create dappled sunlight or light shade; others create a thick canopy with dense shade beneath. Careful planning is necessary to select and integrate understory crops and trees in a way that maximizes available water and nutrients, while minimizing competition. Understory crops must be selected so they are compatible with and make best use of the understory environment. In native/conservation forest areas, it also may be important to provide for ongoing regeneration of the overstory trees.

Understory Resources

Agro-Forestry in the Pacific Islands: Systems for Sustainability

Editors: W.C. Clark and R.R. Thaman, 1993

Publisher: United Nations University Press, Tokyo

ISBN: 92-808-0824-9

Very thorough treatment of agroforestry practices in the Pacific. Includes tables and descriptions of many traditional agroforestry species.

Agroforestry Technology Information Kit (ATIK)

Author: Various authors, 1990

Publisher: International Institute of Rural Reconstruction (IIRR), Cavite, Philippines

ISBN: 0-942717-31-7

This practical agroforestry guide details nursery techniques, seed collection, seed treatment, soil and water conservation strategies, animal systems, and more. Available from IIRR Bookstore and several other sources. Highly recommended.

Income Opportunities in Special Forest Products: Self-Help Suggestions for Rural Entrepreneurs (Agriculture Information Bulletin AIB-666)

Authors: M.G. Thomas and D.R. Schumann, 1993

Publisher: USDA Forest Service, Washington, DC

In depth discussion of temperate special forest products (nontimber forest products) that represent opportunities for rural entrepreneurs to supplement their incomes. Order from Southern Research Station, USDA Forest Service, Blacksburg, Virginia; or download at:
http://www.sfp.forprod.vt.edu/pubs/pubs.htm

Integrating Understory Crops with Tree Crops: An Introductory Guide for Pacific Islands

Nontimber Forest Products for Pacific Islands: An Introductory Guide for Producers

Authors: K.M. Wilkinson and C.R. Elevitch, 2000

Publisher: Permanent Agriculture Resources, Holualoa, HI

Available from Permanent Agriculture Resources, P.O. Box 428, Holualoa, Hawaii 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129;
E-mail: par@agroforestry.net; Web site: http://www.agroforestry.net

An Introduction to Agroforestry

Author: P.K.R. Nair, 1993

Publisher: Kluwer Academic Publishers, Dordrecht, The Netherlands

ISBN: 0-7923-2134-0

A widely used comprehensive textbook on agroforestry which is both practical and theoretical, covering many agroforestry practices and species. Highly recommended.

Other Tree-Integrated Systems

This guide introduced eight agroforestry practices found in Pacific Islands. However, trees can be integrated with crops in many different ways not covered here. These include:

Tropical home gardens/forest gardens

A long tradition in Pacific Islands and many other tropical regions, home gardens are usually very diverse, multi-strata systems that include trees, shrubs, herbaceous plants, and vines. These gardens are managed for household production of multiple products, including fruits, vegetables, herbal medicines, firewood, animal feed, and/or building materials (Landauer and Brazil 1990).

Aquaforestry

Marine aquaforestry includes the management of mangroves or other coastal trees to maintain or improve conditions for fish and other marine foods. Aquaforestry may also involve freshwater systems, such as augmenting the diet of pond-raised fish with leaf fall from sesbania trees (Young 1997).

Entomoforestry

There are many systems that combine trees with production from insects. One of the most common involves trees and honey bees, where trees provide shelter and nectar for honey bees. In turn, the bees improve pollination, enhancing the production of seeds or fruits from the trees. Examples of species that provide nectar for honey bees include citrus species, coconuts, and *Gliricidia sepium* (Wilkinson and Elevitch 1999). In other parts of the world, trees are used to produce food insects, such as combining cultivation of the edible sago grub (*Rhynchophorus* sp.) with sago palm production.

Summary

The eight practices introduced in this guide are:

- Silvopastoral systems (trees and livestock)
- Windbreaks
- Live fences/border plantings
- Hedgerow intercropping and contour hedgerows
- Improved fallow and land rehabilitation
- Woodlots (for timber, firewood, or fodder banks)

- Sequential cropping systems
- Dispersed trees/understory cropping

Integrating trees into farm systems can benefit the farmer and the environment. Diversified yields, more efficient use of land, and reduced need for inputs from off-farm can all improve the bottom line for the farmer. Diversified species and more trees in the landscape can also improve watershed health, enhance wildlife habitat, and conserve soils. Careful planning is essential to minimize problems and enhance the benefits of integrating trees.

Local Resources

Landowners are encouraged to contact the local offices of the Natural Resources Conservation Service and/or Cooperative Extension Service for personal assistance.

The Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) provides assistance with conservation practices such as windbreaks and contour plantings. They also have a Forest Incentive Program, to increase the supply of timber products from nonindustrial private forest lands. They have offices throughout the American-affiliated Pacific. To find the office nearest you, contact:

NRCS State Office
P.O. Box 50004, Honolulu, HI 96850-0050
Tel: 808-541-2600, Fax: 808-541-1335 or 541-2652
Web site: http://www.hi.nrcs.usda.gov

The Cooperative Extension Service (CES) of the University of Hawaii can assist landowners with further information. There are CES offices throughout the State of Hawaii; to local one near you contact:

Cooperative Extension Service Main Office
3050 Maile Way, Gilmore Hall 203, Honolulu, HI 96822
Tel: 808-956-8397, Fax: 808-956-9105
E-mail: extension@ctahr.hawaii.edu
Web site: http://www2.ctahr.hawaii.edu

The State of Hawaii Department of Land and Natural Resources Division of Forestry and Wildlife provides information, education, and support for forestry. Some cost-sharing and other partnerships with private landowners are available. Contact:

Division of Forestry and Wildlife
1151 Punchbowl St. Room 325, Honolulu, HI 96813-3089
Tel: 808-587-0166, Fax: 808-587-0160
Web site: http://www.hawaii.gov/dlnr/dofaw/

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Agroforestry Guides for Pacific Islands

Introduction to Integrating Trees into Pacific Island Farm Systems is fifth in a series of eight Agroforestry Guides for Pacific Islands, published by Permanent Agriculture Resources with support from the U.S. Department of Agriculture's Western Region Sustainable Agriculture Research and Education (WSARE) Program. The guides can be downloaded from the internet free of charge from http://www.agroforestry.net. Master copies are also available to photocopy free of charge from Pacific Island offices of the Natural Resources Conservation Service (NRCS) or the Cooperative Extension Service (CES) of the University of Hawaii.

Each guide includes a resource section with books, periodicals, and web links for further information on the subject.

1. Information Resources for Pacific Island Agroforestry

Provides an introduction to agroforestry, followed by descriptions and contact information for books, guides, periodicals, organizations, and web sites useful to practitioners of agroforestry in Pacific Islands.

2. Multipurpose Trees for Agroforestry in the Pacific Islands

Introduces traditional Pacific Island agroforestry systems and species. Provides a species table with over 130 multipurpose trees used in Pacific Island agroforestry, detailing information on uses (food, fodder, timber, etc.) and tree characteristics such as height, growth rates, and habitat requirements.

3. Nontimber Forest Products for Pacific Islands: An Introductory Guide for Producers

Discusses the environmental, economic, and cultural role of nontimber forest products. Provides planning suggestions for those starting a nontimber product enterprise. Includes a species table of over 70 traditional Pacific Island nontimber forest products.

4. Integrating Understory Crops with Tree Crops: An Introductory Guide for Pacific Islands

Introduces planning considerations for planting crops with forestry, orchard, or other tree-based systems. Examples of understory intercropping systems in the tropics are included, as well as a species list of over 75 trees, shrubs, and vines used as understory crops in the region.

5. Introduction to Integrating Trees into Pacific Island Farm Systems

Presents eight Pacific Island agroforestry practices that integrate trees into farm systems. Includes silvopasture (trees and livestock), windbreaks, contour hedgerows, live fences, improved fallow, woodlots, sequential cropping systems, and understory cropping.

6. Choosing Timber Species for Pacific Island Agroforestry

Discusses seven steps for choosing timber species that meet the project goals, product requirements, and environmental conditions for a farm forestry or agroforestry project. Includes a species table of over 50 Pacific Island agroforestry species that provide quality wood products, detailing environmental tolerances and multiple uses.

7. Economics of Farm Forestry: Financial Evaluation for Landowners

Introduces strategies for determining the financial returns of small-scale forestry and farm forestry projects. Includes a discussion of the advantages and disadvantages of investing in farm forestry, and the steps in determining the costs involved, estimating returns, and comparing farm forestry with other land uses. Also explores the potential of improving economic picture through value-added strategies or agroforestry practices.

8. Multipurpose Windbreaks: Design and Species for Pacific Islands

Covers information on windbreak design, followed by a discussion of planning considerations for multiple-use windbreaks for timber, fruit/nut production, mulch/fodder, or wildlife habitat. Includes species table of over 90 windbreak species for Pacific Islands, detailing environmental requirements and uses/products.

Agroforestry Guides for Pacific Islands

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