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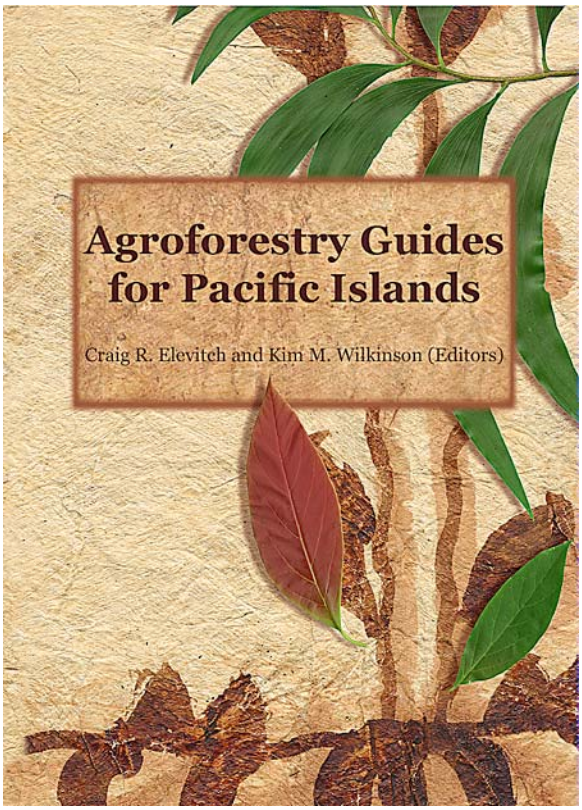

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Agroforestry Guides for Pacific Islands #8

Multipurpose Windbreaks: Design and Species for Pacific Islands

by Kim M. Wilkinson and Craig R. Elevitch

PAR

Western Region Sustainable Agriculture Research and Education

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Multipurpose Windbreaks: Design and Species for Pacific Islands

Abstract: Effective windbreaks can improve crop production and health, while conserving soil and water. Pacific Island farmers face a number of challenges in windbreak design, including a scarcity of land that makes efficient land use essential. Planting a multipurpose windbreak can increase the benefits of the windbreak by providing commercial or farm products.

This guide covers the criteria of basic windbreak design, including orientation, spacing, density, height, length, number of rows, and continuity. Additional design criteria for multiple uses and products, including timber, fruit, fodder, mulch, and wildlife habitat, are also presented. A species chart of over ninety multipurpose trees suitable for windbreaks in Pacific Islands is included.

Keywords: windbreak, shelterbelt, multipurpose, design, fodder, fruit, mulch, multi-use, planning, sustainable, timber, trees, wildlife, wind

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Introduction

This guide discusses the planning of productive, multipurpose windbreaks in Pacific Island environments. Pacific Island farmers face a number of challenges in windbreak design. These include variable wind patterns (prevailing winds, trade winds, storms, etc.) a scarcity of land, and a shortage of practical information on windbreak design and species for tropical climates.

This guide introduces the basic principles of windbreak design, layout, and management. It examines design criteria of multipurpose windbreaks, including uses for fruit/nut production, timber, mulch/animal fodder, and wildlife habitat. Issues that must be incorporated in the planning process to maximize secondary yields while maintaining effective wind protection are featured. A species table of over ninety multipurpose plants that are suitable components in Pacific Island windbreaks is included.

Effects of Wind on Crops

In Pacific Island environments, wind can be detrimental to crop production in many ways:

- Wind stresses plants, reducing their growth, vitality, and yield.
- Wind physically damages plants by breaking stems or branches, stripping leaves, or tearing fruit or flowers from crop plants.
- Wind dries the air around plants, causing them to lose moisture.
- Wind pulls moisture from soil pores on the surface, drying soil.
- Wind removes topsoil and organic matter from exposed soil.
- Wind carries salt, especially near coastal areas or on small islands, which draws moisture out of the soil and can harm plant tissue (AIS 1993).

Windbreaks prevent crop damage, conserve moisture in plants and the soil, and reduce soil wind erosion and salt spray.

What is a Windbreak?

Windbreaks (sometimes known as shelterbelts) are rows of vegetation, usually trees, strategically placed to protect an area from wind damage. A windbreak works by filtering and slowing the wind that enters the protected area. Effective windbreaks provide protection from prevailing winds, and can also limit damage from storms.

What is a Multipurpose Windbreak?

Planting windbreaks is a long-term investment for landowners. The benefits of planting a windbreak can be increased by creating a multipurpose windbreak. A multipurpose windbreak is designed to provide multiple functions and/or products, in addition to wind protection. Multiple products or uses from a windbreak can include fruit, timber, animal fodder, wildlife habitat, and other economic or farm products. Adding multiple functions or products to a windbreak can make the installation and management more satisfying and economically viable for the landowner.

Multipurpose windbreaks require additional care in planning and management to maintain the primary function of wind protection while maximizing secondary yields. The desire for additional yields from a multipurpose windbreak must always be balanced by the need to maintain the integrity of the wind protection.

Potential Benefits of Windbreaks

As with any farm practice, landowners must weigh the potential benefits and costs of designing, installing, and managing a windbreak as it relates to their goals and site conditions. The primary benefits of planting windbreaks are:

- To improve crop quality and yield by protecting crops from wind damage.
- To conserve moisture by reducing evaporation and transpiration.
- To protect from extremes of salt spray or hot, dry winds and dust.

Other benefits of windbreaks can vary depending on the area to be protected, the severity of wind in the region, and other factors. The types of benefits and the degree of each based on past experience in the mainland United States is summarized in Table 1.

Benefits of Farm Windbreaks	
Property value	Improved 6-12%
Crop production	Improved 6-44%
Working conditions	Variable
Irrigation	Variable
Equipment/Structure maintenance	Variable
Noise levels	Reduced 10-20%
Wind erosion	Reduced 50-100%

Adapted from (Wight and Townsend 1995)

Some specific examples of how production can be improved by windbreaks follow.

- Fresh vegetables and fruits get premium prices based on appearance; crops that are bruised, blemished, or damaged by wind usually have to be sold at a lower price. Protecting specialty crops improves their appearance and allows them to fetch top dollar in the marketplace (Brandle et al 1995).
- Orchards for fruit production benefit from wind protection. In a fruit orchard protected by a windbreak, more fruit can be produced because flowers and young fruits sustain less wind damage; stress on the trees can be reduced, improving their growth and productivity; and in some cases fruit set can improve because insect pollinators tend to be more active in the protection of a windbreak.
- Animal production can also be improved by windbreaks. For example, when animals such as swine, cattle, and goats are protected from wind, stress on the animals is significantly reduced. A windbreak for livestock can result in lower mortalities, improved health, and lowered feeding costs (Hintz 1983).
- Windbreaks may allow the landowner to cultivate more valuable crops in the protected area than in an area unprotected by a windbreak, because the windbreak will create a more mild and hospitable microclimate. This can expand business and marketing opportunities that would otherwise not be open to the farmer (AIS 1993).
- A windbreak can create a more pleasant living and working environment for the farmer and farm workers, which can lead to improved productivity.

Although results are variable, there are a number of statistically documented cases of windbreaks improving the quality and quantity of yields for many different kinds of crops. For example, windbreaks installed to protect specialty crops like fruit trees and vegetables in the mainland United States improved yields

between 5-50% (Brandle et al 1995). The use of windbreaks with crops like corn, millet, rice, and soybeans in Africa and China increased yields between 10-74% (Pimentel and Wightman 1999). In these studies, the increased yields per acre usually include the area occupied by the windbreaks.

Well-designed and managed windbreaks have in many cases been shown to protect the health, productivity, and quality of crops enough to make the practice economically viable.

Additional Benefits of Multipurpose Windbreaks

Designing windbreaks for multiple products or functions as discussed in this guide can expand the benefits of the windbreak beyond improving the productivity of their current crops. For example, multipurpose windbreaks can:

- Provide additional economic products such as fruits, nuts, or timber.
- Increase on-site resources for farm use such as animal fodder, mulch, food, poles, fuelwood.
- Improve the aesthetic value, property value, and/or recreational value of the property.
- Provide greater ecological and economic stability through the addition of diverse species to the farm system.

Potential Drawbacks of Windbreaks

Landowners must also consider the potential drawbacks of installing a new practice like a windbreak. Advance planning can prevent some of these factors from becoming problematic.

- A windbreak installed or managed incorrectly can create wind damage rather than preventing it.
- Windbreaks take up space and land that could be used for production of the primary farm product.
- Windbreaks may compete with crops in the root zone and may also create shading or other competition problems.
- Windbreaks are a long term investment in trees, planning time, and installation. The benefits will usually not begin for at least a year or more after installation.
- Windbreaks planned or installed improperly can interfere with access, view planes, power lines, and neighbor's borders.

An Introduction to Basic Windbreak Design

A windbreak has to form a physical structure that will, in time, slow and filter wind. This section introduces the basic physical/structural design criteria essential to planning an effective windbreak.

Planning of a windbreak is necessary to optimize its effectiveness and avoid future problems. Appropriate species selection is also a key factor in creating an effective windbreak. The essential physical factors to consider are:

- Orientation
- Spacing/Density
- Height/Distance Protected
- Length
- Profile/Number of Rows
- Continuity

Orientation

Correct windbreak orientation is essential for effective protection from wind damage. The ideal windbreak is oriented perpendicular to the prevailing wind, on the windward side of the land-area to be protected.

Figure 1. Orient within 45 degrees of perpendicular (90 degrees) of prevailing wind.

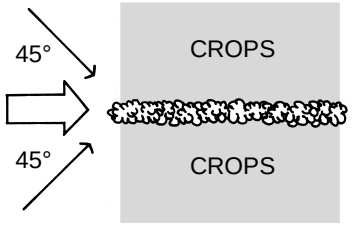


Figure 2. Wrong orientation will not protect crops, and may accelerate wind speed.

Figure 3a. If damaging wind comes from 2 directions

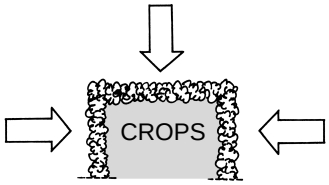


Figure 3b. If damaging wind comes from 3 directions

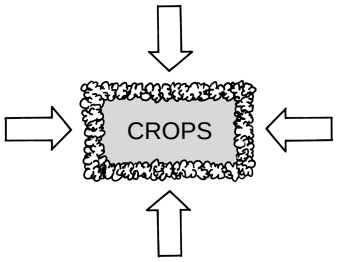


Figure 3c. If damaging wind can come from any direction

If the prevailing winds come from only one direction, a single-leg windbreak can be effective when oriented properly. Single-leg windbreaks oriented perpendicular to prevailing wind will also provide protection if the wind varies within 45 degrees of the perpendicular (Figure 1). Note that single-leg windbreaks must also have enough length to prevent wind from coming around the ends into the crop area (as discussed in the section on length below).

In some Pacific Island locations, trade winds may shift direction throughout the year, and damaging storm winds can come from almost any direction. In these situations, the orientation and pattern must provide protection from strong variable winds as well as from the prevailing winds. A windbreak pattern surrounding the property may be more effective in these situations (Figures 3a-3c).

Spacing/Density

A windbreak should be designed to slow and filter the wind, but not to block it entirely (Figure 4a). A windbreak that is too dense can lead to severe turbulence over the crop area (Figure 4b).

Ideally, windbreaks are about 20-50% permeable (Joy 1993). This can be achieved with correct spacing of the species in the windbreak. Spacing within rows should be laid out so that when mature in about ten

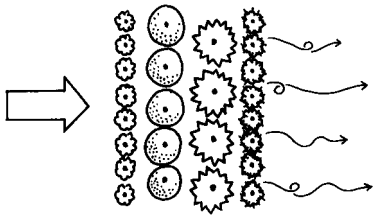


Figure 4a. Varied spacing filters and slows wind.

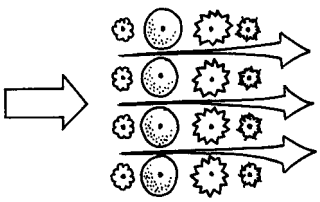


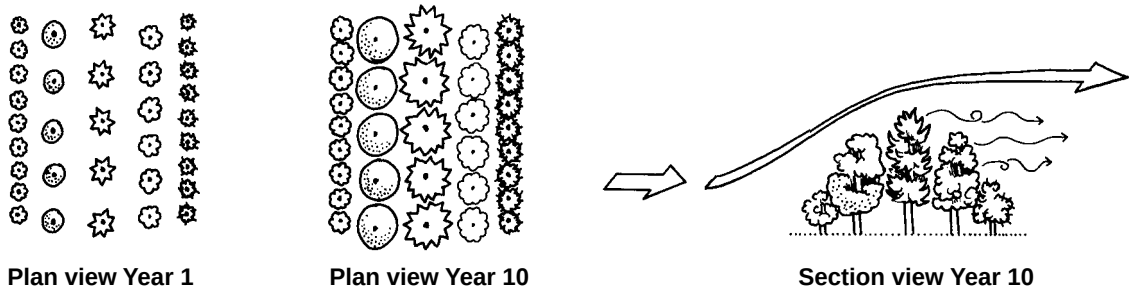
Figure 4b. Even spacing can create gaps that accelerate wind into crop area.

years, the crowns of the trees will touch or overlap slightly, but not crowd each other. Planting trees too closely can cause early deterioration of windbreaks, especially on dry, unirrigated sites, due to excessive competition for water between the trees. Wider spacing may mean additional time for the windbreak to become effective, but will prolong the effective life of the windbreak (Joy 1993). Species choice will also affect the density of a windbreak, as foliage and canopy density varies.

Spacing Guidelines	
Spacing within row	
Short trees (up to 20 ft (6 m))	2-6 ft (0.6-2 m)
Medium trees (20 -50 ft (6-15 m))	3-10 ft (1-3 m)
Tall trees (over 50 ft (15 m))	6-15 ft (2-5 m)
Spacing between rows	
If adjacent row is short	5-10 ft (1.8-3 m)
If adjacent row is medium	6-15 ft (2-5 m)
If adjacent row is tall	8-20 ft (2.5-6.2 m)

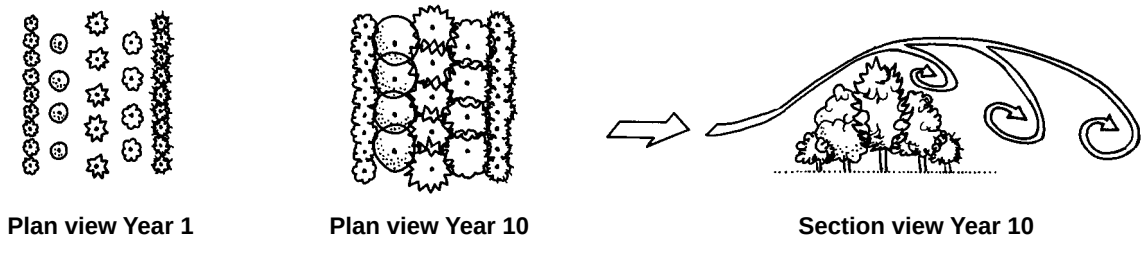
(source: USDA NRCS 1991)

For multiple-row windbreaks, trees should be on staggered and varied spacing, as depicted in Figure 5a. This filters and slows the wind.



Plan view Year 1 **Plan view Year 10** **Section view Year 10**

Figure 5a. Proper spacing creates a semi-permeable barrier that filters and slows wind.



Plan view Year 1 **Plan view Year 10** **Section view Year 10**

Figure 5b. An overly dense windbreak blocks wind and creates turbulence in the crop area.

Height/Distance Protected

Windbreaks reduce wind speed for a distance of about ten times their height (10 X height, or 10H). For example, a windbreak whose tallest trees are 30 ft (9 m) tall will protect a field area up to about 300 ft (90 m) downwind. Windbreaks also provide some protection on the windward side—usually, about one to three times their height (Figure 6a). The wind will begin to regain speed as the distance from

the windbreak increases (Figure 6b). Plants will receive the most protection within 7H of the windbreak. If plants are not very wind-sensitive, the protected zone could be considered to extend up to 15H in some cases.

For large properties, secondary wind strips may be necessary within the property to adequately protect the entire area (Figure 7).

The height of the windbreak should also be determined by the expected height of the crops. Windbreaks should be taller than the crop plants—ideally at least twice as tall as the crop (Figure 8).

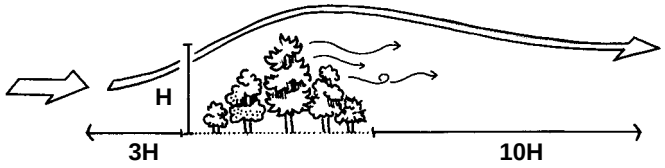


Figure 6a. Windbreak protects crop area to about 10 times the height of the tallest tree in the windbreak.

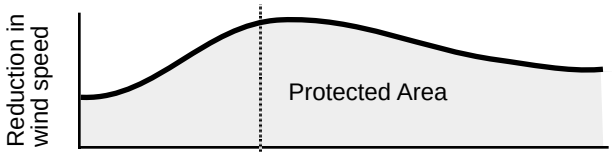


Figure 6b. The reduction in wind speed tapers off as distance from the windbreak increases.

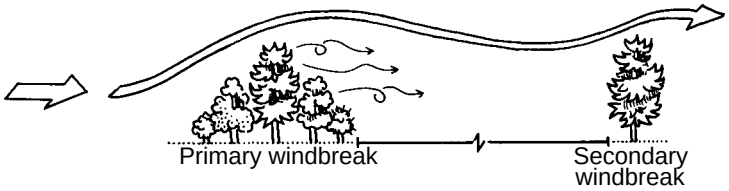


Figure 7. If crop area longer than 10X windbreak height, add secondary wind strips to continue protection.

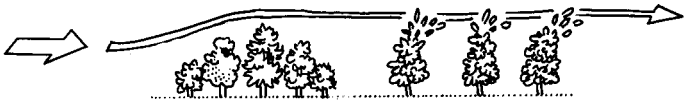
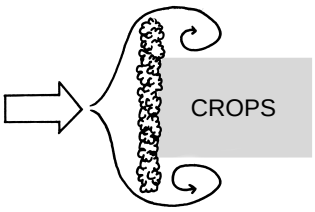


Figure 8. The tallest row of the windbreak must be taller than the crops—ideally 2X taller.

Length

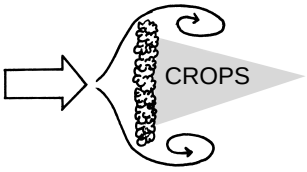
Windbreaks should be designed to prevent damaging wind from coming around the ends. This involves either additional length beyond the area to be protected, or additional legs that prevent wind from whipping around the end and into the crop area.

For a single-leg windbreak, the length of the windbreak should extend about 5 times the height of the windbreak beyond the area needing protection (Figure 9). For example, a windbreak 30 ft (9 m) high should extend 150 ft (45 m) on either side past the crop area to be protected.



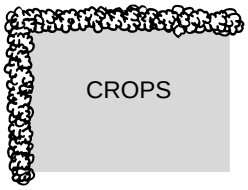
YES

Figure 9. Extensions beyond the crop area provide better protection in a single-leg windbreak when damaging winds come from one direction.



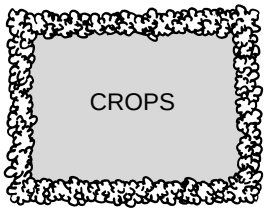
NO

Figure 10. A windbreak that is too short will create turbulence in the crop area.



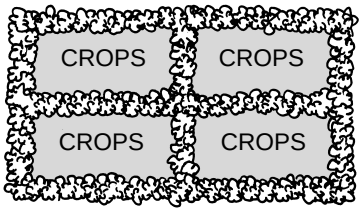
YES

Figure 11. Additional legs protect more area, and protect from variable wind directions.



YES

Figure 12. A windbreak surrounding the crop area can protect from variable winds.



YES

Figure 13. For large crop areas, secondary wind strips supplement the primary, surrounding windbreak.

Where damaging winds come from several directions, windbreaks surrounding the protected area may be more appropriate. If a windbreak completely surrounds the crop area (Figure 12), crops are protected on all sides. For large crop areas, secondary internal wind strips are necessary to supplement the surrounding windbreak (Figure 13).

Profile and Number of Rows

The wind protection provided by a windbreak should be effective from the ground up. This usually requires at least two rows of trees. Tall trees will protect a larger area of the field, but they usually have high canopies which can create an understory gap (Figure 14). Smaller trees with lower canopies are planted in an additional row to fill this gap (Figure 16).

A single row windbreak can be effective if the species used has uniform, semi-permeable, wind-strong branches to the ground (Figure 15). However, there are a number of drawbacks to single-row windbreaks. Desirable species that fit this description are limited. Single row windbreaks must be carefully maintained to avoid gaps. And, as with any single-species planting, there is greater risk of loss of the entire investment in the event of pest or disease problems that affect that one species. However, they have the advantage of taking up less space on the property.

Multiple-row windbreaks consist of three or more rows, and of several kinds of species (Figure 17). These kinds of windbreaks take up more space than single-row windbreaks. However, there are a number of advantages to multiple-row windbreaks, particularly when secondary products or functions are desired from the windbreak. These include:

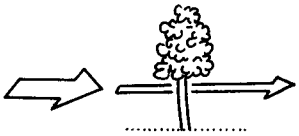
- Greater flexibility in species selection, layout, and management, while maintaining the necessary structure.
- Reduced maintenance burden because multiple rows help prevent gap problems.
- Greater opportunities for harvest—some trees or products may be harvested from the windbreak without compromising its function.
- Increased opportunity for secondary yields with several species and levels of

protection in the windbreak.
- Decreased risk of loss of the entire investment in the windbreak through pest or disease problems that affect a single species.

The landowner must decide how much land and resources can be devoted to a windbreak to determine how many rows will be appropriate for their situation.

NO

Figure 14. A single row of a tall species may have understory gaps.



GOOD

Figure 15. Single species can be effective if they have uniform, semi-permeable, wind-strong branches to the ground.

GOOD

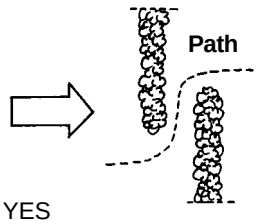
Figure 16. A short and tall row can prevent understory gaps.

GOOD

Figure 17. A multiple-row windbreak (3-5 rows) allows for more flexibility in species and management.

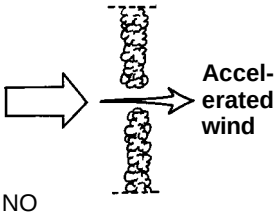
Continuity

It is essential to maintain continuity in a windbreak, because any gaps can become "wind tunnels" that funnel and accelerate the wind through them, increasing wind damage. For this reason, roads, paths, gates, and



YES

Figure 18. Windbreak overlaps the gap and management.



NO

Figure 19. Gaps create a wind tunnel, accelerate the wind into crop area.

other necessary openings in the windbreak should be taken into account when planning the windbreak, and the windbreak designed carefully to eliminate gaps.

When an opening in the windbreak is needed for access or other reasons, the effects can be ameliorated. The windbreak should overlap the gap to maintain the continuity of the windbreak and prevent the opening from becoming a wind tunnel (Figure 18).

Summary: Checklist for an Effective Windbreak

Orientation:
- Oriented perpendicular to prevailing damaging winds?
- One leg sufficient?
- Additional legs or surrounding planting necessary to protect from shifting winds?

Spacing/density:
- Number of rows sufficient for proper density (50-80% dense)?
- Spaced adequately for healthy growth?
- Crown closure in about 10 years?
- Trees on variable/staggered spacing?

Height/distance protected:
- Crops area to be protected located within 10 H zone?
- Secondary wind strips planted if crop area exceeds ten times the height of the tallest windbreak trees?
- Tallest trees in windbreak at least twice as tall as the crops?

Length:
- If single-leg windbreak, does the length extend 5 H beyond crop area on either side?
- Additional legs necessary to protect from variable winds?

Profile/number of rows:
- Understory gaps eliminated by short rows?
- Shrubs and short trees in outer rows?
- If single-species, has uniform branches to the ground?

Continuity:
- Wind funnel effects minimized (no gaps)?

Other variables such as soil type, soil depth, topography, and other localized site and climatic conditions will impact the effectiveness of a windbreak in different situations. Windbreak planners should consult other references for more information on designing an effective windbreak (see resource section for recommended sources of information). The assistance of local experts, including resource professionals and experienced neighbors, is invaluable in designing a windbreak optimally suited to the needs and site conditions.

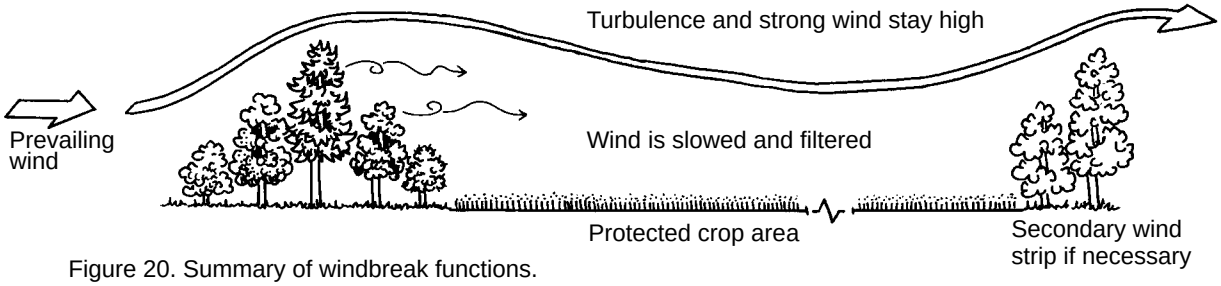


Figure 20. Summary of windbreak functions.

Multipurpose Windbreak Design

The previous section introduced basic design criteria for any windbreak. A multipurpose windbreak must have effective wind reduction as its primary goal, and meet all the above criteria.

Adding multiple functions or products to a windbreak can provide more benefits, making the installation and management more satisfying and economically viable for the landowner. However, maintaining the primary windbreak function while managing for additional uses or products requires more careful planning at the outset, and special management practices for the life of the windbreak. This section is intended as a design guide for maintaining windbreak effectiveness while maximizing a secondary yield from windbreaks. It discusses four multiple uses: fruit/nut production, timber production, mulch/fodder production, and wildlife habitat. It also introduces some other multiple uses that can be provided by a windbreak.

General Guidelines for Multipurpose Windbreak Design

While the multiple uses discussed here have different characteristics that must be considered in the planning process, there are a number of factors that are common to any multipurpose windbreak design:

- The species used should be selected first for their wind tolerance and appropriateness for the site (climate, soils, etc.); the products should be a secondary consideration in selecting species.
- The productive trees in the windbreak should be supplemented by windbreak species that do not need to be managed for production. This affords some protection of the producing trees by the other trees in the windbreak.
- Windbreaks designed for multiple products should have multiple rows and multiple stories. This enables more flexibility in management and harvest of products without compromising wind protection by creating gaps.
- Trees yielding products such as fruit, food, fodder, or mulch should ideally be located in the interior or more sheltered rows of the windbreak for greatest productivity.
- A diversity of species should be used to allow for greater flexibility in management and for reduced risk of damage to the windbreak as a whole from pest or disease problems.

Landowners must also consider the possible drawbacks of including any kind of production in a windbreak. For example, species that are used for commercial production are often not eligible for government cost-sharing. Planning and managing for multiple products can also be more time-consuming. An analysis of the potential drawbacks or problems associated with attaching part of productivity to a windbreak will help determine the appropriateness of the practice in a given situation.

Fruit or Nut Production in a Windbreak

Including fruit or nut-bearing trees in a windbreak can provide additional economic yields or family food in addition to wind protection.

Fruit trees in the windbreak will usually have reduced yields due to poorer pollination and increased damage to flowers and young fruits. The fruits may also be damaged or ruined if they are blown off. In areas where winds are only seasonal or not too strong, fruit production may be a good combination in a windbreak. In windier areas, produce from windbreaks is generally useful only

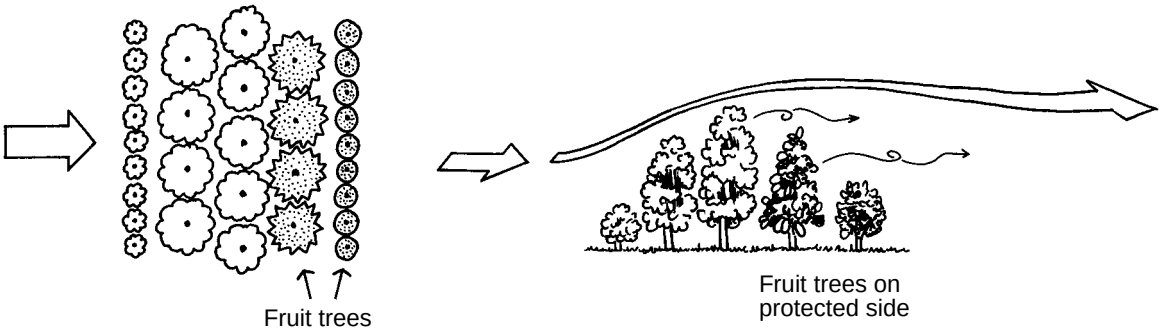


Figure 21. Wind hardy fruit trees should be used on the protected side of the windbreak.

for family consumption, or marketed in a processed form such as jam where bruising or appearance is not as important as in the fresh fruit market. In areas with strong, constant winds, fruit production from a windbreak may not feasible.

To maintain the windbreak's primary function, wind-tolerant fruit tree species should be used. These should be integrated with other wind-tolerant species that are not managed for production. Also, keep in mind that fruit trees in a windbreak should be pruned only very sparingly, as pruning can compromise wind resistance.

There are a number of things that can be done to improve the productivity and quality of yields from fruit trees in a windbreak:

- If strong winds are seasonal, choose species that flower and bear in calmest months.
- Plant fruit trees in the more sheltered windbreak rows to maximize fruit production and quality (Figure 21).
- Select trees which bear fruit on main branches, trunk, or interior of tree, rather than on outer branches (for example, fruits like jackfruit (*Artocarpus heterophyllus*) or jaboticaba (*Myrciaria cauliflora*), as these kinds of fruits are less susceptible to wind damage than fruits borne on the more mobile outer branches.
- Know the cultural requirement of the fruit trees and care for them appropriately with fertilizers, irrigation, etc. as necessary.

Examples of Fruit or Nut Production in a Windbreak

Location: Barrigada, Guam. 280 ft (90 m) elevation

Primary windbreak species and fruit-bearing species: *Musa balbisiana* (dwarf Brazilian banana)

This windbreak consists of three rows of bananas on staggered spacing.

Banana example—Guam

Row	Species	In row spacing	Distance from Row 1 (ft)
1	*Musa balbisiana*	8 ft (2.5 m)	0
2	*Musa balbisiana*	8 ft (2.5 m)	8 ft (2.5 m)
3	*Musa balbisiana*	8 ft (2.5 m)	16 ft (5 m)

(Lawrence, personal communication 1999)

Location: Barrigada, Guam. 280 ft (90 m) elevation

Primary windbreak species: *Casuarina equisetifolia* (ironwood)

Fruit-bearing windbreak species: *Annona muricata* (soursop), *Randia formosa* (blackberry jam fruit)

Soursop/blackberry jam example—Guam			
Row	Species	In row spacing	Distance from Row 1 (ft)
1	*Casuarina equisetifolia*	10 ft (3 m)	0
2	*Annona muricata*	10 ft (3 m)	15 ft (4.5 m)
3	*Randia formosa*	2 ft (0.6 m)	30 ft (9 m)

(Lawrence, personal communication 1999)

Location: Molokai, Hawaii
Primary windbreak species and fruit-bearing species: *Musa balbisiana* (dwarf Brazilian banana)

This windbreak consists of one row of bananas on 6 ft (2 m) spacing.

Banana example—Hawaii			
Row	Species	In row spacing	Distance from Row 1 (ft)
1	*Musa balbisiana*	6 ft (2 m)	0

(Joy, personal communication 1999)

Examples of fruit or nut-bearing tree species used as windbreak components in Pacific Islands: (see Species Selection for Multipurpose Windbreaks for more information for each species):

Fruit/nut-bearing windbreak species	
Short—under 20 ft (6 m)	
Annona muricata	soursop
Averrhoa carambola	starfruit
Citrus reticulata	tangerine
Coccoloba uvifera	seagrape
Eugenia uniflora	Surinam cherry
Morus nigra	mulberry
Myrciaria cauliflora	jaboticaba
Psidium guajava	guava
Medium—20-50 ft (6-15 m)	
Anacardium occidentale	cashew
Casimiroa edulis	white sapote
Chrysophyllum cainito	caimito/star apple
Cocos sp.	dwarf coconut palm
Dimnocarpus longan	longon
Eriobotrya japonica	loquat
Macadamia integrifolia	macadamia
Mammea odorata	mammee apple
Manilkara zapota	sapodilla
Musa balbisiana	dwarf Brazilian banana
Persea americana	avocado
Syzygium malaccense	mountain apple
Tamarindus indica	tamarind
Tall—50 or more ft (15 m)	
Aleurites moluccana	kukui
Artocarpus altilis	breadfruit
Artocarpus heterophyllus	jackfruit
Cocos nucifera	coconut
Litchi chinensis	lychee
Mangifera indica	mango
Syzygium jambos	rose apple

Timber Production in a Windbreak

Since planting a windbreak involves a long-term investment, including trees that can be harvested in the future for timber appeals to many landowners. There are many design options for timber production from a windbreak that landowners can explore.

The main drawback of having timber as a secondary yield from a windbreak is that wind stress or damage may compromise the timber tree's form or produce timber of reduced quality. Also, since windbreak trees should be pruned only sparingly or not at all, the lack of pruning may reduce timber yields on certain species that require extensive pruning for optimal timber production.

To Maximize Timber Yield

There are a range of design options that can enable the harvest of timber from a windbreak. These include:

- The harvest and removal of the entire windbreak at maturity, to be replanted if the wind protection is still necessary.
- The harvest of interior rows of timber trees from the windbreak, while leaving several outer rows for permanent protection.
- The careful selective harvest of rows or individual trees within the windbreak.

Some of these options can be relatively simple, such as planning to remove the entire windbreak at maturity. Plans involving selective harvest are more complex, as the planting, harvesting, and replanting must be coordinated to maintain the correct density and structure of the windbreak. It is especially important to avoid creating gaps.

In some of these cases, the areas that were harvested will be replanted. In other cases, the removal of trees may be predominantly a thinning practice, where the existing trees will fill in the space as they mature. Figure 23 gives an example of a more complicated timber/windbreak plan.

When considering timber production in a windbreak, landowners must also recognize the skills required for felling and harvesting trees for timber. If skilled tree fellers are unavailable in the region, a simpler plan will be more feasible. The harvest must be planned to avoid damage to the adjacent crop area.

Many other factors are important to consider when planning a viable timber harvest, including tree growth rates, soil conditions, spacing, maintenance, and other issues that are beyond the scope of this guide. Consultation with a professional forester is recommended.

Field Examples of Timber Species in a Windbreak

Location: Dededo, Guam 500 ft (160 m) elevation

Primary windbreak species: *Casuarina equisetifolia* (ironwood)

Timber windbreak species: *Swietenia macrophylla* (mahogany)

Other windbreak species: *Leucaena leucocephala* (haole koa)

Mahogany windbreak example

Row	Species	In row spacing	Distance from Row 1 (ft)
1	*Casuarina equisetifolia*	8 ft (2.5 m)	0
2	*Swietenia macrophylla*	8 ft (2.5 m)	15 ft (4.5 m)
3	*Leucaena leucocephala*	8 ft (2.5 m)	30 ft (9 m)

(Lawrence, personal communication 1999)

Location: Barrigada, Guam 280 ft (90 m) elevation
Primary windbreak/timber species: *Pterocarpus indicus* (narra)
Secondary windbreak/timber species: *Dalbergia sissoo* (sissoo rosewood)

Narra and sissoo rosewood windbreak

Row	Species	In row spacing	Distance from Row 1 (ft)
1	*Pterocarpus indicus*	8 ft (2.5 m)	0
2	*Dalbergia sissoo*	8 ft (2.5 m)	15 ft (4.5 m)

(Lawrence, personal communication 1999)

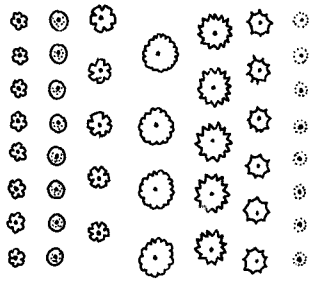
Examples of timber species used as windbreak components (see table at the back of this guide for other information for each species):

Timber-producing windbreak species	
Short—under 20 ft (6 m)	
Acacia koaia	koaia
Thespesia populnea	milo
Medium—20-50 ft (6-15 m)	
Azadirachta indica	neem
Bambusa oldhamii	oldhamii bamboo
Cordia subcordata	kou
Intsia bijuga	Borneo teak
Melia azedarach	chinaberry
Pithecellobium dulce	Manila tamarind
Senna siamea	pheasantwood
Thyrostachys siamensis	monastary bamboo
Tall—50 or more ft (15 m)	
Acacia koa	koa
Acacia mangium	mangium
Acrocarpus fraxinifolius	pink cedar
Azadirachta excelsa	sentang
Calophyllum inophyllum	kamani
Dendrocalamus asper	giant bamboo
E. dunnii or E. microcorys	eucalyptus species
Guadua angustifolia	guadua bamboo
Meterosideros polymorpha	ohia-lehua
Pterocarpus indicus	narra
Swietenia macrophylla	mahogany
Tristania conferta	Brisbane boxwood

A Note on Timber Bamboos in a Windbreak

Some bamboos are excellent multiple-purpose plants, and a number of species are wind-resistant and provide quality timber or construction materials. Timber bamboo can be an effective windbreak component, as harvesting a small percentage of bamboo stems (culms) will not compromise the function of the windbreak. When selecting bamboo species, it is recommended to always choose clumping rather than running types, as the running types spread easily and can create problems from competition and invasiveness. All bamboo species listed in this guide are clumping types. Also, landowners should find out how wide and tall the clumps will become, as this is important for proper spacing.

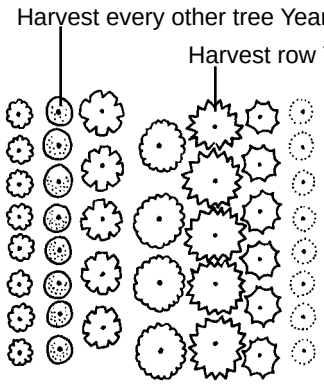
Year 1: Trees are planted on careful spacing. This seven-row design will create a long-term windbreak whose fundamental shape and structure will not be overly compromised by the removal of some trees in later years.



Plan view Year 1

Section view Year 1

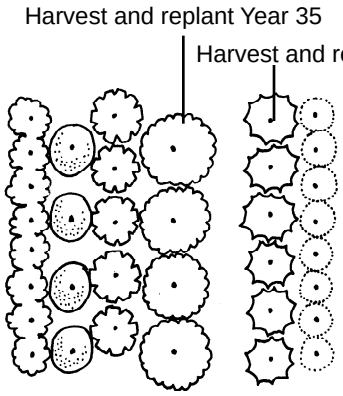
Year 15: As the windbreak fills in, the fast-growing timber species in row five are becoming large. In year 15, this entre row will be harvested, as well as every other tree in row two removed, to make space for the slower-growing species to mature.



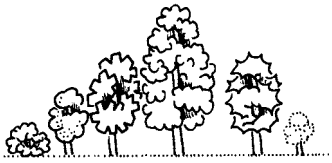
Plan view Year 10

Section view Year 10

Year 25: The slower-growing species have filled in the space created by the removal of row five. In year 25, row five of this windbreak will be harvested and replanted. The new trees planted in row five will be sizable by year 35, allowing the harvest and replant of row four.



Plan view Year 25



Section view Year 25

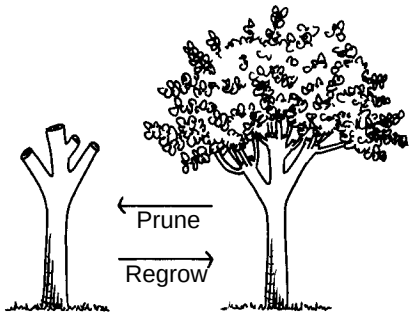
Figure 22. An overly dense windbreak blocks wind and creates turbulence in the crop area.

Nitrogen Fixing Trees as a Windbreak Component

Nitrogen fixing trees (NFTs) are used widely in agriculture in the tropics, mainly to provide fertility and mulch for crops, or fodder for animals.

Nitrogen fixing trees are a major source of nitrogen fertility in tropical ecosystems. When integrated with a farm, orchard, or garden, some species of NFTs provide a major source of nitrogen fertilizer and mulch for crops. The fertility is transferred from the NFTs to the crops by pruning the NFTs and applying the pruned foliage and young stems to the soil as a nutrient-rich mulch.

Some species of nitrogen fixing trees provide an important source of nutritious animal fodder. The foliage of the trees is used to supplement the diets of livestock, as well as some kinds of small animals and poultry such as rabbits, chickens, and other animals. NFTs for use as animal fodder must be researched



YES
Figure 23. Prune regularly (best for fodder or mulch production, maintains wind resistance).

NO
Figure 24. Pruned NFTs allowed to return to a large size are very susceptible to wind damage.

carefully, as some NFTs can be harmful or toxic to some kinds of animals. The rate at which NFTs can supplement other kinds of fodder ranges between 5 and 30% of the animal's daily diet, depending on the species of tree and the species of animal to be fed. The practice of planting property borders with NFTs and cutting the trees back to feed the foliage to animals is common in intensive agricultural areas of Asia and Africa (Gutteridge and Shelton 1994). (See reference section for further reading on the uses of nitrogen fixing trees).

For either mulch/fertility or animal fodder uses, nitrogen fixing trees can be integrated into a windbreak. Because they will be kept pruned in a hedge-like fashion, they are included as the short row or rows of a multi-row windbreak.

Although as a general rule, severe pruning or pollarding should be avoided for most windbreak trees, the practice of cutting back NFTs and allowing them to resprout can be successfully integrated with windbreak management. It is important to prune the trees regularly, usually every 3-6 months depending on site conditions and species (Figure 23). If they are allowed to regrow to a large size, however, pruned NFTs will be much more susceptible to wind damage (Figure 24). Therefore, to maintain the windbreak's primary function with this

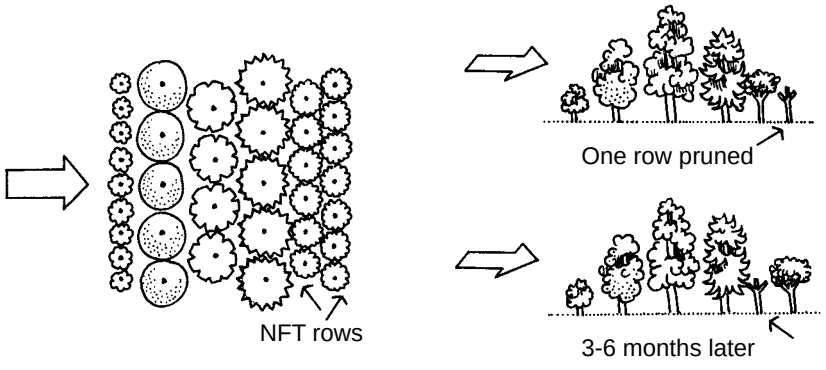


Figure 25. Rows of NFTs are alternately cut to provide mulch or fodder while maintaining their function in the windbreak.

practice, it is essential to prune the NFTs regularly. Regular pruning is also an excellent practice to maximize the secondary yield as well, because the younger regrowth is the most nutritious and palatable for animal fodder and the most nutrient-rich and beneficial as mulch for plants, as compared to the older, woody material that comes from older regrowth.

To Maximize Secondary Yields:

- Use productive NFT species selected for the characteristics most desired (different species are suitable for different sites and uses. For example, some species make better fodder, some are best for mulch/fertility).
- Use NFT species that are known for their wind tolerance (see table in this section and at the end of this guide).
- Prune regularly to keep the sprouting branches from reaching a large a size. This will maintain the wind resistance capability of the tree's branches and also result in a more valuable mulch or fodder.
- Place the NFT rows closest to where they will be used, for ease of cutting and carrying to crops or animals.
- If possible, plant the NFTs on the most sheltered side of the windbreak to improve their productivity.

See reference section at the end of this guide for further reading on the use and management of NFTs.

Nitrogen fixing windbreak species	
Cajanus cajan	pigeon pea
Calliandra calothyrsus	calliandra
*Erythrina variegata**	coral tree
Gliricidia sepium	madre de cacao
Leucaena leucocephala	giant haole koa, K636
*Senna siamea***	pheasantwood
Sesbania sesban	sesban

* This species is an alternate host for mango fruit-piercing moth. If mango crops are in the area, select an alternate species.
** Senna siamea is not a nitrogen-fixer, but is used successfully in the same way for fertility/mulch.

While the nitrogen fixing species listed above vary in height class when allowed to grow to their full size, for the purpose of this practice all NFTs will be pruned, maintaining a hedge-like structure that is considered a short row.

A Note about Species Selection for Nitrogen Fixing Trees:

By their nature many NFTs grow vigorously under adverse conditions and can seed prolifically. Species selection and management of NFTs is critical to avoid the introduction of a new weedy species into an area. When selecting NFTs for a particular use and site, it is recommended to select species that do not seed prolifically, and prune regularly to eliminate seed production. If an NFT species is already naturalized or common in the area, its use may be considered as well, although it should still kept pruned to eliminate seed production.

Wildlife Habitat

The ability of windbreaks to provide wildlife habitat in farmlands is one of the most documented, both in tropical and temperate areas. In some areas of the tropics, for example Central America, windbreaks on farmlands have been shown to harbor not only native wildlife, but also to foster native tree seedlings and ecosystem regeneration processes within the windbreak (Harvey 1999). The fragile

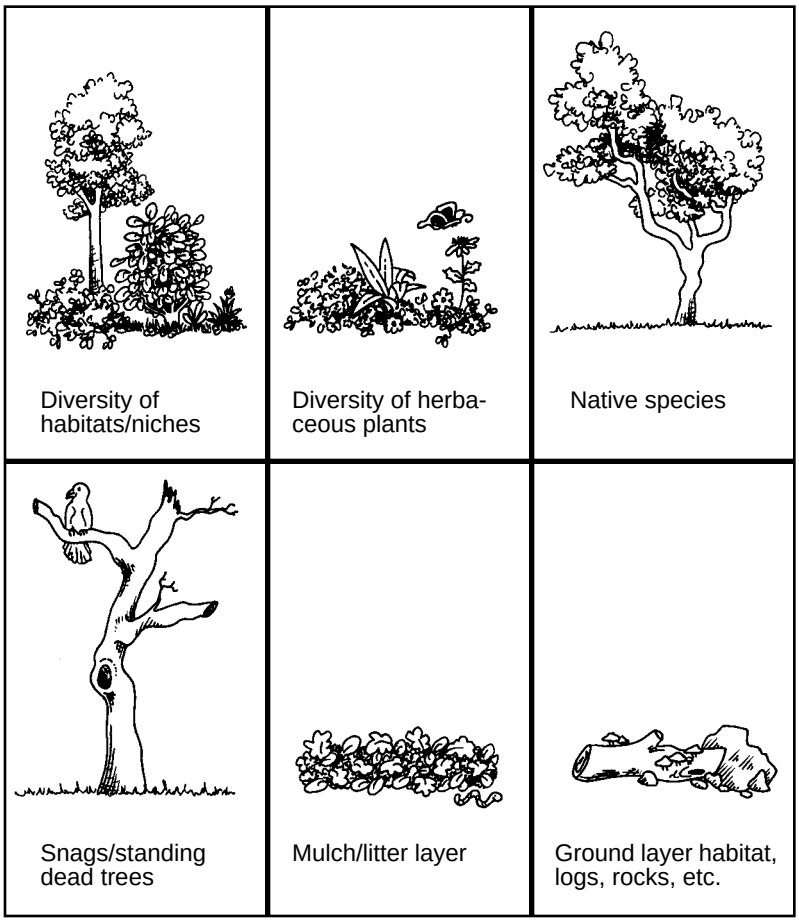


Figure 27. Examples of ways to enhance wildlife habitat in a windbreak.

and specialized nature of native plant and animal life in Pacific Islands makes this occurrence less common in the region. However, Pacific Island windbreaks can be designed to foster a diversity of exotic and native wildlife, from soil organisms to insects, birds and larger mammals. Windbreaks can also be part of a plan to cultivate and preserve remnants of native species or forests that landowners may have on their property.

Many landowners enjoy providing important ecological benefits from their windbreak. There are a number of benefits to planning a windbreak which is hospitable to wildlife:

- A windbreak with wildlife in it can add to the beauty and interest of the property.
- The harvest of wild game or the expansion of recreational opportunities on the property may be a potential additional source of income the farm.
- The windbreak may harbor beneficial insects and birds that help to balance out populations of crop pests, reducing needs for pesticides (Stace 1995).

In many cases, some forms of wildlife will be attracted to the windbreak regardless of the landowner's intention. It is important to recognize that the same strategies that attract desirable wildlife may also attract birds, rodents, or other life forms that may be considered pests that interfere with crop production. Landowners should consider this issue as it relates to their crops when planning a windbreak.

Following the guidelines below to attract wildlife to windbreaks will not compromise the windbreak's primary function.

Wildlife will be attracted to windbreaks that can meet their needs for food and forage, travel corridors, reproductive habitat/nesting sites, and shelter from weather and predators. Here are some strategies that help maximize the benefit of a windbreak to wildlife (Figure 27):

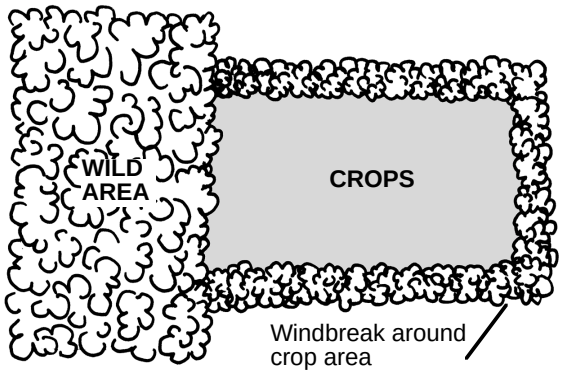


Figure 28. Windbreaks can extend habitat and/or act as wildlife corridors when connected to wild areas such as forest reserves, gulches, riparian areas, fallow or reforested areas, or to neighboring windbreaks/wildlife corridors.

1. Create a variety of habitats for wildlife within the windbreak. Tall trees, understory species, shrubs, and herbaceous plants provide important niches where different animals can find their preferred shelter, forage for food, nest, and so forth.
2. Avoid clean culture management practices when possible, as long as it does not pose a safety problem. Instead, some leaf litter, scrub, dead logs, and snags can be left, which are important to many kinds of wildlife.
3. Plant a variety of species. Complex, multi-storied plantings are more attractive wildlife than plantings of just a few species.
4. Create wildlife corridors—contiguous areas where wildlife can live or travel through in safety. Ideally, the corridors should be contiguous, avoiding large gaps. If the property is near a larger forest, riparian area, wood lot, or other refuge for wildlife, creating a corridor between this area and the windbreak will help species colonize the windbreak area (Figure 28).
5. If additional width can be added to the windbreak, that will make it even more beneficial to wildlife. Cooperation with neighbors may also help create larger corridors.
6. If a specific wildlife species is desired, learning about the intended guest's needs for food, habitat, and other necessities will help tailor the windbreak to provide for it. Plant the known food/pollen sources for target species. Native plant species are most likely to support native life, from soil fauna to birds. However, some native wildlife may also have become accustomed to exotic species for food or habitat as well.

Other Potential Products or Services from Multipurpose Windbreaks

With careful research and planning, windbreaks can be productive and versatile. Aside from the multiple uses listed above, there are many other products or services that windbreaks can provide. Some examples follow.

Bees/Honey Production

Honey production can be an additional yield from a windbreak. Bees are more active in sheltered areas, and the protected edges of windbreaks can be excellent places to keep bee colonies (Brandle et al 1995).

Good honey production requires that the bees have access to nectar-producing flowers. There are a number of tree species in the tropics that produce good nectar for honey bees and are also wind-tolerant.

Honey forage windbreak species	
Short—under 20 ft (6 m)	
Cajanus cajan	pigeon pea
Calliandra calothyrsus	calliandra
Cassia spectabilis	cassia
Citrus sp.	citrus
Gliricidia sepium	madre de cacao
Pimenta dioica	allspice
Psidium cattleianum	strawberry guava
Psidium guajava	guava
Sesbania sesban	sesban
Medium—20 to 50 ft (6-15 m)	
Albizia lebbeck	Tibet tree
Azadirachta indica	neem
Cocos sp.	dwarf coconut
Melia azedarach	Chinaberry
Pithecellobium dulce	Manila tamarind
Tall—50 or more ft (15 m)	
Eucalyptus species	eucalyptus
Mangifera indica	mango
Prosopis pallida	kiawe, mesquite

Floral Products: Cut Foliage, Flowers, or Decorative Branches

Cut foliage, flowers, or decorative branches used by the floral industry can also be produced in a windbreak. A number of species are wind-strong enough to serve as a windbreak component. These can produce saleable foliage, branches or flowers if they are in the more sheltered areas of the windbreak or if they are productive in a season of milder winds.

In addition to the species listed below, cultural plants for leis or other uses can be integrated in windbreaks as vines or understory crops.

Cut Flower/Foliage Windbreak Species	
Alpinia nutans	shell ginger
Codiaeum variegatum	croton
Cordyline terminalis	ti
Dracaena species	dracaena
Heliconia species	heliconias
Pandanus odoratissimus	hala
Various bamboo species	bamboos

Medicinal/Natural Health Products

A number of wind-tolerant species are valued for their medicinal properties. Their products may find markets with traditional healers, or in the growing herbal supplement industry. Some of these products may be marketed fresh, or can be processed into dried products, juices, extracts, concentrates, or oils for added market value.

Medicinal Windbreak Species	
Aleurites moluccana	kukui, candlenut
Azadirachta excelsa	sentang
Azadirachta indica	neem
Eucalyptus species	eucalyptus species
Morinda citrifolia	noni
Morus nigra	mulberry
Saccarum species	traditional sugarcane sp.
Syzygium aromaticum	clove

Living Fence

When the proper windbreak orientation corresponds well with the boundaries of the property, the windbreak can also double as a "living fence." A living fence is a line of trees or shrubs that controls the movements of animals or people (Westley 1993). It may be used to keep them in (such as for livestock, chickens, small children) or out (such as dogs, feral animals, teenagers!). In some situations, the use of thick or thorny species can create adequate boundary protection. Other situations may require that wire or other nonliving fence materials be strung between "living fence posts" to supplement the effectiveness of the fence.

Living Fence Windbreak Species	
Agave americana	sisal
Bamboo species	various bamboos
Carissa grandiflora	Natal plum
Erythrina variegata	coral tree
Gliricidia sepium	madre de cacao
Prosopis pallida	kiawe

Species Selection for Multipurpose Windbreaks

The many varied climates and conditions found in the Pacific Islands makes species selection for windbreaks challenging. The table below is meant to be used as a general guide only in selecting species for use as components in a windbreak. It includes the height class, growth rate, and climatic zone for over 90 species, as well as their potential products including fruit, fodder, medicine, timber, and more. Tolerances to salt, drought, and water logging are also noted.

When selecting species, the guidance of local experts, including knowledgeable neighbors as well as resource professionals, is invaluable in making wise decisions. Local guides should be consulted for a history of species use, availability, and their adaptability/appropriateness to the site.

Multipurpose Windbreak Species

Short Species under 20 feet (6 meters) —————Products————— ——Characteristics——

Botanical Name	Common Name	Nitrogen fixer	Crop shade	Erosion control	Fruit/Nut/Food	Leaf vegetable	Medicine	Fodder	Bee forage	Organic matter/mulch	Wood/timber	Fuel wood	Salt/saline	Drought	Water logging	Potential weed/invasive	Growth rate	Climatic zone
Acacia koaia	koaia	•									•			•			S	A
Alpinia nutans	shell ginger			•										>	•		M	H
Annona muricata	soursop				•											P	S	A, H
Averrhoa carambola	starfruit				•			•			•		•	>			S	H
Cajanus cajan	pigeon pea	•	•	•	•	>		•	•	•		•		•		P	F	H, A, U
Calliandra calothyrsus	calliandra	•	•	•				•	•	•	>	•		>	>	N	F	H, A, U
Carissa grandiflora	Natal plum				>								>	•			S	H, A, U
Cassia spectabilis	golden shower		•	•			>		•	>	>	>		•		N	M	H, A, U
Citrus mitis	calamondin				•				•								S	H, U
Citrus reticulata	tangerine				•				•								S	H, U
Coccoloba uvifera	seagrape			>	>								>	•			S	H
Codiaeum variegatum	croton													•			S	H, A
Cordyline terminalis	ti			•	>			•		>			>	•	•		S	H, A, U
Dracaena spp.	dracaena							>						>	•		S	H, A, U
Eugenia braziliensis	gruminchama				•								>	•		P	S	H, A, U
Eugenia uniflora	Surinam cherry				•			>					>	>		P	S	H, A, U
Feijoa sellowiana	feijoa				•			>					>	•		P	S	U
Heliconia spp.	heliconia			•										>	•		M	H
Hibiscus rosa-sinensis	hibiscus						>		>					>			S	H, A
Morinda citrifolia	noni				>	•	•	>					>	•	•	P	S	H, A
Morus nigra	mulberry			•	•			•	•	>	>	>	•	•	•	P	M	H, A, U
Myrciaria cauliflora	jaboticaba				•								•				S	H
Otatea acuminata	Mexi. weep. bamboo			>	>						•			•			M	H, A, U
Pimenta dioica	allspice				>				•		•	>	>	•		P	M	H, A, U
Psidium cattleianum	strawberry guava			•	•			•	•		•	>	•	•	•	N	M	H, A, U
Psidium guajava	guava				•		>	>	•		>	>		•		N	S	H, A, U
Saccarum officianale	sugarcane (Haw'n)			•	•			•					•	>	>		M	H, A, U
Scaevola sericea	beach naupaka			•	>								>	•			S	H
Sesbania sesban	sesban	•	•	•	>	>		•	>	•		•	>	•	>	P	F	H, A, U
Sophora tomentosa	silver bush	•					•					•	•				S	H
Thespesia populnea	milo										•		•	•	>		S	H, A

Nitrogen fixer - - - - - - - - fixes atmospheric nitrogen
Crop shade - - - - - - - - - used for shading other crops
Erosion control - - - - - - - erosion control, soil holding
Fruit/Nut/Food - - - - - - - human food
Leaf vegetable - - - - - - - leaves used for vegetables
Medicine - - - - - - - - - - - medicinal uses for various parts
Fodder - - - - - - - - - - - - used for animal feed
Bee forage - - - - - - - - - - good/prolific bee forage for honey production
Organic matter/mulch - - - prolific source of organic matter/mulch
Wood/timber - - - - - - - - - solid wood or timber products
Fuel wood - - - - - - - - - - wood easily burned for fuel
Drought - - - - - - - - - - - tolerates drought
Water logging - - - - - - - - tolerates water logged soils
Salt/saline - - - - - - - - - tolerates salt spray
Potential weed/invasive - - N=extremely invasive in some areas, P=spreads, but rarely causes problems
Growth rate - - - - - - - - - S=slow, M=medium, F=fast
Climatic zone - - - - - - - - H=humid lowland, A=arid/semi-arid, U=upland

Key
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blank means not used or not known

Medium Species 20 to 50 feet (6-15 meters) ——————Products—————— ——Characteristics——

Botanical Name	Common Name	Nitrogen fixer	Crop shade	Erosion control	Fruit/Nut/Food	Leaf vegetable	Medicine	Fodder	Bee forage	Organic matter/mulch	Wood/timber	Fuel wood	Salt/saline	Drought	Water logging	Potential weed/invasive	Growth rate	Climatic zone
Acacia confusa	Formosa koa	•	•	•					>		>	•		•		N	M	H, A
Acacia holosericea	holoserica	•	•	•	•				>		>	•	•	•		P	M	A
Albizia lebbeck	Tibet tree	•	•					•	•	>	•	•	•	•		P	M	A
Anacardium occidentale	cashew				•			•			•	>	•	•			S	H, A
Artocarpus integer	champedak				•			•			>	>	•				S	H
Azadirachta indica	neem		•	•			•	•	•	>	•	•		•		P	M	H, A
Bambusa multiplex Alph-Ka	hedge bamboo			•				>			>			>			M	H, A, U
Bambusa oldhamii	Oldhamii			•	•			>			•			•			M	H, A, U
Casimiroa edulis	white sapote				•			>			>		•	•			S	A, U
Ceratonia siliqua	carob				•			•			•	•	•	•			S	A, U
Chrysalidocarpus lutescens	areca palm			>										•	•		M	H, A, U
Chrysophyllum cainito	caimito			>	•			>				>	•	•			S	H, A
Cocos sp.	dwarf coconut palm			>	•				•		>		•	•	•		S	H
Cordia subcordata	kou										•	•	•	>	•		S	H
Dimnocarpus longan	longan				•		•				•	•	•	•		P	S	H, U
Eriobotrya japonica	loquat				•			•					•	>		P	S	U
Erythrina poeppigiana	poro	•	•	•				•		•				>			F	H
Erythrina variegata	coral tree	•	•	•				•		•				•	>	P	M	H, A
Gliricidia sepium	madre de cacao	•	•	•				•	•	•	•	•	•	•		P	F	H, A
Intsia bijuga	Borneo teak										•	•	•				S	H
Lansium domesticum	langsat				•								•	>	•		S	H
Macadamia integrifolia	macadamia				•			•			>	•	•	>	>	P	S	H, U
Mammea odorata	mammee apple				•			>			•	>					S	H
Manilkara zapota	sapodilla				•			•			•	>	•	•	>		S	H, A
Melia azedarach	chinaberry		•						•		•	•		•		P	M	H, A, U
Musa balbisiana	dwf Brazilian banana			>	•			•					•	>	•		M	H
Pandanus odoratissimus	hala, screwpine				>						•		•	•	•	P	S	H, A
Persea americana	avocado				•			•					•	>		P	M	H
Pithecellobium dulce	Manila tamarind	•	•	•	•			>	•	>	•	•	•	•		N	M	H, A
Pouteria campechiana	canistel				•						>		•	>			S	H
Schinus molle	Brazilian pepper tree				>								>	•		P	M	H, A, U
Senna siamea	pheasantwood		•	•	>			>		•	•	•	>	•		P	F	H, A
Syzygium aromaticum	clove				•		•							•		P	S	H
Syzygium jambos	rose apple			>	>			>			>	•	>	•	•	N	M	H, U
Syzygium malaccense	mountain apple				•			>			>		•	•			S	H, A
Tabebuia pentaphylla	pink tecoma		•								•	>					S	H, A
Tamarindus indica	tamarind				•			•			•	•	•	•			S	H
Thyrostachys siamensis	monastery bamboo			•	•			>			•						M	H, A

Nitrogen fixer - - - - - - - - fixes atmospheric nitrogen
Crop shade - - - - - - - - - used for shading other crops
Erosion control - - - - - - - erosion control, soil holding
Fruit/Nut/Food - - - - - - - - human food
Leaf vegetable - - - - - - - leaves used for vegetables
Medicine - - - - - - - - - - medicinal uses for various parts
Fodder - - - - - - - - - - - used for animal feed
Bee forage - - - - - - - - - good/prolific bee forage for honey production
Organic matter/mulch - - - - prolific source of organic matter/mulch
Wood/timber- - - - - - - - - solid wood or timber products
Fuel wood - - - - - - - - - - wood easily burned for fuel
Drought - - - - - - - - - - - tolerates drought
Water logging - - - - - - - - tolerates water logged soils
Salt/saline - - - - - - - - - tolerates salt spray

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Tall Species 50 feet (15 meters) and taller ——————Products—————— ——Characteristics——

Botanical Name	Common Name	Nitrogen fixer	Crop shade	Erosion control	Fruit/Nut/Food	Leaf vegetable	Medicine	Fodder	Bee forage	Organic matter/mulch	Wood/timber	Fuel wood	Salt/saline	Drought	Water logging	Potential weed/invasive	Growth rate	Climatic zone
Acacia auriculiformis	auri	•	•	•							•	•		•		P	F	H
Acacia koa	koa	•	•								•	•		>		P	F	H, U
Acacia mangium	mangium	•	•	•							•	•		•		P	F	H
Acrocarpus fraxinifolius	pink cedar		•								•	•		•			F	H, A, U
Aleurites moluccana	kukui, candlenut		•	>	>		>	>				>	>	•	•	P	M	H, A
Araucaria heterophylla	Norfolk Island Pine										•	•		•		P	S	H, U
Artocarpus altilis	breadfruit			>	•			•			>		•	•			S	H
Artocarpus heterophyllus	jackfruit				•			•			•	•	•	•			S	H
Azadirachta excelsa	sentang						•				•	•					M	H, U
Calophyllum inophyllum	kamani			>							•	>	•	•			S	H
Casuarina cunninghamiana	ironwood (small cone)	•		•							•	•	•	•	•	N	F	H, A, U
Cocos nucifera	coconut		•	•	•			•	•		•		•	•	•	P	S	H
Cryptomeria japonica	Japanese Sugi Pine										•	•		>			S	U
Dendrocalamus asper	giant bamboo			•	>						•		>	•			M	H
Eucalyptus dunnii	Dunn's white gum								•		•	•					F	H, U
Eucalyptus microcorys	tallowwood								•		•	•					F	H, U
Grevillea robusta	silk oak		•						•		•	•		•		N	M	H, A, U
Guadua angustifolia	guadua bamboo			•	•			>			•			•			M	H
Litchi chinensis	lychee				•			>			•	•	•	>			S	H, U
Mangifera indica	mango				•			>	>		•	•	•	•		P	S	H, A
Meterosideros polymorpha	ohia-lehua		•								•	•		•	>	P	S	H, A, U
Pinus caribaea	Caribbean pine										•	•					M	U
Prosopis pallida	kiawe	•		•	>			•	•	>	•	•	>	•		N	S	A
Pterocarpus indicus	narra	•	•					>			•	•		•			M	H, A, U
Sandoricum koetjape	santol				>						>		>	>			S	H
Swietenia macrophylla	mahogany										•	•					M	H
Terminalia catappa	false kamani				•						•	•					M	H
Tristania conferta	Brisbane boxwood										•	•		•		P	F	H, U

Nitrogen fixer - - - - - - - -fixes atmospheric nitrogen
Crop shade - - - - - - - - -used for shading other crops
Erosion control - - - - - - -erosion control, soil holding
Fruit/Nut/Food - - - - - - - -human food
Leaf vegetable- - - - - - - -leaves used for vegetables
Medicine - - - - - - - - - -medicinal uses for various parts
Fodder - - - - - - - - - - -used for animal feed
Bee forage - - - - - - - - -good/prolific bee forage for honey production
Organic matter/mulch - - - -prolific source of organic matter/mulch
Wood/timber- - - - - - - - -solid wood or timber products
Fuel wood - - - - - - - - - -wood easily burned for fuel
Drought - - - - - - - - - - -tolerates drought
Water logging - - - - - - - -tolerates water logged soils
Salt/saline - - - - - - - - -tolerates salt spray

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Resources and Recommended Reading

Local Assistance

There are government agents, professional forestry consultants, computer models, and informed neighbors that can assist landowners in designing windbreaks for their situation. There is no substitute for direct, locally appropriate 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 one 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/

The USDA National Agroforestry Center has brochures on agroforestry which can be ordered from:

National Agroforestry Center
USDA-NRCS, East Campus—UNL, Lincoln, NE 68583-0822
Tel: 402-437-5178
Web site: http://www.unl.edu/nac/

Publications

FACT Sheets (formerly NFT Highlights)

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. Many available in Spanish, French, Indonesian, Chinese, Vietnamese, and Khmer.

Nitrogen Fixing Tree Start-up Guide by C.R. Elevitch and K.M. Wilkinson covers selection, propagation and uses of many important agroforestry trees, including many wind hardy species. Download from:
http://www.agroforestry.net

The USDA National Agroforestry Center's Windbreaks and Wildlife brochure provides more detail on managing windbreaks for wildlife. Order from:

National Agroforestry Center
USDA-NRCS, East Campus—UNL, Lincoln, NE 68583-0822 USA
Phone: 402-437-5178
Web page for brochure: http://www.unl.edu/nac/pubs/ec/ec1771.htm

Agroforestree database: a tree species reference and selection guide is a selection guide for agroforestry trees covering more than 300 species. Valuable for field workers and researchers who are engaged in activities involving trees suitable for agroforestry systems and technologies. Available as CD-ROM from ICRAF, P.O. Box 30677, Nairobi, Kenya; Tel: +254-2-521450 or +1 650 833 6645; Fax: +254-2-521001 or +1-650-833-6646; E-mail: ICRAF@cgiar.org; or view online at: http://198.93.235.8/cfdocs/examples/treessd/AFT/AFT.htm

Trees on the Treeless Plains: Revegetation Manual for the Volcanic Landscapes of Central Victoria by D. Holmgren covers design of revegetation systems in detail including windbreaks and farm forestry. Order through Permaculture International LTD, P.O. Box 6039, South Lismore, NSW 2480, Australia; Tel: +61-2-66220020, Fax: +61-2-66220579; E-mail: pij@nor.com.au

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

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Agroforestry Guides for Pacific Islands

Multipurpose Windbreaks: Design and Species for Pacific Islands is the eighth 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
from: http://www.agroforestry.net