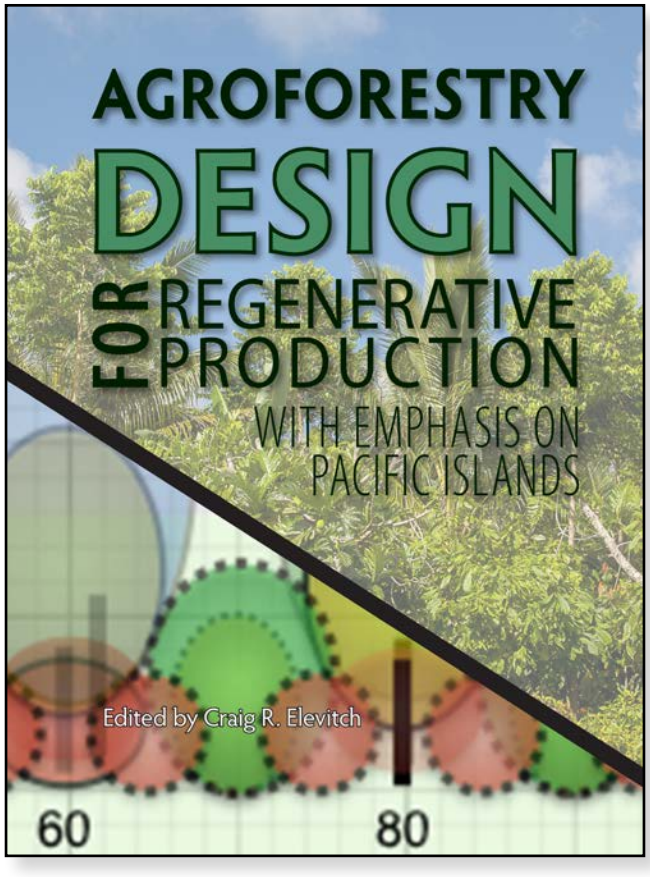
Chapter 5
Species Selection



By Craig R. Elevitch and Neil Logan

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Agroforestry Design for Regenerative Production

Chapter 5. Species Selection

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Chapter 5. Species selection

by Craig R. Elevitch and Neil Logan

Selecting species to include in a project is a challenging process involving all aspects of project planning from the environmental and goals assessments, to prospective planting configurations, to financial and other benefits evaluations (Table 5.1). Resilient agricultural systems are especially needed in the face of climate change and the unpredictable weather extremes it brings. Food security and disaster preparedness are increasingly emphasized in species selection as a complementary benefit to sales potential. Additionally, the assembly of species seen as a whole leads to a number of benefits including resiliency, diversity of benefits, and ecosystem regeneration (Figure 5.1).

Table 5.1. Crop selection criteria and information sources.

Crop selection criteria	Information source
Environmental conditions	Site assessment (Ch. 3)
Tolerance for weather extremes	Species references
Suitability for planting configuration	Agroforestry design references (Ch. 4)
Labor capacity	Management planning (Ch. 6)
Market potential	Market research
Financial outcomes	Market research, analysis (Ch. 7)
Suitability for value-added processing	Species references, market research
Food and nutrition security	Species references
Cultural appropriateness	Experience
Personal preferences	Goals assessment (Ch. 3)
Expert recommendations	Consultation

Environmental conditions

A fundamental principle that guides species selection is matching the crop to the environment. Modern industrial agriculture suffers because it tries to shape the environment to fit the crop by artificially adding or draining water from fields. Mismatching crops to the environment can also lead to poor crop health, which may require extreme and costly measures to address pests and diseases that result. Attempting to force crops to perform in unsuitable environments only leads to failure. With this in mind, we recommend utilizing the species assessment carried out

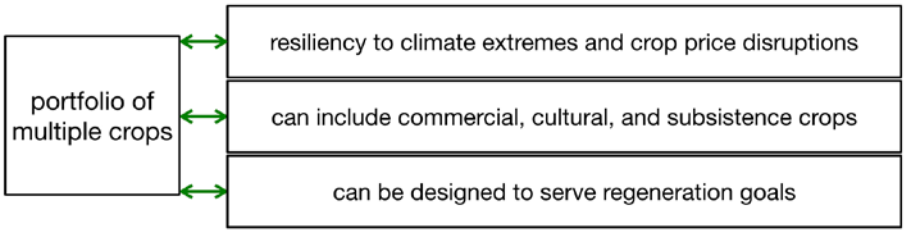


Figure 5.1. Growing a suite of crops confers multiple benefits.

for the site and neighboring lands as an initial indicator of how species will perform in a region.

Existing plants also offer a rough evaluation of current site conditions. For example, a degraded site tends to have a majority of species that tolerate harsh conditions (for example, pioneering plants such as Guinea grass and leucaena). The existing flora gives a good indication of how much, if any, work needs to be done to regenerate the soil health and water-holding capacity in order to grow the crops that require abundant conditions (e.g., most large tree fruits and nuts). Such an analysis at the project outset helps determine the progression of crops that can take place to improve site conditions, leading to another assortment of crops in following project phases.

There is often considerable variation of the conditions across a site, meaning that species selection will vary depending on location within the site. For example, where rainwater concentrates in gullies or rapidly disperses on rises, two different sets of species may be chosen, one set that grows well with moisture and protection, and one set that grows well in well-drained and more exposed sites. Therefore the topography of the site is crucial information for species selection, and should be documented during the site assessment. Similar to differences in topography, other factors affect the local suitability of crops such as predominant wind direction, soil quality, depth, and type, road access, security concerns, and cultural preferences. Diverse sites will therefore require division for species selection purposes into various regions with relative uniformity in each (Figure 5.2).

Planting configuration

One of the challenges with species selection in multistory agroforestry is to select an assembly of species that can grow well together over time and space. Over time, there are species that grow quickly and produce early yields, then exit the system leaving long-term crops. Over space, we would like to have crop assemblies where each crop occupies its own favored strata without conflicts for light and space with neighboring plants. In this publication, we have chosen to begin by deciding upon a planting configuration which determines the different strata occupied and the density of the various species occupying each strata (Chapter 4). One could also choose to begin by selecting species, followed by determining a suitable planting configuration. In reality, one will likely go back and forth between determining a planting configuration and species selection during the design process. An example presented in

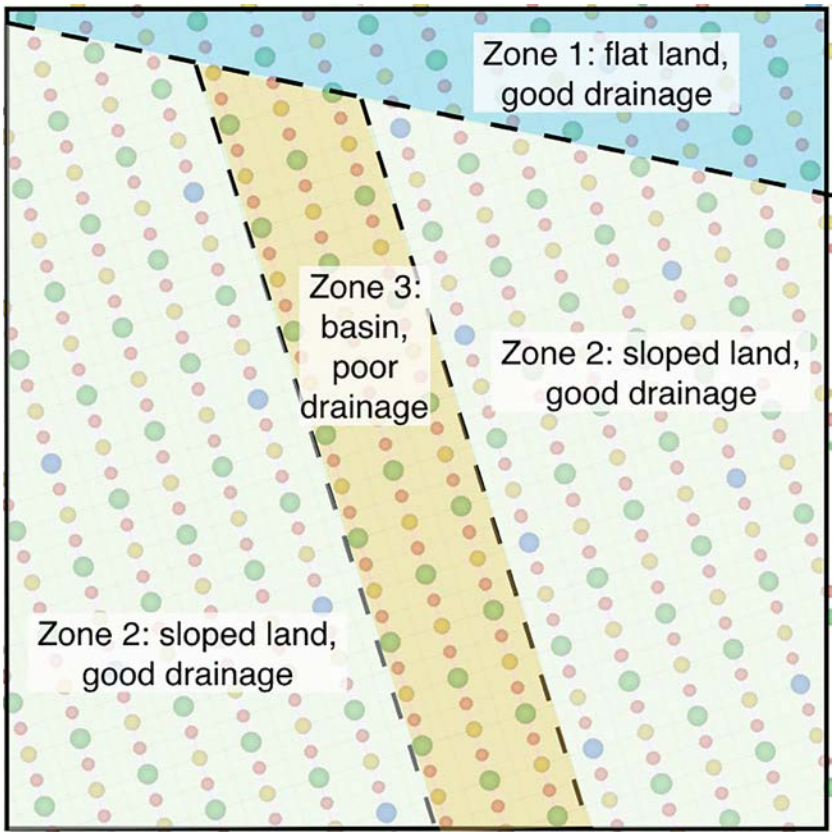


Figure 5.2. Each zone of similar topography and soil should have its own species assembly. The planting configuration may also change depending on zone.

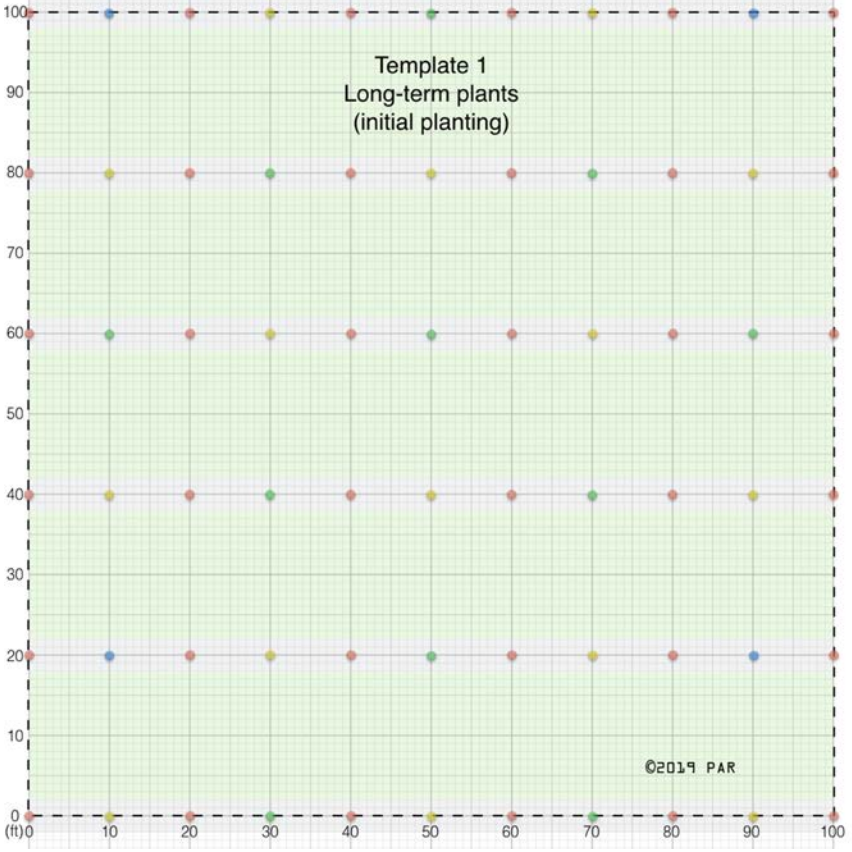
Figure 5.3 (see also additional similar examples presented in Chapter 4) shows an example planting configuration and the numbers of plants needed for each height class.

Market potential

For those who plan for commercial sales, market potential is a significant criteria for species selection. As demand for crops fluctuates due to various factors, advance research on markets can pay off many times over the effort required. Some primary questions to consider follow:

- Which crops will fetch the greatest return for the effort required?
- What primary crops are stable, consistent, and dependable in the marketplace?
- What crops can tolerant weather extremes on your site? (Cold, drought, wet, high wind, and so on.)
- Which crops can expect an oversupply in the next few years due to previous planting trends?
- Which crops are suitable for value-added processing as part of your operation?
- How available is suitable propagation material?
- Will your capacity be sufficient to meet market needs consistently enough to keep the market?

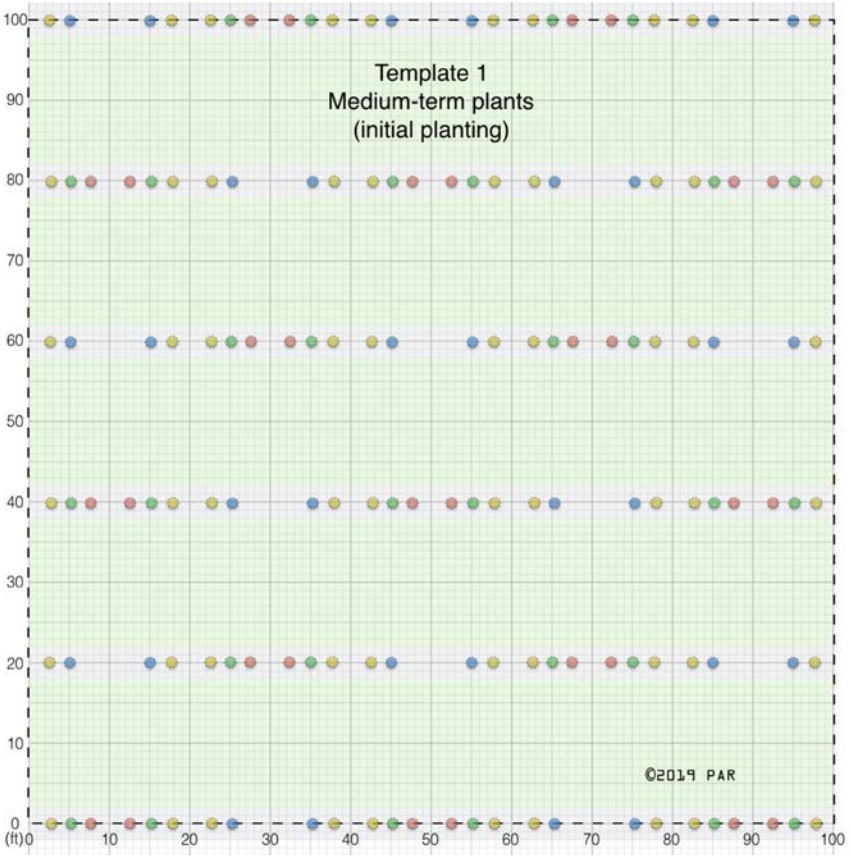
Figure 5.3. The planting configuration determines which height classes of plants are represented. This template from Chapter 4 includes species from all four height classes in both long- and medium terms. The numbers of plants for each height class and time frame are highlighted in orange.



Template 1

Mid-density commercial, 4-story

Long-term height class	color
emergent	blue
high	green
medium	yellow
low	red
within row spacing (ft)	between row spacing (ft)
40	40
40	20
10 & 30	20
5 & 20	20
Count in 100 ft x 100 ft	Approximate count/acre
4	16
11	44
15	60
36	144



Medium-term height class	color
emergent	blue
high	green
medium	yellow
low	red
within row spacing (ft)	between row spacing (ft)
10 & 30	20
10 & 20	20
5 & 15	20
5 & 35	20
Count in 100 ft x 100 ft	Approximate count/acre
30	120
30	120
60	240
30	120

Other considerations in selecting species

In addition to the selection criteria listed above there are a number of other considerations used in selecting species that take into account a wide range of values:

Ecosystem services

Plants for erosion control, windbreak, shade, living trellis, living fence posts, impenetrable physical barriers, and noise and pollution absorption.

Social/cultural

Plants that are used in ceremony, ritual, storytelling, art, and spiritual practice.

Native

Plants whose populations are at risk or gone from their original habitat due to human or animal impact.

Endangered

Plants that have become rare and are threatened by extinction.

Supports pollinators

Plants that provide important habitat and/or forage for pollinators.

Sentimental/inspirational

Plants that hold special personal meaning and give a sense of appreciation and joy.

Beauty

Plants that have special visual impact or appeal.

Small-scale trials

Often a new agroforestry system includes introduction of new or unfamiliar species to a site or putting together new combinations of species in time and space. Rather than making large investments of time and money on new species and systems, it is often wise to conduct small-scale trials.

Plants to use in first trials

- Appear to be thriving in surrounding areas with little or no care
- Known to tolerate harsh conditions such as wind, drought, and poor soils
- Widely adapted to many different soil and climatic conditions
- Have multiple uses to people, such as timber, food, and medicine
- Can be easily propagated from seed or vegetative parts (cuttings, suckers, etc.)
- Native plants, especially those that are known to grow in the area

- Selected from wide range of plant families
- Several varieties of each species, including modern as well as traditional varieties used by indigenous farmers

Avoid

- Introducing known invasive species
- Thorny and spiny species, especially those that are self-seeding
- Poisonous species
- Rapidly spreading plants, such as running bamboo
- Illegal or offensive species

Invasive species caution

People have introduced numerous species around the world. Some of these have been beneficial for people and the environment, and some have become harmful to ecosystems due to their rampant or invasive nature. The USDA defines invasive species as, "Plants, animals, or pathogens that are non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause harm." Numerous species have been evaluated for their invasive potential (see Hawaii Pacific Weed Risk Assessment and other web sites). Moving invasive species to new areas should be avoided. Where present, invasive species often increase the costs of management. On a given site, invasive plants can either be replaced with other species that are less problematic or in some cases can be managed as part of the agroforestry system.

Species references

In addition to countless books that have been published on regional species and crops, there are numerous species references available online. A brief list is presented below.

Agro-Forestry in the Pacific Islands: Systems for Sustainability by Clark and Thaman (1993) presents a very thorough treatment of agroforestry practices in the Pacific. Includes tables and descriptions of many traditional agroforestry species. http://archive.unu.edu/unupress/unupbooks/80824e/80824E00.htm

Agroforestry Guides for Pacific Islands edited by Elevitch and Wilkinson (2000) is a series of 22–50 page guides covering eight topics in Pacific Island agroforestry including multipurpose trees, nontimber forest products, understory crops, and windbreaks. http://www.agroforestry.org/free-publications/agroforestry-guides

Agroforestry Design Tool is a free on-line software application that guides the user through the design process and generates planting configuration diagrams in overhead and side-views, a 15-year animation of the project, and a project summary. Developed by Permanent Agriculture Resources and FARM Center with support from USDA NRCS. http://www.agroforestryX.com

Agroforestree (AFT) database by the World Agroforestry Centre is a tree species reference and selection guide for agroforestry trees covering more than 500 species. Valuable for field workers and researchers who are engaged in activities involving trees suitable for agroforestry systems and technologies. http://www.worldagroforestrycentre.org/resources/databases/agroforestree

"Food-producing agroforestry landscapes in Hawai'i and other Pacific Islands" is a series of publications focusing on low-input and sustainable techniques for food producing landscapes. http://agroforestry.org/projects/food-producing-landscapes

The Native Plant Network is devoted to the sharing of information on how to propagate native plants of North America (Canada, Mexico, and US) and has propagation protocols for US, Hawaii, Canada, Mexico, US Virgin Islands, Hawaii, and other Pacific Islands. http://www.nativeplantnetwork.org/

Pacific Islands Area (PIA) Vegetative Guide by USDA NRCS contains plant species information that corresponds to Conservation Practice Standards and Specifications in Section IV of the PIA Field Office Technical Guide (FOTG). A public plant database can be queried to create custom plant lists for specific site conditions. http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/hipmstn9761.pdf

Specialty Crops For Pacific Island Agroforestry published by Permanent Agriculture Resources includes detailed profiles for 32 crops including their roles in mixed-species agroforestry. http://agroforestry.org/free-publications/specialty-crops-for-pacific-island-agroforestry

Traditional Pacific Island Crops by the University of Hawai'i provides access to quality, free Web resources on twelve important traditional Pacific Island crops. http://libweb.hawaii.edu/libdept/scitech/agnic

The Traditional Tree Initiative—Species profiles for Pacific Island Agroforestry published by Permanent Agriculture Resources provides detailed over 50 of the most important Pacific island agroforestry tree species. http://www.traditionaltree.org/

Examples crop assemblies

The following examples of working agroforestry systems demonstrate successful species assemblies. Substituting crops that occupy the same ecological niches (favored canopy layer, timing in the succession of species, and so on) is one strategy for introducing new species to existing crop assemblies.

Homegarden agroforestry

Breadfruit does well interplanted with a wide array of plants. More than 120 useful species have been documented in traditional breadfruit agroforests on Pohnpei. Short-term fruit crops (e.g., pineapple, banana, and papaya) or field and vegetable crops (e.g., taro, tomato, and eggplant) can also be grown during establishment between the long-term crops.

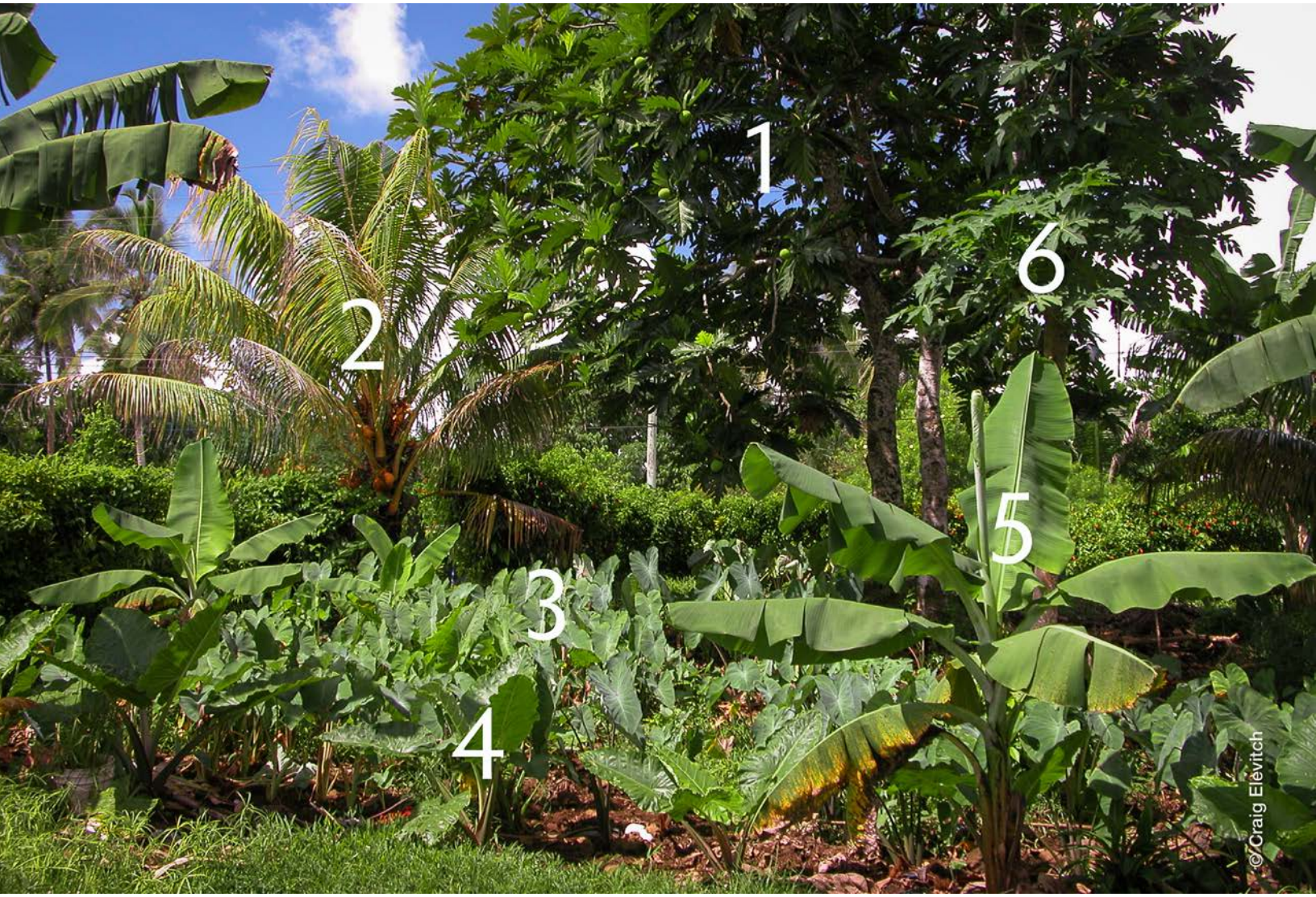


Figure 5.4. Breadfruit tree (1) growing with coconut (2), taro (3), giant taro (4), banana (5), and papaya (6) in a homegarden in Samoa.

Example medium- and long-term plant assemblies for homegardens

Emergent	High	Medium	Low
betel nut	avocado	banana	coffee
cocobolo	breadfruit	cacao	giant taro
coconut	durian	citrus	kava
Cook pine	jackfruit	fig	pineapple
kapok	macadamia nut	noni	taro
poumuli	mango	papaya	ti
Tahitian chestnut	pili nut	sugarcane	yam

Complex commercial multistory system

Multistory agroforestry systems are complex, diverse plantings of trees, shrubs, vines, and herbaceous plants occupying two or more canopy layers. There are no recipes for multistory systems, but successful models exist throughout the world that can be adapted for variations in species selection.

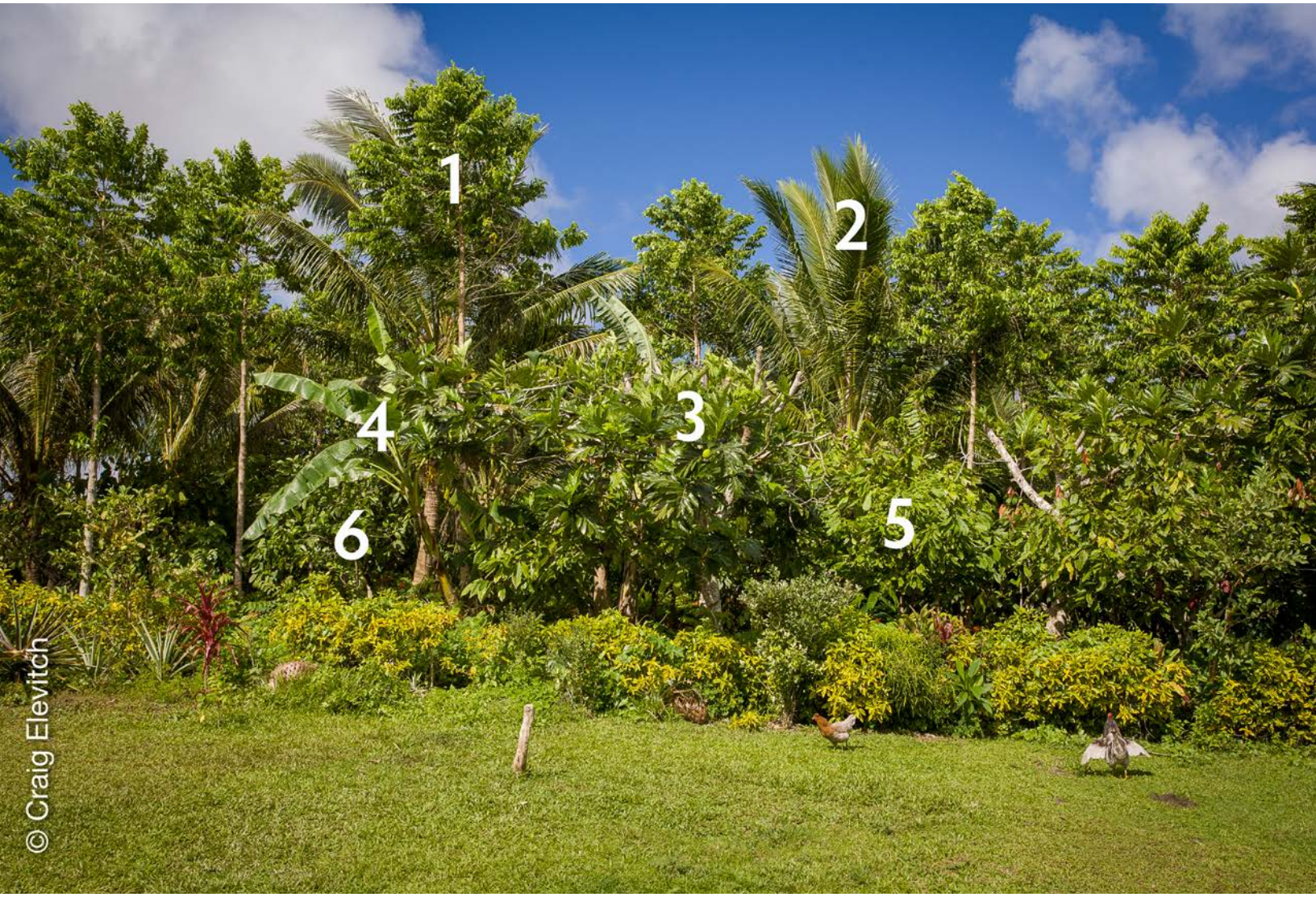


Figure 5.5. Poumuli timber tree (1) growing with coconut (2), breadfruit (3), banana (4), cacao (5), and noni (6) in a large scale commercial system in Samoa.

Example medium- and long-term plant assemblies for complex multistory agroforestry

Emergent	High	Medium	Low
Australian red cedar	breadfruit	banana	acerola
coconut	iliahi	cacao	calamansi
Honduran mahogany	longan	citrus	cardamom
koa	lychee	papaya	coffee
Norfolk Island pine	plantain	peach palm (for heart)	pineapple
rainbow eucalyptus	tamarind	rambutan	maile

Simplified commercial multistory system

For those who are more comfortable with simplified management than required for complex multistory agroforestry, simpler systems with 2–4 crops are also possible. Such systems may not have the full suite of ecological and economic benefits, but are often an improvement over monocultures in total productivity and resiliency.

Figure 5.6. Noni (1) planted in a commercial production orchard together with banana (2), betel nut (3), and bamboo (4) in Palau. This system had an understory of pineapple at an earlier stage.

Example medium- and long-term plant assemblies for simplified multistory agroforestry

Emergent	High	Medium	Low
betel nut	leucaena	cashew	black pepper
coconut	ear pod tree	egg fruit	coffee
New Guinea green	gold tree	jaboticaba	ginger
peach palm (for fruit)	ice cream bean	mulberry	pineapple
sago palm	kukui	noni	turmeric
pink cedar	neem	papaya	Tahitian taro
kauri	pheasant wood	tangerine	vanilla

Coffee agroforestry

In many parts of the world, coffee is interplanted with other crops. These crops vary in size and description and are chosen depending on the needs of the producer. Since coffee is tolerant of moderate shade, it is commonly grown beneath taller plants. These plants can be part of a relatively simple agroforestry system composed of a small number of tree species or a complex, multi-strata forest.

Figure 5.7. Coffee (1) growing together with poró extranjero (2), laurel (3), and timber eucalyptus (4) in Turrialba, Costa Rica.

Example medium- and long-term plant assemblies for coffee agroforestry

Emergent	High	Medium	Low
coconut	breadfruit	atemoya	chaya
eucalyptus	avocado	banana	collards
koa	ice cream bean	citrus	eggplant
laurel (*Cordia* sp.)	jackfruit	grapefruit	giant taro
Mexican cypress	macadamia	guava	katuk
teak	monkeypod	Indian sandalwood	vanilla

SPECIES LISTS

Based on your elevation, rainfall, topography, soils, and your project goals, select species in different height and lifespan categories. The lists below provide a small sample of species—other species references should be used to include additional species suitable to a particular location. Select at least one species from each category of height and lifespan from the template or other planting configuration that you have chosen. Every site and situation is different—this species guide is only a general guide to plant preferences. Extreme terrain requires additional consideration of species tolerances.

Key to the species tables

Habit	Type of plant (e.g., tree, palm)
Products	Primary products (e.g., fruit, timber)
Rainfall	Average annual rainfall in inches
Elevation range	Typical elevation for acceptable growth in feet
Canopy height	Typical unpruned maximum in feet
Canopy diameter	Typical unpruned maximum in feet
Topography	1 = sloped (10–20%) 2 = flat to gently sloped (0–10%) 3 = basin 4 = rise
Soil	a = sandy b = clay c = rocky d = loam

LONG-TERM (4+ YEARS)

Long-term emergent (60+ ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
Australian red cedar (*Toona ciliata*)	tree	timber	40–200	0–6600	106	60	1, 2, 4	b, c, d
betel nut (*Areca catechu*)	palm	fruit	20–240	0–2600	56	10	1, 2, 3	a, b, c, d
blue marble (*Elaeocarpus angustifolius*)	tree	timber	50–200	20–3600	100	50	1, 2, 3	b, c, d
cocobolo (*Dalbergia retusa*)	tree	timber	20–80	100–2500	60	60	1, 2, 3, 4	a, b, c, d
coconut (tall) (*Cocos nucifera*)	palm	fruit	20–250	0–2000	55	30	1, 2, 3	a, b, c, d
Cook pine (*Araucaria columnaris*)	tree	timber	30–240	0–3000	180	30	1, 2, 3, 4	a, b, c, d
ear-pod wattle (*Acacia auriculiformis*)	tree	timber	40–80	0–2000	80	35	1, 2, 4	a, b, c, d
Hirosi bamboo (*Bambusa oldhamii*)	clumping bamboo	timber/ shoots	40–200	0–3000	60	25	1, 2, 3, 4	a, b, c, d
Honduran mahogany (*Swietenia macrophylla*)	tree	timber	30–200	20–2000	175	100	1, 2, 4	b, c, d
ironwood (*Casuarina equisetifolia*)	tree	timber	15–200	0–2500	80	40	1, 2, 3, 4	a, b, c, d
kapok (*Ceiba pentandra*)	tree	timber	30–200	20–4500	100	70	1, 2, 4	a, c, d
kauri; kauri pine (*Agathis robusta*)	tree	timber	40–200	50–1800	115	65	1, 2, 3	a, b, c, d
koa (*Acacia koa*)	tree	timber	35–200	200–6500	85	50	1, 2, 4	b, c, d

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
Mexican cypress (*Cupressus lusitanica*)	tree	timber	40–120	20–3000	110	60	1, 2, 3, 4	a, b, c, d
New Guinea green (*Nastus elatus*)	clumping bamboo	shoots	40–200	0–4000	50	25	1, 2, 3	c, d
Norfolk Island pine (*Araucaria heterophylla*)	tree	timber	30–240	0–3000	160	60	1, 2, 3, 4	b, c, d
peach palm (for fruit) (*Bactris gasipaes*)	palm	fruit	80–160	0–3000	45	28	2, 3	a, c, d
pink cedar (*Acrocarpus fraxinifolius*)	tree	timber	40–120	100–4000	120	60	1, 2, 3, 4	a, b, c, d
poumuli (*Flueggea flexuosa*)	tree	timber	70–175	0–2000	45	22	1, 2, 3, 4	a, b, c, d
rainbow eucalyptus (*Eucalyptus deglupta*)	tree	timber	30–160	20–3500	115	75	1, 2, 3, 4	a, b, c, d
redgum eucalyptus (*Eucalyptus camaldulensis*)	tree	timber	10–30	20–4900	120	65	1, 2, 3, 4	a, b, c, d
sago palm (*Metroxylon* spp.)	palm	thatch	80–250	20–2300	50	36	2, 3	a, c, d
she-oak (*Casuarina cunninghamiana*)	tree	timber	25–120	20–3000	60	30	1, 2, 3, 4	a, b, c, d
spanish cedar (*Cedrela odorata*)	tree	timber	40–120	100–4000	120	60	1, 2, 3, 4	a, b, c, d
tallowwood (*Eucalyptus microcorys*)	tree	timber	40–160	20–3500	150	100	1, 2, 3, 4	a, b, c, d
teak (*Tectona grandis*)	tree	timber	40–150	20–2500	100+	60	1, 2, 4	a, b, c, d
timber bamboo (*Dendrocalamus asper*)	clumping bamboo	timber/ shoots	40–200	0–4000	80	60	1, 2, 3, 4	a, b, c, d
Torell's eucalyptus (*Eucalyptus torelliana*)	tree	timber	40–160	20–3500	90	45	1, 2, 3, 4	a, b, c, d
tropical almond (*Terminalia catappa*)	tree	timber/ nuts	40–140	0–1250	100	100	1, 2, 4	a, b, c, d

Long-term high (≈20–60 ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
avocado (*Persea americana*)	tree	fruit	30–200	20–3000	48	32	1, 2, 4	a, c, d
banana (*Musa species*)	shrub	fruit	50–240	0–3500	25	10	1, 2, 3, 4	a, b, d
bird-catcher tree (*Pisonia grandis*)	tree	fruit, leaves	70–120	0–1700	70	65	1, 2	a, c, d
breadfruit (*Artocarpus altilis*)	tree	fruit	40–240	0–2500	70	30	1, 2	a, b, c, d
breadnut (*Artocarpus camansi*)	tree	fruit, seed	40–240	0–2500	70	30	1, 2, 3	a, b, c, d
coconut (dwarf) (*Cocos nucifera*)	tree	nut, thatch	20–250	0–2000	55	30	1, 2, 3	a, b, c, d
dugdug (*Artocarpus mariannensis*)	tree	fruit, seed	40–240	0–2500	70	25	1, 2	a, b, c, d
durian (*Durio zibethinus*)	tree	fruit	60–240	20–1600	90	80	1, 2, 3	a, c, b, d
ear pod tree (*Enterolobium cyclocarpum*)	tree	wood, mulch	30–100	0–4000	100	100	1, 2	a, c, b, d
gold tree (*Roseodendron donnell-smithii*)	tree	flower, wood	40–140	20–3000	70	35	1, 2, 3, 4	a, b, c, d

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
ice cream bean (*Inga* spp.)	tree	fruit, mulch	45–200	20–5000	62	45	1, 2, 3, 4	a, b, c, d
iliahi (*Santalum paniculatum*)	tree	timber, oil, nut	15–150	1500–6500	40	20	1, 2, 4	a, b, c, d
jackfruit (*Artocarpus heterophyllus*)	tree	fruit	45–200	0–3000	75	30	1, 2, 3, 4	a, b, c, d
kamani (*Calophyllum inophyllum*)	tree	timber, nut	25–200	0–1000	45	30	1, 2	a, c, d
koaia (*Acacia koaia*)	tree	wood	30–80	200–4900	25	30	1, 2, 4	a, b, c, d
kou (*Cordia subcordata*)	tree	timber	25–200	0–500	35	20	2	a, c, d
kukui (*Aleurites moluccana*)	tree	nut, mulch	40–240	20–2500	70	50	1, 2, 3	a, b, c, d
leucaena (*Leucaena leucocephala*)	tree	wood, mulch	30–100	0–2500	50	20	1, 2, 3, 4	a, b, c, d
longan (*Dimocarpus longan*)	tree	fruit	50–120	20–2500	35	20	1, 2	b, c, d
loulu (*Pritchardia maideniana*)	tree	fruit, thatch	70–200	1000–2000	40	12	1, 2, 3, 4	a, b, c, d
lychee (*Litchi chinensis*)	tree	fruit	40–200	100–3300	62	35	1, 2, 4	a, d
macadamia nut (*Macadamia integrifolia*)	tree	nut	60–160	20–2500	42	22	1, 2	a, c, d
madre de cacao (*Gliricidia sepium*)	tree	wood, mulch	25–200	0–3000	50	25	1, 2, 3, 4	a, b, c, d
mango (*Mangifera indica*)	tree	fruit, wood	25–200	0–2000	95	65	1, 2	a, b, c, d
monkeypod (*Samanea saman*)	tree	fruit, wood	30–200	0–1000	45	45	1, 2, 3, 4	a, b, c, d
mountain apple (*Syzygium malaccense*)	tree	fruit	60–160	20–3500	60	35	1, 2, 3, 4	b, c, d
narra; Burmese rosewood (*Pterocarpus indicus*)	tree	wood	80–200	0–2500	85	30	1, 2, 3, 4	a, b, c, d
neem (*Azadirachta indica*)	tree	seed, leaf, wood	20–200	0–2000	65	45	1, 2, 3, 4	a, b, c, d
ohia (*Metrosideros polymorpha*)	tree	wood, honey	25–240	0–7250	100	25	1, 2, 3, 4	a, c, d
Pheasant wood (*Senna siamea*)	tree	wood	25–110	0–2500	60	35	1, 2, 3, 4	a, b, c, d
pili nut (*Canarium* species)	tree	nut	80–240	20–3000	60	30	2	a, b, d
pito (*Erythrina berteroana*)	tree	seed	60–200	30–3000	35	20	1, 2, 3, 4	a, b, c, d
plantain (*Musa* x *paradisiaca*)	tree	fruit, mulch	50–240	0–3500	25	14	1, 2, 3, 4	a, b, d
podocarpus (*Podocarpus gracilior*)	tree	wood	35–240	0–6000	45	30	1, 2, 3, 4	a, b, c, d
starapple (*Chrysophyllum cainito*)	tree	fruit	20–40	0–1300	50	40	1, 2, 3, 4	a, b, c, d
tamarind (*Tamarindus indicus*)	tree	fruit, wood	20–240	0–3000	50	35	1, 2, 4	a, b, c, d
vi (*Spondias dulcis*)	tree	fruit	40–200	20–3000	60	25	2, 4	b, c, d
ylang ylang (*Cananga odorata*)	tree	flower	30–240	20–2500	55	25	1, 2	a, b, d
yoga tree (*Elaeocarpus joga*)	tree	nut, wood	60–120	20–1700	60	40	1, 2, 3	b, c, d

Long-term medium (≈6–20 ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
annatto (*Bixa orellana*)	tree	seed	35–90	0–5000	15	12	1, 2, 4	a, b, c, d
abiu (*Pouteria caimito*)	tree	fruit	40-120	0-2000	33	15	1, 2, 3	b, c, d
Ahgao (*Premna obtusifolia*)	tree	wood	50-240	0-1700	25	15	2, 3	a, c, d
atemoya (*Annona* x *atemoya*)	tree	fruit	50-240	20-3500	30	25	1, 2, 4	a, b, c, d
banana (dwarf) (*Musa* spp.)	shrub	fruit	50–240	0–3500	15	10	1, 2, 3, 4	a, b, d
beach gardenia (*Guettarda speciosa*)	tree	flower	50-200	0-1700	33	20	1, 2	a, c, d
beach heliotrope (*Tournefortia argentea*)	tree	wood, mulch	12-200	0-50	23	15	1, 2	a, c, d
cacao (*Theobroma cacao*)	tree	fruit	50–200	20–1500	35	25	1, 2, 3	a, b, c, d
canistel; egg fruit (*Pouteria campechiana*)	tree	fruit	40-120	0-3000	25	25	2	a, b, d
cashew (*Anacardium occidentale*)	tree	fruit	35-240	20-2300	33	45	1, 2, 4	a, c, d
chaya (*Cnidoscolus aconitifolius* var. Estrella)	tree	leaf, mulch	20-100	0-3000	22	20	1, 2, 3, 4	a, b, c, d
cherimoya (*Annona cherimola*)	tree	fruit	50-240	2500-6000	23	20	1, 2	a, b, c, d
chopak (*Mammea odorata*)	tree	wood	70-200	20-1700	40	40	1, 2	a, c, d
fig (*Ficus carica*)	tree	fruit	20-80	20-5000	24	15	1, 2, 3, 4	a, b, d
grapefruit (*Citrus paradisi*)	tree	fruit	30-50	0-2600	41	20	1, 2, 4	a, b, c, d
guava (*Psidium guajava*)	tree	fruit, wood	40-80	0-3300	30	12	1, 2, 3, 4	a, b, c, d
hau (*Hibiscus tiliaceus*)	tree	wood, mulch	30-200	0-2000	24	25	1, 2, 3, 4	a, b, c, d
Indian sandalwood (*Santalum album*)	tree	wood, oil	20-150	20-2300	25	20	1, 2, 4	a, b, c, d
jaboticaba (*Myrciaria cauliflora*)	tree	fruit	50-200	20-3500	23	30	1, 2, 3, 4	a, b, c, d
kaffir lime (*Citrus hystrix*)	tree	fruit	30-200	0-1500	22	9	1, 2, 4	a, b, c, d
lama (*Diospyros sandwicensis*)	tree	fruit, wood	15-150	20-4000	35	15	1, 2, 4	a, b, c, d
lantern tree (*Hernandia nymphaeifolia*)	tree	wood	60-200	0-1000	35	20	1, 2	a, c, d
lemon (*Citrus limon*)	tree	fruit	20-200	0-6600	20	15	1, 2, 4	a, b, c, d
mamane (*Sophora chrysophylla*)	tree	wood, honey	20-120	1500-9000	50	20	1, 2, 4	a, b, c, d
mangosteen (*Garcinia mangostana*)	tree	fruit	60–240	20–1500	50	40	2	a, c, d
milo (*Thespesia populnea*)	tree	wood	20-200	0-1000	66	30	1, 2, 3, 4	a, b, c, d
moringa (*Moringa oleifera*)	tree	leaf, mulch	20–200	20–4000	35	12	1, 2, 3, 4	a, b, c, d
mulberry (*Morus* spp.)	tree	fruit	24–98	20–4500	22	18	1, 2, 3, 4	a, b, c, d
noni (*Morinda citrifolia*)	tree	fruit	20–240	0–1800	16	14	1, 2, 4	a, b, c, d
orange; sweet orange (*Citrus sinensis*)	tree	fruit	40–120	20–3300	35	15	1, 2, 4	a, b, c, d
pandanus (*Pandanus tectorius*)	tree	fiber, fruit	40–240	0–2000	33	25	1, 2, 3, 4	a, b, c, d

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
peach palm (for heart) (*Bactris gasipaes*)	palm	heart	75–200	0–3000	35	12	1, 2, 3	a, c, d
plantain (dwarf) (*Musa x paradisiaca*)	tree	fruit, mulch	50–240	0–3500	15	14	1, 2, 3, 4	a, b, d
plumeria (*Plumeria rubra*)	tree	flower	20–240	0–2000	25	25	1, 2	a, c, d
pomegranate (*Punica granatum*)	tree	fruit	25–200	20–4000	25	11	1, 2, 4	a, b, c, d
pua kenikeni (*Fagraea berteroana*)	tree	flower	40–200	20–3000	35	30	1, 2, 3, 4	a, b, c, d
pummelo (*Citrus maxima*)	tree	fruit	35–200	0–2500	28	20	1, 2, 4	a, b, c, d
rambutan (*Nephelium lappaceum*)	tree	fruit	70–200	20–2000	30	20	1, 2	a, b, c, d
rollinia (*Rollinia deliciosa*)	tree	fruit	60–240	300–3000	50	35	2, 3	a, b, d
screw pine (*Pandanus dubius*)	tree	fruit, leaf	40–240	0–1700	21	12	1, 2	a, c, d
soursop (*Annona muricata*)	tree	fruit	40–240	20–1000	25	15	1, 2, 4	a, c, d
starfruit (*Averrhoa carambola*)	tree	fruit	70–240	20–3000	36	25	1, 2	a, d
sugar apple (*Annona squamosa*)	tree	fruit	30–240	0–3500	15	15	2, 3	a, b, d
tangerine (*Citrus reticulata*)	tree	fruit	20–120	0–3300	24	20	1, 2, 4	a, b, c, d
twin apple (*Neisosperma oppositifolia*)	tree	flower	35–200	0–900	45	23	1, 2	a, c, d
water apple (*Syzygium aqueum*)	tree	fruit	40–160	20–3500	20	15	1, 2, 3, 4	a, b, c, d
williwilli (*Erythrina sandwicensis*)	tree	wood	15–80	0–2000	40	23	1, 2, 3, 4	a, b, c, d

Long-term low (≈2–6 ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
black pepper (on trellis) (*Piper nigrum*)	vine	spice	80–240	20–2000	12	5	1, 2, 3, 4	a, b, c, d
coffee* (*Coffea arabica* and *C. robusta*)	tree	beverage	45–220	20–4000	10	5	1, 2, 3	a, b, c, d
ti* (*Cordyline fruticosa*)	shrub	leaf, root	30–220	0–3000	8	4	1, 2, 3, 4	a, b, c, d
vanilla (on trellis) (*Vanilla planifolia*)	vine	fruit	40–240	0–1600	8	3	1, 2	a, c, d
maile (*Alyxia stellata*)	vine	leaf	25–200	150–6500	20	10	1, 2, 3	c, d
calamansi (*Citrus* x *Citrofortunella mitis*)	tree	fruit	30–200	0–2400	16	12	1, 2, 4	a, b, c, d
chaya (*Cnidoscolus aconitifolius* var. Redonda)	tree	leaf	30–120	0–3000	7	10	1, 2, 3, 4	a, b, c, d
kumquat (*Fortunella* spp.)	tree	fruit	40–160	20–4000	11	10	1, 2, 4	a, b, c, d
acerola (*Malpighia glabra*)	tree	fruit	35–100	0–3300	15	15	1, 2, 3, 4	a, b, c, d
mao hau hele (*Hibiscus brackenridgei*)	shrub	flowers	12–120	0–3500	15	15	1, 2, 3, 4	a, b, c, d
cardamom (*Elettaria* and *Amomum* species)	shrub	spice	60–180	0–3000	5	3	1, 2, 3	a, d
katuk (*Sauropus androgynus*)	shrub	leaf	25–150	0–5700	3	3	1, 2, 3	a, b, c, d
Tahitian taro (*Xanthosoma brasiliense*)	shrub	leaf, corm	40–240	0–2000	3	3	1, 2, 3, 4	a, b, c, d

MEDIUM-TERM (0–4 YEARS)

Medium-term plants tend to establish quickly relative to long-term plants, but have a short lifespan. Some of the species listed here may live longer than four years in favorable conditions, but generally lose their vigor around this time and are removed or replanted.

Medium-term emergent (10+ ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
papaya (*Carica papaya*)	tree	fruit	20–120	0–3300	20	6	1, 2, 3, 4	a, b, c, d
sesban (*Sesbania sesban*)	tree	leaf, mulch	35–160	0–2500	24	12	1, 2, 3, 4	a, b, c, d
agati (*Sesbania grandiflora*)	tree	fruit, leaf	35–160	0–2500	20	15	1, 2, 3, 4	a, b, c, d

Medium-term high (≈6–10 ft)

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
pigeon pea (*Cajanus cajan*)	tree	seed	25–160	20–2500	9	4	1, 2, 3, 4	a, b, c, d
tree tomato (*Solanum betaceum*)	tree	fruit	40–120	20–2000	7	5	1, 2	a, b, c, d
cassava (*Manihot esculenta*)	shrub	root	30–120	0–4000	5	4	2	a, b, c, d
sugarcane (*Saccharum officinarum*)	grass	stalk	35–200	0–3000	6	2	2, 3	a, b, c, d

Medium-term medium (≈4–6 ft)

Common name (*Genus species*)	Habit	Prod-ucts	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
giant taro (*Alocasia macrorrhizos*)	shrub	root	80–165	0–3300	8	4	1, 2, 3	a, b, d
kava (*Piper methysticum*)	shrub	root	40–80	0–2300	8	6	1, 2, 3	a, b, c, d
mamaki (*Pipturus albidus*)	shrub	leaf	50–240	20–6000	7	4	1, 2, 3, 4	a, b, c, d
Pacific spinach (*Abelmoschus manihot*)	shrub	leaf	40–180	0–3000	6	3	1, 2, 3	a, b, c, d
chili pepper (*Capsicum annuum*)	shrub	fruit	30–90	0–3600	4	3	1, 2, 4	a, b, c, d
naranjilla (*Solanum quitoense*)	shrub	fruit	40–120	400–2000	6	4	1, 2	a, b, c, d

Medium-term low (≈2–4 ft)

Common name (*Genus species*)	Habit	Prod-ucts	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topo-graphy	Soil
yam (seasonal) (*Dioscorea* spp.)	vine	root	40–80	0–3300	8	3	2, 4	a, b, c, d
poha (*Physalis peruviana*)	herb	fruit	15–200	20–6000	2	2	1, 2, 3, 4	a, b, c, d
eggplant (*Solanum melongena*)	herb	fruit	25–160	20–3000	2	2	2	a, b, d
collard, kale (*Brassica oleracea*)	herb	leaf	30–160	0–7000	2	1	1, 2, 3, 4	a, b, d
ginger (*Zingiber officinale*)	herb	root	60–250	0–5000	1.5	2	2, 3	a, b, d
taro (*Colocasia esculenta*)	herb	root	30–240	20–3000	2	2	1, 2, 3	a, b, d
turmeric (*Curcuma longa*)	herb	root	40–140	20–4000	1	1	2, 3	a, b, d
pineapple (*Ananas comosus*)	shrub	fruit	25–150	0–5700	3	3	1, 2, 3	a, b, c, d

SHORT-TERM (0–1 YEAR)

Short-term crops are quick to establish and become productive, but generally lose their vigor within a year. Exceptions to this exist, of course. For example, certain collard and lima bean varieties can live for two or more years. This is only a brief list of what is possible to grow in the short term.

Common Name (*Genus species*)	**Habit**	**Products**
amaranth (*Amaranthus hypochondriacus*)	herb	seed, leaf
arugula (*Eruca vesicaria* subsp. *sativa*)	herb	leaf
basil (*Ocimum basilicum*)	herb	leaf
broccoli (*Brassica oleracea* var. italica)	herb	flowers
buckwheat (*Fagopyrum esculentum*)	herb	Seed, biomass
burdock (*Arctium lappa*)	herb	root
catnip (*Nepeta cataria*)	herb	leaf
cauliflower (*Brassica oleracea* var. botrytis)	herb	flowers
celery (*Apium graveolens*)	herb	leaf, stalk
chayote (*Sechium edule*)	vine	fruit
chinese cabbage (*Brassica rapa* subsp. *chinensis*)	herb	leaf
collards (*Brassica oleracea* var. viridis)	herb	leaf
corn (*Zea mays*)	grass	seed
cow pea (*Vigna unguiculata*)	vine	leaves, seeds
daikon radish (*Raphanus sativus* var. *longipinnatus*)	herb	seed, root
eggplant (*Solanum melongena*)	herb	fruit
garlic chive (*Allium tuberosum*)	herb	leaf
kale (*Brassica oleracea*)	herb	leaf
lablab (*Lablab purpureus*)	vine	Seed, biomass
lemon balm (*Melissa officinalis*)	herb	leaf
lettuce (*Lactuca sativa*)	herb	leaf
lima bean (*Phaseolus lunatus*)	vine	beans
new Zealand Spinach (*Tetragonia tetragonoides*)	herb	leaf
oat (*Avena sativa*)	grass	Seed, biomass
okra (*Abelmoschus esculentus*)	herb	fruit
peanut (*Arachis* spp.)	herb	root
soybean (*Glycine max*)	herb	Seed, biomass
spearmint (*Mentha spicata*)	herb	leaf
sunflower (*Helianthus annuus*)	herb	seed
sweet potato (*Ipomoea batatas*)	vine	root
tomato (*Solanum lycopersicum*)	herb	fruit

Permanent ground cover

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topography	Soil
beach pea (*Vigna marina*)	vine	leaves, seeds	20–200	20–2500	3	3	1, 2, 3, 4	a, c, d
lemon grass (*Cymbopogon citratus*)	herb	heart	50–200	0–4000	5	4	1, 2, 3, 4	a, b, c, d
Okinawan spinach (*Gynura bicolor*)	herb	leaf	40–180	0–3000	2	2	1, 2, 3, 4	a, b, c, d
perennial peanut (*Arachis pintoi* or *A. glabrata*)	herb	root	50–240	0–3000	0.5	1	2	a, b, d
sissoo spinach (Alternanthera sissoo)	herb	leaf	40–180	0–3000	2	2	1, 2, 3, 4	a, b, c, d
sweet potato (*Ipomoea batatas*)	vine	root	20–200	20–4500	1	3	2, 3	a, b, c, d

Biomass/cover crop

Common name (*Genus species*)	Habit	Products	Rainfall (inches)	Elevation (feet)	Canopy height (feet)	Canopy diam. (feet)	Topography	Soil
peanut (*Arachis* spp.)	herb	root	50–240	0–3000	0.5	1	2	a, b, d
Guinea grass (*Panicum maxima*)	grass	biomass	15–180	0–2500	4	2	1, 2, 3, 4	a, b, c, d
elephant grass (*Pinnesetum* spp.)	grass	biomass	40–200	20–2500	6	1	1, 2, 3, 4	a, b, c, d
oats (*Avena sativa*)	grass	Seed, biomass	40–150	700–7000	3	1	2	a, b, d
lablab (*Lablab purpureus*)	vine	Seed, biomass	40–160	20–3000	12	2	1, 2, 3, 4	a, b, c, d
Sudan grass (*Sorghum bicolor* var. *sudanese*)	grass	Seed, biomass	40–200	0–2500	10	2	1, 2, 3, 4	a, b, c, d
vetiver grass (*Chrysopogon zizanioides* var. 'sunshine')	grass	leaves, oil	35–200	20–3000	7	5	1, 2, 3, 4	a, b, c, d
Sunn hemp (*Crotalaria juncea*)	shrub	biomass	20–200	20–2500	6	4	1, 2, 3, 4	a, b, c, d
soybean (*Glycine max*)	herb	Seed, biomass	40–200	20–2500	4	4	1, 2, 3, 4	b, c, d
buckwheat (*Fagopyrum esculentum*)	herb	Seed, biomass	40–200	20–4000	1	1	1, 2, 3, 4	a, b, c, d
daikon radish (*Raphanus sativus* var. *longipinnatus*)	herb	seed, root	30–180	20–4000	3	2	1, 2, 3, 4	a, b, c, d
cow pea (*Vigna unguiculata*)	vine	leaves, seeds	40–200	20–2500	3	3	1, 2, 3, 4	a, b, c, d

Example species selection

For a site with 80 inches of annual rainfall, elevation of 200 ft above sea level, flat land, and loam soils, the following example species may be selected. Additional species may be included, but this list is left relatively short, as it is used in the "Cost/benefit analysis" in Chapter 7.

Lifespan	Height category	Crop
Long-term	Emergent	coconut
Long-term	High	breadfruit
Long-term	Medium	banana
Long-term	Medium	cacao
Medium-term	Emergent	papaya
Medium-term	Medium	kava
Medium-term	Low	pineapple
Medium-term	Low	taro

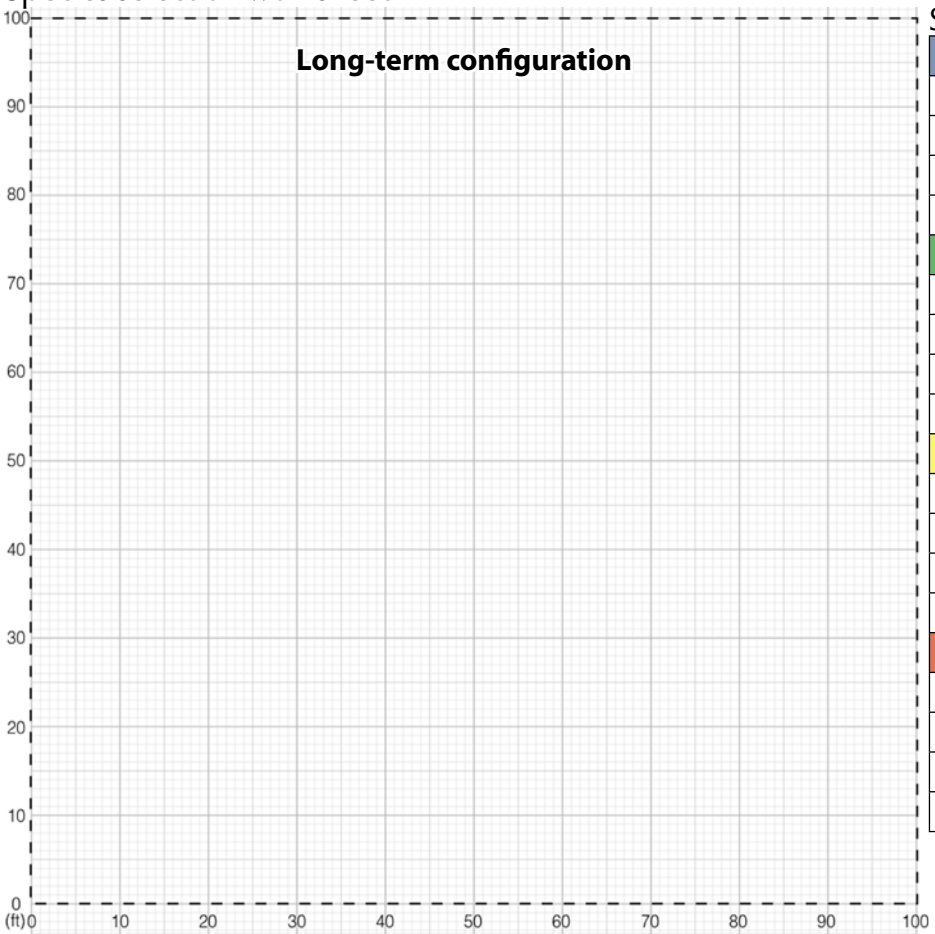
Further research on selected crops gives a better sense of the production life of each crop as well as their managed sizes. The table below gives further information for the eight crops selected.

EXAMPLE

Crop characteristics for planning purposes (adapted from Elevitch 2011).

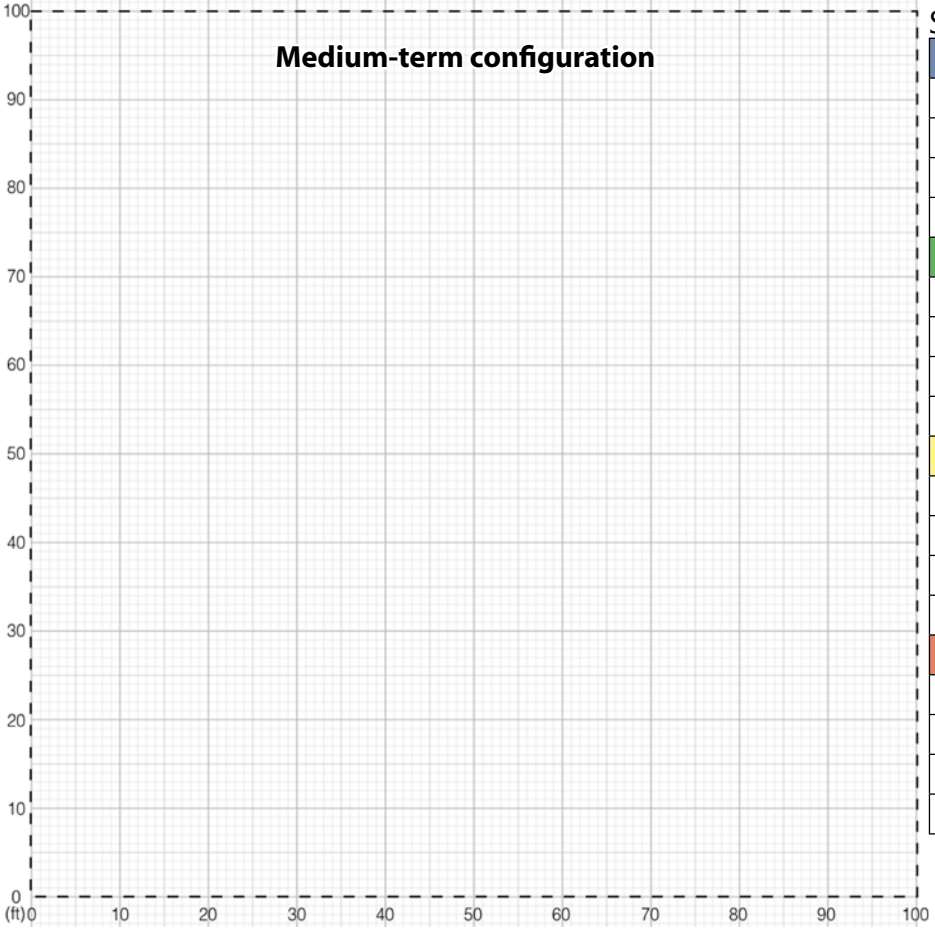
	Propagation material	Crop production life cycle	Size
Banana (short cultivar)	Sword sucker	Begins in 12–18 months, can continue for many years if managed	For this system, select cultivars of about 5 m (16 ft) in height
Breadfruit	Small field-ready tree from tissue culture, root sucker, air layer, etc.	Begins in 3–4 years, with commercial quantities in Year 5 with productive life of 50+ years	Pruned to stay at height of 5–8 m (16–26 ft) and canopy diameter of 5–7 m (16–23 ft)
Cacao	Grafted seedling	Begins in Year 3 and continues for decades	Pruned to 3–4 m (10–13 ft) in height and canopy diameter
Coconut	Seedling (cyclone-resistant dwarf cultivar for drinking nuts)	Begins in Year 6 with productive life of 40–50 years	Can reach 20 m (65 ft) in productive life with canopy diameter of 10–12 m (33–40 ft)
Kava	Rooted stem cutting	Entire plant harvested in 2–4 years	Up to 3 m (10 ft) tall and 2 m (6.5 ft) canopy diameter
Papaya	Seedling or direct sow	Fruiting begins in 12–18 months with 2–3 years of production before removal	Can reach 10 m (33 ft) tall × 2 m (6.5 ft) in width, but is usually removed at about 5–6 m (16–20 ft) tall
Pineapple	Crowns, slips, or suckers	Fruiting begins in 12–18 months with a productive life through Year 4	Plants can reach 1.5 m (5 ft) in height and 1 m (3.3 ft) in diameter
Taro	Setts (20–30 cm [8–12 in] of stem and top of corm)	Harvest of entire plant at 6–12 months, depending upon cultivar	Reaches 1–2 m (3.3–6.5 ft) in height and canopy diameter

Species selection worksheet



Species list

Long-term emergent
Long-term high
Long-term medium
Long-term low



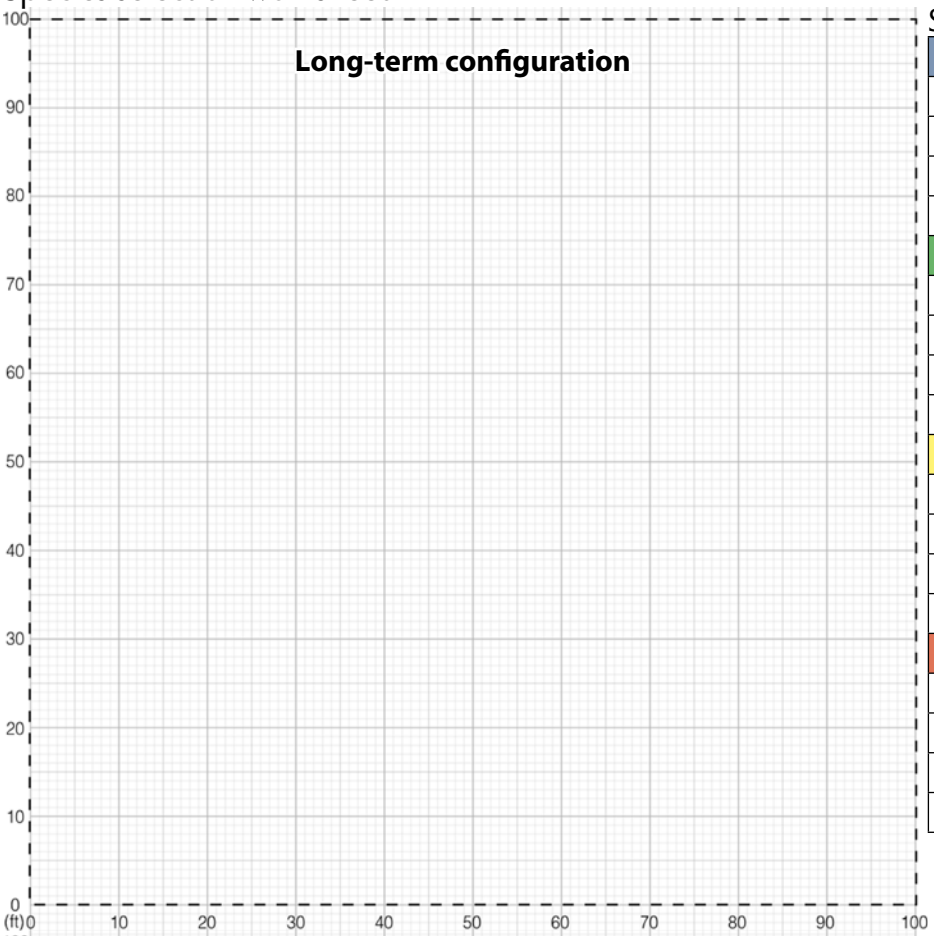
Species list

Medium-term emergent
Medium-term high
Medium-term medium
Medium-term low

WORKSHEET

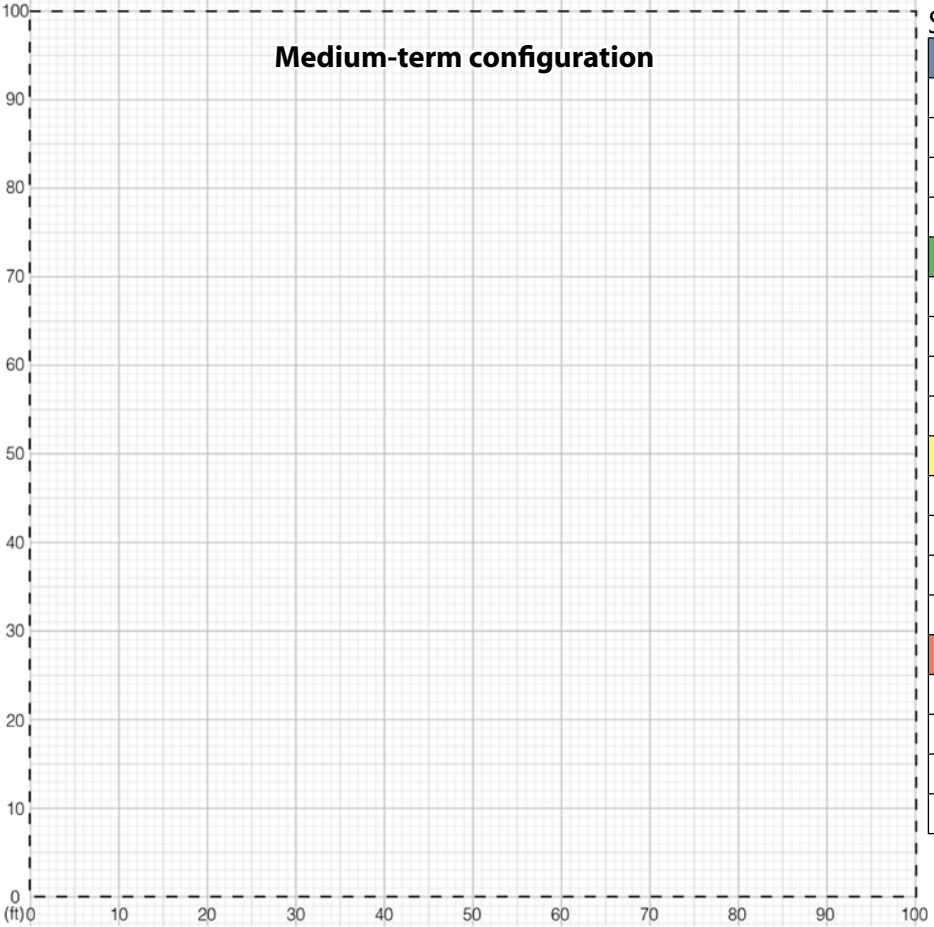
WORKSHEET

Species selection worksheet



Species list

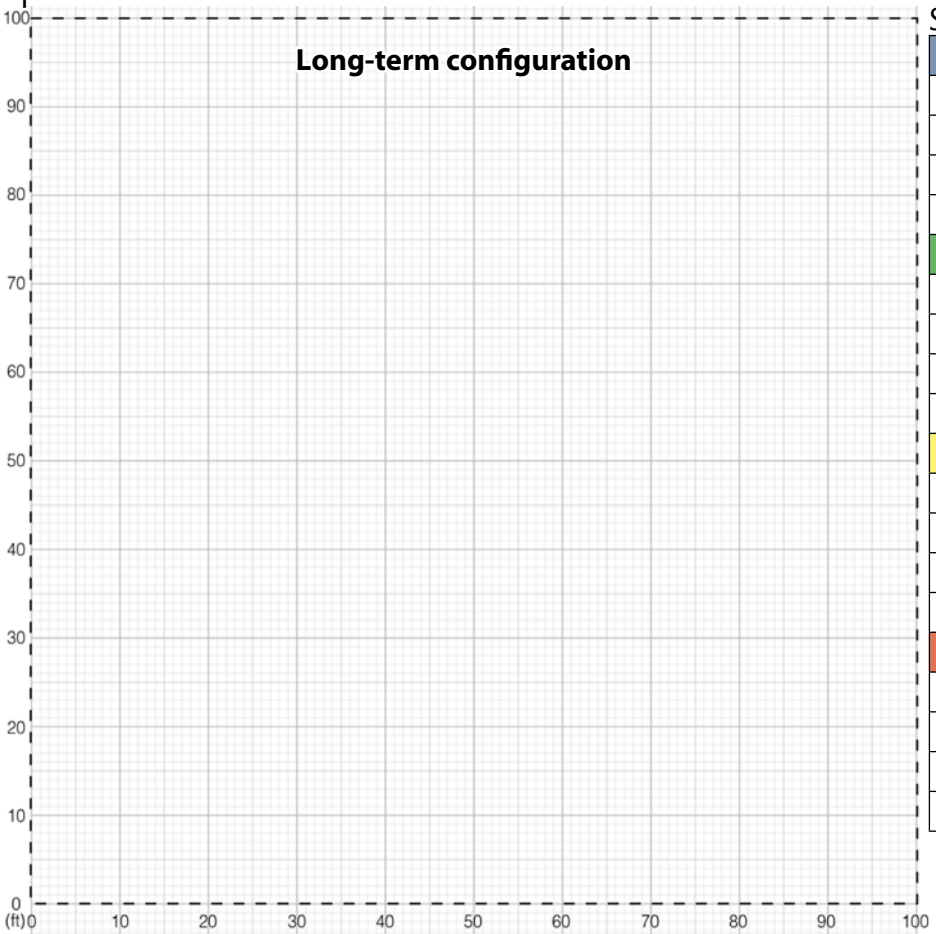
Long-term emergent
Long-term high
Long-term medium
Long-term low



Species list

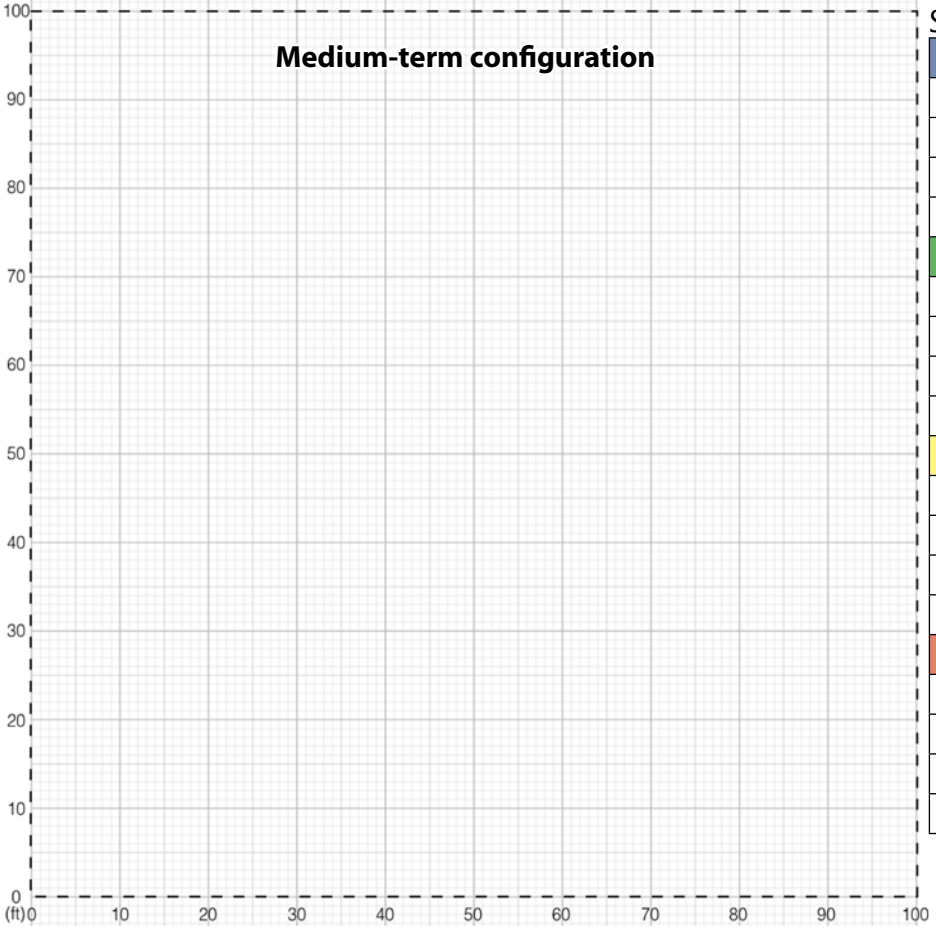
Medium-term emergent
Medium-term high
Medium-term medium
Medium-term low

Species selection worksheet



Species list

Long-term emergent
Long-term high
Long-term medium
Long-term low



Species list

Medium-term emergent
Medium-term high
Medium-term medium
Medium-term low

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