BREADFRUIT GUIDE: PREPARATION

Module 2 contains an overview of needs when establishing a smallholder breadfruit agroforestry orchard, including site evaluation and preparation, choice of varieties, spacing and complementary / cover crops. It also helps guide research into the cost of various inputs, data needed for the financial spreadsheet. The model will make some assumptions about how your operation will improve over time (accounting for extreme climatic events), then annual fruit yields as your trees mature and fruit yields are maximised.

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About Us

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1.0 Site evaluation and preparation

Site evaluation is an essential activity. If you already have a farm then you will likely know your site and what is needed to make it work for breadfruit. In evaluating your site you need to consider the following:

- What is the condition of your soil – fertility, drainage, etc?
- Is drainage needed or will mounding of trees suffice to reduce waterlogging?
- Are drains and drop structures needed to minimise soil erosion
- Should windbreaks be established?
- Should an irrigation system be installed?
- Are you converting from a monoculture or degraded forest system to an agroforestry system/orchard system involving intercropping; what work needs to be done to make the change?
- Is there any need for roads, pathways or any other structures?
- Do you need additional machinery, equipment and labour to complete this work?

Consider these questions carefully, taking into account the information provided in Module 1 and below in Table 1, regarding the growing conditions preferred by breadfruit and also in the key documents connected with this module.

Table 1: Acceptable and ideal environmental conditions for breadfruit

Environmental conditions	Acceptable range	Ideal range
Elevation	0-1500 m depending on latitude	Below 600-650 m
Mean annual rainfall	1500-3000 mm but trees can yield regularly with 1000mm	1525-2540 mm
Rainfall pattern	-	Prefers bimodal pattern (or uniform with summer maximum)
Dry season (consecutive months with <40 mm rainfall)	3-6 months depending on cultivar and soil depth	No dry season
Mean annual temperature	15-40°C	21-32°C

Mean maximum temperature of hottest month	32-38°C	-
Mean minimum temperature of coldest month	16-18°C	-
Minimum temperature tolerated	5-10°C. At low temperatures, can get leaf and shoot drop, no fruit & crown dieback.	Above 10°C
Soils	Light & medium texture, free-draining, pH 6.1-7.4	Deep, fertile & well-drained.

With the changing climate and increasing occurrence of climate extremes, it is important to be aware of breadfruit's environmental tolerances (Table 2) so you can make decisions about windbreaks, drainage and shade requirements. It is unlikely that increasing temperature will have too much impact on breadfruit at least up to a 2°C increase however if heat stress is accompanied by low rainfall, then fruit drop and smaller fruit may become problems.

Table 2: Breadfruit's environmental tolerances

Environmental variable	Breadfruit tolerance
Drought	Can withstand drought for a few months but will prematurely shed fruits.
Shade	Young trees prefer 20-50% shade but can be grown in the full sun.
Waterlogging	Tolerates waterlogged soils for only brief periods. Trees can die when standing in water for a few days (or less in brackish/salt water associated with king tides)
Salt spray	Some cultivars are more tolerant than others. Generally trees can tolerate spray for brief periods but leaves will turn yellow and drop off.
Wind	Branches break and shed in heavy winds, especially if fruit load is heavy, but shoots and branches quickly regrow.

Cyclones	Trees are seldom uprooted by cyclones (except for direct hit from the most intense Category 5 cyclones), with damage usually confined to the outer branches. Shoots and branches quickly regrow. This was confirmed with category 5 cyclones in Fiji and Vanuatu - Winston and Pam respectively.

Each site is unique and therefore no specific recipe can be given for what to do. If there is vegetation on the site decisions will have to be made regarding what should be cleared and what is best retained. It is recommended to retain some tree cover (especially any useful trees, such as nitrogen fixing, timber and/or fruit trees) to provide wind protection and shade in the establishment phase. The land should be sheltered from strong or persistent winds which may be experienced on windward sites that are close to the sea. Breadfruit can be used as a windbreak, but the trees can suffer considerable branch breakage and windthrow (especially if using marcotted or root sucker-derived plants) during intermediate and severe cyclones. It is preferable to have multi-layered multispecies windbreaks surrounding and through the breadfruit agroforestry orchard system, for example, with *Casuarina equisetifolia* (nokonoko), *Agathis macrophylla* (dakua madre, kauri) or *Agathis robusta* in Tonga, and *Atuna racemosa* (makita).

The soil conditions will have to be assessed for any compaction or other physico-chemical characteristics that might have changed as a result of previous land uses – soil testing might be needed if you have any concerns about soil nutrient deficiencies. Mowing and tilling can be a cost-effective way to prepare the site if conditions allow. Land which has been under sugar cane cultivation may have a build-up of herbicides, such as diuron, and need to be fallowed for several years before being suitable for cultivation of broad-leaved crops such as breadfruit.

The Breadfruit Agroforestry Guide (P42/43) gives an example of a site evaluation where a breadfruit monoculture is being converted into a multi-story agroforest. The evaluation shows all the different parameters that need to be considered in a site evaluation.

2.0 Choice of varieties and propagation

"How do I decide which variety/varieties to grow?"

Large diversity of varieties exists which provides growers with opportunities to select for variability in fruiting times (thereby prolonging the fruiting season), productivity, and traits such as nutritional qualities, keeping qualities, fruit size and texture. Some varieties have larger fruits and/or are firm-fleshed, which makes them more suitable for many

value-added products; whereas others are softer which means they are easier to cook, and process into dough. There is a wealth of information on breadfruit diversity which can be found in the key documents. The size of the market, prices and pattern of demand are also relevant to the choice of variety because issues such as productivity and seasonality become important.

Table 3 below shows Fiji's main commercial breadfruit varieties.

Table 3 Fiji's main commercial breadfruit varieties

Variety name and leaf	Fruit	Comments on eating and keeping qualities
Uto dina 	Oval-shaped & can weigh up to 2-3kg per fruit. Seedless  	Traditional variety grown throughout Fiji Islands. Shelf life of 3-5 days. Good eating quality when boiled.
Uto buco ni Samoa 	Shape and size varies; either oval weighing up to 2-3kg per fruit or round weighing up to 2kg. Yellow flesh with 1-2 seeds  	Samoan variety with a few characteristics of traditional *buco* variety. Good eating quality but should be harvested when fully mature due to problem with heavy latex flow if harvested immature. Shelf life of 3-4 days

Uto loa/ Vonu 	Can weigh up to 3-4kg per fruit. Seedless variety with good flesh content  	Eating quality similar to *uto dina* when boiled or roasted. Better harvested when fully mature due to heavy latex flows if harvested immature. Shelf life of 2 days
Uto koga 	Round shape white-fleshed variety weighing up to 2-3kg per fruit. Similar flesh content *to uto dina*  	Tastes best when boiled. Good eating quality – 1 fruit can feed 3 people. Good fruiting season with shelf life of 3-4 days.
Uto buco 	Seedless variety weighing up to 5-6kg per fruit with more flesh content than other varieties  	One of the biggest traditional varieties. Good eating quality. Can feed 5 members of the family. Shelf life of 4-5 days.
Balekana	Small size white-fleshed fruit, round-oval in shape weighing 500g-1kg	Smallest variety but very good eating quality, best when boiled or roasted. Makes flour of

		attractive appearance (as with all white-fleshed varieties). Shelf life 4-5 days

Nature's Way Manual lists the characteristics that are needed for breadfruit to be suitable for fresh export:

- Good eating qualities when harvested at the mature green stage – especially as perceived by the Samoan ex-pat community (the main fresh export market).
- Tolerance at the mature green stage of ripeness to the High Temperature Forced Air (HTFA) quarantine treatment;
- Smaller uniform size (when mature) required for quarantine treatment, packing, shipping and marketing; and,
- Fruiting season(s) that would allow for extension of the marketing period.

To date two Fiji varieties, *uto dina* and *bale kana*, meet these requirements (see Fig. 11, Module 1). Samoa exports two varieties – *ma'afala* and *puou*. *Ma'afala* appears to be similar to *bale kana* in fruit appearance, eating and keeping qualities. *Puou* is more similar to *uto dina*.

You will need to decide for what purpose you are growing breadfruit so that you can pick the most suitable cultivar(s). If you are unfamiliar with breadfruit then you should seek expert advice.

The Breadfruit Agroforestry Guide provides information about fruit size, quality, seasonality, fruit texture (firmness) and tree habit and special growing conditions. Some examples of varieties suited for specific purposes are also provided. Fruit size can vary depending on the age of the tree and variety with fruit weights varying between 0.5 to 3.5 kg. Larger fruit can provide advantages for processing, but the core size of these fruits can be relatively large in some varieties of similar size and weight, reducing the edible portion.

Fruit quality also varies significantly. Flesh texture can be dense, smooth, starchy, creamy, gummy, mealy, fibrous, or stringy, depending primarily upon the structure of the fruit and

the species. The firm flesh of dense starchy varieties makes them suitable for many value-added products, such as chips and fries. Softer varieties, such as *ma'afala* and *bale kana*, are more easily cooked and processed into a dough, which can be used immediately or frozen for future use as a base for baked goods, bread and snack foods.

"How is breadfruit propagated?"

Breadfruit can be propagated by root suckers (shoots that grow from roots), root cuttings (cut pieces of roots that will grow into plants) and aerial (air) layering or marcotting (inducing roots from a young green branch about 1-2 cm in diameter). Root suckers (Figs. 1a-1d) are the traditional and most common method practiced on small farms. The roots are wounded to stimulate production of more suckers at the damaged areas. Rooted suckers are removed attached to a piece of the parent root, and transplanted. Survival rate can be as low as 20%, but very high (approaching 100%) for experienced practitioners and when rooted suckers are first transferred into nurseries with some protection, shade and misting or other regular watering system. Some breadfruit varieties produce considerable numbers of root suckers (such as bale kana) while others (such as uto dina) produce few or no suckers.

Figure 1a: Select healthy, juvenile root sucker

Figure 1b: Sow in rich potting mix

Figure 1c: Regrowth of shoots

Figure 1d: Root sucker planted in the field

When selecting juvenile root suckers, 75% of leaves are to be removed. Root suckers must not be allowed to dry out as drying decreases viability. The nursery must have 70% intense shading with additional coconut leaves to keep the root sucker cool during the seedling phase. This method is the fastest propagation method with time taken to raise plants between 4 – 6 months.

Figure 2 Breadfruit root cutting nursery in Fiji (Sabeto Valley)

Figure 3 Marcotting breadfruit (Sabeto Valley, Fiji)

Higher success rates are achieved with root cuttings which are taken from mature trees at the beginning of the rainy season, with root sucker segments planted into a nursery (Fig. 2) or favourable environment (part-shaded with moist soil). Root cuttings can suit mass propagation. Root cuttings can take 9-12 months before they are ready for field planting.

Aerial layering/marcotting (Fig. 3) produces a large plant that is quickly ready for transplanting to the field and is capable of achieving quick fruiting. However, trees initially have weaker root systems which can make the trees more susceptible to uprooting when there are strong winds and cyclones. Further, few plants can be produced from each parent tree and some varieties are not amenable to marcotting. This method is appropriate for limited and quick plant production. It requires a large plant population where re-growth is common (upright shoots give better results than laterals). This method is labour intensive compared with other propagation methods and requires an additional further nurturing of two months on the tree and in the nursery. Figures 4a-4f (from the Nature's Way Breadfruit Manual) outlines the steps involved in marcotting (more detail can be found in the Manual).

4a: Remove strips of bark from newly-developed shoots (not one that has flowered or fruited).

4b: Continue bark removal right around the stem. Go to next stage immediately

4c: Hold a piece of clear plastic, cut to a convenient size. Apply the damped soil/peat moss/ coconut coir mix evenly around the stem as illustrated.

4d: Encase the mix with the plastic wrapping. Squeeze the mixture firmly into shape. Adjust the wrapping so that it holds the soil mixture tightly.

4e: Using a pre-cut rubber strip secure plastic sleeve at top and bottom. Rubber allows branch to expand as it grows.

4f: During next few months roots will develop. The branch can be cut below the bottom tie and rooted cutting planted in a nursery area where it can be watered and cared for. After six weeks it should be ready for planting.

The manual for the growing and marketing of breadfruit for Fiji and other Pacific islands describes how to carry out each of these methods. A video from the Caribbean demonstrates root cuttings and can be found on this link: https://www.youtube.com/watch?v=k2WHyHtMDEo

Tissue culture (micropropagation) techniques have been developed for some cultivars of breadfruit providing vigorous, disease-free plants that can begin bearing fruit in 2.5 to 3 years.

The cost of breadfruit propagule (planting material) is approximately FJD 5-10 depending on method of propagation and size. It is recommended that you propagate your own breadfruit plant locally to keep costs down, and ensure better quality and known planting stock. Note: larger plants produced through marcotting often do not travel well due to rough roads/shaking and wind damage. Prior to road transport breadfruit plants need to be very well watered, and are best transported on cloudy/rainy days, and/ or in a covered van, and/or at low speeds to reduce desiccation and wind damage.

If you are going to produce your own planting material you will need to consider the cost of a nursery as root suckers and cuttings should be planted in a damp, shaded area in the nursery.

3.0 Complementary crops

Wide variety of annual and perennial crops can be grown with breadfruit and can be divided into short-term (1-3yrs), medium-term (3-5yrs) and long-term (10+yrs) crops depending on their life cycles and time to maturity. An agroforestry system can also be comprised of several layers if you look at the system vertically; the height of the crop indicates its position vertically in the system. The number of levels in an agroforestry system can vary from five levels, for example, ground (0-1m); low (up to 2m); medium (2-5m); tall (5-8m); and over-story (8+m). The sketch below (Fig. 5) from the Breadfruit Agroforestry Guide shows

the layers multi-storey agroforestry – with breadfruit occupying the taller layer once it reaches a productive age.

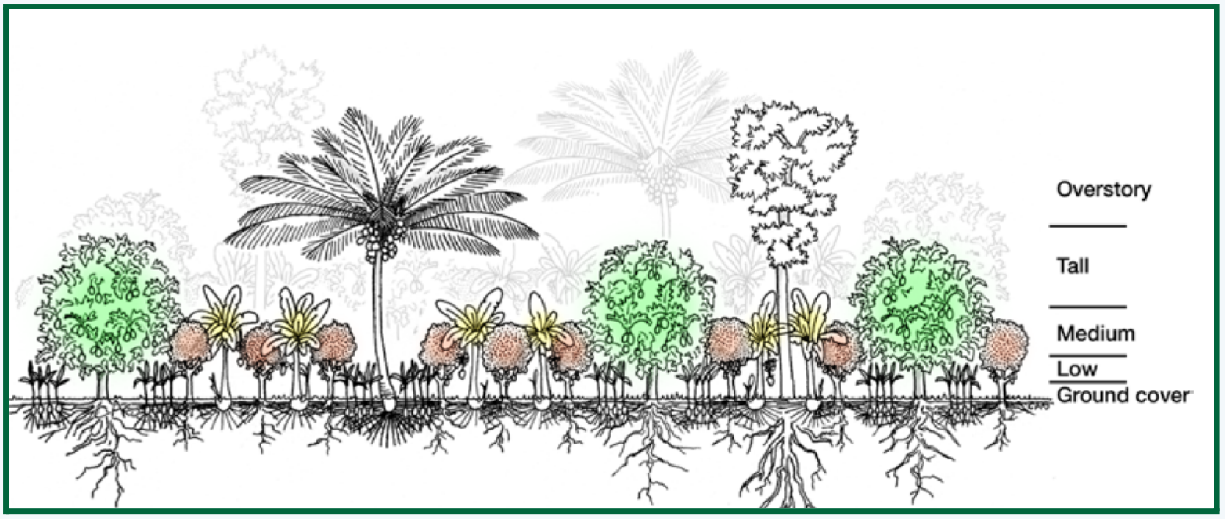

Figure 5 Layers of a multistory agroforest

The following table (Table 4), extracted and adapted from a more detailed table (Table 3.1) in the Breadfruit Agroforestry Guide, provides a list of crops which can be grown in such a system.

Table 4 Short-, medium-, and long-term crops compatible with breadfruit

Length of cycle	Height & level in agroforestry system				
	Ground (0-1m)	Low (up to 2m)	Medium (2-5m)	Tall (5-8m)	Over-story (8+m)
Short term (1-3yrs)	Ginger, kumala, vegetables, taro 	-	Cassava, sugarcane	-	Yam (seasonal)

Medium term (3-5yrs)	Pineapple 	Kava, giant taro, bele/ island cabbage 	Banana, papaya 	Banana, plantain	-
Long term (10+yrs)	Turmeric	Black pepper, vanilla, coffee, kava 	Cacao, noni, soursop, coffee	Breadfruit, mango, sandalwood, avocado 	Coconut, various timber species including bamboo, betel nut 

Alternatively you can decide on a less complex system such as described in the Breadfruit Production Guide (P8/9) –

Ground cover	Understory	Middle story	Over-story
Pinto peanut/mucuna bean	Various annual vegetables, pineapple, taro, yam, pumpkin and squash	Banana, kava, papaya, cacao, noni	Coconut, various timber species

The Agroforestry Guide gives an example of a planting layout at 3 months, 18 months, and 5 years, where the crops are pineapple, taro, banana, breadfruit, papaya, kava, cacao and coconut. A side view of this example of this planting layout from the Agroforestry Guide is shown below (Figs. 6a-c). Figures 6 and 7, Module 1, show breadfruit grown with pineapple (Fig. 6) and papaya (Fig. 7) in Fiji.

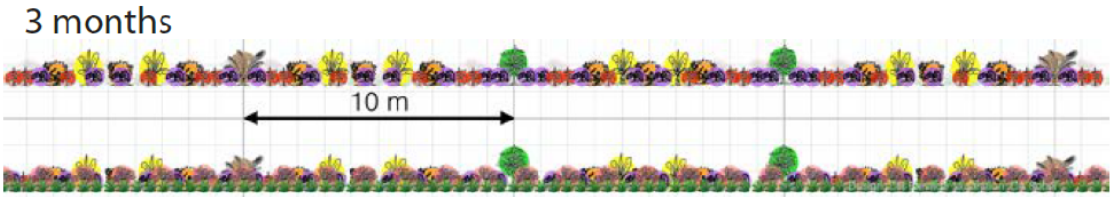

Figure 6a: All crops planted simultaneously & canopy closure achieved in 3-4mths within crop rows.

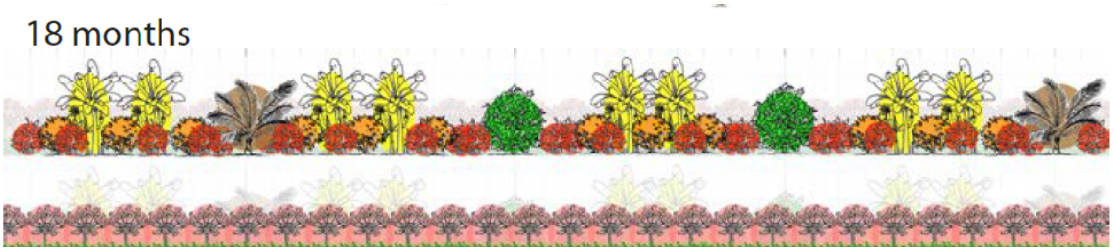

Figure 6b: Short-term taro crop has been harvested & banana, papaya & pineapple have begun to produce.

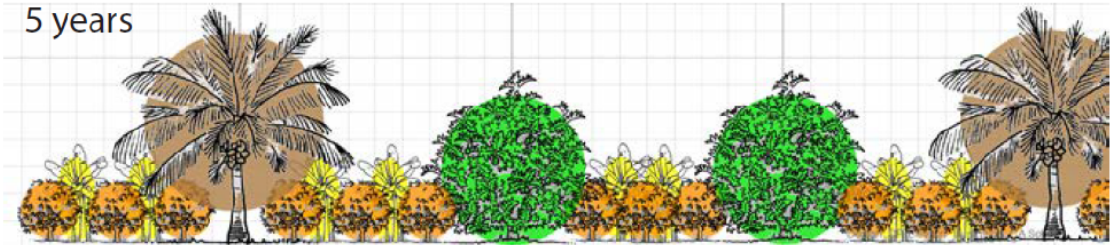

Figure 6c: Papaya & pineapple have been harvested & removed, kava plants have been harvested & the 4 remaining productive crops are breadfruit, coconut, cacao and banana.

The initial planting density is high but crop numbers are reduced over time as the short- and medium-term crops complete their productive life cycles.

"What do I need to consider when selecting crops for my site?"

Crop selections have to take into account the following:

- Suitability for site conditions (rainfall, temperature, soils etc.)
- Area/space available
- Availability and quality of plant material
- Current and anticipated market demand
- Personal preferences

- Family and community subsistence needs
- Complementarity of the selected crops with regards to markets

4.0 Cover crops

Cover crops are planted at ground level and when permanent, are groundcover crops. Groundcover crops are especially useful after site preparation for establishing a new agroforest by providing organic material and wind protection for the young new crops. They fill the space between crop plants and within crop rows, providing a layer of organic mulch that inhibits erosion and reduces moisture loss and nutrient leaching. As groundcover crops also suppress weeds, labour costs for weed control are also reduced. Ongoing research in Hawai'i suggests that cover crops enhance the fitness and production of the breadfruit trees with significantly higher yields where cover crops existed. In Hawai'i pinto peanut has proven a particularly valuable cover crop (Agroforestry Guide). In Fiji, Tonga and Samoa mucuna beans have been successfully utilised as a cover crop – enhancing soil fertility and controlling weeds.
(http://digilib.library.usp.ac.fj/gsdl/collect/usplibr1/index/assoc/HASH421b.dir/doc.pdf)

Groundcover crops are selected for shade tolerance and low growth so that they do not interfere with crop growth or result in extra maintenance work. They should also be inexpensive and easy to propagate. Groundcover crops need to be selected on the basis of the local site conditions. Table 3.2 in the Breadfruit Agroforestry Guide (P26) suggests a number of groundcover crops.

5.0 Spacing – number of trees and plants

Traditional breadfruit agroforests are generally not well-suited to commercial operations, mainly because the scattered planting of such agroforests makes management activities difficult and inefficient, while tall trees make fruit harvesting time-consuming and potentially dangerous.

As a result, such agroforests usually receive less management than is necessary to optimize both the quantity and quality of crops necessary for profitable production. Traditional systems must be modified to meet the requirements of a commercial system. The modifications are namely:

- A systematic layout pattern in rows that streamlines management operations, facilitates harvest, and allows mechanization (if appropriate)
- Management techniques such as regular pruning that improve overall health and productivity of all the crops growing together to maximise yield and quality, and make fruit harvesting easy with minimal need for climbing (using step ladders and poles).

Figure 7 taken from the Breadfruit Agroforestry Guide schematically illustrates the difference between the configuration a traditional agroforestry system (left) and more commercial agroforestry orchard (right). Organizing the planting of the crops in rows, often along curves that follow the contours can minimise soil erosion and increase the efficiency of crop management including harvesting.

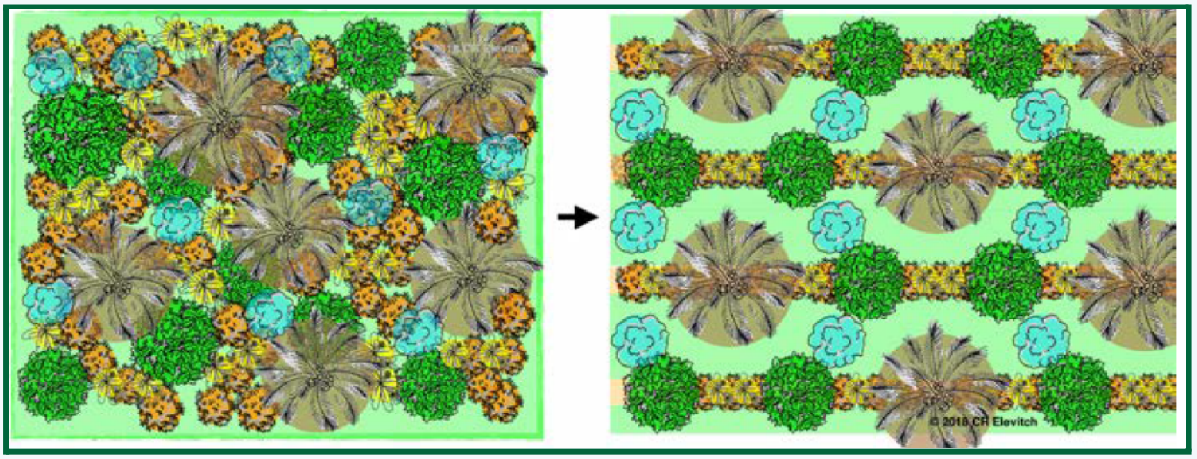

Figure 7: Scattered planting of traditional agroforests compared with organizing crops in rows

"What do I need to consider when selecting crops for my site?"

Spacing is determined by several factors – firstly and most obviously the land area, but also the pruned size of the trees and desired number of breadfruit trees and other crops in the plantation. Once you have selected the breadfruit cultivars and the complementary crops, and know the growth rate of the crops, you can determine the most appropriate spacing. Each breadfruit tree should have ample space around it for air circulation and light penetration into the canopy to maximise yield and minimise disease. Pruning size can vary depending on the desired harvest height and the size of the neighbouring crops. If you have

a small tree size, this will make harvesting easier but may reduce the total fruit production per tree. Smaller canopied trees also make the trees less susceptible to breakage of large branches and wind-throw during strong winds/cyclones.

The Breadfruit Agroforestry Guide describes the spacing and harvesting times for a system which incorporates breadfruit, coconut, cacao, kava, pineapples, papaya and taro. The Guide has used as reference a pruning height of 5m and canopy diameter of 5m for breadfruit. Assuming pruning every 12-18 months to this height, trees are expected to grow to a maximum height of about 8m and canopy diameter of 7m before the next pruning. Working out a productive sequence of crops to fill the available space is one of the biggest challenges of designing your agroforestry system. But you will need this information for your business plan.

Figure 8: An irrigated breadfruit orchard intercropped with vegetables (Lautoka, Fiji)

As discussed in Module 1 orchards can either be planted in a block or be linear, for example, to mark a farm perimeter. The size of an orchard block in Fiji typically ranges from 0.5-2 ha acres: there are 123 trees per ha when planted using a spacing of 9 x 9 m.

The following questions take into account what has been presented in this module. You should consider them carefully as the answers will provide the information you need for the business plan.

Questions	Answers
Will your site need any modifications to improve drainage?	Y / N
Is the site particularly exposed presenting a risk at times of strong winds? Is there a need to establish a windbreak?	Y / N
Will you have to install irrigation? Will this be required continuously or just for the initial establishment of the trees?	Y / N
Is there a need for roads, pathways or any other infrastructure?	Y / N
Do you have the necessary machinery and equipment to prepare the site or will you have to hire or purchase what is needed?	Y / N
What will be the labour input for preparing the site?	Y / N
Soil conditions: do you know the soil or will you have to carry out soil testing to assess soil nutrient status? Would you expect to carry out regular soil testing as part of your nutrient management practice?	Y / N
What market are you targeting for the breadfruit – and therefore what breadfruit cultivars do you expect to be growing?	Y / N

How many plants will you need and where will you get them from? What numbers are required?	Y / N
If you are producing your own plants, do you need to construct a basic nursery?	Y / N
What crops are you going to grow with breadfruit? Will you provide your own planting material for these crops or will you source from elsewhere? If the latter, you need to identify your source and cost.	Y / N