BAMBOO AGRIBUSINESS COMPENDIUM

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PARDI2


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The Bamboo Compendium: an overview

Bamboos offer considerable potential for rural development in the South Pacific. Globally there are about 1500 species and numerous varieties. Different species and varieties of bamboo offer major potential to provide building materials, pulpwood, handicrafts, edible shoots, livestock fodder, charcoal and environmental protection: they are a vital and often missing component in South Pacific Islands agroforestry systems.

Bamboo grows in many of the Pacific island countries, being particularly abundant in the larger islands. In Fiji the Ministry of Forestry, together with SPC and the Indonesian Embassy, have been conducting training in bamboo utilisation and handicrafts over many years. In Solomon Islands bamboo is more commonly used in building, for purposes related to farming, and to manufacture their renowned panpipe instruments. However, bamboo industry has failed to gain momentum in Fiji—and elsewhere in the Pacific—partly because the few native and naturalised species do not have especially desirable properties for utilisation as building material and for human food. The necessary quantities of plants of desirable clumping bamboo species and varieties have not been imported, propagated and distributed to farmers. Also training programs have often neglected a more holistic approach including appropriate technologies for preservation of the starch-rich, widespread and common introduced bitu ni vavalagi (Bambusa vulgaris).

The right species and varieties of bamboo have tremendous untapped potential throughout the South Pacific including in agroforestry systems and as associates with our major timber species. For example, mahogany planted adjacent to bamboo will develop an excellent straight long single form, while sandalwood grows well near to bamboo possibly due to the protection afforded. Bamboos can also compete well with environmentally invasive pest trees, such as African tulip (Spathodea campanulata), and play a major role in agroforestry systems as windbreaks, and as a permanent crop for steeper slopes to provide soil protection and reduce sediment runoff, which occurs when cassava and ginger are grown in such areas. The best varieties of bamboo also have considerable and untapped export market potential, for example as charcoal and edible shoots to East Asia.

This Bamboo Compendium was developed to provide practical information for prospective agribusinesses, particularly in the Pacific Islands, about aspects of bamboo use, production and marketing.

Module 1

Before you start, gives an insight into bamboo—a woody grass—the varieties of bamboo species suited to the South Pacific Islands for different uses. It also highlights issues to consider before embarking on bamboo farming and agribusiness.

Module 2

Establishing your bamboo plantation or agroforest, contains an overview of what is needed to establish a smallholder bamboo plantation or agroforest. This module aims to provide enough detail to help prepare the data needed for a financial spreadsheet for different bamboo-based agribusiness opportunities.

Module 3

Planning your bamboo nursery business, provides the information that is needed to develop a commercial bamboo nursery business in the Pacific Islands.

Module 4

Mixed bamboo smallholder farming business, focuses on developing a mixed farming business producing edible shoots and timber/poles from two promising bamboo species in Fiji and other humid, tropical zones in the Pacific Islands.

Module 5

Production of bamboo charcoal and biochar, presents a case study of the production of charcoal and biochar from bamboo as a commercially-promising and environmentally friendly business.

Module 6

Bamboo markets and marketing, provides an overview of the market opportunities and marketing for bamboo, including the different value chains in which bamboo products could be sold.

The final section of the compendium is a list of Bamboo references for further information about bamboo production, use and marketing, including links to useful websites, reference books, chapters and articles.

Acknowledgements

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About us

The Bamboo Compendium was funded by the Australian Centre for International Agricultural Research (ACIAR) through collaboration and engagement with AGB-2014-057 Pacific Agribusiness Research in Development Initiative Phase 2 (PARDI 2). PARDI 2 seeks to promote sustainable livelihood outcomes for Pacific Islands households through research and innovation, catalysing and informing a more vibrant, diverse and viable agribusiness sector.

The project spans 2017-2022, with a geographical focus on Fiji, Tonga and Vanuatu.

MODULE 1: BEFORE YOU START

Module 1: Before you start

This module provides an insight into the varieties of bamboo species suited to the South Pacific Islands for different uses. It also highlights issues to consider before embarking on bamboo farming and agribusiness.

1.0 About the bamboo plant

Bamboos are woody grasses that range in height from 0.5 m to 50 m, mostly from 8 to 25 m tall. The main structural component is the underground rhizome system from which the above ground stems—called culms—emerge. Culms are woody but hollow, except at the nodes, which are periodic ring-like thickenings all the way up the culm. The distance between nodes varies with species. Culms are usually very hard and contain large amounts of silica.

Bamboo flowers and seeds are rare. Many bamboos only flower after a long interval, for example 50-100 years, which is specific to a particular cultivar. All plants of the same bamboo variety will flower at the same time (or gregariously), set seed and die afterwards. Individual flowers are small, but borne in longitudinal inflorescences, and seeds of most bamboos are about the size of a grain of rice. Some tropical bamboos, such as *Schizostachyum* species, flower all the year, and the culms do not die.

Bamboos have one of two growth strategies. ***Clumping types*** grow by developing new culms (shoots) at the margin of the existing clump. Clumping bamboo types are the only species and varieties which should be cultivated in the South Pacific Islands, as they present a negligible risk of becoming environmentally invasive weeds. The other type of bamboo, ***Running Types***, may spread through long, running shoots of many meters and are near-impossible to control and contain. Running bamboos must never be introduced into the South Pacific Islands.

What is the expected productivity from bamboos?

The initial growth rate depends on the propagation mode (division, cutting, seed or tissue cultured plantlet), environment, management and species. Once established many types of bamboo are amongst the fastest growing plants in the world, with new culms elongating by more than one meter per day. They also shed large quantities of bracts, which, combined with shading and shallow fibrous rooting systems, provides excellent weed control.

Are there a lot of different varieties?

While there are many bamboo species and varieties that may be grown in the South Pacific, there are only a small number for which planting material will be available and which will yield good commercial returns.

This compendia will focus on two groups:

1. Native and naturalised species that are already growing in large patches in many Pacific countries,
2. Exotic species that have excellent growth and utilisation traits, which have already been introduced into the South Pacific and shown to have excellent adaptability.

Bamboo species that are native to the Pacific Islands, as well as naturalised and introduced (or exotic) species, along with their common name(s), description and uses, are listed in Table 1.

Table 1. Characteristics of commercially promising bamboo species for South Pacific

Pacific Islands native species

NAME	HEIGHT (M) & CULM DIAM. Ø	DESCRIPTION	PROPAGATION	FLOWERING	USES AND YIELD	NOTES
Nastus elatus New Guinea green bamboo, konya, PNG	"15–20 m ø 8 cm"	Tall erect bamboo. Internodes short 30 - 40 cm	Not known	Flowering sparsely or freely (not gregarious).	Most important native bamboo in PNG. Shoots can be eaten raw. Hollow stems sometimes used as water containers.	Light green culms turn yellow when older. Common in E. and W. Highlands of PNG.
Schizostachyum glaucifolium Polynesian bamboo; bitu dina, Fiji; 'ofe Samoa; kofe, Tonga)	"3–15 m ø 3.5–8 cm"	Culms dark green and thin walls (to 5 mm), long internodes- ≤ 100 cm. Slender branches above the tenth node	Offsets, culm and branch cuttings	Observed to flower sporadically in Fiji (not gregarious and not dying after flowering)	Building, wall panels, fishing materials, traditional medicine, and battens for sago palm roof thatch. Erosion control. New uses include as substitute for plastic drinking straws.	Native to Fiji and Samoa, likely Polynesian introduction into Tahiti (French Polynesia), Cook Islands and Hawai'i.
Schizostachyum tessellatum Solomon Is Bamboo	2-3 m	Culms thin walled.	Offsets, culm and branch cuttings	Flowers sporadically	Light construction for house walling, rafters and battens for affixing thatch; shelving and scaffolding, fencing and poultry pens;	Also fishing rods, nose flutes, pan pipes, yam stakes or trellising, makeshift spears, cooking and water containers.

Naturalised and commonly planted exotic species

NAME	HEIGHT (M) & CULM DIAM. Ø	DESCRIPTION	PROPAGATION	FLOWERING	USES AND YIELD	NOTES
Bambusa vulgaris common bamboo; bitu vavalagi, Fiji; 'ofe Fiti, Samoa; Fi'i kako, Solomon Is.	10–20 m ø 10–12.5 cm (near base)"	Medium sized bamboo, open clumps, internodes 25 - 35cm, culms often not straight bending outwards. Moderately thick walled. Varieties "Wamin" and "striata".	Offsets, culm and branch cuttings (easily established from cut portions of green culms)	Some reports of gregarious flowering, with occasional reports of sporadic flowering	Construction (including split and plaited into rough walls), furniture, handicrafts, tools (such fish traps and spear shafts), paper and pulp, erosion control, ornamental. 20 tonnes/ ha/year. Spacing 6(+) x 6 (+) m	Very adaptable species, good on poor or flooded land. 'Striata' - culm internodes a clear light yellow with a few dark green vertical streaks (common ornamental).
Bambusa multiplex (multi bamboo; dwarf bamboo; Chinese bamboo)	"2–4.5 m ø 1–2 cm	Low-growing, very dense, thin stemmed bamboo	Offsets, culm and branch cuttings	Flowers sporadically through the year	Hedges/ live fences/ windbreak, garden stakes, handicrafts, ornamental	Shoots are reported to be edible (Smith 1979)

Useful exotic species previously introduced into the South Pacific

NAME	HEIGHT AND CULM DIAM. Ø	DESCRIPTION	PROPAGATION	FLOWERING	USES AND YIELD	NOTES
Bambusa oldhamii Oldham's bamboo CI, F, FSM, K, N, S, T, W&F	12–18 m ø 10–15 cm	Medium-sized bamboo, dense upright clump, internodes 20 - 35cm long	Offsets, culm and branch cuttings	Not known - sporadic flowering observed occasionally	Excellent multipurpose - construction, woven articles, pulp, edible shoots, windbreaks	Grown commercially for its edible shoots
Bambusa textilis gracilis Weaver's bamboo CI, Fiji, W&F	9–15 m ø 3–5(+) cm	Medium-sized bamboo, internodes 25–60 (+) cm long, several cultivars and varieties known,	Offsets, culm and branch cuttings	Not known - sporadic flowering observed occasionally	Woven articles (excellent quality), ornamental. Spacing 5 x 5 m	
Bambusa tulda Bengal bamboo Samoa	16–23 m (7–28 m) ø 8–12 cm	Medium-large upright bamboo. Dull green internodes 30–60 cm long. Prominent side-branches on lower parts of culms.	Offsets, rhizome cuttings, culm and branch cuttings	Gregariously for 2 yrs in a cycle of 25-40 yrs Produces viable seed. Also flowers sporadically or in small groups, without an obvious cycle.	Construction (near solid culms/ strong timber), scaffolding, furniture, boxes, basketry, mats, household utensils, handicrafts and paper pulp. Edible slightly bitter shoots (best pickled first).	One of the most useful bamboos in India and SE Asia. Near solid culms and hence very strong timber.
Bambusa tuldoides Verdant punting pole bamboo Fiji	7–15 m ø 5 cm	Medium-sized bamboo. Thin walled culms. Internodes 30–50 cm long.	Offsets, culm and branch cuttings (rarely from seed)	Sometimes flowering gregariously more often sporadic flowering often seen with varying levels of mortality	Fishing rods and poles. Split canes used for weaving and handicrafts. Screen & hedges. Edible (young shoots) and traditional Chinese medicine.	
Dendrocalamus asper Asper bamboo Cook Is, Fiji, FSM, Kiribati, Niue, Palau, Samoa, Tonga	20–30 m ø 8–20 cm	Large bamboo, internodes 20–45 cm long with thick walls (11–20 mm)	Offsets, culm and branch cuttings	Not reported to flower gregariously (perhaps flowering at very long intervals)	Construction (culms are large). Also for good quality furniture, woven items, utensils. Shoots are high quality. Spacing 5–6 (–10) x 5–6 (–10) m. 20 tonnes shoots per ha per annum.	Excellent multipurpose bamboo
Dendrocalamus giganteus Giant bamboo Fiji	24 - 60m ø 10–20 cm	Very large bamboo, internodes 40 - 50cm.	Offsets, culm, branch cuttings (rarely seed)	Flowers gregariously at about 30-40 years then dies.	Culms are large and excellent for construction, shoots are high quality, pulp and handicrafts, laminated boards. 10 x 10 m 200 culms per ha per annum (once fully established)	Striking ornamental due to its vast proportions.
Dendrocalamus latiflorus Taiwan giant bamboo, Ma bamboo CI, F, FSM, K, N, P, S, T, W&F	14–25 m ø 8–20 cm	Medium sized bamboo, internodes 20–70cm long	Culm cuttings, air and ground layering	Sporadic flowering common	Excellent edible shoots. Also used for furniture, crafts and pulp. "Mei nung' provides excellent construction-use culms. Spacing 4–5 m x 4–5 m. 12–30 tonnes shoots per ha per annum	Commercially very important edible species in Asia. Leaves traditionally used for cooking rice.
Gigantochloa apus Tashbir bamboo Fiji	8–30m ø 4–13 cm	Medium-large bamboo, internodes 35 - 45cm	Culm cuttings	No gregarious flowering reported; thought to flower sporadically after about 50 yrs old	Construction, furniture, woven articles. Shoots are poor quality for consumption. Spacing 5–7 m x 5–7 m. 1000 culms per ha per year	Its overlapping fibres render it unsuitable for stick-type products
Gigantochloa atter Pring legi bamboo CI, FSM, K, N, P, T, S, W&F	15–22 m ø 5–10 cm	Dense clumping with straight culms. Internodes 45–60 cm. Branching only at top.			Good construction (thick culm walls), furniture and musical instruments; sweet edible young shoots	
Gigantochloa lako Timor black bamboo Fiji, Walllis & Futuna	10 (–20) m ø 6–10 cm	Upright, medium sized bamboo. Black culms with green stripes.	Offsets		Highly ornamental (beautiful black culms, open), good construction, edible shoots	Lower portion (2 m)of culms free from foliage
Guadua angustifolia (Columbian giant thorny bamboo) Samoa	30 (+) m ø ≤ 25 cm	Large bamboo, internodes 10–25 cm long, clumps open	All methods	Unknown. No gregarious flowering reported	Excellent construction-use bamboo, furniture, handicrafts, woven articles, pulp, boards. 20 – 40 tonnes per ha per annum	The most widely used bamboo in Latin America, highly versatile

Schizostachyum glaucifolium (*bitu dina* in Fiji) is a promising native bamboo species in Fiji and an ancient introduction in several Polynesian countries. The thin culm walls make it ideal for weaving thatch walls, other panels and handicrafts, but reduce its value for construction and production of charcoal. The most promising native bamboo species in Papua New Guinea (PNG) is *konya* (*Nastus elatus*): this is an excellent food source in PNG highlands with potential to be commercialised as a food source. The introduced *Bambusa vulgaris* or common bamboo is very easily propagated and has become widely naturalised especially along riverbanks and in low-lying areas. It is non-durable and needs to be treated for use in construction, except for temporary structures and scaffolding. It is useful for production of charcoal and biochar, pulp and fodder. The young shoots are bitter and edible only after several brining rinses (and accordingly very little used as human food).

As listed in Table 1, there are a number of exotic species of bamboo—already introduced into South Pacific countries—that have excellent potential for production of timber and/or edible shoots. However, it remains a challenge to obtain planting materials of desired exotic bamboo in sufficient quantity to develop a largescale bamboo plantation or agroforest. Hence, there are opportunities for the development of specialist small-medium nursery businesses to propagate and supply highly sought-after bamboo species. These include well-adapted versatile, multipurpose species such as *Bambusa oldhamii, Dendrocalamus asper, Guadua angustifolia and Gigantochloa lako*.

The Fiji Bamboo Association (FBA) has identified priority species for cultivation in Fiji, in addition to the ones already well established in the country, which are *Schizostachyum glaucifolium* and *Bambusa vulgaris*. These species which may also be highly suitable for other Pacific island countries include:

- *Dendrocalamus asper* (used for heavy construction, culinary, board and furniture),
- *D. giganteus* (heavy and light construction, board, furniture, paper and culinary use), and
- *Guadua angustifolia* (heavy construction, furniture and handicrafts).

For climate change and land restoration purposes, the FBA has also identified *Oxytenanthera abyssinica* (African lowland or savannah bamboo). This species has yet to be introduced into the South Pacific but also has good potential for construction, furniture, fencing, weaving for basketry, and charcoal production and likely to perform well in dry-zones (where Asia-Pacific bamboo species are not well adapted).

Gigantochloa atter
(photo: Bamboo Land)

Dendrocalamus giganteus – flowering
(photo: Bamboo Land)

Nastus elatus; canopy (L) and culms (R)
(Photos: Bamboo Land).

Schizostachyum glaucifolium**,** Pacific Harbour, Fiji;
(Photos Lex Thomson, L and Mark Borg R)

Bambusa vulgaris, Wainibokasi, Fiji
(photo: L. Thomson)

Bambusa vulgaris
(photo: Mark Borg)

Bambusa multiplex
(photo: Bamboo Land)

Bambusa textilis, Kiribati
(photo: Lex Thomson)

Bambusa oldhamii, Colo-I-Suva, Fiji
(photos: Lex Thomson)

Bambusa lako
(photo: Bamboo Land)

Bambusa tulda
(photo: Bamboo Land)

Dendrocalamus asper, Deuba
(photo: Masi Latinara)

Dendrocalamus asper
(photo: Bamboo Land)

Dendrocalamus latiflorus, Niue
(photo: Terry Mokoia)

Dendrocalamus latiflorus
(photo: Bamboo Land)

1.2 Bamboo cultivation

Bamboo agroforestry

Agroforestry is a farming system that integrates trees, shrubs and perennial plants with crops and/or livestock in ways that provide economic, environmental and social benefits. In the Pacific Islands, agroforestry is commonly seen in home gardens where a wide diversity of food crops and often medicinally and culturally significant plants are cultivated. Surprisingly, bamboo was seldom included in traditional agroforestry systems. This was due, firstly, to the absence of multipurpose bamboo species from tropical Asia which can provide a multitude of useful products, and, secondly, the lower frequency of more intense cyclones that favour the growth of bamboos—which can recover rapidly from severe cyclone damage—compared with trees which are either uprooted or snapped off during the most intense cyclones.

How is modern agroforestry different from traditional agroforestry?

A modern approach to agroforestry uses principles from the traditional systems, namely:

- Short-, medium-, and long-term crops are inter-planted simultaneously after site preparation
- Quick coverage of the area with a dense planting of the crops and other desired plants
- The planting can have multiple vertical layers at all ages from the beginning of the planting

Longer-lived crops replace shorter-lived crops, as the latter complete their productive life cycles.

The more traditional system has been adapted along the following lines to establish an agroforestry system that can be more efficiently managed by the farmer's household:

- Plants are arranged in rows with regular, systematic crop spacing for ease of management
- Space between rows provides ease of access and is based upon the desired pruned dimensions of the crop trees.

Bamboos are ideally suited to growth in polycultures and can be grown with many other tree and crop species. Bamboos can be introduced into South Pacific farming and agroforestry in myriad useful ways, such as plantings:

- Along boundaries – marking boundaries and providing shelter and windbreak functions. Some species, such as *Bambusa oldhamii*, are especially suited to boundary plantings and can increase existing food crop cultivation through providing protection and acting as windbreaks.
- Along drainage lines and in swampy sites to provide soil protection and site control. The more vigorous and larger bamboo species are best suited for these purposes, as they are more resilient to flooding and drying out the sites, reducing mosquito breeding habitats and facilitating human access.
- Along walking tracks (preferably on each side of track) to keep tracks dry, weed free, clear, with soft mulch of bracts and a joy to walk along.
- Throughout farmed landscapes to act as windbreaks, reduce evapotranspiration of crops and provide shade and shelter for livestock. Bamboos can also provide raw materials for simple construction on the farm, including animal pens, sheds, agricultural implements, and support structures for yams, pumpkins, cucumbers, passionfruit and other climbing crops.

Bambusa oldhamii
(photo: Bamboo Land)

Bamboo plantations

Orchards can take different forms, including traditional block-shaped orchards. Bamboo spacing will vary depending on species (see Table 2), for example, from 5 x 5 m for small-medium bamboos to 10 x 10 m for large or giant bamboos.

Bamboo plantations can be intercropped with more short-term crops to generate income before the bamboo is ready for harvesting, such as vegetables, kava, pineapple, cassava, taro, ginger, turmeric and papaya, thereby adopting a temporal agroforestry approach.

Table 2: Comparative advantages and disadvantages of bamboo agroforestry and plantations

	BAMBOO AGROFORESTS	BAMBOO PLANTATIONS (AS MONOCULTURE OR MIXTURE OF BAMBOO SPECIES)
Advantages	• Multiple crops, more options, better risk management • Early returns because of different crops • Higher total productivity • More tolerance of pests and diseases • Crop maintenance rather than weed control • Environmental benefits (improved soil, erosion control, carbon sequestration	• Simpler to plan and manage • Labourers require less skill • Easier to mechanize • Maximises production of one crop
Disadvantages	• No recipe for implementation • Knowledge intensive depending on a number of different crops • More complex management, including attention to timing of management. • More difficult to mechanise certain operations"	• Reliance on the market for a single crop • More susceptible to pests and diseases • Not using all ecological niches so lower total productivity • Surges and lulls in labour demand • No early yields – all early cash flow is negative

So what are the benefits of the agroforestry approach?

Economic benefits: the combined yield of all crops growing together in an agroforestry/orchard system can exceed that of monocultures by 10-60%. With one crop a grower is at the mercy of supply and demand where excess production and market gluts can result in low prices. A diverse set of crops is less impacted by fluctuations in market prices and can provide a better and more nutritious diet for the farmer's family. An agroforestry orchard system can also create opportunities to generate an income before the longer-term crops, such as bamboo, come into production. The annual peak season of bamboo shoots provides opportunities for both local and export markets for shoots, including the use of surpluses for value-added, processed products, such as bamboo shoots in brine. Finally, multiple crops allow for labour inputs to be better distributed throughout the year.

Environmental benefits: agroforestry orchard systems address soil and water resource concerns through erosion control, soil health improvement, wind shelter and greater resilience to pests and diseases than monocultures. Because of these benefits, agroforestry orchard systems are more resilient to climate change and provide growers with opportunities to incorporate crops/varieties which offer an insurance against crop loss from climate extremes. Most bamboo species will be flattened when they are growing directly in the path of the more severe cyclones (Categories 3 to 5). However, most of the flattened bamboo culms can generally be recovered and used immediately for rebuilding and/or stored for later use (depending on species).

Social benefits: diversification of crops strengthens food and nutrition security and also supports livelihoods through increasing the opportunities for product development.

But there must be some disadvantages to agroforestry systems?

The main disadvantage centres on more complex management, especially if you are going to incorporate many different crops. Further, as each site is different, there is no 'recipe' or plan for implementation – no 'one size fits all'. The first stage of selecting crops requires a lot of thought – crops have to grow well together and have a local use and/or market (or purpose such as soil improvement). Because of the diversity within the system management activities are generally more complex and time-sensitive, and of course, because there are several different crops being grown together, wider knowledge and experience is needed compared to when a single crop is being cultivated.

1.3 Establishing your bamboo agroforest

Good planning is important for reducing costs and at the same time optimising outcomes and income potential. Planning is more complex than planning for a monoculture system, because of the number of crops that can be involved and the need to source appropriate planting materials ahead of plantation establishment. Table 3 provides a guide to the timing of activities to consider in an agroforestry approach to bamboo production in the South Pacific. Compatible crop selection, spacing, and maintenance are all planning issues that require consideration before starting on establishment. Planning consists of collecting site and market information, evaluating the different crop options and complementarities and then developing an implementation plan.

Table 3: Implementing an agroforestry approach to bamboo production in South Pacific

TIME RELATIVE TO PLANTING THE SITE	ACTIVITY
December-January (12 months before planting)	Planning, site assessment, project design, and begin sourcing and assembling appropriate plant materials.
August– September (2-5 months before planting)	Prepare planting site (spraying, weeding, cultivation, fencing against wandering livestock)
Early-mid November 1 week before planting	Pruning of any trees and shrubs that will be retained and integrated into the new planting
Late November- early December Planting time	Site preparation finalized before onset of rainy season with planting immediately after site is prepared and first heavy rains
December-January 0-4 weeks after planting	Intensive maintenance, watering (only if needed)
January to early Feb (c. 5-6 weeks after planting)	Regular maintenance, replanting where needed, additions of organic matter/mulch

Site evaluation and preparation

Site evaluation will help you make decisions about such issues of soil and water resources, drainage and irrigation. On sloping land you will need to identify the contours and install drains and drop structures with bamboo planted along the contours to minimise soil erosion.

If you already have bamboo growing on your farm or nearby and the plants are productive and healthy, then your site is likely well suited to bamboo production. If you are starting from scratch, then you will have to ensure that your site provides the conditions favourable for bamboo cultivation and productivity.

If you already have bamboo growing on your farm or nearby and the plants are productive and healthy, then your site is likely well suited to bamboo production. If you are starting from scratch, then you will have to ensure that your site provides the conditions favourable for bamboo cultivation and productivity.

Any intercrops selected to grow with bamboo must be adapted to the same conditions.

Machinery and equipment

A bamboo orchard or agroforest can be developed with basic farm equipment such as a cane knife/machete for clearing and weed control, a digging spade for planting holes and a knapsack sprayer for spraying herbicide (preferably once only spray prior to planting out bamboo). A sharp knife is required for harvesting new shoots and a special hand saw is preferred for harvesting mature bamboo culms.

Labour needs

Bamboo does not require much care. In fact much of it already grows wild without any care. In the case of any newly introduced species, an individual farmer with family support can generally look after a modest scale bamboo agroforest or plantation.

General agribusiness skills

Ideally if you are embarking on an agribusiness enterprise you should also have, or seek to strengthen, the following skills/experience: (a) knowledge of the value chain and an understanding of the importance of quality throughout the entire production and marketing system; (b) accurate record-keeping and strict financial management; and (c) an understanding of pest and disease management.

1.4 Pests and diseases

Bamboos are generally considered to be a relatively pest and disease-free tree besides scale and lerps which can be controlled when plants are young through a spray of white oil on a dry day. Maintain vigorous and healthy bamboo clumps through:

- Slight mounding of planted stock in areas that experience temporary waterlogging;
- Ensuring that good air circulation is maintained through the clumps by harvesting and utilising culms that are mature (2-3 years old).

Practices to improve soil microbial biodiversity, such as mulching and growing appropriate ground cover crops, can also help mitigate the impact of disease organisms. However, bamboo does not require supplementary fertiliser in most Pacific soils. As bamboo can be grown free from pesticides and chemical fertilisers, it can easily be marketed as a green (or even organic, if one wants to obtain certification) product.

1.5 Harvesting, products and commercial markets

Is there scope for processing and value-adding?

Modules 3 and 4 deal specifically with processing and a few of many value-adding opportunities that are available.

There are export marketing opportunities for several value added products from bamboo, such as edible shoots (fresh and in brine), charcoal and pulp. However, smallholder bamboo growers and producers will need to work together, and in partnership with an agribusiness or trade association, to common standards and address issues of economy of scale.

What about the local market?

Immediate local market opportunities exist for bamboo in local construction, edible shoots for Asian customers and tourists, charcoal for domestic fuel and as a biochar soil amendment.

What income you can expect to make and the capital you need?

Financial models for three business models are provided in modules 3 (bamboo nursery), 4 (mixed production – shoots, timber and fodder) and 5 (charcoal).

1.6 The Basics

Now you should have a reasonably good understanding of bamboo as a crop and what is required to grow bamboo commercially. If you are interested in learning more and developing a business plan then you can proceed to the next modules. It is recommended you think carefully about and answer the following questions:

QUESTIONS	ANSWERS
Do you have access to farmland, either your own or that you can lease for at least 20 years, or else access to nearby native or naturalised bamboo stands which you can harvest.	
Does your land or proposed land provide conditions well suited for cultivating bamboo? Your land must not be subject to saltwater inundation from king tides (on atolls)	
Is there easy access to water for irrigation if necessary – that is, in areas with a strong dry season and/or less than 2000mm annual rainfall?	
Have you carried out any preliminary discussions regarding marketing bamboo products, for example, a small scale processor, local market vendors, local builders and architects and exporters?	
Do you have access to planting material of the preferred variety or a range of suitable varieties which will provide fruit over an extended period during the year?	
Do you have the labour available to establish and maintain a bamboo agroforestry orchard?	

If you have answered 'yes' to the questions above then you can now proceed to the next module. If there are some questions to which you have not answered 'yes' or where you are unsure and/or unclear, then it would be best to talk to a Ministry of Forestry extension officer (or any other person with the relevant detailed knowledge of bamboo, its production and marketing, such as the Fiji Bamboo Association in Fiji).

Key references referred to in this Module:

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Websites:

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2. Pacific Green Business Centre http://greenbusiness.solutions/bamboo/
3. Bamboo Australia https://www.bambooaustralia.com.au/
4. Bambusa Nusa Verde http://www.bambunusaverde.com/english/ (commercial supplier of tissue-cultured bamboo plantlets)
5. Bamboo Land Nursery and Parklands https://www.bambooland.com.au/

A general references list of resources is also provided with the compendium.

MODULE 2: ESTABLISHING YOUR BAMBOO PLANTATION OR AGROFOREST

Module 2: Establishing your bamboo plantation or agroforest

This module contains an overview of what is needed to establish a smallholder bamboo plantation or agroforest. The module aims to provide enough detail to help you prepare the data needed for a financial spreadsheet for different bamboo-based agribusiness opportunities (including those described in modules 3, 4 and 5).

It is important to do some research on how much the various, albeit modest, inputs will cost. The model will make some assumptions about how your operation will improve over time (taking into account extreme climatic events), and also each year your bamboo yields will increase as your clumps mature.

Mixed bamboo planting established on Butaritari Atoll, Kiribati (photo: Lex Thomson).

2.1 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 bamboo. In evaluating your site you need to consider the following:

- What is the condition of your soil – especially fertility, structure and drainage?
- Will slight mounding be needed (for periodically waterlogged sites)?
- Are drains and drop structures or contour/keyline system needed to minimise soil erosion
- Should windbreaks be established?
- Should an irrigation system be installed?
- Are you converting a degraded farming system or weedy secondary 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 internal tracks/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, in Table 1 below, regarding the preferred growing conditions for bamboo, and also in the key documents connected with this module.

Table 1: Acceptable and ideal environmental conditions for bamboo

ENVIRONMENTAL CONDITIONS	ACCEPTABLE RANGE	IDEAL RANGE
Elevation	0–1,500 m depending on latitude and species	"Below 500 m (for tropical species) > 500 m (for sub-tropical/warm temperate species)"
Mean annual rainfall	>2,000 mm but some bamboo species can grow well down to 1,500 mm if grown in lower parts of the landscape with locally high water-table	2,000–3,500 mm (or up to 5,000 mm)
Rainfall pattern	-	Prefers bimodal pattern (or uniform with summer maximum)
Dry season (consecutive months with <40 mm rainfall)	< 3–4 months depending on cultivar and soil depth	No dry season
Mean annual temperature	25–40°C	27–35°C
Mean maximum temperature of hottest month	32–38°C	-
Mean minimum temperature of coldest month	20–25°C (depending on species	-
Minimum temperature tolerated	10-12°C. At low temperatures, the canopy will die back. Some species, such as *Bambusa oldhamii*, are more cold tolerantt	Above 15°C
Soils	Almost any soil is acceptable, except highly alkaline, free-draining sands on atolls. Bamboos are not well adapted to brackish or saline soils.	Deep, fertile and well-drained. Over time bamboos will improve soil organic matter, fertility and drainage

With the changing climate and increasing occurrence of climate extremes, it is important to be aware of bamboo's environmental tolerances (Table 2), so you can make decisions about windbreaks, drainage and shade requirements. Increasing temperatures will generally increase bamboo growth rates but if heat stress is accompanied by low rainfall in marginal locations (<1,500 mm) then growth may decline with culm dieback.

Bambusa oldhamii in Niue (L) and Fiji (R). This species is growing slowly on makatea soils at Vaipapahi, Niue and is 'offsite' and unsuitable, whereas it is growing vigorously on red acidic clays at Colo-I-Suva, Fiji, indicating the importance of species selection and site matching.

Table 2: Bamboo's environmental tolerances

ENVIRONMENTAL VARIABLE	BAMBOO TOLERANCE
Drought	Can withstand drought for a few months but growth will reduce and culms may die back if drought is longer than 3 or 4 months
Shade	Bamboo grows best in full sunlight, but newly planted bamboo will do better under light shade
Waterlogging	Generally tolerate waterlogged soils for several days to weeks. Well established bamboo clumps are much better able to withstand waterlogging.
Salt spray	Some species/cultivars are more tolerant than others. The canopy/leaves will show burning
Wind	Most bamboos are tolerant to moderate strength winds (up to 80 km per hour) and most species make excellent windbreaks.
Cyclones	Bamboo will generally be flattened in more severe cyclones but will regrow well either in the current or next growing season. Bambusa oldhamiii has proven to have better cyclone resistance than other bamboos tested in Fiji.

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, fruit and nut trees) to provide soil protection and shade in the establishment phase.

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.

2.2 Choice of species and varieties

How do I decide which species/varieties to grow?

Table 3 below shows the South Pacific's most promising and more readily available bamboo species (a selection of the best from Table 1 in Module 1).

Table 3. Selection of the most valuable and readily available bamboo species in Pacific Islands

SPECIES	NATIONS	COMMERCIAL PRODUCTS	ENVIRONMENTAL AND LOCAL SUBSISTENCE PRODUCTS	SOURCING PROPAGATION AND RAW MATERIALS
Bambusa multiplex	Fiji	• Handicrafts	• Low dense windbreak, soil protection	• Readily available and easily propagated. Unmanaged clumps become very dense.
Bambusa oldhamii	Cook Islands, Fiji, FS Micronesia, Kiribati, Niue, Samoa, Tonga, Wallis & Futuna	• Edible shoots • Construction • Pulp, charcoal	• Excellent windbreak • Soil protection and carbon sequestration • Fodder and biochar	• Present in several Pacific countries with limited local clumps which might be propagated from Import tissue culture plantlets
Bambusa vulgaris	All	• Pulp, charcoal and fodder	• Temporary structures (unless treated with salt water or boron) and rafts • Edible shoots (needs several brining cycles to remove bitterness) Fodder and biochar • Windbreak (but spreading), soil protection and carbon sequestration	• Widely naturalised, growing on riverbanks and wastelands, and easily propagated. There are better bamboo species for managed plantations and agroforests
Dendrocalamus asper	Cook Is, Fiji, FS Micronesia, Kiribati, Niue, Palau, Samoa, Tonga	• Construction, furniture, woven items, utensils. Edible shoots (fresh or brine) Pulp, charcoal and fodder	• Windbreak, soil protection and carbon sequestration Fodder and biochar	• Present in several Pacific countries with limited local clumps which might be propagated from offsets, culm and branch cuttings • Import tissue culture plantlets
Dendrocalamus latiflorus	Cook Is, Fiji, FS Micronesia, Kiribati, Niue, Palau, Samoa, Tonga, Wallis & Futuna	• Construction, furniture, woven items, utensils. • Edible shoots (fresh or brine) Pulp, charcoal and fodder	• Windbreak, soil protection and carbon sequestration • Fodder and biochar	• Present in several Pacific countries with limited local clumps which might be propagated from offsets, culm and branch cuttings • Import tissue culture plantlets
Gigantochloa atter	Cook Is, FS Micronesia, Kiribati, Niue, Palau, Samoa, Tonga, Wallis & Futuna			
Schizostachyum glaucifolium	Fiji, Polynesia	• Split and woven partitions (export) • Pulp, charcoal and fodder	• Split and woven for traditional wall thatch • Windbreak, soil protection and carbon sequestration • Fodder and biochar	• Sourced locally and easily propagated from offsets, culm and branch cuttings
Schizostachyum tessellatum	Solomon Islands	• Split and woven partitions (export)	• Local light construction and handicrafts, esp. musical instruments • Soil protection and carbon sequestration	• Sourced locally and easily propagated from offsets, culm and branch cuttings

You will need to decide for what purpose you are growing bamboo so that you can pick the most suitable species and cultivar(s). If you are unfamiliar with bamboo then you should seek expert advice from the local Forestry Department, local bamboo association and/or specialist bamboo nursery.

2.3 Propagation and sourcing planting materials

Propagation is best done at the beginning of the growing season which in the South Pacific is around September-November. Note that a propagule can only be considered successful once a new culm has grown from the original, and has rooted, which can take anything from a few months to a year. Always choose one or two-year old healthy culms as the propagation material, because they are more vigorous than older culms. Bamboo species can be propagated by seven main methods as indicated below, but some methods are not appropriate for all species:

How is bamboo propagated?

- **Division**
- **Offsets**
- **Culm cuttings**
- **Branch cuttings**
- **Air layering**
- **Tissue culture**
- **Seeds**

Division

Division involves digging up the clump and using an axe, sharp spade, or machete/strong cane knife to divide the clump into several pieces. Experience in the Pacific Islands indicates that for predictably greater success one should take “three generations” of culms as a propagule unit from the mother plant: A new generation with branches hardened off, its “parent,” and its “grandparent.” It is essential to trim back the branches partially before planting, thereby removing most of the leaves which would otherwise result in rapid water loss, while ensuring some leaves are retained for photosynthesis. Plant in a large bucket or well-prepared hole, including some bulky organic matter and loamy soil backfill. Field plantings of divisions should only be done after the wet season has commenced (unless they can be given supplementary watering).

Offsets

One or two-year old culms with rooted rhizomes attached are detached from the parent clump, cut back to about 1–1.5 m tall or higher if there are no viable branch buds on the lower nodes, and planted in a nursery propagation bed or in very large pots/polybags.

Culm cuttings

One or two-node sections of the culm, usually taken from the middle portion of the culm, are severed. Side branches and leaves are removed, leaving the strongest branchlet which is cut back to about 2–3 nodes. The culm cutting is then buried horizontally in soil directly in the field or preferably in a pot in the nursery where it can be more readily and regularly watered until after roots have developed. Root-inducing chemicals may be useful with those species that make few roots.

Culm cutting *Schizostachyum glaucifolium* directly established in the field in Fiji (photo: Mark Borg)

Branch cuttings

A culm with primary branches that have swollen bases is selected and the branches severed. Branches are cut back to 2 to 6 internodes from the base and buried at an incline in a propagation bed so only the tip is sticking out. They are then watered in well, and a mulch of leaves or other shading material is applied on top. Branch cuttings take longer to reach a plantable size and culm cuttings are usually preferable.

Air layering (or marcotting)

This method ensures the cuttings are well rooted on the plant before severing. Transparent plastic sheet is tied below a healthy node, and a few handfuls of moistened, well-drained rooting material (e.g. coconut coir fibre and coir dust) is packed around the node. The sheet is wrapped around and tied at the top to make a water-tight enclosure. Rooting usually takes a few months, after which the culm can be severed and the rooted node planted out. This method works best only in areas of high humidity. Additionally, access is often limited to the lower parts of the plant, which is often not ideal propagating material.

Moso bamboo seedlings 40 days after germinating (Photo: Permatree.org)

Seeds

Bamboo seeds are rare and plants take a long time to reach harvestable size when propagated from them. Seeds are usually the size of grains of rice (depending on species) and can be sown in standard well-drained seedbeds under shade. Once they have produced at least two very small shoots they can be transplanted into nursery beds. Seeds are also often used to start tissue cultures.

Tissue culture

While tissue culture methods for bamboo have been developed and commercially practiced for many years, the protocols are often in the public domain. In vitro multiplication of tissues of mature bamboo exhibiting superior traits enables elite germplasm to be cloned. Tissue culture starting from germinated seedlings will usually not be true-to-type (i.e., possess all the desired qualities of the mother plant). Tissue culture protocols have now been developed for many priority tropical bamboo species, including species of *Bambusa* and *Dendrocalamus*, and others in the genera *Gigantochloa*, *Guadua*, and *Phyllostachys*. Bamboo plantlets may be produced either by direct multiplication or more often by somatic embryogenesis, usually from seed explants (with inherent genetic variability), although some species have been propagated from vegetative explants that maintain the characteristics of the parent. There are currently no laboratories in the Pacific Islands that are undertaking commercial tissue culture of bamboo, and tissue cultured plantlets would need to be imported from outside the region, such as Indonesia (Bambusa Nusa Verde http://www.bambunusaverde.com/english/).

Bamboo tissue cultured plantlets in plugs. Photo- PT Bambu Nusa Verde

Preparation before arrival of tissue cultured plants

REQUIREMENT	VOLUME	COMMENTS
1. Polybag	Total number of seedlings + 1.5% (spare based on previous shipments)	Polybags : size 18 × 18 cm (or 20 cm for bigger roots) for acclimatisation of about 1-2 months. New leaf or shoot indicated that the plants has passed "shipping stress". Plug: 15 × 15 cm for acclimatisation for about 3 month (grown until minimum 60 cm tall)
2. Growth medium	Top soil, compost, cow manure (ready to use) 3:2:1 ratio or 3:2:0.5 ratio with chicken manure. If manure is not available use 20 g of NPK per plant	Chicken manure must be well composted and ready to use. Use soil that does not have too much gravel and sand (loam and clay loam preferred).
3. Tunnel	Sufficient to cover all seedlings (plug size)	For adaptation after arrival for 2-4 weeks
4. Water	Sufficient for watering	If not rainy season
5. Nursery	Recommended to use shade cloth with 65% protection against the sun	Or put in a shaded place. Not required if cloudy all day/rainy season.

- Ground cover to prevent weed growth but water can still penetrate to the ground.
- Transfer or planting seedlings to the field is done about 2 months after transplanting in polybag.

If you are going to produce your own planting material you will need to consider the cost of a nursery, as culm and branch cuttings should be planted in a damp, shaded area in the nursery, while tissue-cultured plantlets will need to be carefully hardened off and grown on in the nursery until large enough to plant in the field.

2.4 Complementary crops

A wide variety of annual and shorter-duration perennial crops can be grown with bamboo plantations in the early years, while a diversity short and long-term crops can be integrated into bamboo agroforests 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 vertical position in the system. The number of levels in an agroforestry system can vary up to five levels, for example, ground (up to 1 m); low (up to 2 m); medium (2–5 m); tall (5–8 m); and overstorey (≥8 m). The sketch below (Fig. 1) shows the layers of a multi-storey agroforestry system – with bamboo, shown here as boundary/windbreak, and occupying the overstorey layer (at maturity).

Figure 1. Layers of a multi-storey agroforest, showing bamboo in the overstorey, and configured as boundary planting (slightly adapted from Elevitch and Ragone, 2018).

The following table (Table 4) provides a list of crops which can be grown in such a system.

Table 4. Short-, medium-, and long-term crops compatible with bamboo agroforestry

LENGTH OF CYCLE	HEIGHT & LEVEL IN AGROFORESTRY SYSTEM				
	Ground (0-1m)	Low (< 2m)	Medium (2–5m)	Tall (5–8m)	Overstory (≥8 m)
Short-term (1-3yrs)	Ginger, kumala, taro, vegetables	Cassava Yam, cucumber, pumpkin, watermelon (seasonal) (on stakes)			
Medium term (3-5yrs)	Pineapple	Kava, giant taro, bele/ island cabbage	Banana, papaya	Banana, plantain	
Long term (10+yrs)	Turmeric, Layalaya (wild ginger)	Black pepper, vanilla, coffee, kava	Cacao, noni, soursop, coffee	Breadfruit, mango, sandalwood, avocado	Coconut, various timber species, bamboo, betel nut

Alternatively you can decide on a less complex system:

GROUND COVER	UNDERSTORY	MIDDLE STORY	OVERSTOREY
Pinto peanut /mucuna bean (both N-fixing). Note: mucuna is unsuitable with most tree species as it will quickly strangle them and/or damage stem form)	Various annual vegetables, taro, pineapple, yam, pumpkin and squash	Banana, kava, papaya, cacao, noni	Coconut, various timber species

The initial planting density in many agroforestry systems is high—in order to more rapidly establish site control, i.e. reducing opportunities for infiltration of weeds—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)
- Area/space available
- Availability of suitable planting materials
- Anticipated family/community needs, local and export market demand
- Complementarity of the selected crops, including with regards to markets

2.5 Cover crops

Cover crops occupy the ground and low levels and when perennial, act as permanent groundcover crops. Groundcover crops are especially useful when establishing a new agroforest by providing organic material, weed control 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. The role of groundcover crops in suppressing weeds is especially vital, with labour costs for weed control greatly reduced.

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.

Pinto peanut (*Arachnis pintoi*) is an excellent long-term cover crop to grow with bamboo (Photo: Dlium)

Bambusa textilis var gracilis (photo: Bamboo Land). Initial spacing about 1.5–2.5 m apart for boundary windbreak, but wider spacings of 4–5 x 4–5 m are appropriate for pole production.

2.6 Spacing

Wild stands of bamboo are generally not as well-suited to commercial operations as well-planned bamboo agroforests and plantations. Nevertheless, they can provide a cheap and ready source of valuable raw materials, while planned bamboo plantings of better species are maturing. In most parts of the South Pacific Islands wild stands are comprised of suboptimal commercial species (*Bambusa vulgaris* and *Schizostachyum*) and receive less management than is necessary to optimise both the quantity and quality of produce necessary for profitable production. Planted stands have the advantages of:

- A systematic layout pattern in rows that streamlines management operations and facilitates harvest; and
- Management techniques, such as timely harvesting, that improve overall health and productivity of the bamboo crops to maximise yield and quality.

Organising the planting of bamboo in rows—along the contour in a keyline arrangement—will substantially enhance soil water recharge and reduce soil erosion.

Table 5. Recommended spacings for priority bamboo species

SPECIES	RECOMMENDED SPACING	CLUMPS PER HECTARE
Bambusa multiplex	1m apart for barriers/hedges, 2 m × 2m for stem production	2500
Bambusa oldhamii	4–5 m × 4–5 m	400–625
Bambusa vulgaris	5–6 m × 5–6 m	278–400
Dendrocalamus asper	7 m × 7 m	204
Dendrocalamus latiflorus	6 m × 5 m (or 5.5 m × 5.5 m)	333
Gigantochloa atter	6 m × 5 m (or 5.5 m × 5.5 m)	333
Schizostachyum glaucifolium	4 m × 4 m	625
Schizostachyum tessellatum	2.5 m × 2.5 m	1600

How do I work out spacing between all the crops?

Spacing is determined by several factors – firstly and most obviously the land area, but also the extent of mature clumps and desired number of clumps and other crops in the plantation. Once you have selected the bamboo variety and the complementary crops, and know the growth rate of the crops, you can determine the most appropriate spacing. Each bamboo clump requires ample space around it for air circulation and light penetration into the canopy to maximise yield and minimise disease, and also for management and maintenance.

Working out a productive sequence of crops to fill the available space is one of the biggest challenges of designing your bamboo agroforestry system. But you will need this information for your business plan.

As discussed in Module 1, bamboo can either be planted in a block or be linear, for example, to provide a windbreak and or mark a farm perimeter (see Figure 2, for example). The size of a bamboo planting in the South Pacific will vary depending on land availability and planting objectives. The smallest viable planting might consist of 8-10 clumps of *Bambusa multiplex* as part of a small handicrafts business through to a 10,000 ha planting for pulpwood using a highly productive, adaptable and easily propagated bamboo, such as *Bambusa vulgaris*. A typical smallholder planting might consist of 1 to 2 hectares of 2 or 3 multipurpose bamboo species which can provide timber, panels/handicrafts and food for home use, local and export markets.

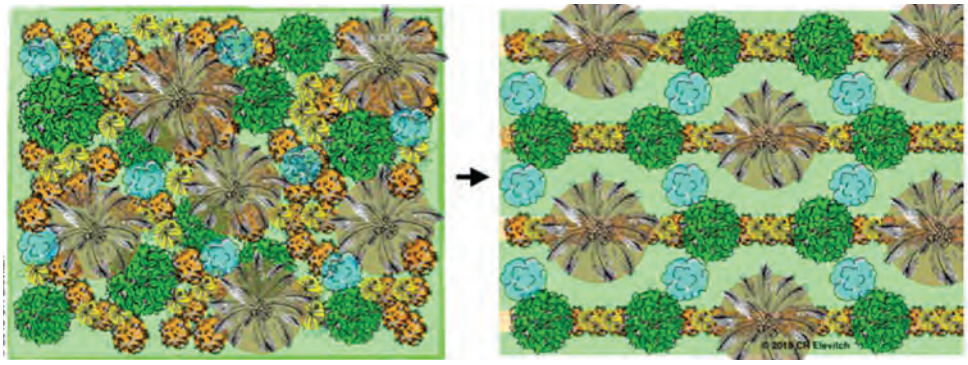

Figure 2: Scattered planting of traditional agroforests compared with organizing crops in rows

2.7 Establishment

The steps for field establishment of your bamboo plantation (adapted from Dart 1999) are as follows:

1. Calculate the within and between row spacings remembering that it is preferable to plant bamboo along contours to maximise water retention, especially in dry and intermediate rainfall zones (see Table 5).
2. Slash and/or use livestock to graze the grass and weeds (and cut out any unwanted woody vegetation), and heap in lines between the bamboo planting lines.
3. Make sure livestock are excluded from the planting site prior to planting, as bamboo—being a grass—is attractive to grazing animals.
4. Prepare the planting site by digging in compost and organic matter to a depth of 30 cm, or preferably deep rip with tractor and plough to 45 cm.
5. If using a tractor for site preparation, then this should be done in the dry season as follows:

   a) mound or hill soil to a width of 2 m (along contour).

   b) run disc harrows over the mounded soil with at least two runs in each direction to break up the lumps of soil and evenly distribute the soil across the mound
6. Manually (or use post-hole digger) to dig a hole slightly larger than the root mass of the new bamboo plants as the pre-determined spacings along the row.
7. Add several spadesful of compost and or 1-2 handfuls of organic fertiliser (e.g. fish fertiliser) into the planting hole and mix with soil. With experience larger amounts of fertiliser will speed growth and up to 5 kg of manure or 300g of NPK can be added to the planting hole if well mixed in.
8. Transplanting bamboo is preferably done on overcast/cloudy and/or rainy days at the start of the rainy season, usually late November-December.
9. Keep root disturbance to a minimum while teasing out the roots prior to planting in the hole.
10. Hold the plant upright while backfilling the planting hole with soil. Tamp or tread down the soil to eliminate any air pockets. If the soil is not moist or saturated, then water in well.
11. In dry/intermediate zones, dig two trenches uphill of the planting hole to channel rainwater/runoff to the newly planted bamboo with a semi-circular mound/soil bank on the downhill/lower side to prevent water running away.
12. Bamboo must be planted on mounds if the area is subject to flooding.
13. Mulch deeply/heavily around the newly planted bamboo using locally available cut grass/weeds/brush.

2.8 Maintenance (adapted from PT Bambu Nusa Verde)

Cultivated bamboo plants also require maintenance, but it is not too intensive. Maintenance for bamboo plants include weeding, soil working and moisture conservation, mulching, mounding, pruning, cleaning, fertilising, intercropping, and pest and disease management.

Weeding

Regular weeding in the initial two to three years is very important for quicker establishment and faster growth of bamboo clumps. Soon after the rainy season has started clear knife weeding will have to be carried out depending on the site condition and amount of weed present in the plot. It is recommended to weed at least three times per year, at the start, middle, and end of rainy season. At least an area of 60 cm around the bamboo should be kept clear of weeds particularly climbers which can smother the young plants. By the third or fourth year when usually the clump gets established, bamboo starts shedding its own leaf thus preventing the growth of other weeds under the clump.

Soil working and moisture conservation methods

The soil around the plant should be loosened twice every year for better rhizome growth and shoot production. Soil working also improves the water retention, capacity and fertility of the soil, adjusts temperature and air permeability, improves soil physical and chemical composition and decreases weed competition for water and nutrients.

The soil at the base of the clumps should be worked with care to avoid damage to the new emerging rhizomes underneath. Spreading rice husk and other mulching materials like leaf litter in plantations will help in increasing the moisture retention. The use of machinery should be explored for soil working in the larger plantations.

Mulching

Mulching is providing for a cover over the soil around the bamboo plant which reduces loss of moisture through evaporation and checks weed growth around the clumps. Degradation of the mulch by the natural decay process eventually releases nutrients into the soil and improves the texture through addition of organic carbon. The branches, tips of harvested culms and particularly the leaves and sheath accumulated below the clump will serve as a mulch. Weeds can also be used as mulch. It is recommended that in larger plantations, the litter be shredded or chipped mechanically to improve the mulch quality. In plantations maintained for edible shoots, the mulch helps keep the emerging shoot in a healthy good condition by retaining the moisture and protecting it against sunlight.

Mounding

Roots emerging from below the new culms need soil to establish. However, as the clump gets older the rhizome system tends to get exposed above the ground. This usually happens when the soil is eroded and the mulch is minimal. When the rhizomes are seen exposed in a clump, usually after several years of establishment, soil mounding may be considered. Loosening of the soil is needed around the clump and mounding so as to cover the base of clump, just prior to the culm emergence. Weeds after weeding activity can be used as additional mix for the mound. Soil mounding is usually done to a height of 30-60 cms.

Pruning

Some bamboo species have a tendency to produce a large number of branches at the base of the clump thus producing a congestion. This indirectly can affect the development of new sprouts. In order to prevent the congestion, it is advisable to prune these branches when the clump is two to three years old and continue every year preferably from November to February.

Pruning of bamboo plants is done by cutting down the branches that grow in the main culm to 2-3 m from the base of the culm. The reduced branches will make the flow of food more concentrated to the main culm. It is hoped that bamboo culm with larger diameter and good quality can be obtained. Pruning can also help air flow or aeration conditions, thereby reducing pest or disease attack. It also aims to stimulate shoot growth. On bamboo plants that are pruned the shoots grow more often and usually larger in size. Pruning is usually done at the beginning of rainy season.

Cleaning

Cleaning of the clump is done by removing the dead and dying culms from the clump and thinning the clump by removal of weaker culms and this will facilitate proper growth of new shoots.

The clump takes about one year for establishment and by the third year production of new culms starts regularly. Pruning and clump management should start from the third year onwards, otherwise congestion will set in. Usually new shoots - the younger ones, are produced towards the outer side and those seen towards the inner portion are the older ones. The older culms will have to be cut and removed when the clump is around five years of age. All the dead and malformed culms seen towards the inner side will have to be removed and the clump should be left clean all the time.

Fertilising

Fertiliser application will ensure higher yield and overall profitability from plantations. In general, bamboo responds well to phosphorous, potassium and especially nitrogen.

COW MANURE		NPK (AS ADDITION IN UPPER 50 CM)	
Year	Dosage per clump (kg)	Year	Dosage per clump (kg)
1	5	1	0.45
2	5	2	0.675
3	10	3	1.35
4	20	4	2.25

If cow manure is not available, chicken manure can be used with dosage of half the rate of cow manure. After first harvest, 1.5 kg of ammonium phosphate and 750 g of potash and 45 kg of cow dung can be added annually. The fertiliser is added in the trench made (about 15 cm deep) around the clump.

Fertilisers should be buried around the clump when the soil has enough moisture, and then covered with soil. If the stands are situated in steep slopes, it is better that the fertiliser is directly applied at the base of the clump but taking care that rhizomes do not come in direct contact with the fertiliser. Organic fertilisers are best applied during the onset of the wet season. Organic fertilisers can provide a range of nutrients to the soil. They encourage microbial activity, which allows the fertiliser to provide nutrients over a longer period of time. Unlike chemical fertilisers, the nutrients in organic fertilisers are less likely to leach away in rainwater.

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 water infiltration, i.e. ploughing, contour mounding?	
Is there a need for roads, pathways or any other infrastructure?	
Do you have the necessary machinery and equipment to prepare the site or will you have to hire or purchase what is needed?	
What will be the labour input for preparing the site?	
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?	
What products and markets are you targeting for bamboo – and therefore what bamboo species and varieties do you expect to be growing?	
How many plants will you need and where will you get them from? What numbers are required?	
If you are producing your own plants, do you need to construct a basic nursery?	
What crops are you going to interplant with bamboo, especially in early years? 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.	

Key references referred to in this Module:

1. Benton A, Thomson LAJ, Berg P, and Ruskin S. 2011. Farm and Forestry Production and Marketing Profile for Bamboo (various species). Pp 1–27 In *Specialty Crops For Pacific Islands: Horticulture, Value-Added Processing, And Marketing.* Ed by Elevitch CR. Permanent Agriculture Resources: Holualoa, Hawaii. Available: https://www.inbar.int/resources/inbar_publications/farm-and-forestry-production-and-marketing-profile-for-bamboo/
2. Dart, DL 1999. *The Bamboo Handbook.* Bamboo Australia: Belli Park, Queensland
3. Elevitch, CR and Ragone, D, 2018. *Breadfruit Agroforestry Guide: Planning and implementation for regeneration.* Breadfruit Institute of the National Tropical Botanical Garden, Kalaheo, Hawai'i and Permanent Agriculture Resources, Holualoa, Hawai i. www.ntbg.org/breadfruit and www.agroforestry.net

Useful websites:

1. International Bamboo and Rattan Organisation INBAR https://www.inbar.int/
2. Bamboo Australia https://www.bambooaustralia.com.au/
3. Bambusa Nusa Verde http://www.bambunusaverde.com/english/ (commercial supplier of tissue-cultured bamboo plantlets)
4. Bamboo land Nursery and parklands https://www.bambooland.com.au/
5. Permatree Ecuador https://www.permatree.org/yantza-farm/food-forest/bamboo/

A general references list is also provided with the compendium.

MODULE 3: PLANNING YOUR BAMBOO NURSERY BUSINESS

Module 3: Planning your bamboo nursery business

The key factor holding back development of bamboo farms and agribusiness in the Pacific Islands is the lack of planting materials of the most desirable species and varieties of bamboo, especially those that can provide both edible shoots and timber/fibre products. There are currently no, or very few, nurseries in Pacific Islands countries that are supplying planting stock of the most desired species of bamboo such as *Dendrocalamus asper* and *Bambusa oldhamii*.

Module 3 provides the information that is needed to develop a commercial bamboo nursery business in the Pacific Islands. Two generalised nursery models may be envisaged:

1. Specialist bamboo nursery growing large quantities, i.e. several thousand bamboo propagules per annum, and in which bamboo is the primary source of income, and
2. An existing small nursery growing mainly ornamentals and fruit trees, extending its range by growing several bamboo species.

This module will only focus on the first agribusiness opportunity, although of course this option may best be pursued by an existing nursery entrepreneur. It will be prudent to proceed at a measured pace, progressively growing more bamboo each year in a learning-by-growing process, while at the same time developing your clientele of local bamboo growers.

Another option is to combine development of a commercial bamboo farm with your nursery operation, such that the rate of bamboo planting on the farm can be varied depending on resources and the availability of excess nursery stock. An advantage of fibrous-rooted bamboo is that plants can be kept potted or in ground for long periods (up to two years) in the nursery, without diminishing their quality as planting stock †. Of course, more rapid turnover of stock is highly desirable in order to maintain cash flow.

The specialist bamboo nursery will need to import tissue cultured bamboo plantlets of desired species/cultivars initially, and probably also in the long-term. The tissue-cultured plantlets are then hardened and grown to a larger size for sale (and suitable for field planting).

Bamboo planting stock may also be grown by other propagation methods, such as by division, offsets, air layering, and culm and branch cuttings (as described in Module 2). The latter methods can be used to diversify the range of species/cultivars being grown, reduce costs and create a resilient nursery model in case of difficulties importing tissue cultured plantlets.

Growing bamboo stock will only be a commercially rewarding activity when production is well-matched to demand and with stock production undertaken using best and low cost practices.

This is where you use the information from the previous modules to decide if you want to proceed with a bamboo nursery business and what form it will take. Subsequent modules provide information on other bamboo agribusiness opportunities such as combined production of edible shoots and timber (module 4), and production of charcoal and biochar (module 5).

† Most forestry trees require a short nursery cycle e.g. less than 3-4 months, as otherwise the taproot will be damaged. Exceptions are sandalwood (*Santalum yasi*) for which larger seedlings (about 25-30 cm tall) will have better field survival, while dakua makadre (*Agathis macrophylla*) can be grown in the nursery for 12-18 months if grown in root-trainer pots and not over fertilised.

3.1 Some key terms you will need to understand to prepare your plan

Cash flow:

The difference between the flow of money over time from selling your bamboo propagules and the amount of money spent producing them. A reasonable time frame to consider the cash flow for a bamboo nursery would be about three years.

Fixed costs:

Fixed costs, for example the cost of land rental, are the same, regardless of how many bamboo plants you sell.

Variable costs:

Variable costs, for example, the cost of labour, vary with the quantity of bamboo plants grown.

Opportunity cost:

The money that could be earned from the resources used to produce bamboo stock, if those resources were used to produce nursery stock of other plants (ornamentals, fruit and nut trees etc) or something else. For example, what you could earn from the same labour if it was used to produce an alternative nursery crop, or if you used your time to be a wage earner employed elsewhere.

The gross margin from a nursery enterprise:

Gross income (quantity of bamboo plants sold multiplied by the price received minus the variable cost of production).

The market:

The growers of bamboo agroforests and plantations.

Marketing:

The process of getting the product to the consumer along the value chain.

The value chain:

The different links that take the product from the source of planting stock, into and through nursery to the buyer/grower, adding costs and value at each step.

Risk:

What could go wrong? For example, a grower may default on contracted bamboo stock purchase or drought may affect nursery water supply.

3.2 A financial model of a small bamboo nursery in Fiji: an example

A financial model for a ¼ acre (0.1 ha) bamboo nursery in SE Viti Levu (Fiji) is presented below. The model involves importing tissue cultured plantlets of highly desirable bamboo species from a tissue culture laboratory in Indonesia and growing them on for 12-18 months before sale to growers. This financial model is only as good as the quality of the data used and will need to be adapted and adjusted for local circumstances and changing/variable input prices. An alternative financial model would need to be developed if using conventional macro-vegetative propagation of bamboo, and may have a longer lead time due to slower rate of propagation.

A financial model for a 0.1 ha or 1,000 sqm (0.25 acre) bamboo nursery in SE Viti Levu, Fiji (in FJD) building up to 7,000 bamboo plants per annum once in full production. (with pot footprint of 225 cm per plant allowing 10 plants per sqm)

YEAR	0	1	2	3	4	5	6
Inflation factor	1	1.020	1.040	1.061	1.082	1.104	1.126
Number of bamboo plants procured	2,000	5,000	6,000	7,000	7,000	7,000	7,000
Number of bamboo plants surviving nursery phase and being sold		1,800	4,750	6,860	6,860	6,860	6,860
Capital Outlays (FJD)							
Land rental (assumed nil as situated on land already owned/controlled)							
Water infrastructure (pump, hoses, fittings)	1,200						
Water (assumed supply is from local creek and at no cost)							
or water from town water supply							
Polyhouse (small structure 6 m x 3 m, with raised benches, initial hardening off area)	1,000						
Shade cloth covered area over about 25% of nursery - 70% shade cloth with gravel surface @ 2 bays 30 m x 3.7 m (about FJD 430 per roll) plus frames (timber/aluminium)	2,500					2500	
Main area - gravel surfacing 27 cubic metres @ FJD 100/m3	2,700					500	
subtotal	**7,400**	**0**	**0**	**0**	**0**	**3,000**	**0**
Operating Costs (FJD)							
Nursery Manager/owner (also involved in day-to-day nursery activities)		15,000	15,300	15,606	15,918	16,236	16,561
Nursery Labour (One person x 45 hours/week @ FJD 2.50/hour)		5,850	5,967	6,086	6,208	6,332	6,459
Water (assumed supply is from local creek and at no cost) or water from town water supply							
Electricity		600	612	624	637	649	662
Imported tissue cultured bamboo (@ FJD 1.8 per plantlet)		3,600	9,000	9,000	9,000	9,000	9,000
Biosecurity fees		2,000	3,000	3,060	3,121	3,184	3,247
Plastic bags (Pxxx @ FJD 1)		2,000	5,100	6,069	6,190	6,314	6,440
Potting media mixed with soil (50 cents per plant)		1,000	2,550	2,601	2,653	2,706	2,760
Sub-total		**30,050**	**41,529**	**43,047**	**43,728**	**44,422**	**45,131**
TOTAL COSTS	**7,400**	**30,050**	**41,529**	**43,047**	**43,728**	**47,422**	**45,131**
Sales (12-month old plants @ FJD 10 per plant)		**$18,000**	**$48,450**	**$69,972**	**$69,972**	**$69,972**	**$69,972**
CASH FLOW	**-$7,400**	**-$12,050**	**$6,921**	**$26,925**	**$26,244**	**$22,550**	**$24,841**

3.3 The Plan for your bamboo nursery business

The purpose of the business plan is to help you decide if you want to proceed with this venture and, if so, give you the best chances of succeeding. As the saying goes "***failure to plan is planning to fail***". Your business plan may also help to secure financial and technical assistance that may be available from your Ministry of Forestry or organizations such as Fiji Bamboo Association and METI (Matuaileoo Environment Trust Inc, Samoa).

A business plan will also be necessary if you wish to try and access a loan from a financial institution to commence your nursery. However, securing a loan from a commercial bank for an nursery enterprise in the Pacific Islands is likely to be difficult regardless of the expected financial viability of your proposal. This option should only be pursued if loan finance is absolutely necessary to implement your business plan.

Writing the business plan is about answering some specific questions, and then writing the answers down in a structured organized way. Your Business Plan does not have to be complicated, but it does need to be a clear explanation of what you intend to do and when.

The information you need to assemble to write your Business Plan

To prepare your business plan you will need to assemble relevant information regarding the concept and its background – this information has been presented to you in the preceding modules and there are also documents you can access to add further information if you feel it is necessary. You also need to undertake a SWOT analysis. You would need to gather the same information if you were considering processing as an agribusiness. The information you require is discussed briefly below:

The concept

This section introduces your idea and puts forward suggestions as to why you think it is a good idea, what you have been able to do so far and what assistance and advice you have received. Some examples of the reasons why you might think your bamboo nursery is a good idea might include:

> *"I have some good land that is available and have experience in propagating and selling seedlings"*
>
> *"I am planning to develop my own bamboo agroforest, and the nursery would supply both my own planting stock and act as early source of cashflow."*
>
> *"Bamboo is able to regrow quickly after cyclones and with predicted more frequent severe cyclones it is becoming too risky to grow other perennial tree crops".*
>
> *"I attended a meeting of the Fiji Bamboo Association and was impressed by the opportunities to supply bamboo plants to its members who are having trouble sourcing planting stock of the bamboo species that they want to grow"*

In presenting your idea and explaining why you think it is a good idea it is also useful to talk about: what you have already discovered about the market and marketing; and the resources and experience you have so that you can take advantage of market opportunities. For example:

> *"A recent global bamboo market study I have read, shows that demand for bamboo products exceeds the readily available supply and this is expected to be increasingly so in the medium term".*
>
> *"Certain exotic bamboo species can be converted into a multitude of different products and these species will be most attractive to new bamboo growers in Fiji but planting material is not available in any quantity"*
>
> *"I know of some reliable bamboo processors who keen to buy bamboo shoots and they seem to be offering a good price"*
>
> *"Farmers in my village are looking for new crops which can grow on degraded land, including former cropping land which has been taken over by African tulip tree, and bamboo has potential to restore degraded lands and grows extremely fast and can compete with weeds."*

Background

The background should include as the following information:

- Information on you and your agribusiness, especially nursery business, experience: Are you a registered business entity? What is your business and nursery experience? What relevant training you have received? What specifically is your experience with bamboo and other crops? Are other members of your extended family to be involved in your nursery business etc.?
- Information on the land you propose to utilise to develop your bamboo nursery (ownership /lease details, location, assets on the land, previous and current usage, soil type and results of soil tests, water supply, risk of flooding, access to the land etc.).
- Information on labour in your area – its availability, cost and skill level.

SWOT analysis

What is a SWOT analysis? A SWOT analysis provides an organised structure for you to use to evaluate your business idea. To do this, you list in four squares the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats (SWOT) to your business. You will use these answers to help you decide if and how your plan should proceed. You can use the Strengths and Opportunities that you listed as reasons WHY you want to start a bamboo nursery business as well as highlighting the importance of price and profit as drivers for your business. However, perhaps more importantly, you need to identify the Weaknesses Risks and Threats the business could expect to face, and if and how these can be addressed.

Below is a list of the type of questions you need to consider in undertaking the SWOT analysis:

QUESTIONS	ANSWERS
1. What experience do you have in propagating bamboo or other seedlings or tissue cultured plants? Do you have any experience with the management of and working on a nusery? *Clearly the more experience you have in these areas the greater your strength for establishing and maintaining a viable bamboo nursery. If you do not have much experience then it is a weakness, but one you can mitigate through training, bringing in expertise etc. Is this training and experience available and what will it cost you? If you are in Fiji, have you been able to make contact with the Fiji Bamboo Association? They may be able to provide you with training and expertise in bamboo propagation.*	
2. Do you have an existing nursery or assured access to sufficient nursery land for at least 6 years (preferably 10 years)? How much will this access to land cost you? Yo*u will need access to a suitable site for at least 6-10 years as this time period will be necessary to justify your investment (money and time).*	
3. Is your site and aspect well-suited to a bamboo nursery? *If the site has access to a local water supply and transport, and is not flood prone then these are strengths. If not, then you will have to know and explain how you will check that the land is suitable and make any modifications necessary.*	
4. Is your site vulnerable to drought, strong winds/cyclones, floods and/or salt inundation? *If your site is prone to any of these weather and climate variables, then that is a threat which you will have to address, for example, establish a windbreak for protection against strong winds. Are you aware of the soil conservation measures (contour planting, drain and drop structures etc.), that can be adopted and what such measures will cost?*	
5. Do you have finance or else donor or government support to procure your bamboo tissue culture stock? *Ready access to quality planting material will be seen as a strength. If you don't have this access then you will need to develop conventional macro-vegetative propagation techniques for bamboo and identify and secure access to stock plants/clumps.*	
6. What is your labour supply situation – both within your household and available for hire? How much time do you have available to devote to your nursery (if it is your side business?) *Ready access to productive labour will be an important strength. Labour shortage can be a serious weakness that will need to be addressed. You may need to have an employee or neighbour who can maintain or water the nursery if you are called away for family or other reason (for more than a day or two).*	
7. Are you already propagating bamboo or other plants? Do bamboo grower already operate in your area and are they interested to purchase improved planting stock? *Your assessment of the strength of the bamboo value chain could either be considered as a strength or a weakness.*	
8. Will you have alternative markets for your bamboo propagules if buyers are not forthcoming? For example do you have your own bamboo plantation or mataqali land which can be utilised? *There are potential strengths, weaknesses and opportunities here*	
9. Do you have other business skills that you can put forward as a strength or as an opportunity, for example, knowledge of and experience in composting nursery media, marketing, record-keeping, and an understanding of nursery irrigation systems, pest and disease management etc. *List potential strengths and weakness here*	
10. How many nurseries and bamboo farmers are there nearby or within range of cost-effective plant delivery? Have you been able discuss their operations with them and inspect what they do? *Can you work with them? Other nurseries propagating bamboo may constitute a threat (competitors), but if you can work together with them, share and grown the market for bamboo, then this is an opportunity.*	
11. What is the projected demand for bamboo propagules and how will this develop over time? What is the basis of your market assessment? *The more bamboo farmers the greater the strength of your business and the greater likelihood of more opportunities.*	
12. What support for the development of your new bamboo nursery is being offered by the Ministry of Forestry and other agencies? This could present an important opportunity.	

You would have to put together a similar list of questions if you are considering processing as an agribusiness and some of the questions posed at the end of the module 4 are relevant. For example, 'have you identified a market for your processed product and the arrangements for marketing the product?' and 'can you incorporate other staple food crops into your processing business?'

An appropriate summary template for presenting the findings of your SWOT analysis would be:

SWOT ANALYSIS IN EACH BOX, YOU NEED TO LIST ALL THE THINGS ABOUT YOUR BUSINESS THAT ARE RELEVANT FOR EACH BOX.	
A. Strengths	B. Weaknesses
C. Opportunities	D. Threats

In the final Business Plan template exercise, you can expand on the answers to the questions above.

3.4 Your written Business Plan

Now that you have gathered all the information required and completed the SWOT analysis you can now decide whether or not you wish to proceed with your bamboo nursery business venture or not. If you do decide to proceed, you will then need to write up your business plan. As the saying goes "***not to plan is to plan to fail***".

An appropriate table contents for your written Business Plan would be:

- Outline of proposal
- Why it is a good idea
- Details of the proposed nursery
- Goals and timetable for achieving your goals
- Risks and challenges you might face to achieve the goal (cyclones, competition, pests and diseases, etc.) and what you can do to reduce these risks.
- Business risk analysis.
- Financials
- Supporting Annexes

MODULE 4: MIXED BAMBOO SMALLHOLDER FARMING BUSINESS

Module 4: Mixed bamboo smallholder farming business

Bamboos include species which are capable of providing a multitude of products. However, some species are not especially useful, at least without considerable treatments, while other species may be best suited for just one product. This module will focus on developing a mixed farming business producing edible shoots and timber/poles from two promising bamboo species in Fiji and other humid, tropical zones in the Pacific Islands. Edible shoots and timber/poles are products which in the first instance can be sold into local markets and later on, value added, aggregated with supplies from other producers and exported (see Module 6 on Markets and Marketing).

What are the best bamboo species for mixed production in the Pacific Islands?

The two selected species are *Bambusa oldhamii* (Oldham's bamboo) and *Dendrocalamus* asper (Asper bamboo), both of which have been already introduced into Fiji, Samoa, Tonga and some other Pacific Islands. Where available there are other edible multipurpose species which are able to be substituted including *Dendrocalamus giganteus* (large poles for construction), *D. latiflorus* and *Gigantochloa* species (G. apus, G. atter and G. lako) and *Bambusa tuldoides* (the latter for fishing poles and alike).

Most bamboos will also provide important services, including for soil protection and improvement, windbreaks, carbon sequestration and production of other items.

The model presented here is for the development of 1 ha of permanent bamboo estate within an existing larger mixed smallholder farming business. Ideally, the bamboo plantings would be established in those parts of the farm which are poorly suited to crop production. These include especially:

1. **Low-lying areas** which are subject to waterlogging and periodic shallow flooding. These locations are not generally suitable for other productive crops, with some exceptions such as ivi (*Inocarpus fagifer*) and soga (*Metroxylon* species). Bamboo, once well established after 3-4 years, is resistant to short-duration (1-2 days) flooding and will help hold together and protect fragile alluvial soils. They will also dry out wet and waterlogged soils making them more useable, including adjacent walking tracks.
2. **Hillsides/sloping terrain.** More steeply sloping parts of the farm are poorly suited to cropping as they are difficult to work and cultivate, and prone to soil erosion. Bamboos are ideal for sloping sites, protecting fragile soils, and are much more easily managed and harvested in comparison with short-term crops.

Can bamboos also be used for animal fodder?

Bamboos can also provide animal fodder: bamboo leaves have potential as a forage for ruminants, including dairy and beef cattle, sheep and goats. Bamboo leaves are a good source of nitrogen for ruminants and may be complementary to silage and other fodders in mixed rations, without compromising milk and meat production. This allows ruminants to maintain their performance during the dry season, which is a period of forage shortage.

Farmers can integrate bamboo cultivation in their forage system to enhance the feed sufficiency and diversity, in order to improve the animal productivity, as well as the food security. It is important to identify the optimal stage and period to harvest bamboo leaves, in order to reach a moderate fibre content and improve intake and digestibility. However, this may not be possible if the leaves are a by-product of harvest for timber.

Whilst this model proposes block plantings of bamboo, they are also suited for linear plantings such as windbreaks and boundary markers. They can also be planted scattered throughout the farm, improving productivity and farm aesthetics and providing welcome shade for humans and livestock alike during the heat of the day.

4.1 Mixed bamboo farm

The bamboo section of the farm will comprise 1.0 ha as part of a larger farming enterprise, comprised of 0.5 ha of each species: 200 clumps of *Bambusa oldhamii* established at 5 x 5 m and 100 clumps of *Dendrocalamus asper* established at 7 x 7 m. A 1.0 ha planting of bamboo is considered to be a commercially viable operation for a smallholder farming family, but obviously a smaller or larger parcel of bamboo might be developed depending on available resources, markets etc.

It is envisaged that the bamboo plantation will be established in an agroforestry configuration over a ten year period as follows:

Year 1 – 0.5 ha D. *asper*/cassava intercrop

Year 2 – 0.5 ha D. *asper*/peanut or bean intercrop; 0.5 ha B. *oldhamii*/cassava intercrop

Year 3 – 0.5 ha D. *asper*/mixed vegetable and root crops (eggplant, bele, kumala, dalo ni tana etc) and 0.5 ha B. *oldhamii*/peanut or bean intercrop

Year 4 – 0.5 ha D. *asper*/turmeric (haldi) intercrop (i.e. partially shade-tolerant crop) and 0.5 ha B. *oldhamii* /mixed vegetables crops and root crops (eggplant, bele, kumala, dalo ni tana)

Year 5 – 0.5 ha D. *asper* & 0.5 ha B. *oldhamii*/turmeric (haldi) intercrop (i.e. partially shade-tolerant crop)

Year 6 onwards – 0.5 ha monocrop of each of the two bamboo species (site control provided by bamboos). First small scale harvests undertaken.

Year 8 onwards – production increasing to near full production in year 10.

4.2 Selection of intercrops in early years

Each smallholder will have different needs, preferences, environments which will affect the choice of intercrop.

In this model, cassava (tavioka) was selected for the first intercropping cycle, as it is usually easy to obtain planting material locally, grows well and is productive in most soils (including infertile acidic red clays). Cassava can be used as staple family food and/or readily sold in local markets. It is also highly compatible with bamboo culture (and tree crops) providing an ideal low windbreak during the first year.

A nitrogen fixing crop, peanut or bean (long bean or other types, including shrubby pigeon pea) was selected as the intercrop for the year 2 cropping cycle. These nitrogen fixing crops will help to build soil fertility and organic matter.

Mixed crops were selected for the year 3 cropping cycle. Almost any desired food crop which is used in family diet or has good local market can be used. On well-drained sites, ginger and/or kava can be included in year 2 or 3 as these high value crops grow well in association with bamboo (as does sandalwood on sunny edge on bamboo plantings)

After year 3 the bamboo, if well grown, will be beginning to provide substantial amounts of shade and sun-demanding crops cannot be grown. The best crops include more shade tolerant crops such turmeric (haldi) or mango ginger (amba haldi) or leafy greens such as dalo ni tana (for rourou) and ota (edible local fern species). By year five or six the site will have become heavily shaded and dominated by bamboo and most likely unsuitable for intercropping.

When will I get my first harvest of bamboo?

The first bamboo harvests can be initiated thinning out the clumps while retaining the best 3 to 4 evenly spaced largest culms/shoots. Depending on site fertility it is best to adopt either a 3:3:3 or 4:4:4 pattern, i.e. the same number of shoots from the current year as the previous year and the year before that. When news shoots emerge and are retained there will be either 12 or 16 shoots, until the oldest 3 or 4 culms are removed for timber/poles.

4.3 Indicative costs for bamboo plantation development

The additional extra costs for establishing bamboo in the early years are principally those associated with plant cost and fertiliser.

The cost for bamboo plants is estimated to be FJD 1000 in year 1 (100 @ FJD 10 for D. asper) and and FJD 2000 in year 2 (200 @ FJD 10 for *B. oldhamii*).

It is recommended that bamboo are fertilised with chicken manure (at a rate of about 10 kg per bamboo in first five years). The cost for chicken manure in Fiji is about FJD 3.5-4/bag (from Ram Sami) with about 35kg per bag, making the cost of fertiliser per plant is FJD 50 per bamboo over the first five years. Therefore, the total cost for fertiliser (chicken manure) is FJD 1000 in year 1 and then FJD 3000 per year thereafter. Note: for more fertile soils, such as more recent volcanic soils, fertiliser is not required (or only at planting). Mulching with N-rich organic matter or other local manures may also alleviate the need for chicken manure application.

The estimated additional costs in FJD of growing a 1 ha bamboo plantation are:

YEAR	1	2	3	4	5	6	TOTAL
Bamboo planting stock	1,000	2,000					3,000
Fertiliser (chicken manure)	1,000	3,000	3,000	3,000	3,000	3,000	16,000
Subtotal	2,000	3,000	3,000	3,000	3,000	3,000	**19,000**

There will be additional costs such as for planting, maintenance and fertiliser application, but these costs are considered to be able to be absorbed in the normal running costs for the farm (and based on using own/family labour).

4.4 Income from sale of products from 1 ha bamboo plantation

Income for sales of edible shoots and bamboo timber/poles from year 6 onwards

YEAR	6	7	8	9	10	>10
B. oldhamii: 5-15 shoots per clump at 750 g av. after peeling x 200 plants	750 kg	1050 kg	1350 kg	1,800 kg	2,250 kg	2,250 kg
Sale of oldhamii shoots at FJD 10/kg (less harvest, peeling, packing & transport costs of FJD 2/kg)	FJD 6,000	FJD 8,400	FJD 10,800	FJD 14,400	FJD 18,000	FJD 18,000
D. asper: 5-15 shoots per clump at 1.8 kg av. after peeling x 100 plants		900 kg	1260 kg	1620 kg	2160kg	2700 kg
Sale of asper shoots at FJD 10/kg (less harvest, peeling, packing & transport costs of FJD 2/kg)		FJD 7,200	FJD 10,080	FJD 12,960	FJD 17,280	FJD 21,600
Income from sales of edible bamboo shoots	**FJD 6,000**	**FJD 15,600**	**FJD 20,880**	**FJD 27,360**	**FJD 35,280**	**FJD 39,600**

Note: prices vary considerably depending on location and place in value chain, e.g. retail price for fresh bamboo shoots in USA is FJD 18/kg, while export price from Japan is FJD 11/kg and farmgate price in China is FJD 2-4 /kg

YEAR	6	7	8	9	10	>10
B. oldhamii: sale of timber poles 2 to 4 poles per clump, 10 m x 7.5 cm diameter x 200 plants @ FJD 6/pole (less FJD 2 harvest, processing, transport)	FJD 1,800	FJD 2,700	FJD 3,150	FJD 3,600	FJD 3,600	FJD 3,600
D. asper: sale of timber poles 2 to 4 poles per clump, 12 m x 10 cm diameter x 100 plants @ FJD 12/pole (less FJD 3 harvest, processing, transport)		FJD 1,950	FJD 2,925	FJD 3,413	FJD 3,900	FJD 3,900
Income from sales of bamboo poles for timber	**FJD 1,800**	**FJD 4,650**	**FJD 6,075**	**FJD 7,013**	**FJD 7,500**	**FJD 7,500**
TOTAL	**FJD 7,800**	**FJD 20,250**	**FJD 26,955**	**FJD 34,373**	**FJD 42,780**	**FJD 47,100**

The above sales figures are conservative and it is likely that considerably higher prices will be able to be achieved if linkages can be formed by the bamboo industry/growers with the high end resort development industry and local architects and builders.

Key findings:

1. Bamboo cultivation, at this scale, is not suitable for most Pacific Island smallholders as they would not be able to bear the high costs, about FJD 20,000, over the first six years
2. The period for payback, or the time to when the plantation becomes cash flow positive is about 7 or 8 years.
3. A one hectare bamboo plantation is a highly profitable and sustainable farming enterprise, returning about FJD 45,000 per annum after 10 ten years.
4. The production of edible shoots provides the bulk of the financial returns from this mixed production system, however the production of bamboo poles helps to diversify the markets and risks.
5. Higher intensity cyclones (categories 3 to 5) will cause major damage to bamboo plantations. There may be a short-term windfall from flattened poles which will be needed for rebuilding (but harvesting can be challenging and then there will be a hiatus from income from poles for 3-4 years while the plantation recovers). Income from edible shoots will be far less impacted by cyclones compared with pole production.

Another option for poorer smallholders is to progressively develop commercial bamboo plantings, growing the bamboo planting stock yourself and using local fertilisers and mulch. A much slower rate of bamboo development might be envisaged, e.g. 20-30 plants per year.

MODULE 5: PRODUCTION OF BAMBOO CHARCOAL AND BIOCHAR – A CASE STUDY

Module 5: Production of Bamboo Charcoal and Biochar – a case study

People everywhere are demanding greater environmental and social responsibility from their governments and businesses alike. For tropical Pacific Islands—where bamboo grows profusely—the production of charcoal and biochar from bamboo is a commercially-promising and environmentally friendly business. Bamboo charcoal and biochar can profitably make use of a sustainable resource that grows in abundance and is known to be climate friendly.

Source: https://en.m.wikipedia.org/wiki/Biochar#/media/File%3ABiochar_pile.jpg

Charcoal is used as a non-smoky, high calorific fuel for cooking in many developing countries and for barbeques in developed countries.

The increasing use of efficient and hot burning rocket stoves in the Pacific provides a good business opportunity for local charcoal producers. People commonly use wood for fuel in rocket stoves. Wood is not as efficient a fuel as charcoal as heat energy goes into the pyrolysis of the wood rather than the cooking of the food, whereas with charcoal, all the energy in the burn goes towards heating and the cooking process. Also for this reason there is much less smoke produced in the cooking process which is healthier for the cook, their families and the local environment.

Pyrolysis is the chemical decomposition of organic (carbon-based) materials through the application of heat

5.1 What is Biochar?

Biochar is a charcoal-like substance made from organic plant matter through a process called pyrolysis. One can use any form of organic matter—usually wood off-cuts, other waste wood and crop residues—to make biochar. Like charcoal it is produced by a process known as pyrolysis involving the heating of this plant material at very high temperatures in the (near) absence of oxygen.

What is biochar used for?

Whereas charcoal is used as a form of fuel commonly used for cooking, the use of biochar is less well known. In fact there are a number of uses for biochar. Importantly, biochar is today considered as one of the key materials for a sustainable agricultural future for our planet. Many promote it as an important element of an integrated organic system of farming. However, it is also used in building, clothing, electronics, filtering systems, cosmetics, medication and other consumer goods.

In farming it is mostly used as an additive to compost and fertilisers or simply as a soil mixture. Biochar provides a long-lasting increase in soil carbon content as its carbon is recalcitrant and not quickly broken down. It is well proven that biochar improves soil quality by improving carbon sequestration, providing a vast substrate for beneficial microbes and also a number of other soil health benefits. Biochar improves the water retention capacity of soils and, in combination with fertilisers, leads to sustainable crop yield increases. It helps to build up humus, reduces GHG emissions from agriculture, reduces nitrate pollution of ground and surface water, promotes tree growth, increases the stress resistance of urban trees and enables the rehabilitation of contaminated soils. Biochar is stable—only slowly broken down—and can endure in soil for thousands of years.

Why bamboo charcoal and biochar?

Bamboo grows at up to one meter per day and can be harvested for use in just three to five years after field planting. In comparison, many tree species take much longer to become established and productive. Thus, bamboo can produce a good, more environmentally friendly alternative charcoal to use for cooking and barbeques, as well as being a great material to produce biochar to improve soil quality.

At a time where people the world over —not least in the Pacific Islands—are suffering from the disastrous impacts of climate change, bamboo charcoal and biochar provide a much better alternative to other charcoal and biochar commonly found in the market. Although they look the same and could perform the same functions, the biochar pyrolysis process is specifically designed to reduce contamination and enhance carbon storage. Thus it becomes vital that people going into this business adopt optimal processes.

Bamboo's properties make it a preferable material for producing charcoal compared to wood, having a calorific value similar to that of wood and almost half that of petroleum by weight, bamboo charcoal produces fewer pollutants than either.

In addition, bamboo biochar is an excellent amendment for use in improving soil quality. Therefore, there are obvious advantages to the use of bamboo charcoal for cooking. Besides its more environmentally friendly production, you can simply throw the left over bamboo charcoal and ashes straight into the soil and it will act as biochar, and by doing so you will be improving the health and productivity of your soil. On the otherhand, the commercial charcoal that is normally used for cooking may contain actual burned coal in the mix as well as chemical fire starters, which would make it inadvisable to mix in the soil after use.

Bamboo is a woody grass with very fast rates of growth under suitable conditions. Nevertheless, it does take from 3 to 5 years for clumps to develop and culms to thicken enough for harvesting. Bamboo is an underutilised resource in the Pacific.

Since bamboo is rich in silica (a form of silicon dioxide), its biochar also contains higher levels of silica than that derived from other biomass. Silica is widely known as a superfood for plants as it is known to increase growth rates, which in turn leads to quicker harvests. Silica also increases nutrient uptake by plants, increases the plants' strength and vigor, and also increases their resistance to pests and diseases.

Bamboo charcoal is generally considered a commercially safe product. Its sales seem to be resistant even to economic crisis, as witnessed in South Africa (Scheba et al., 2017).

5.2 The raw material.

Whether a bamboo charcoal business venture will be a successful largely depends on the supply of the primary resource, that is where the business will get its bamboo from.

Since charcoal/biochar can use bamboo that is defective, unsuitable for other uses or cut-offs from other industries, the resource could be obtained from these industries where they exist. Currently there is no commercial bamboo industry in the Pacific, although there are major efforts to establish one in Fiji, and it is expected that other Pacific island countries will follow. In such cases the raw material could be obtained at very low cost since it is a waste for the other industries. Another low cost source of bamboo, could come from the scaffolding industry. In Asian countries bamboo is used extensively in scaffolding, offering a cheaper alternative to steel. If this practice is introduced to the Pacific, together with the practice of replacing the bamboo after a single use (to guarantee its integrity for safety reasons), this bamboo can be used for other purposes, including charcoal/biochar. In Asian countries bamboo obtained from scaffolding is used for producing disposable chop sticks.

Common bamboo naturalised along Waidina River, Naitasiri, Fiji – an excellent source of raw material for charcoal/biochar manufacture (Photo: Lex Thomson)

If the proposed business is within a land-owning unit that already has bamboo growing on its land (the ideal scenario), obtaining the resource would only require the labour and transport costs involved in harvesting the bamboo. Scattered throughout Fiji are vast areas of bamboo—most often in valleys—of both common bamboo (*bitu vavalagi*) and Polynesian bamboo (*bitu dina*) that are ideal, immediate resources upon which to base a bamboo charcoal business.

Alternatively the business could sell the bamboo cane that is in good condition, keeping the second grade and third grade bamboo for pyrolysis.

Under the right conditions and local environment, the harvesting of bamboo clumps can be combined with established of short term/ temporary crops such as kumala, medium-term crops like kava (in higher rainfall zones) and long-term high value tree crops. Mahogany is particularly well suited to grow in bamboo groves as the side shade from bamboo promotes exceptional straight, long bole form free of lower side branching. Sandalwood also grows well in association with bamboo, but requires other hosts such as *Calliandra* to also be planted.

There are large tracts of common bamboo in the Upper Ba Valley, Fiji suitable for conversion to charcoal/ biochar (Photo: Lex Thomson)

5.3 The pyrolysis process

Since pyrolysis involves the burning of the bamboo to produce charcoal or biochar without turning it into ashes, it is important to know when to turn off the heat and stop the burning. The chart in Figure 1 shows us what happens to the bamboo when burned at different levels of heat.

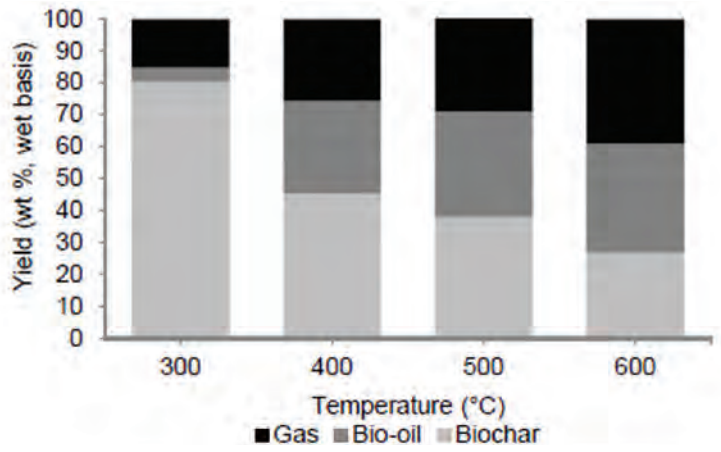

Figure 1: Relative yields of pyrolysis products at different temperatures (Hernández-Mena et. al. 2014)

At different heat levels, the production of the three different products of pyrolysis (biochar, gas and bio-oil) varies. If the primary aim is to produce biochar, the temperature should be kept at around 300°C. If one also needs the oil and gas, say to power carbonisation machinery or for commerce, one would opt for higher temperatures.

Labour

The level of labour required in production of biochar depends on a number of factors including:

- the size of the enterprise, whether it is a community enterprise or a small scale industrial one;
- the amount of charcoal/biochar one plans to produce on a daily basis; and
- where the resource is obtained from, whether it comes as off-cuts from another bamboo enterprise, or harvested solely for charcoal/biochar.

Whether a small business, initially with one or two workers, or a bigger enterprise with dozens of workers all the labour related costs need to be incorporated in a business plan. Besides a decent salary, preferably above the minimum wage, one must also incorporate other costs, such as Provident Fund payments and medical insurance. One must also consider the expense related to other services such as management, accounting, sales and marketing and communications (web, graphic design and social media).

5.4 Producing charcoal and biochar in Pacific Island communities

Biochar production is a simple process and does not necessarily require elaborate equipment. It can be done by villagers living in our different communities. For small scale production there are small startup costs and ongoing expenses involved. Initially burning in the open can be done with virtually no start-up costs: just a cane knife for harvesting, a shovel for loading the char and hessian bags. The profits from such a basic operation can soon be invested into simple and more efficient pyrolysis equipment.

One can carry out the pyrolysis in used oil-drums, brick kilns or even open pits. These methods, however, are generally ineffcient, waste the important oil and gas by-products and are more polluting than the more advanced, but more costly, systems. In Japan, a remarkably efficient process of burning bamboo in the open to produce char has been developed, but requires very active management of the burning bamboo, and experience into how to optimise char formation. Some examples of simple kilns are shown in Figure 2.

When producing biochar, one would need to crush the resultant charred bamboo. This can be easily done manually for smaller quantities, for example using a grog pounder, or with the use of a light mechanical grinder for larger quantities.

Biochar kiln in Naitasiri, Fiji: constructed by John Bennett from an old cement mix truck (Photo: Lex Thomson)

Industrial production of Biochar

For those who have access to substantial land and an abundant amount of bamboo resources, they may want to take up biochar production on an industrial scale. This would require the procurement of industrial machinery and therefore involves considerably higher investment. Before undertaking such an investment one needs to ensure there are enough bamboo resources to make this scale of investment worthwhile. The only Pacific countries that could possibly sustain such an industry would be Papua New Guinea, Timor-Leste, Solomon Islands and potentially Fiji. Importantly, one should identify an overseas buyer before undertaking this investment, as the amount of charcoal and biochar produced would be well above the needs of a small island's domestic needs.

It is important to carry out a comparative analysis to determine whether there are more profitable

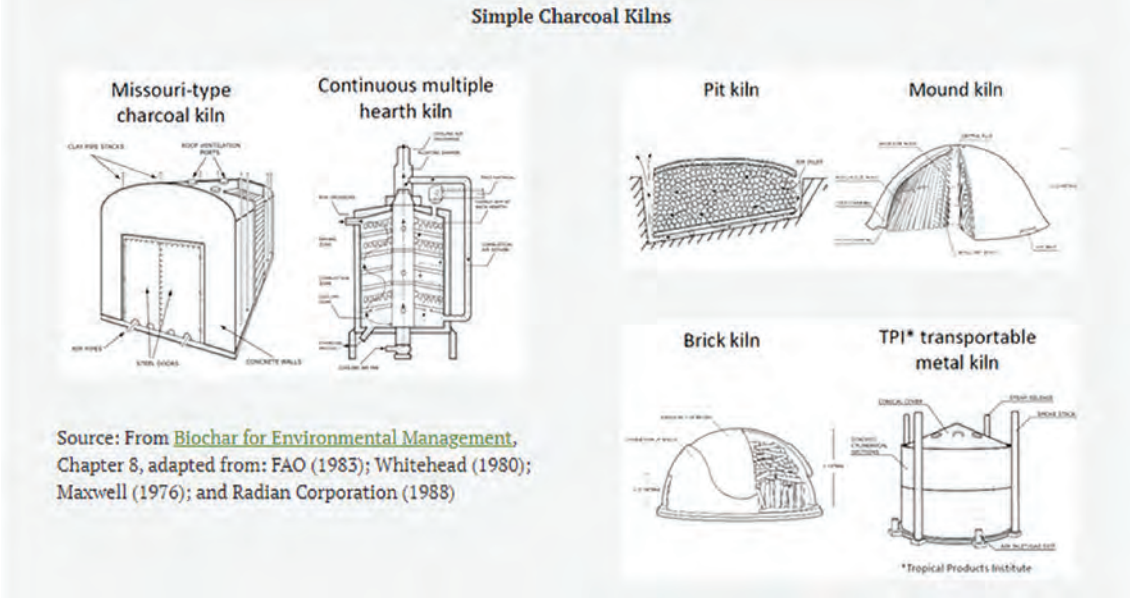

Figure 2: Examples of simple kilns

ways of using this bamboo resource (e.g. paper pulp, fibe extraction, poles for construction or furniture making, etc.) before embarking into considerable investment in pyrolysis equipment.

The investment involves the procurement of a carbonisation machine and a crusher with an investment of some USD 55,000 for the smallest model (example provided by Beston Machinery) with an output of up to 500 kg/hr.

The process involves the combustion of the bamboo raw material which then passes into a cyclone separator that separates the biochar from the oil (see Figure 3). The biochar is collected in a char collector, whereas the oil can be returned into the system to power your machinery.

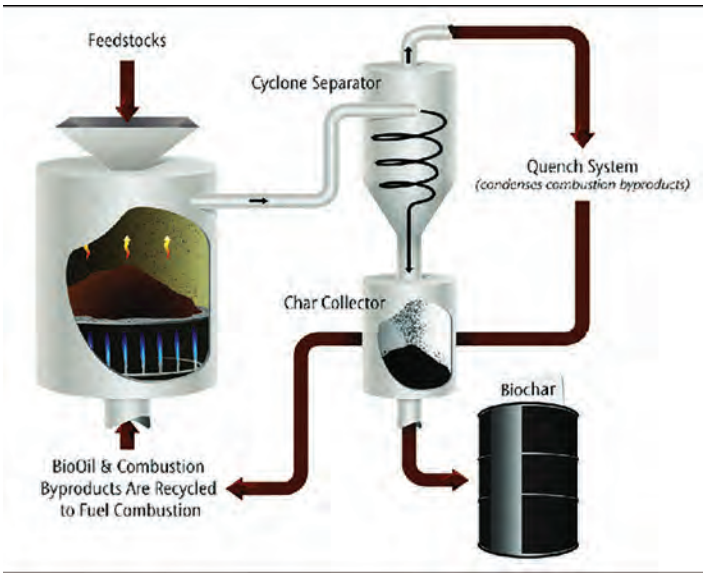

Figure 3: Production of biofuel and biochar by pyrolysis. Illustration by Andrew Mack, PREC.

Very importantly for the efficiency of the system, your raw material must be dry when it is fed as feedstock. This is also a requirement for community based systems as well. Ideally a dry sheltered area is established where bamboo can be left to dry for a few weeks before use. For small scale systems open stacking in layers alternating at 90o works well for drying bamboo and can be used for cottage scale operations.

When producing charcoal the product is left in a chunky or brisquet form, whereas if producing biochar this needs to go through the crusher to be turned into powdery form.

Businesses that involve the use of machinery must also incorporate in any business plan the costs of the energy used to operate that machinery.

Figure 4: The BST-05 carbonisation machine from Beston Machinery

Some safety precautions

Since biochar production involves the application of heat, standard safety precautions during the processing need to be taken as with all processes that involve heat and fires. The risks very much depend on the method for pyrolysis being used. In all cases, the process should be carried out outside and away from buildings, in a clearing in the yard or farm, away from trees or dry brush or timber, to avoid the risk of uncontrolled fire. Personal precautions are needed to reduce smoke inhalation and accidental burns, such as wearing protective gloves, a face mask and protective goggles to avoid eye irritation. Efficient pyrolysis will not produce much smoke, except initially. If it does, it may mean that the bamboo has not been dried enough.

5.5 How does bamboo charcoal and biochar compare against the competition?

Bamboo charcoal vs firewood

Firewood is still used abundantly in Fiji. Unfortunately, the wood commonly used is Dogo (Large-leafed Mangrove; Bruguiera gymnorhiza) resulting in the degradation of mangroves in the country, at a time when more mangroves are needed to combat climate change. Firewood is sold for FJD 2.50 in piles of about 3kg in weight (83 Fiji cents or about 40 US cents per kilogram) at most petrol service stations in Fiji.

There is no doubt that bamboo is a more environmental and climate friendly resource. There is also no doubt that it is more efficient than firewood in terms of its calorific value. However, for bamboo charcoal to be considered by people as a possible alternative to firewood it needs to be priced competitively. As demonstrated in the next section, imported charcoal is too expensive to replace firewood. Nevertheless, bamboo charcoal can be produced locally at a competitive enough price to replace firewood as a fuel for most people who have to buy their firewood and do not have direct access to it from the wild. However, this shift away from wood harvesting to use bamboo charcoal to meet more people's local energy needs can only happen if value chains, markets and technologies to produce a steady supply are in place.

Bamboo charcoal vs other charcoal

The imported charcoal products found in the Fiji market give an indication of the competition a local product would need to overcome. The first, a US product, is sold for FJD 29.95 for a 3.5 kg bag (USD 4 per kg), whereas another product, an Australian one, is sold for FJD 23.95 for a 4 kg bag (USD 2.80 per kg). A local product that does not need to incur international transport costs and duty should be able to be in the market with a much lower price; a price that would not only be favourable when compared to the imported competition but also competitive with firewood.

Brands of charcoal imported from Australia and USA being sold in Fiji

Bamboo biochar

Biochar is not widely available on the Fiji market. There does not seem to be enough appreciation of the benefits of biochar to soil health in the country and any business that produces biochar would need to invest in marketing and farmer/gardener education, as is likely the situation in other Pacific countries. It is very easy to produce biochar at a price that is competitive with international prices. In the USA, biochar is sold for anything from USD 4 to 10 per kg (price varies with quantity).

5.6 Marketing your bamboo charcoal, biochar and any derived products.

It is straightforward to market a product of high quality and with competitive price. Therefore, the primary task is to produce a product that you can be proud of both for its performance as well as its social and environmental benefits. There are no doubts at all on the benefits of bamboo for the environment, subject to the resource being harvested on a sustainable basis. The social benefits will depend on how your business is structured. Your business's interaction with the people and their culture is of extreme importance when buiding an ethical business that will be reflected in an environmentally friendly product. The longevity and sustainability of a business is dependent on sound relations with the owners of the resource that the business depends on, which could be the other landowning members or the clan from which the land is leased.

Due to the ever-increasing importance of social media, it is critical to build an online presence for your product. A simple website and a Facebook page are the minimum. These should be updated regularly and have clear contact details along with your product range and price. Ideally, it should also reflect the story behind your product and your branding. If a picture tells a thousand words, this is very much magnified on an online environment. Ensure you take pictures as these will be a vital for your online story.

The story behind your bamboo charcoal and biochar

The story behind a product will help to make your product a best seller, and there are potentially great stories associated with bamboo charcoal. Your story needs to feature the people of the community where the bamboo comes from, highlighting the fact that the purchase of the product is helping people with their livelihoods. The story also needs to capture the tropical beauty of the Pacific island country where it comes from as well as the impacts of climate change, emphasising the leadership the Pacific takes at international forums to address and limit the impacts of climate change. Importantly, the story needs to underscore the fact that this is a green product and include the benefits of using bamboo, recognised for its environmental and climate benefits.

Branding

Once you have your story figured out, you have to work on the branding of your bamboo charcoal or biochar. In today's world, obsessed as it is with image, it is imperative that you get your branding right. Branding is important to communicate the story of your product in the most succinct manner so your target market would pick your product over competitors. They will do so if they have confidence that your product meets the quality they expect, is priced competitively, and is readily available in a choice of convenient packaging sizes.

Time and effort will be rewarded in talking to a sample of your target market to find out what their expectations are when buying a charcoal, biochar and similar products. Feedback from prospective customers will then influence brand development. If, as we propose above, your product is to be of good quality, it can be marketed as one that is helping your country and community, as well as being environmentally and climate friendly.

Your story and associated branding will need to be displayed prominently on your product's packaging.

Packaging your charcoal and biochar

Biochar needs to be packaged in a convenient and eco-friendly packaging. By its nature it is a product that marks and stains clothing and therefore needs to be packaged in bags that are resistant to breakage, easy to handle and available in different sizes, giving clients as wide a choice as possible. Because of the way you will need to market this bamboo charcoal and biochar—as being an environmentally and climate friendly product—the packaging will need to match, which rules out plastic, generally derived from petroleum products.

Biochar can be packaged in multi-layer (usually two-ply) paper bags. These can be packed in convenient 5 and 10 kg bags. For anything bigger than this (20 kg and upwards), one should consider jute bags or even reuse potato sacks for packing the biochar. It is usually better to provide the market different weight options, so consumers have a choice in accordance to their needs. In time you would learn which is more popular with consumers and organise packing accordingly, ensuring higher availability of the more popular packaging. Large scale organic farmers, such as those supplying tourist hotels or export markets, may prefer to purchase biochar in bulk and essentially unpackaged (covered loads in trailers and lorry trucks).

As is the case with these trades, the price of the bags usually varies according to the quantity bought rather than the size of the bags. Of course, the more you buy the cheaper it would be per bag. One overseas source offers 20,000 bags at USD 4,300 (USD 22 cents per bag); 50,000 bags for USD 8,000 (USD 16 cents per bag); and 100,000 at USD 11,000 (USD 11 cents per bag). This cost would also need to be added to the transport costs.

If you are going to take biochar production seriously and have access to the bamboo reource, it makes economical sense to opt for the procurement of bags in larger quantities, as this would cut your production costs and you would be able to offer clients more competitive pricing as well as ensuring better profit margins.

Paper bag production is available in Fiji and the procurement of strong paper bags would normally be recommended. However, two-ply bags are not available. The alternative is to have single-ply bags thick enough and strong enough to withstand rough handling. The paper thickness of paper bags made in Fiji is 150gsm (special orders for bags for paper thickness of 170gsm is also possible). These can easily carry 5 and 10 kg loads. The price of bags in Fiji are FJD 40,607 for 50,000 bags (USD 39 cents per bag) or FJD 17,142 for 20,000 bags (USD 41 cents per bag) for the larger size bags with dimaensions 380mm width x 460mm height x 120mm depth. For medium size bags (dimensions 315mm x 370mm x 120mm) the price for 50,000 bags is FJD 17,859 (USD 17 cents per bag) and FJD 7,873 for 20,000 bags (USD 19 cents per bag). Bags sourced in Fiji do not include local transport costs for those businesses based outside Suva. Wherever bags are sourced, these need to be to be printed with the product information and branding of choice and incur minor additional costs, depending on volume.

5.7 Financing your bamboo charcoal and biochar production.

Once you have reached a decision to pursue this business, it is time to crunch the numbers. You should not embark on any business venture unless there is a high degree of certainty that it will be profitable. Businesses that can be initiated with very low start-up costs, such as bamboo charcoal/biochar, are attractive to Pacific Islanders/ smallholder farmers with limited capital.

There are a several avenues for funding bamboo charcoal/biochar businesses. Development Banks are often willing to provide financing for these kind of initiatives. Commercial banks are also likely to support these businesses if supported by a robust business plan and demonstrated entrepreneurial commitment. It is important that you ensure all your expenses are more than covered by sales leaving a clear profit margin which you should manage well, possibly leaving a portion of this profit aside for reinvestment in the business and potential future expansion.

Biochar production for sustainable development.

In the post-2015 development agenda, these benefits mean bamboo could emerge to become a key input to the Sustainable Development Goals (SDGs) – specifically SDG 7 (Affordable and Clean Energy), which aims to provide affordable, sustainable, and reliable modern energy services for all. It also contributes to SDG 8 (Decent Work and Economic Growth), as charcoal production can help to reverse high levels of unemployment and out-migration in developing countries, including urban drift. The input of biochar can greatly improve the fertility of agricultural soils and this in turn would contribute to SDG 2 (Zero Hunger). The demand for bamboo would also increase its area of growth—even into lands that require restoration—which in turn would contribute to SDGs 13 (Climate Action) and 15 (Life on Land).

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MODULE 6: BAMBOO MARKETS AND MARKETING

Module 6: Bamboo markets and marketing

This module provides an overview to help you appraise the market opportunities and marketing for bamboo. It is important to have an appreciation of the value chain(s) in which you would be involved.

There are likely to be several different bamboo value chains in which your products could be sold. You need to know who the various actors/participants are in the chain and what they contribute to the final product that is sold to the consumer. You will need to decide if you just want to be involved only in the growing of bamboo and/or whether you want to also invest in additional value-adding activities. It is noted at the outset that for most Pacific Islands bamboo agribusiness and growers that competition with China, India, or other nations who already have bamboo resources, culture, and industrial technology is not likely to prove economically viable.

6.1 Local uses and markets for bamboo products

As your bamboo plantation begins to come into production—about five or six years after planting—the quantity of bamboo product generated will be rather small. The early products will be best suited for:

- domestic use,
- local markets, and also for
- testing future markets, e.g. samples of edible shoots to Asian/Chinese restaurants and exporters, and poles/culms to local architects and construction and processing industries.

Home use and sharing of bamboo shoots/cooked meals in the village will provide both a good source of family nutrition and may help generate interest and new local markets. Local markets will be limited in both their scale and prices—lower than for markets in major cities and export markets—but can be a value stepping stone on the path to production of larger commercial quantities of bamboo shoots.

It is recommended that you thoroughly get to know your own bamboo shoots: this can be done through tasting fresh shoots (to check for any bitterness or astringency), cooking and preservation (in brine) trials. A good knowledge, and indeed a passion, for your edible bamboo shoots will be essential in properly marketing them and achieving higher sales, both price and volumes.

The same applies for your first bamboo poles/culms. It will be instructive to link up with local builders and architects to trial your products in construction including panels and splits for woven panels, fencing/barriers, concrete reinforcement and scaffolding. An example of a high value use for bamboo culms in south-eastern Viti Levu (Fiji) is for the battens in *soga* (sago palm) frond rafters, for which the thin-walled local *bitu vatu* (*Schizostachyum*) is suitable.

Bamboo products are seldom sold in local markets in the south Pacific, with the exception of some uses in packaging, roofing thatch and handicrafts. Hence, there will be obstacles and challenges with developing local market opportunities for edible shoots and construction due to unfamiliarity from prospective customers. Value-addition to bamboo culms is a useful option to pursue, including for tourist/handicraft markets.

Value-added bamboo products to generate income from sales in local and tourist markets include furniture and crafts (toys, wood working inlay, trim work, panelling, basketry weaving, frames, jewellery, fishing poles, garden stakes and yam trellis poles) and musical instruments (flutes, wind chimes, pan pipes and xylophones). In the past there had been considerable training in Fiji—provided through SPC in collaboration with Indonesian assistance—and there is an unutilised craft talent pool that might be called on to produce bamboo handicrafts.

6.2 Market opportunities for edible shoots

The market opportunities for edible bamboo shoots appear almost limitless into East Asian markets: for example, in PR China between 3.2 and 4.0 million tons of bamboo shoots are produced each year, mainly for local consumption. However, with farmgate prices for bamboo shoots in China at around FJD 2-4 per kg, Fijian and Pacific Islands growers cannot compete in China and most East Asian markets, especially taking into account transport, biosecurity and other costs associated with export.

Accordingly, Pacific Island producers of edible bamboo shoots will need to focus on nearer and more lucrative markets. These will include, in addition to local/domestic Asian food outlets, fresh bamboo shoot markets in Pacific rim countries with sizeable diaspora populations of Chinese, Koreans and Japanese and an associated vibrant restaurant industry, for example Australia, NZ, Hawai'i, W Coast USA and Canada. It will be essential to produce a fresh edible shoot product consistently in the volumes required for a selected niche market(s) and of the highest quality. A simplified value chain for edible bamboo shoots in Fiji is shown in Figure 1.

Pacific Islands bamboo producers are advised to work through their grower associations, Pacific Trade Invest and diplomatic/trade missions to connect with prospective local Asian buyers of fresh bamboo shoots.

It is considered improbable that Pacific processors might be able to produce an internationally competitive canned bamboo shoot product.

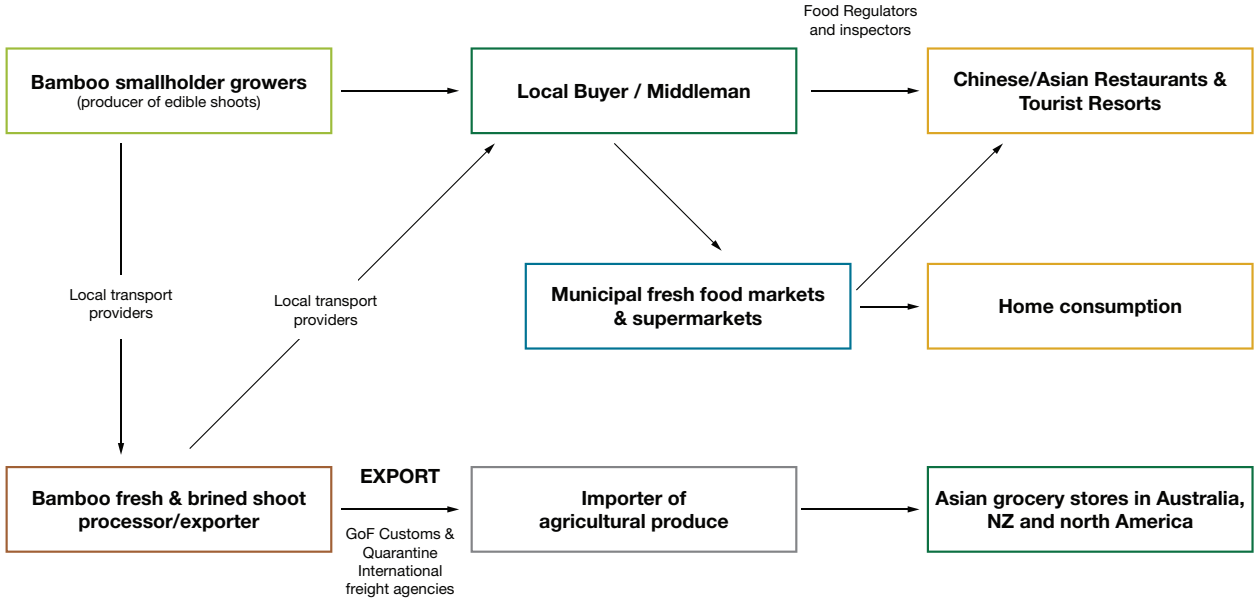


Figure 1: Bamboo shoot value chain for Fiji

6.3 Marketing opportunities for construction

Bamboo has a multitude of prospective uses in construction and the building industry. Much of the South Pacific islands experience earthquakes (especially Vanuatu and Solomon Islands) and increasingly poorly constructed cement block structures are being built which pose serious risks to their occupants during strong earthquakes. Bamboo has great potential in the development of low cost, light weight building structures which are flexible and able to sway safely during earthquakes.

However, in some Pacific countries, such as Fiji, there are legal barriers with bamboo not being included in the building code. Accordingly, there is a need for the bamboo industry (association, processors, growers and architects) to work with governments to update their building codes to include bamboo. Once bamboo is incorporated into building codes then the demand for bamboo in construction by architects and builders will potentially substantially increase.

There are also opportunities for incorporating bamboo in new, state-of-the-art, composite materials for use in building walls and panels: some of this research is being undertaken in Thailand and Fiji (Arnie Duckworth, pers. comm.). Such developments might greatly expand the market demand for bamboo in the future.

A simplified value chain for bamboo construction materials is shown in Figure 2:

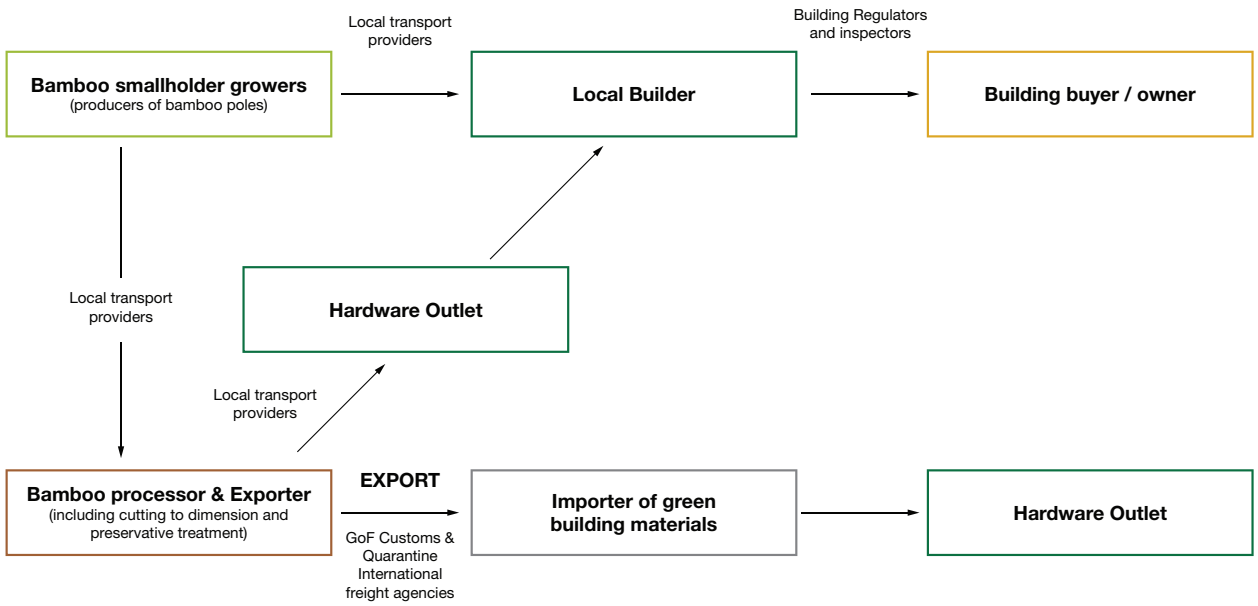


Figure 2: Simplified bamboo construction value chain for Fiji

6.4 Market opportunities for niche and novelty products

There are immediate domestic market opportunities for diverse bamboo market products in the Pacific Islands. In addition to edible shoots and construction (Module 4) and biochar and charcoal (Module 5), these opportunities include:

- Diverse products from the Fiji native and widespread *Schizostachyum glaucifolium (bitu dina)* such as:
  - battens for sago thatch rafters;
  - splits for woven products including traditional panelling;
  - reusable drinking straws from narrow culms;
  - poles and biomass for novel composite building products.
- Narrow diameter poles (*especially from Bambusa tuldoides)*:
  - fishing rod poles;
  - Semi-durable garden stakes and poles—lasting multiple cropping cycles—for use in covered plastic houses, for yams, beans etc
- Flexible, narrow culms (especially from *Bambusa textilis gracilis* (Weaver's bamboo) and B. multiplex):
  - Woven articles and handicrafts, including baskets.

Woven thatch of *Schizostachyum glaucifolium* for walls of traditional Fijian Bure, Nausori Highlands, Fiji (image: Lex Thomson).

Dried bamboo handicrafts and stems are light weight in relation to their volume, strength and value and accordingly are relatively low cost to ship and have export market potential, including through the 'carry on' tourist market

6.5 Future market opportunities for bamboo created by climate change, environmental degradation, plastic pollution, changing consumer awareness and demand

Climate change is having a devastating impact on Pacific Islands peoples, environments, agriculture and forestry. This is due to increasingly severe tropical cyclones, as well as king tides, more severe droughts, and flooding/landslips due to torrential rains during cooler periods. Bamboo is an outstanding crop to address climate change both through mitigation—sequestering carbon in above and below-ground biomass, long-term soil carbon sequestration in bamboo phytoliths, and potential to convert biomass to biochar—and adaptation through being a component in climate resilient agroforestry and farming systems, and protecting catchments and soils during extreme climatic events. Accordingly, there is an opportunity to market bamboo products as climate-friendly with their production contributing to the survival and health of Pacific islands peoples and ecosystems.

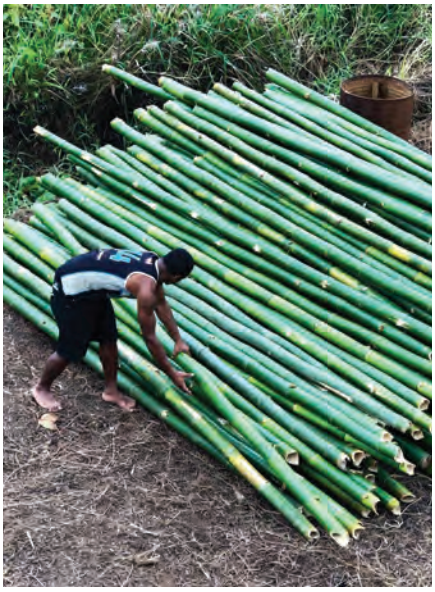
Bambusa vulgaris used in construction of canoes (image: Colin Philip)

Bamboo agroforestry systems are ideal for replacing flammable grasslands and unsustainable cropping on steep slopes. They assist in reducing soil erosion, building soil organic matter and fertility and moderating water flows out of degraded catchments, thereby improving the health of downstream freshwater and coastal ecosystems which are vital for food production, tourism and biodiversity conservation. The environmental benefits and sustainability of bamboo production systems are another dimension for marketing bamboo to environmentally-conscious consumers.

Increasingly, plastic pollution, including microplastics permeating the food chain, are of great concern to human and ecosystem health and wellbeing. Governments, entrepreneurs and consumers are looking to natural and biodegradable products which can replace plastics, and bamboo products have a role to play. Bamboo drinking

straws have already been mentioned, but also there is vast potential to make disposable cutlery, plates, clothes, underwear and socks from bamboo fibre (replacing synthetic fibres which are a major source of microplastics, which are generated each time synthetics are washed). Bamboo furniture can also replace short-lived moulded plastic furniture which contributes to land fill and plastic pollution.

In summary, there are major opportunities to market bamboo products as clean, green, climate friendly, environmentally sustainable and contributing to the livelihoods, health and well-being of Pacific Islanders.



Bambusa vulgaris poles for use in canoe building (image: Colin Philip)

6.6 Understanding your bamboo product value chain

The successful development of a bamboo-based enterprise will require a thorough understanding of the value chain. It is important to familiarise yourself with any existing value chains, the key players and undertake market research. Market research is an important type of economic research with respect to the development and recommendation of new technologies for growing and/or processing bamboo. For an agribusiness entrepreneur to invest in new bamboo technology, it is essential to have data on input markets (resources used in bamboo production or processing) and output markets.

The main marketing aspects to be considered will include:

- input supplies (scale of available bamboo resources and new planted sources and prices, equipment required and prices);
- expected output increases;
- market potential (demand, both local and for export);
- capacity of the marketing system to handle increased output; and
- anticipated government interventions (including existing regulations).

It can be challenging for an individual bamboo grower to conduct market studies and these may be best undertaken or commissioned by the Fiji Bamboo Association, Bamboo Development Centre and/or Ministry of Forestry. However, individual entrepreneurs need to undertake their own SWOT (Strength, Weakness, Opportunity and Threats) analysis to assure themselves that their prospective bamboo business is worth pursuing.

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Useful websites:

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3. Pacific Green Business Centre http://greenbusiness.solutions/bamboo/
4. Bamboo Australia https://www.bambooaustralia.com.au/ (commercial supplier of bamboo plants)
5. Bambusa Nusa Verde http://www.bambunusaverde.com/english/ (commercial supplier of tissue-cultured bamboo plantlets)
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