Chapter 8
Plantation Crops

Yan Diczbalis, Jeff Daniells, Smilja Lambert and Chris Searle

Abstract Plantation horticulture is an important part of the economic landscape of many tropical countries. Plantations were developed in association with colonial expansion and the original models were based on the production of monocrops which had a ready export market, using cheap or slave labour. Plantations in the twenty first Century are less likely environments for exploitation of human and environmental capital. They are however, linked to crop production on a large scale for produce to be sold, at profit, for export to distant markets rather than local sale. A range of crops can be broadly categorized into plantation crops. Plantations continue to be effective models for efficient agricultural production and will evolve in response to the continued demand for food, fruit, fibre, oil crops and timber from a growing population.

Keywords Plantation · Crop categories · Cocoa · Banana · Macadamia

Introduction

The word "plantation" evokes images of hot humid locations, far from the highly urbanized communities most of humanity inhabit, producing the necessities of domestic life such as tea, coffee, sugar, spices, and industrial crops such as rubber and

Y. Diczbalis (✉) · J. Daniells
Department of Agriculture, Fisheries and Forestry, Centre for Wet Tropics Agriculture,
PO Box 20, South Johnstone 4859, Queensland, Australia
e-mail: yan.diczbalis@daff.qld.gov.au

J. Daniells
e-mail: jeff.daniells@daff.qld.gov.au

S. Lambert
Cocoa Sustainability Research Manager Asia/Pacific, Mars Chocolate Australia, Ballarat,
Victoria, Australia
e-mail: smilja.lambert@effem.com

C. Searle
Suncoast Gold Macadamias, Bundaberg, Queensland, Australia
e-mail: c.w.searle@bigpond.com

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cotton. The strains of a gospel song are linked with images of slaves picking cotton or cutting sugarcane in the southern USA during the mid 1800s. Similar examples existed throughout the colonial empires in the Caribbean, South America, Africa, India and Australia. The word plantation is linked with colonialism, exploitation of human capital and environment.

The term “plantation” is broad and ill defined yet the essential ingredients of the plantation include;

- commonly owned by local wealthy families or foreign owned,
- a monocrop made up of an industrial, food, fibre or beverage crops,
- located in the tropics ideally suited to the climatic requirements of the crop,
- large production areas,
- low cost, or at times in history no cost slave labour, which allowed for the production of goods at relatively low cost and maximisation of profit.

Definitions for plantations abound and crops included are; bananas, cocoa, coconuts, coffee, cotton, hemp, jute, oil palm, pineapple, rubber, sisal, sugar cane, tea and tobacco (Courtenay 1965; Stephens et al. 1998; Hartemink 2005). The annual production and area under cultivation of these crops is a challenge to accurately quantify. The Food and Agriculture Organisation (FAO) collects and presents data, with qualifications, on its FAOSTAT website. Areas of production and yield data, for 2010, are presented in Table 8.1 (FAOSTAT). Coffee, coconut and oil palm each have production areas which exceed 10 million hectares (Mha), while the area under sugar cane exceeds 23 Mha. The economic value of plantation crops is considerable. Most plantation crops are produced in developing countries located through out the tropical regions of the world. The economies of many developing countries are highly reliant on crop production with plantation crops being prominent amongst them. The world top five producers of palm oil are Indonesia, Malaysia, Thailand, Nigeria and Colombia. The coconut industry is predominately based in developing countries with Indonesia, Philippines and India accounting for 37, 21 and 12.5 % of the value of production respectively. Agro-industrial plantation crops such as cotton and sugar are also important income sources for developed nations. The USA and Australia rank 4th (US$ 5,432 M) and 5th ($US 4,068M) respectively for the value of cotton lint production and 8th (US$ 1142 M) and 10th (US$ 798 M) respectively for the value of sugarcane production. China ranks 1st for value of production of sugarcane and cotton lint producing US$ 31,128 M and US$ 9,700 M of raw product respectively (FAOSTAT).

Plantation Crop Categories

Plantations in the 21st Century are less likely environments for exploitation of human and environmental capital, although the potential still exists. They are however, linked to crop production on a large scale for produce to be sold, at profit, for export or distant markets rather than local sale. A range of crops can be broadly

Table 8.1 Plantation crop production, harvested area and average yield adapted from FAOSTAT 2010a[a]

Crop categories and crops	World production (tonnes)	World area harvested (ha)	Average yield (Hg/Ha)	Average yield (t/ha)*
Beverages				
Coffee green beans	8,228,018	10,234,363	8,040	0.80
Cocoa beans fermented dried	4,187,587	9,541,698	4,389	0.44
Tea—manufactured	4,483,954	3,130,566	14,323	1.43
Sugar				
Sugarcane raw	1,711,087,173	23,877,378	716,614	71.66
Spices				
Nutmeg mace cardamom	59,198	260,964	2,268	0.23
Pepper sp.	426,925	557,057	7,664	0.77
Vanilla	6,680	72,512	921	0.09
Cloves	135,887	533,085	2,549	0.25
Cinnamon	202,299	209,470	9,658	0.97
Spices nested	1,985,226	936,257	21,204	2.12
Fruit				
Banana	102,028,171	5,014,058	203,484	20.35
Plantains	36,387,578	5,407,363	67,293	6.73
Mangoes, mangosteens, guavas	37,124,742	4,946,313	75,055	7.51
Pineapples	19,408,581	879,175	220,759	22.08
Citrus Fruits, nested	11,776,311	1,264,642	93,120	9.31
Papaya	11,568,346	433,057	267,132	26.71
Avocadoes	3,891,626	462,662	84,114	8.41
Tropical fresh fruit nested	18,484,427	2,492,813	74,151	7.42
Nuts				
Almonds with shell	2,556,816	1,684,746	15,176	1.52
Brazil Nuts with shell	99,917	640	1,561,203	156.12
Cashew nuts with shell	2,757,598	4,715,046	5,849	0.58
Walnuts with shell	2,555,090	844,162	30,268	3.03
Nuts nested	807,005	574,381	14,050	1.41
Oil, fibre and rubber				
Coconut (fresh, copra and dried)	59,421,273	11,376,698	52,231	5.22
Oil palm fruit	217,925,795	15,410,262	141,416	14.14
palm oil	43,573,470	na	na	na
Cotton lint	23,295,107	na	na	na
Fibre crops nested	312,840	361,608	8,651	0.87
Natural rubber (dry weight of latex)	10,004,206	9,624,577	10,394	1.04

[a] Calculated by conversion from Hg/ha

Fig. 8.1 **a** Tea plantation recently harvested by machine, Malanda, Queensland. (©Drinnan). **b** Mechanical coffee harvesting, Atherton Tableland, Queensland. (©Drinnan)

categorized into plantation crops. These can be further categorized as beverage, spice, sugar, fruit and nuts; oil and biofuel, and fibre and industrial crops.

Beverage Crops

Beverage crops, chiefly tea, coffee and cocoa, became rapidly industrialised from the nineteenth century.

Tea (*Camellia sinensis*), native to northern Myanmar and southern Yunnan province in China (Purseglove 1968; Eden 1965) was cultivated in south east China for 2 to 3 millennia in the WuYi mountains in Fuzian province China prior to the plants distribution to other growing regions. The story of how tea departed China for north east India with the aid of the British botanist, Robert Fortune (1812–1880) in 1848, is enjoyably told by Rose (2009). Once tea was established in India by the East India Company, the commercial stranglehold the Chinese had on the tea trade was broken. Successful cultivation and production of tea depended on cheap labour for hand plucking the fresh shoots required to make tea. Tea plantations spread from India to the colonial Malaya with production in the Cameron Highlands and then Tanzania, Kenya, Indonesia and Russia. Newer centres of production include Australia (Drinnan 2008), particularly following the development of mechanical harvesting (Fig. 8.1a). However, purists argue that the finest boutique teas are still picked by hand.

Coffee (*Coffea arabica*), native to the highlands of Ethiopia where it occurred naturally in forests at altitudes between 1,200 and 2,000 m, was reportedly introduced to Arabia by the fifteenth century (Haarer 1962). Coffee spread rapidly via colonialisation (England, Dutch, French, Italian, Belgian, Germans and North Americans) but is now produced dominantly by independent countries in Latin America (Topik and Clarence-Smith 2003; Bigger 2006). The labour intensive nature of picking coffee berries lead to plantation production methods. The development of coffee harvesting machinery lead to expansion of the industry and the development of boutique coffee production in high cost labour countries such as Australia (Fig. 8.1b).

Fig. 8.2 Low intensity and intensive vanilla production, Vavau Island, Tonga. (©Diczbalis)

Cocoa (*Theobroma cacao*), native to the Amazon basin and cultivated by the Aztecs as far north as southern Mexico, was brought back to Europe by the Spanish (Wood and Lass 1985). Further reference to cocoa and its evolution as a commercial beverage plantation crop is presented in detail as a case study, later in the chapter.

Spice Crops

Although much of the world's spice production is supplied by smallholder growers, the crops are considered to be part of the plantation category. The Journal of Plantation Crops covers all the major spices. Spice production is often carried out as an intercrop with coconut (Newman 1985; Liyanage et al. 1986).

Major historical events were driven by the spice trade (Milton, 1999; Hemphill 2000). Spices naturally distributed throughout the tropical latitudes were rapidly "plantationised" by colonial powers following growing demand from European and British consumers who cherished the fragrant properties of spices to enhance the culinary properties of unrefrigerated meat and food (McGee 2004). Commonly used spices include cardamom (*Elettaria cardamomum*), chilli (*Capsicum spp.*), cinnamon (*Cinnamomum zeylanicum*), cloves (*Syzygium aromaticum*), ginger (*Zingiber officinale*) nutmeg (*Myristica fragrans*), pepper (*Piper nigrum*), turmeric (*Cucurma longa*), and vanilla (*Vanilla planifolia*). A number of spices are reported to have medicinal properties, chief amongst them turmeric which reportedly could clear plaque deposits associated with Alzheimer's disease (Barry 2007). Major centres of spice production include India, Indonesia, Malaysia, PNG and Pacific Islands, Central America and tropical Africa. Boutique industries for pepper and vanilla can be found in Hawaii, Papua New Guinea and far north Queensland, Australia. Intensive methods of production are gaining a foothold in developing countries, as is the case for many plantation crops (Fig. 8.2).

Fig. 8.3 Mechanical harvesting of sugarcane. (©Diczbalis)

Sugar

The discovery of sugarcane (*Saccharum officinarum*), a tall clumping grass, is thought to have originated in the tropical regions of the western Pacific (Barnes 1953; Barlow et al. 1991). The spread of sugarcane initially occurred to southern China and India and then made its way from Persia (Iraq and Iran) to the Mediterranean, north Africa and Egypt. Sugarcane reached Spain in the eighth century and was widely cultivated in southern Spain during the early twelfth century (Mangelsdorf 1950; Sharpe 1998). Columbus is credited with introducing sugarcane to the islands of the West Indies in 1493 where it spread to the southern USA, and to Central and South America. Brazil is the largest producer of sugarcane with 9.8 Mha in production in 2010 producing 660 Mt (Barros 2010). The evolution of sugarcane production is closely linked to slavery and/or indentured cheap labour due to the requirement for hand planting, cultivation and harvesting. Sugarcane was first introduced to Australia by the First Fleet in 1788. The first viable cane production was recorded near Brisbane, Queensland in 1862 and shortly thereafter indentured labour was imported from the Pacific. A reported 62,500 labourers were imported over the next 40 years until 1904 when the Commonwealth of Australia banned the practice (Irvine 2004). Following the repatriation of indentured workers from 1906, sugarcane production and processing was carried out by higher paid Anglo–Celtic and European labour. This resulted in the rapid mechanisation of the industry with Australian producers leading the development of mechanical harvesting (Griggs 2011). Sugarcane harvesting is primarily mechanised in the major producing countries but still relies on low cost labour in south Asia, India, Central and South America and the Pacific.

Mechanised cane harvesting has contributed to a substantial reduction in preharvest burning, necessary when hand harvesting sugarcane (Fig. 8.3). Pre-harvest burning contributes to air pollution through the emission of particulate matter and greenhouse gases (França et al. 2012).

Oil and Biofuel Crops

There are a wide range of oils produced from crops which include castor oil (*Ricinus communis*), coconut oil (*Cocos nucifer*a), cotton seed oil, shea butter (*Vitellaria paradoxa*) and oil palm.

Oil palm (*Elaeis guineensis*), native to West Africa, is the major source of cooking oil produced from processed kernel and mesocarp of this monecious palm. It accounts for 60 % of the traded vegetable oil. Oil palm is a tropical species and, as such, production occurs throughout the tropical regions of the world. World production in 2010 was estimated at 217.9 Mt produced from 15.4 Mha (Table 8.1). Indonesia and Malaysia are the major producers, followed by Nigeria and Colombia (Anon 2011; Soh et al. 2008). Additional production occurs in a number of West African countries, Central America and Brazil. Smaller production areas occur in Thailand, China and the Philippines. The bulk of consumption occurs in China, India and Europe. Oil palm is the quintessential plantation crop (Verheye 2010). The vast bulk of production occurs in the developing world where low wages allow for a large labour force and hand harvesting. Plantations in Indonesia and Malaysia vary in size, often as large as 5,000 ha with production feeding a central processing plant. Oil palm production is controversial with reports of destruction of virgin rainforest, environmental degradation and relocation of native communities by government sanctioned development projects (Colchester et al. 2007; McCarthy and Cramb 2009; Wilcove and Koh 2010; Irawan et al. 2011). Oil palm is also produced as a biofuel in some locations; however the high value of the oil for food production currently makes this economically unsound.

Coconut (*Cocos nuciferia*), the "tree of life" (Foale 2003) plantations are the foundation for the production of copra (dried coconut flesh). Coconuts are primarily produced in Asia (Indonesia, Sri Lanka, Philippines, south India, Sri Lanka, Malaysia and Thailand), Oceania (PNG, Fiji, Tonga, and Vanuatu), Latin America and Africa. Some 59 Mt of nuts are produced from 11.3 Mha (Table 8.1). Coconut oil produced from copra is no longer dominant as a vegetable or industrial oil, however there is a resurgence in production for virgin coconut oil derived from cold pressing of the coconut meat (Foale and Robeling 2006). Coconut based agrosystems are diverse and are often intercropped with a diversity of species (Nobre Lages 1996). With the increasing scarcity of fossil fuels and resultant price increases, oil crops are being increasingly utilised as a replacement "biofuel" product. Coconut oil is also converted into biofuel, particularly on isolated Pacific Islands where fuel oil prices are restrictive due to the high cost of transport. Coconut oil can be used directly in standard compression diesel engines with modifications to allow for its increased viscosity, mixed with diesel or converted to biodiesel (Anon 1983; Walton 2008).

Fibre and Industrial Crops

The principal fibre crop is cotton. There are approximately 30 species of *Gossypium* growing across Africa, Asia, Australia and the Americas. Cotton, primarily produced from *Gossypium hirsutum*, with its centre of origin in Central America, from northern Guatemala, developed rapidly into an industrial crop from the mid 1800s with plantations established in the southern USA, chiefly to supply the growing industrial mills of Great Britain and Europe (Purseglove 1968). Prior to the development of mechanical harvesters, the bolls of cotton required manual picking by an abundant labour source. Cotton is grown extensively throughout Egypt, central Asia, China, Australia, USA and Brazil. Since 1980, average cotton yield has increased 60 % but the area cultivated has remained stable at approximately 30 Mha (Anon 2012a). Much of the world's cotton still relies on intensive labour inputs for planting, management and harvesting. In 2008/2009 India had the largest area sown to cotton (9.4 M ha) with a rapid growth in yields since 2003 due to the introduction of biotech varieties and improved hybrids (Osakwe 2009). Cotton production in the USA, Brazil and Australia is grown on a large scale, mechanically intensive and efficient due to a range of innovative agronomic inputs which include genetically modified insect and herbicide resistant varieties, global positioning system controlled tilling, planting, fertilising and harvesting operations and efficient computer controlled irrigation.

Rubber (*Hevea brasiliensis*) is native to the central Amazon and Orinoco Valleys and is tapped from the trunk of trees for its latex. It is utilised for the production of tyres, mats, wire coatings, shock absorber pads and associated rubberised products. Rubber is a tropical crop and, like oil palm, coconuts and cocoa, is generally restricted to production within 10° of the equator. Temperatures below 18° C will reduce latex production. Rubber was reportedly used by the Amazonian Indians for making balls, simple footwear and for waterproofing fabrics (Purseglove 1968). Initial efforts to commercialise rubber looked at the potential of a number of species, including Ule rubber (*Castilla elastica*), Jelutung (*Dyera costulata*), Indian rubber (*Ficus elastica*) and Zanzibar rubber vine (*Landolphia kirkii*). *Hevea* species, in particular *H. brasiliensis,* was considered the most productive. The commercialisation of rubber is credited to Sir Henry Wickham who collected 70,000 seeds from an area in the central Amazon basin in 1876. The collection and export of the rubber seed to Kew Gardens in London remains controversial with the common view that the seeds were smuggled out. Purseglove (1968) reports that it was done with the goodwill and cooperation of the Brazilian authorities. Although less than 4 % of the seeds germinated, they established the nucleus stock which was sent to Ceylon (Sri Lanka) and later to Singapore, a secondary site for establishment. The first rubber plantations were established in Malaysia in 1890 and Uganda and Nigeria in 1903, the Belgian Congo in1904 and Liberia in 1924. Rubber tapping remains labour intensive with one person tapping approximately 450 trees per day (Fig. 8.4). A yield of 1.6 t/ha is considered reasonable. Some 10.0 Mt are produced from 9.6 Mha, averaging 1.0 t per hectare. Today, Southeast Asia (Thailand, Vietnam, Malaysia

Fig. 8.4 Rubber plantation and rubber collection following tapping, Guatemala. (©Diczbalis)

and Indonesia) is the centre of commercial production with some production also occurring in Central America and in Brazil, the origin of the crop.

Extensive areas of coconut, rubber, and oil palm, particularly in their establishment phase, are also a valuable grazing resource. Coconut plantations, in particular, allow for permanent integration of cattle because of the relatively low density of palms and penetration of light for pasture growth between trees (Shelton and Stür 1991).

Tropical Fruits and Nuts

Tropical and subtropical fruits, principally dessert bananas such as Cavendish, mango, avocado, citrus, pineapple, papaya and to a lesser degree litchi are increasing being grown in plantation style production units (Paull and Duarate 2011). Banana production is discussed in greater detail as a case study in this chapter.

Pineapple (*Ananas comosus*) is the only fruit in the Bromeliad family, consisting of 45 genera, grown for commercial sale. The Great Giant Pineapple plantation (GGP), is an excellent example of a modern plantation model. Located in Lampung, southern Sumatra, Indonesia, GPP produces 500,000 t of pineapple from 33,000 ha. It is the third largest producer of canned pineapple and juice concentrate in the world. The company exports to 30 countries in the Asia Pacific, North America, Europe, Middle East and South America. The company's own promotional video suggests that every fifth can of pineapple in the world is from the GGP (http://vimeo.com/6938824).

Avocado (*Persia americana*), native to Central America, is widely grown throughout tropical and sub tropical regions. Orchards in Chile, Australia and South America are managed on a plantation model with farms ranging up to 5,000 ha. The

Fig. 8.5 A large scale (50 ha) papaya farm, South Edge, Queensland. (©Diczbalis)

establishment of avocado orchards in Chile, Israel, Spain and South Africa is primary based on the export markets of North America and Europe whereas Mexico, the largest producer of avocado (1.0 Mt annum), is primary aimed at the domestic market. (Anon no date; Naamani 2007).

Papaya (*Carica papaya*), with a centre of origin between southern Mexico and Nicaragua, is widely produced throughout the tropics and subtropics (Chan and Paull 2006). It is the third largest tropical fruit crop with 11.22 Mt or 15.4% of total tropical fruit production (Evans and Ballen 2012). India is the largest producer of papaya with an estimated 4.7 Mt produced in 2010. In 2009, world exports of papaya were 279,684 t mainly from Mexico, Brazil and Belize. Papaya orchards, although not at the size of some crops, are being "plantationised" with orchards in Australia up to 50 ha (Fig. 8.5). These large production units need a large skilled labour force and a high level of mechanisation to efficiently harvest, sort and pack the crop.

Litchi (*Litchi chinensis*) and longan (*Dimocarpus longan*) are grown on a large scale in southern China (Yen and Paull 2006; Zee and Paull 2006) with orchards as large as 2,000 ha (Fig. 8.6). Many of the larger schemes were initiated under the direction of regional and provincial governments during the 1980's (Zhang 1977). The farms are state-managed with the workforce drawn from the surrounding villages. Similarly, rambutan (*Nephelium lappaceum*) is grown in plantations in Guatemala with 35,000 plus trees managed by the company, Lafinita. The availability of a relatively cheap labour force combined with a high level of technical and managerial inputs are common ingredients to a successful export orientated plantation.

Tree nut crops are increasingly becoming "plantationised" as the drive to increased efficiency of production, with the aid of technology and mechanisation. Nut crops, in particular Macadamia, are one of the case studies examined later in the chapter.

Fig. 8.6 A litchi plantation known as the "litchi forest" near Maoming, China. (©Diczbalis)

Forest Crops

Forests planted for timber and wood pulp now occupy approximately 300 Mha or 2 % of global land area (FAO 2006). Forest plantings range in size from smallholder plots to large agro-industrial scale plantations and occur over a range of climatic zones. Planted forests are long-term investments that require careful planning prior to establishment, in order to avoid negative impacts. Hence, issues such as germplasm selection, site preparation, nursery production, planting, agronomic management and harvesting will all impact on the success of the plantation

In 2015 the projected forest plantation area is 327 Mha with approximately a 50 % split between non-tropical and tropical forests. By 2020 an estimated 412 Mha will be produced with 62 % coming from tropical based plantations (Anon 2007). Internationally; plantation forests account for approximately 95 % of wood pulp production, 85 % of reconstituted panels, 25 % of plywood and 22 % of sawn wood production. The situation changes depending on continent with a high proportion of wood products coming from plantation forests in Latin America and the Caribbean while most African forest products are largely dependent on wood supply from natural forests (Anon 2007).

Plantation forest areas are increasing rapidly to meet the rising demand for wood products. The global outlook to 2030 and recent areas of planted forests by country and the role planted forests play for the future of the worlds forest resources is covered by FAO (2009).

Case Studies

Three case studies are presented which attempt to define the past, evolution and future of plantations.

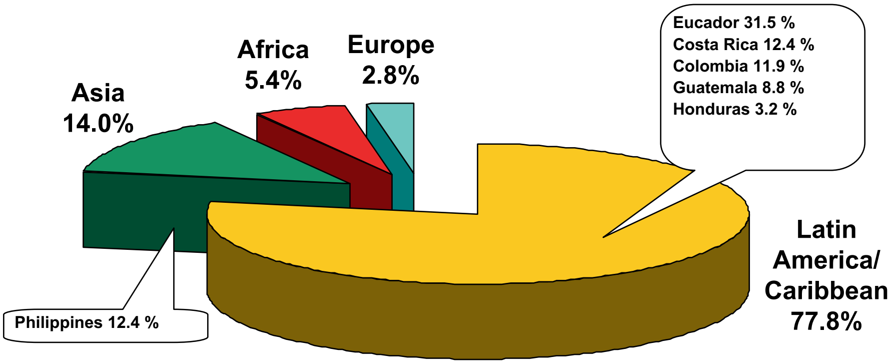

Fig. 8.7 Values from Lescot (2012) have been adjusted to take into account exportation from non-banana producing countries

Bananas

Introduction

Banana is the developing world's fourth most important food crop after rice, wheat and maize, with total production estimated at 130 Mt in 2010 (Lescot 2012). Bananas as such include plantains which are a type of banana usually cooked before consumption. The crop is grown in more than 130 countries throughout the tropics and subtropics. Banana is a staple food for millions of people, particularly in Africa (Daniells 2009). It is also the most important fruit crop in world trade with about 16.2 Mt being exported in 2010. It is this latter aspect of export where bananas manifest as the quintessential plantation crop.

The world trade in bananas was valued in excess of US$ 8 B in 2009 (FAO 2012). Over 80 % of the export production comes from just 6 countries in the tropics (Fig. 8.7) and the total area involved is in excess of half a million hectares (Daniells 2006) and employs millions of workers. Latin America and the Caribbean account for 78 % of export banana production because of relative proximity to the major markets of North America and Europe. Most of the production is sold competitively on free markets in North America, Europe, the Arabian Gulf States and Japan.

Brief History

The banana export trade began in the 1860s with shipments of Gros Michel bunches from Central America and the Caribbean to North America (Simmonds 1966). The trade in bananas expanded rapidly as individuals/companies realised the profits that could be made from the fruit. During the 1870s, there were 114 banana companies registered in the U.S. However, only 22 of these lasted until the end of the century

Fig. 8.8 Banana plantations can cover hundreds, sometimes thousands of hectares. They are mainly located on rich well drained alluvial soils. Packing sheds are often centrally located. (Photo courtesy MacKay family)

and only 4 were of significant size. United Fruit Company (UFC), the first of the large transnational banana companies, was incorporated in 1899 which marked the beginning of a new era that converted the highly perishable tropical banana into an important item of world trade. UFC was the first truly vertically integrated fruit company having large production in widely separated localities, control of dedicated shipping assets, expertise in fruit transportation methods, a marketing organisation and sufficient capital to develop new production and marketing areas (Roche 2000). Thus, bananas for export took on the many qualities and attributes of plantation horticulture, mostly corporately-owned large estates (Fig. 8.8), especially in the tropics, employing cheap labour on a large scale, monoculture cropping, and producing for sale in distant markets. These ingredients laid the foundation for bananas, little known in the western world 150 years ago, to become the major fresh fruit in temperate zones where they are not grown.

Laying the Foundations for Plantation Profitability

Banana plantations were at the forefront of industrialised horticulture and the characteristics of these plantations have everything to do with the drive for profitability. To produce the required fruit quality at the cheapest price, the large transnational companies and smaller national growers alike employ the following mix of strategies:-

Fig. 8.9 Banana production is labour intensive. Harvesting banana bunches is particularly heavy work with ratoon bunch weights typically in the range of 30–60 kg. (©Daniells)

- Banana growing is very labour intensive (Fig. 8.9) so, to minimise costs, country locations are sought where wages are low, such as Latin America and the Philippines.
- Production in tropical equatorial locations facilitates consistent supply of fruit to importing countries throughout the year. These locations are also sought for their high yields of fruit which has not been damaged by in-field chilling which occurs at temperatures <13 °C. Chilled fruit has an unattractive, dull yellow appearance when ripened. Where possible, locations are sought that seldom suffer severe wind damage from cyclones/hurricanes, which would lead to severe market supply fluctuations. Therefore so the closer to the equator the better, as these storms are generally formed between 7–15° latitude and move away from the equator.
- Choice of the most fertile, well-drained, mostly deep alluvial soils, usually on flat terrain. Poorer soils require more inputs for satisfactory yields and require replanting more frequently. In the early 20th Century, great efforts were made by soil survey teams in difficult tropical jungle conditions to locate the best soils for the plantations.
- Good rainfall and supplementary irrigation is required to ensure optimal fruit quality, particularly fruit greenlife ((= transport life).
- Significant capital investment in plantation infrastructure is required. This includes all-weather roads, irrigation systems, elaborate field drainage networks to minimise waterlogging, cableways to transport fruit to the packhouse (Fig. 8.10) and large packhouses to prepare the harvested fruit for dispatch to market.
- About 95 % of export bananas are of the Cavendish type (*Musa* AAA group, Cavendish subgroup) with production restricted to a handful of cultivars which are genetically very similar. Cavendish bananas are high-yielding and are well suited to the requirements of the supply chain. Most other types of bananas are lower yielding [¼–¾ of Cavendish] so it is difficult for them to compete in the market because of the required premiums for profitability (Daniells et al. 2012).

Fig. 8.10 Networks of cableways are the norm for transporting bunches to the packing shed. They are just part of the significant capital investment necessary in establishing a banana plantation. (©Daniells)

The simplicity of having just one type to manage, in what is a long and complex supply chain, has contributed greatly to successful marketing.

- Transnational companies are divided into administrative units from 250–400 ha each whilst larger national growers range from 50–250 ha. Such size brings with it economies of scale and the capacity to supply 'long lines' of uniform product better meeting the quality specifications of large retail outlets.
- Usually there are from 0.6 to 0.8 workers required to manage one hectare. Thus large workforces are involved and good people management is crucial. Operational procedure manuals which detail the requirements of every on-farm procedure are typically available to staff. Activities are generally broken down into single tasks to be performed by individual workers and this is monitored and necessary feedback provided to ensure standards are achieved.
- Most export fruit is transported to market by ship. In order to efficiently use shipping space and facilitate marketing, it is necessary to predict the amount of fruit available for harvest and sale on a weekly basis. Relatively reliable estimates are possible once the young bunch emerges and this provides predictions about 12 weeks in advance of harvest. Weekly counts of new bunches, coupled with historical information of bunch size, filling rate and expected losses, is commonly used in the calculations.

Banana Plantations—their Impact and Contribution

The world's banana export industry has been almost entirely controlled by 3 large fruit companies: Chiquita, Dole and Del Monte. Many countries, including those in Latin America, depend heavily on the revenue and employment that these corporations provide. The revenue is so lucrative that many governments have gone out of their way to attract the fruit companies to establish plantations in their country. This has allowed transnationals to become very powerful and influential, leading to a transformation of the economic, political and social landscape of the Latin American region (Bucheli 2006).

Banana growing is economically significant in many banana exporting countries because it is very labour intensive. The range of tasks performed include digging planting holes, hand planting, broadcasting fertilisers, deleafing, desuckering, covering bunches, pesticide application, harvest, dehanding fruit, sorting, and packing. In Honduras and Costa Rica, banana plantations employ 5–10 % of the population. Bananas also deliver a relatively quick return on effort and investment, providing a regular income year round. The crop recovers quickly from hurricanes and other natural disasters, in many ways making it an ideal crop.

Much criticism has been levelled at export banana plantations over the years regarding their environmental credentials and poor social conditions. Certainly, hundreds of thousands of hectares of rich and diverse tropical ecosystems have been transformed into banana plantation monocultures over the last 100 years or so. However, on the positive side, development of these regions allowed settlement in areas that were previously inaccessible.

Despite criticisms, progress is being made to improve the sustainability of export banana production, albeit not quick enough for some. For the past 20 years, organizations, including the Rainforest Alliance, have been working with banana producers to conserve biodiversity and ensure sustainable livelihoods by transforming land-use and business practices, and consumer behaviour. For instance, Chiquita has all their banana crops certified by the Rainforest Alliance. Also, since the year 2000, there has been rapid growth of organic exports from 30,000 t to nearly 400,000 t in 2010 (Dawson 2012). However, market penetration for organic bananas is still comparatively small, representing only 2.5–3.0 % of total banana imports in 2010. Fairtrade International is a group of 25 organizations working to secure a better deal for producers. Growers producing Fairtrade bananas receive a minimum price to cover the cost of sustainable production and a premium to invest in projects in their communities. In 2010, there were nearly 26,000 ha of bananas under Fairtrade cultivation.

The overseas export markets have demanding requirements that greatly influence cultivation methods used by banana growers (Figs. 8.11 and 8.12). Plantations strive to produce blemish-free fruit with quality (fruit diameter, or grade, and length) meeting retail specifications. They also strive to protect fruit from mechanical damage during growing, harvesting and transport to the packing shed (Fig. 8.14). This includes padding inserted between hands of fruit on the bunch during early fruit development and plastic between the 2 whorls of a hand (Fig. 8.13), and bunch covering. As well, shoulder padding is worn by workers carrying bunches to the cableways. Export markets are up to 3½ weeks away so fruit needs to stay green (remain preclimacteric) to allow uniform ripening with ethylene gas at the final destination. A method known as age-grade control is used on the plantation to judge those bunches which are optimal for both fruit size and greenlife which is related to bunch age. Additionally, bunches are monitored in the packing shed by examining the pulp colour of indicator fruit fingers to ensure they have sufficient greenlife. Bananas rejected for export amount to 15–20 % of the crop and contribute to local food supplies.

Fig. 8.11 Banana tissue culture nurseries supply tens of millions of pest and disease-free plants worldwide for new plantings so reducing pest problems and the need for some pesticides. (©Daniells)

Fig. 8.12 Aerial application of fungicides for leaf disease control. Monocultures of the susceptible Cavendish-type bananas destined for export are usually grown in wet tropical environments and are highly dependent on pesticide inputs for high yields of the required fruit. (©Daniells)

Serious diseases threaten the future of the banana plantations world wide. These diseases include, in particular, Fusarium wilt tropical race 4 (TR4), black Sigatoka leaf disease and bacterial wilts. All the plantations are monoculture cropped with Cavendish cultivars which are genetically very similar. Thus, they are very vulnerable to disease outbreaks. This was highlighted by the January 18th 2003 *New Scientist* cover story 'Going Bananas' (Pearce 2003). There is still no satisfactory control measure for TR4. The disease, until recently confined to Asia is causing serious losses to plantations in China and the Philippines, has now spread to Africa. In recent years, black Sigatoka has become more difficult to control in many plantations, necessitating weekly fungicide applications which is clearly not sustainable. Major changes in banana culture are needed to face these challenges.

Banana plantations supply most of the western world with its most popular fruit the year round. In just a little over a hundred years bananas have come to be relied upon by the masses as an inexpensive, nutritious fruit. This has largely been

Fig. 8.13 Blemish-free fruit has competitive advantage in the western marketplace. Growers have to go to great lengths to protect fruit from mechanical damage. (©Daniells)

Fig. 8.14 Large banana packing shed—mini-factories preparing fruit for market. Export banana production was at the forefront of industrialised horticulture. Large workforces are required to prepare the fruit for market. (Photo courtesy MacKay family)

possible because of the suitability of bananas to this style of horticulture and the efforts of a great many people.

Cocoa—An Unusual Plantation Crop

Crop Production, Processing and Chocolate Making

Cocoa (*Theobroma cacao*) is a small cauliflorous tree, which produces pods containing seed, referred to as beans, from which chocolate is made (Figs. 8.15 and 8.16). The tree flowers throughout the year but normally there are two distinct harvests that depend on the rain pattern (Knapp 1930). Well-drained soils, constant mild temperature and regularly distributed rainfall of around 2000 mm/year are optimal for cocoa farming, although regions such as West Africa which have an average of 1250 mm/year also produce commercial crops (Wood and Lass 1985). In areas with lower rainfall or a pronounced dry season, cocoa should be irrigated as in Ecuador, Venezuela, India and Vietnam. Cocoa pods require 5–6 months from pollination to maturity and two cycles of pod ripening are normal, with alternating main and secondary harvests.

Fig. 8.15 High yielding cocoa tree. (©Lambert)

Fig. 8.16 Ripe cocoa pods with beans ready for fermentation. (©Lambert)

The proportion of cocoa harvested on each occasion depends on climate. Usually, the main crop that starts flowering at the beginning of the rainy season accounts for some 60 % of the total harvest. However, in West Africa with a more distinctive dry season, up to 85 % of cocoa is harvested during the main crop from October to January. In the trials examining the feasibility of cocoa production under high input conditions in northern Australia, there were two peaks in production, each approximately 25 % of total production with the remaining pods produced throughout the year (Diczbalis et al. 2010).

Cocoa pods contain 30–40 beans enveloped into a white, sweet, juicy pulp that ferments when beans are left in a pile or are placed into a fermentation box. Fermentation is crucial to produce cocoa beans that can be used for the production of chocolate as it is during fermentation that chocolate flavour precursors are formed.

Fig. 8.17 Small cocoa growers in PNG harvesting and opening pods to ferment their beans in small a box fermentery with a kiln drier. (©Lambert)

These precursors react later during roasting, producing the characteristic chocolate flavour. Fermentation is a natural process caused by a microbial succession of yeasts and acetic/lactic bacteria and is performed by cocoa growers after pod opening and bean extraction (Wood and Lass 1985). In Africa, most growers ferment their cocoa in the field in heaps piled on, and covered by, banana leaves but in Asia/Pacific region, cocoa is mainly fermented in wooden boxes (Fig. 8.17).

In Sulawesi, the main cocoa producing region of Asia, growers do not ferment their cocoa, resulting in low quality beans used mainly for extraction of cocoa butter. Following 5 to 7 days of fermentation, the beans are mainly sun-dried on elevated platforms, a cheap method resulting in high quality (Figs. 8.18 and 8.19). However, in many cocoa producing countries, the cocoa harvest coincides with the rainy season and drying can be a big challenge. Many cocoa growers use wood-fired kiln driers (Samoan driers) but, poor maintenance of the fire chamber and flue leads to smoke contamination.. This is a particularly a problem in the Pacific.

Cocoa trees are susceptible to a large variety of pests and diseases that are different on each continent. The most common disease is “black pod” (*Phytophthora palmivora*) which causes pod rot and trunk canker. Devastating fungal diseases in the Americas are witches’ broom (*Moniliophthora perniciosa*) and moniliasis (*Moniliophthora roreri*); in Africa, *Phytophthora megakarya;* and in Asia, *Oncobasidium theobromae* causing vascular-streak dieback The only viral disease of cocoa is the Cocoa Swollen Shoot Virus in Africa. The main insect pests are cocoa pod borer (*Conopomorpha cramerella*) in the Asia/Pacific region and sap-sucking bugs (mirids or capsids) in Africa.

Processing of dry, fermented cocoa is a two phase process that is normally done by different businesses. The first step, cocoa grinding, involves roasting, deshelling, grinding/milling of nibs into a fine cocoa paste called cocoa liquor (mass) that is the base ingredient for chocolate. A good quality chocolate requires additional cocoa butter which is expressed from cocoa liquor in a large hydraulic press, separating it from the cocoa powder.

Fig. 8.18 Large and efficient cascading box fermentation facility in Papua New Guinea. (©Lambert)

Fig. 8.19 Cocoa bean drying and rain shelter in Papua New Guinea. (©Diczbalis)

Cocoa grinding is mainly carried out in Europe (40 % of all global cocoa), the Americas (21 %) and the Asia/Pacific region (20 %). The largest producer of cocoa, Africa, grinds only 18 % of the global cocoa production (Pipitone 2012).

The second step in cocoa processing is manufacturing of chocolate by mixing cocoa liquor, cocoa butter, sugar, lecithin and milk (for milk chocolate), and other ingredients depending on the final product (Beckett 2000; Coe and Coe 2000). Cocoa powder is used in production of chocolate confectionary, drinks and biscuits.

Cocoa Production Statistics

Global cocoa production in 2011/12 reached 4 Mt with West Africa contributing 71 % or 2.826 Mt (Pipitone 2012). Cote d'Ivoire, is the largest producer with production of 1.476 Mt for 2011/12, just below its record in the 2010/11 season of 1,511 Mt, due to favourable environmental conditions and in spite of the political problems during this time (Anon 2012b). Ghana is the second-largest producer, followed by Nigeria and Cameroon.

Although cocoa originated in South America, this region produces only 0.574 Mt or 14% of global production, mainly in Brazil and Ecuador. In the Asia Pacific region, accounts for 15 %, mainly from Indonesia and Papua New Guinea, with Indonesia being the third largest global cocoa producer.

Consumption figures are very different. Most cocoa is consumed in countries that do not produce it. Europe consumes 48%, North America, 24%, South America, 9% while Africa consumes only 3% of global cocoa (Pipitone 2012).

Total area planted to cocoa globally is 9.5 Mha with a total production of 4.2 Mt (Table 8.1). Globally, more than 90% of cocoa is produced by small cocoa growers on 2–5 ha in Africa (Anon 2012c) and 1–2 ha in Sulawesi.

Average productivity per hectare is around 300–470 kg dry bean/ha/year (Table 8.1; Anon 2012c). High yielding cocoa has been achieved in Malaysia with cocoa plantations producing a 5 year average of 3.2 tonnes/ha/year in late 90s (Lass 1999). The highest producing plantations are mainly irrigated plantations in Ecuador and Brazil and some smallholder farms in Asia that have adopted high yielding clonal cocoa, producing between 2–4 t/ha/year.

From Forest Tree to Small-Holder Crop, to Plantation and Back to Small Holder Crop

The centre of origin of cocoa is the Amazon basin rainforests with a secondary distribution in central America, southern Mexico and the Caribbean, between 20 °S and 20 °N of the equator. The high genetic variability that occurs in these regions can be used in varietal improvement (Bartley 2005). In Central America, cocoa was cultivated mainly in Mexico for more than 2000 years by Mayas and other peoples from this region (Wood and Lass 1985). Cocoa was also highly appreciated by the Aztecs who considered it to be a sacred tree, with health-improving properties, used in traditional ceremonies (Lupein 1999). The first recorded use of cocoa was as a fresh, frothy beverage called "chocolatl" prepared from ground cocoa beans with added spices. When cocoa was "discovered" by the Spanish in 1502 on Guanaja, an island off the coast of Honduras, it was already a well-developed, commercial crop, with dry cocoa beans used as a currency by the local inhabitants (Wood and Lass 1985; Dand 2011). Cocoa beans were taken to Europe by Spanish sailors, and during the following centuries, were widely used as a chocolate drink until 1847 when the first block chocolate was produced in UK by J.S.Fry & Sons (Coe and Coe 2000).

Despite cultivation of cocoa trees starting more than 2000 years ago, domestication and improvement of cocoa varieties was very slow. Even now, more than 70% of cultivated cocoa trees are unimproved, wild types (Eskes 2006). Most small growers still identify their best trees and use their seeds as planting materials, as they did some 2000 years ago.

After Europeans discovered the pleasures of chocolate beverages in the sixteenth century, the consumption of cocoa increased. The increased demand lead to production expanding from Mexico to the Caribbean islands of Jamaica and Trinidad. The majority of cocoa was still produced by small growers, but in Trinidad, the first 100 and 160 ha plantations were established. As cocoa cultivation expanded into Venezuela in 16th century, the scenario was repeated with mainly small growers and a few family-owned, large plantations. The 140 ha "Chuao" plantation, established 500 years ago, still produces cocoa of high quality.

Large, family-owned plantations of 100–160 ha was the model for cocoa cultivation as it expanded into Ecuador in 1605. Ecuador dominated world cocoa production in the nineteenth century (Dand 2011). In Brazil, cocoa expanded from smallholder plots in the Amazon region in 1746 to Bahia with 100–200 ha farms. In the Americas, few large company plantations were established, the most well-known being the United Fruits Plantation in Costa Rica where cocoa served as a substitute for bananas due to Panama disease (Wood and Lass 1985).

Currently, Ecuador and Brazil continue with medium size family plantations with a few very large plantations in Ecuador, considered to be the most advanced and profitable, with irrigated areas producing high yields. South America currently has the highest proportions of cocoa plantations over 100 ha but most cocoa is still produced by small growers.

In South America, large, traditional plantations face challenges, especially with high production losses due to fungal diseases such as Witches broom (*Crinipellis perniciosa*) and Frosty Pod rot (*Moniliophthora roreri*) and with high labour costs. In Brazil, to counteract high labour costs, some plantations are developed in dry areas to avoid disease, using superior, high-yielding clones managed intensively with optimal irrigation and fertigation.

Cocoa was introduced from Brazil to the islands of Sao Tome and Fernando Po in 1822 and, by late nineteenth century, from there to Ghana, initiating the largest cocoa expansion ever, based almost entirely on the initiative of smallholder growers. The first cocoa was exported from the Gold Coast (Ghana) in 1891 and, until now, African cocoa production is dominated by small cocoa growers with areas of 1–2.5 ha with few growers having more than 8 ha (Wood and Lass 1985).

In anglophone African colonies, foreigners were not permitted to purchase land. A few locally-owned plantations were established, the best known being the Badoo family plantation of 35.9 ha in Ghana (Beckett 1946). In Cote d'Ivoire, some European settlers established cocoa plantations with mixed success but very few remain operational. There were also some large plantations in Nigeria with few surviving as part of Agricultural Development Corporations. In Cameroon, by 1912, over 80% of exported cocoa was produced on plantations (West and Voelcker 1942). Currently, however, the bulk of production in Cameroon occurs on small family farms (Anon 2012d).

In Africa, the domination by smallholder growers (Fig. 8.20) over the plantation production model is due to several issues, including land ownership, lack of investment security, inappropriate planting material, soil nutrient depletion due to a lack of fertiliser and low organic matter content (Rob Lockwood, personal commu-

Fig. 8.20 A typical scene on a west African cocoa farm. The start of heap fermentation in Ghana and drying fermented beans—producing "golden standard" quality cocoa. (©Lambert)

nication). Additionally, the price of labour, its availability and capacity to manage cocoa correctly also contributed to failure of cocoa plantations in Africa.

In the Asia Pacific region, the expansion in cocoa production happened quite late despite cocoa being transferred from Mexico to Philippines by Spanish colonisers in the sixteenth century (Dand 2011; Wood and Lass 1985). In Indonesia on the island of Java, a few large plantations were established in the nineteenth century under Dutch colonial rule, some still being operational. Most of these large old plantations became government-owned and focused on production of the highly-valued, fine flavoured but low yielding white bean Criollo-type cocoa that attracts a premium price. Later, in 1980s, much larger cocoa expansion occurred in Indonesia on the island of Sulawesi. This was driven by Sulawesi growers returning from Malaysia where they served as labour in large cocoa estates and learned to grow the crop (Dand 2011). Currently, 80 % of Indonesian cocoa is produced in Sulawesi by smallholder growers with one to two ha of land. A recent increase in cocoa production occurred in Sumatra by smallholder growers responding to positive price indicators.

In Malaysia, cocoa expansion started in the 1980s in Sabah (Borneo) with 60 % of production coming from large estates with areas between 1500 and 3000 ha and the remainder from smaller farms less than 100 ha. Large plantations in Malaysia were very active in cocoa research and have developed several high-yielding cocoa clones that are highly valued. These plantations were also the first to start side grafting old cocoa trees with new clones to rehabilitate them and boost productivity.

Malaysian production peaked by 1990 then declined sharply from an annual production of 220,000 t (Dand 2011) to current production of less than 10,000 t due to low prices, lack of labour, cocoa pod borer infestation and plantations reinvesting into oil palm. Oil palm is much less labour intensive with one worker able to manage 8–9 ha of oil palm compared to 1–2 ha of cocoa. Currently, only few smallholders (5–15 ha) still produce cocoa with support from the Malaysian government paying for their planting materials and inputs if they stay in cocoa.

A similar transition from plantation to smallholder production occurred in Papua New Guinea. In 1975/76, 51 % of cocoa was produced in plantations (Wood and

Lass, 1985). Currently only 9 % is produced by plantations and the rest by small growers with land areas of 1–4 ha (Anon 2008).

Cocoa has not performed well as a plantation crop. The reasons behind this are many and varied but include;

- Cocoa is a relatively difficult crop to manage, requiring a high level of inputs and management skills to achieve high yields.
- High labour requirement (1 person for 2 ha) compared to oil palm where 1 person can manage 8–9 ha.
- Cocoa preliminary processing (bean fermentation and drying) does not require a high investment and hence can be carried out on a small scale with negligible infrastructure, often producing a better product. A prime example is the "golden standard" for good quality cocoa produced by small holders in Ghana.
- Smallholders can adapt more rapidly to the fluctuations in world price which are subject to supply and demand. Data from the Malaysian Cocoa Board for 2008 (Dand 2011) shows that the production cost for a plantation "estate" is $ 1,725/ha and $ 1,174/ha for smallholder producers, in spite of the fact that estates employ 50 % less workers than smallholders.
- Cocoa bean prices have significantly decreased in relative and real terms from the 1970s with very low prices in 2000 of less than $ 1000/t. Prices have stabilised in the range of $ 2000-$ 2,500/t of dry cocoa (ICCO 2012). Only plantations with extremely high yields and high technology can still be competitive on the global cocoa market compared to small cocoa growers.

Examples of Efficient Cocoa Production

The most efficient way to produce cocoa depends on local environmental and social conditions. In countries with relatively high labour cost and more developed technology as in Ecuador and Brazil, large, high "tech" irrigated/fertigated clonal cocoa plantations are producing cocoa efficiently and profitably.

In Africa and Indonesia and many other small cocoa producing countries with low labour costs, cocoa is produced on a small scale and is a driver of rural development with important socio-economic benefits to remote communities.

On many smallholder farms, production is low and inefficient because the growers are poor and have a low level of education. To promote efficient, profitable and sustainable cocoa production, training is required. It is critical to educate small holder producers to help them realise that cocoa farming is a good business that can alleviate their poverty and educate their children. This can be achieved by supplying growers with production training and high quality clonal cocoa material (Figs. 8.21 and 8.22). Many chocolate manufacturers have, over the last decade, worked with growers to achieve this aim. Professional and efficient small cocoa growers of the future will produce 1,500–2000 kg of high quality dried bean/ha/year, significantly improving their income and lifestyle.

Fig. 8.21 African cocoa growers receiving training on rehabilitation of cocoa by clonal grafting from Indonesian specialist. (©Lambert)

Fig. 8.22 A well run and operated clonal cocoa nursery in Sulawesi.(©Lambert)

Future of Cocoa Production

By 2020, chocolate manufacturers will need an estimated 5 Mt of dried bean per annum, an additional one million tonnes of cocoa every year. There is immense need for increased production. Cocoa is likely to remain a predominately smallholder crop, with a proportion of the 5–6 million current smallholder embracing professional management and high inputs, resulting in increased productivity and income. Plantations will remain an important production option, becoming more sophisticated and embracing technical solutions to boost productivity and efficiency.

Macadamia Nuts—a Case Study for a Modern Plantation Crop

Background

The major tree nuts, almonds (*Prunus dulcis*), cashews (*Anacardium occidentale*), chestnuts (*Castanea sp*), hazelnuts (*Corylus sp*), pecan (*Carya illinoinensis*), pine nuts (Pinus sp), pistachios (*Pistacia vera*), macadamia (*Macadamia integrifolia)*, and walnuts (*Jugland regia*) are often neglected when it comes to considering the world's tree crops. Tree crops such as apples (*Malus domestica*), citrus (*Citrus sp*), oil palm (*Elaeis guineensis*), rubber (*Hevea brasiliensis*), coffee (*Coffea arabica*) and tea *(Camellia sinensis*) dominating the discussion when it comes to the areas devoted to production and their value to world trade. However, this situation is rapidly changing as the tonnage of nuts in world trade rapidly increases (Table 8.2).

Nut crops have rarely been brought into discussions surrounding 'plantation crops' as they did not share many of the same characteristics such as foreign ownership, tropical locations and a history of slave or low cost labour. However, since the 1950s some of the major nuts crops have taken on a few of the characteristics of 'plantation crops' such as large single-crop focused monocultures with an emphasis on the economies of scale. This is particularly true of the almond industry which is dominated by production originating from California. In 2011/2012 California produced 80% of the world's production; an estimated 887,679 t of kernel from 315,662 bearing hectares (Duerr 2012). Almond production in California consists of both privately and corporately owned large orchards and is highly mechanized. In contrast, Brazil nuts are still largely harvested by hand from the rainforests of Bolivia, Peru and Brazil.

Introduction to Macadamia

Macadamia is one of the smallest tree nuts in terms of global nut production and, unlike many of the other nuts it is almost entirely grown in the tropics and sub-tropics. Macadamias have experienced a large increase in production, 167% between 2002 and 2011, and comprise around 1% of total tree nut production (INC database 2012). Australia has been the leading producer since early in the century but, its share has declined over the last 5 years with South Africa now the number one producer. Africa now accounts for almost 50% of the world's production (Fig. 8.23). There is also substantial emerging production in China and Brazil.

The emergence of competing producers in low labour cost regions, such as in Africa, has been one of the major factors that has placed pressure on some Australian producers to move to a plantation system of production. While there are still elements of the Australian macadamia industry that are still smallholder-based, the majority of Australian production is moving towards large agro-industrial, highly focused, capital intensive, single crop, plantation style systems of production.

Table 8.2 Estimated world tonnage (kernel basis) of the major tree nuts crops in 2011, growth in production from 2002–2011 and share of total production. (Source: International Dried Fruit & Nut Council Statistics Database 2012)

Tree nut[a]	Estimated tonnage (kernel basis)	Total production growth 2002–2011 (%)	Share of world production 2011 (%)
Almonds	1,109,414	228.7	35
Cashews	556,668	227.3	18
Walnuts	497,635	148.1	16
Pistachio	455,266	101.7	15
Hazelnut	354,600	87.6	11
Pecan	89,146	74.9	3
Pine nuts	34,445	363.9	1
Macadamia	29,875	167.4	1
Brazil nut	23,995	70.4	<1

[a] Information for Chestnuts has not been presented due to a lack of credible statistics

Brief History of Macadamia Production

The macadamia is native to the subtropical coastal rainforests of northern New South Wales and south east Queensland and is the only major food crop of Australian origin. The macadamia kernel has a delicate, buttery, crunchy texture and is generally considered to be the premium nut in world trade.

While there are four species of macadamia found in Australia the commercial industry is based primarily on *Macadamia integrifolia* and on hybrids of *Macadamia integrifolia* and *Macadamia tetraphylla*. An Australian industry-based breeding program is currently developing new hybrids with the other species to improve kernel quality, reduce shell thickness and tree size, and improve pest and disease resistance.

The macadamia industry is generally considered to be less than 150 years old with the first commercial orchards being planted in northern New South Wales in the 1870s and 1880s. These first orchards were small, generally less than 100 trees, and were composed of *Macadamia tetraphylla* trees (McConachie 1980). Despite the efforts of various Australian state governments and acclimatization societies to promote macadamia, a large scale industry did not develop in Australia until the 1970s, almost 100 years after the first orchards were planted. In contrast, following the introduction of seeds from the 1880s onwards (Shigeura and Ooka 1984) an industry began to develop in Hawaii in the 1930s and by the late 1940s the first large scale macadamia plantations had been established. The Hawaiian Agricultural Experimental Station then went on to select most of the cultivars on which the world's macadamia industry is currently based. The Hawaiian industry dominated world production until the late 1990s when it was overtaken by Australia. Production in Hawaii was, and still is, a mixture of large corporate plantations and large and small private holdings.

Large scale, commercial plantation style production started in Australia in the 1960s when CSR Ltd established a series of orchards along the Queensland coast

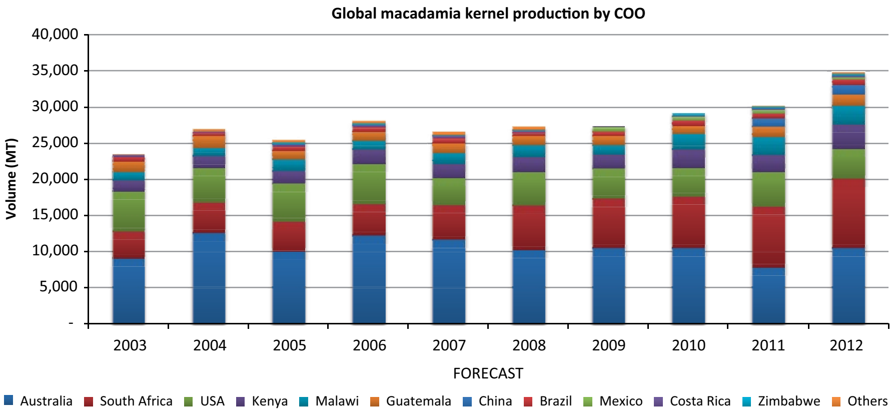

Fig. 8.23 Global macadamia production by origin. (Source: International Dried Fruit & Nut Council Statistics Database)

(McConachie 1980). These orchards were based on imported Hawaiian cultivars and used equipment imported from the Californian almond industry. This demonstrated the potential of macadamia in their country of origin, and there was steady planting of trees throughout the 1980s and 1990s. However, most of the subsequent plantings were made in the higher rainfall areas of southeast Queensland and northern New South Wales and the majority of these were less than 10 ha in extent. The land in these areas is undulating to steep and when combined with the high rainfall, mechanization is difficult and expensive. The density of the orchards in northern New South Wales today is such that in many areas they appear to be one large continuous plantation, but with multiple owners and, consequently, multiple levels and styles of management, they cannot be considered to be a plantation production system.

In the early 1990s, orchards were established in central Queensland around Bundaberg. Land in this area was cheaper than in the traditional southern production areas, was flatter and had a plentiful supply of irrigation water from various government schemes. The combination of these factors meant that agronomically manipulable, economically reliable, large scale mechanized production could be achieved. These orchards continued to gradually expand until 2003 when a wave of new entrants, largely from the highly intensive vegetable industry, decided to plant macadamias and began to create a modern plantation style system of production that prevails today. This change in crop focus was driven, in part, by the desire of the vegetable producers to move away from managing the large, expensive labour forces required in the vegetable industries, towards an industry where mechanisation was rapidly replacing labour.

Production Drivers Today

As around 70 % of the Australian crop is exported, producers have to compete with production from low labour cost countries (Anon 2012e). Labour in Australia is, by world standards, highly regulated and expensive, with the basic agricultural wage above US$ 18 (2012) per hour. It is this need to reduce labour costs that has driven innovation and the creation of a modern plantation production system in Central Queensland. This is a fundamental difference from the traditional plantation crops that have had a history of labour exploitation and are still largely based in developing countries with little or no labour regulation. While low cost labour has been traditionally a driver of plantation production in developing countries, it is high cost labour and the difficulties associated with managing a large labour force that is driving the move toward plantation style production in Australia.

As a consequence of the high labour costs, considerable emphasis has been placed on developing a production system that can not only be mechanized using current technology, but also a system that is able to take advantage of future advances in automation. For mechanisation to be efficient, it also needs to be on a large scale so that the high capital inputs are spread over large areas.

Speed over the ground is the key to making macadamias efficient and profitable with long straight rows and smooth inter-rows allowing the rapid passage of equipment through the plantation. With an average of 18–20 operational passes per inter-row per year, small changes in ground speed can, cumulatively, have a significant impact on orchard economics. Orchard floor preparation prior to planting, to allow high operational orchard speeds, in combination with a good orchard design to channel and manage heavy rainfall, has therefore become a priority in modern macadamia plantations. Since 2004, over 70 % of the new plantations in the Bundaberg area have been established using tractors fitted with satellite guidance systems. The accuracy of these systems (±2 cm) allows large machinery to move at high speed through an orchard with minimal risk to the trees. In addition, the satellite systems have allowed micro-mapping of orchard topography on a scale that was not possible when orchards were surveyed using traditional methods. Micro-mapping not only allows the orchard designer to establish a plantation where water movement from heavy rainfall downpours can be carefully controlled, it also allows for the design of more accurate and efficient irrigation and fertigation systems.

Once the orchard has been designed and the tree row mounds and irrigation installed, the trees are planted using a mechanical planter coupled to a satellite guided tractor (Figs. 8.24 and 8.25). This allows a team of 8–10 people to plant between 6 to 10 hectares per day with an accuracy of ±2 cm within the row. A drip irrigation system is usually installed at the same time with the trees receiving water within four hours of being planted.

Irrigation systems are critical for managing trees in this environment with trees receiving irrigation, scheduled using a range of tools, on a needs basis. Fertigation is almost universally employed with trees receiving nearly constant nutrition throughout the year. The drivers for this investment are not only the cost of nutritional inputs, but the marginal nature of the soils used for macadamia production in this area. Australian soils are, by nature, old and highly weathered. Consequently, they are often poorly structured and have low nutrient and water holding capacities, characteristics which allow the good manager some control over their crop but, in turn, present their own set of problems.

Fig. 8.24 Orchard preparation, tree mounds being prepared. Note satellite relay station in foreground. (©Searle)

Fig. 8.25 Same area 18 months later. Trees were planted to within ± 2 cm within the row using a satellite guided tractor and planting machine. (©Searle)

Mature macadamias fall from the tree onto the ground where they are picked up by specialist harvesters. The harvest period in Australia typically extends from March through to September. As macadamia are ground harvested, the soil under the tree needs to be kept weed free to facilitate harvesting. In the relatively high rainfall, subtropical environment this requires frequent herbicide use. Consequently producers are moving to technology that detects the green foliage of weeds and only applies a controlled jet of herbicide when a weed is detected (Figs. 8.26 and 8.27). The herbicide sprayer sits in the middle of the inter-row, sprays both side of the tree row at once and is capable of travelling at 10 km per hour thus reducing labour and chemical costs.

Harvesters are also becoming more specialized with large self-propelled units that again, sit in the middle of the inter-row and harvest both sides of the row at once. These machines are capable of harvesting and de-husking up to 35 t of de-husked

Fig. 8.26 Herbicide sprayer used on newly planted trees. Trees passed between the two shielded hoods. This machine is used until the trees are 2–3 years old. (©Searle)

nut per day using only one man. This high degree of mechanisation, combined with the economies of scale, means that one man can look after 30–40 ha of macadamia plantation (Figs. 8.28 and 8.29).

The continuing cost pressures are likely to maintain the move to large macadamia "plantations" and while they will continue to share some of the traditional characteristics of plantation crops, sub-tropical/tropical locations, single crop focus and an emphasis on the economies of scale unlike traditional plantations, they are likely to be characterised by the use of a small, highly specialised, well paid workforce.

Conclusion—The Evolution of Plantations

The term plantation, although still loosely defined, is far removed from the traditional association of crops grown on a large scale using low skilled, low cost or at its worst slave labour. Plantation crops are now defined by their scale, efficiency and specialised production techniques using a skilled work force as described in the case studies.

Corporate owned and managed plantations are increasingly striving toward safe working environments linked with economic and environmental sustainability. Consumers are increasingly becoming drivers of agricultural practices (Tuckermanty et al. 2002). Organisations such as the Fairtrade Foundation (http://www.fairtrade.org.uk) seek to influence consumer choice by offering a certification structure that transforms trading structures in favour of third world producers. Corporate plantation owners such as Dole, Great Giant Pineapple, Chiquita and Cargill are increasing their presence electronically on the internet and interacting with consumers *via* social media to assure consumers of their sustainability and ethical production standards.

Fig. 8.27 Herbicide sprayer used on older trees. A sensor detects the presence of green weeds and applies herbicide directly to them. (©Searle)

Fig. 8.28 Part of a large modern macadamia orchard. Rows in this photograph are 300m long before a break for water control. The machinery, from left to right, are a small herbicide tractor fitted with technology that detects the presence of weeds, a large double sided nut harvester and a large mower. The water is an irrigation channel that forms part of a government controlled irrigation supply system. (©Photo courtesy of Macadamia Farm Management)

Plantations remain important production platforms for food, fibre, oil crops and timber and they will continue to evolve in response to increasing demand from a growing population.

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Fig. 8.29 Large harvesters such as this are able to travel at 6–8 km per hour and pick up 98 % of nuts from the ground. A harvester such as this is capable of picking up 35 t of dehusked nuts per 10 h day using only one man. (©Photo courtesy of Macadamia Farm Management)

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