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# The Sri Lankan Coconut Industry: Current Status and Future Prospects in a Changing Climate

**Pathiraja, P.M.E.K.[1], Griffith, G.R.[2], Farquharson, R.J.[3], and Faggian, R.[4]**

[1] PhD Candidate, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia Email: epathiraja@student.unimelb.edu.au
[2] Professor, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia Email: profgarrygriffith@gmail.com
[3] Senior Lecturer, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia Email: bob.farquharson@unimelb.edu.au
[4] Associate Professor - Climate Change Adaptation, Centre for Regional and Rural Futures, Deakin University, Burwood, Vic. 3125, Australia Email: r.faggian@deakin.edu.au

## Abstract

The coconut industry is an important source of foreign exchange and employment generation for Sri Lanka, and an essential component of Sri Lankan cuisine, nutrition and rural livelihood. This paper describes the current status of the industry reviewing its behaviour over the recent past and assessing future possibilities. Coconut occupies 20 percent of Sri Lankan arable land and the majority (82 percent) is operated at small scale. Nearly 63 percent of production is domestically consumed and this proportion is linked with the increasing population. Average coconut yields have been stagnant over time but there is substantial year to year variability due to climatic factors. This volatility generates intense competition for raw materials among the various processing industries. The government allows substitute edible oil imports and bans fresh nut exports when fresh nut prices are increasing. Future coconut supply is uncertain due to climate change and its unknown impacts. However, effective adaptation measures may limit the expected vulnerability depending on the severity of change. The uncertainties of future coconut supply may affect domestic consumers, producers and the coconut processing industries. An analysis of adaptation strategies to predicted climate change for the Sri Lankan coconut industry value chain is considered to be an important research issue.

Keywords: Coconut, Sri Lanka, climate change, adaptation, value chain

## 1. Introduction

Climate change is defined as '"any change in climate over time, whether due to natural variability or as a result of human activity" ' (Houghton et al., 2001: 61). It is confirmed with the observations of global warming and other changes in the climate system (Houghton et al., 2001).

The agriculture sector is one of the most vulnerable sectors to climate change (Burton & Lim, 2005, Fischer et al., 2005, Fisher et al., 2012). According to the International Panel on Climate Change (IPCC), the negative impacts on crop production will be more common than positive

impacts (IPCC, 2014c). Agriculture in low latitude countries is already operating at the maximum temperature limits for crop growth and at a greater production risk than the high latitude countries (IPCC, 2014a). For this reason, crop productivity is expected to improve in mid and high latitude countries whereas in low latitude countries it is expected to decrease, with an expected local temperature increase of 1-2$^{o}$C. Further, an increase in frequency of droughts and floods is expected in these low latitude regions (IPCC, 2014a).

The majority of the countries located in low latitudes are developing countries which have limited economic and technological capacity to develop adaptation strategies, hence they are more vulnerable to climate change than developed countries (Mertz et al., 2009). These countries are mainly in the continents of Africa, Asia and Latin America. The recent IPCC (2014c) report says that there is an increasing chance that climate change will affect food security. According to the FAO definition **'"**Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"'. Climate change would challenge the availability, accessibility, utility and stability of food. For example, daytime temperatures around 30$^{o}$C negatively affect crop yields and elevated $CO_2$ levels reduce the nutritional quality of food. The impact on tropical aquatic production systems is expected to be negative. Increased price instability and price increases following weather extremes will affect food accessibility (IPCC, 2014c).

These impacts are expected to be prominent by 2050 with an expected further temperature increase of 3 to 4$^{0}$ C (at the scenarios of high level of warming) and a worldwide demand for 60 percent more food. The expected global food price increase by this time without considering the impact of $CO_2$ will be up to 84 percent. Tropical regions would not get the benefit of adaptation at this point. For example, the decrease in production in some of African countries is estimated to be 50 percent and it would be 30 percent in South Asia (IPCC, 2007, 2014b). The highest proportions of food insecure people are found in Africa while the highest numbers are found in South Asia, nearly 300 million. There is likely to be a higher risk of drought-related water and food shortages in South Asia leading to malnutrition (IPCC, 2014b).

Sri Lanka is a South Asian tropical island and there is already evidence that its climate has changed. An annual temperature increase of 0.016$^{o}$C was observed during the period 1960 to 1990 across the country as a whole. The day time maximum and night time minimum mean air temperatures have increased by 0.021 $^{0}$C and 0.02 $^{0}$C per year respectively (Basnayake, 2011). Meanwhile, the number of consecutive dry days has increased in the dry and the intermediate zones[1]. The number of warm days and warm nights have increased while the number of cold days and nights have decreased (Ministry of Environment, 2010). The average annual rainfall decreased by 144mm during the same period and the distribution pattern has also changed (Basnayake, 2011). The North East monsoon rainfall has decreased with an increase in rainfall variability. The occurrence of single-day heavy rainfall events has shown an increasing trend.

However, studies on future climate projections for Sri Lanka are limited and the available projections show conflicting outcomes especially for rainfall (Eriyagama et al., 2012). According to Basnayake (2011), monsoon rainfall is predicted to increase by 2025 under the A2 emission scenario. Mean temperatures are expected to increase by 2.9$^{0}$C and 2.5$^{0}$C during the northeast and southwest monsoon periods, respectively, by the end of this century. The occurrence of weather extremes, especially droughts and floods, are expected to be frequent. Wet areas will get more rain and dry areas will become drier by 2025.

Several recent studies have analysed the potential impact of climate change on the agriculture sector of Sri Lanka. These studies were mainly focussed on paddy rice cultivation which is the staple food of Sri Lanka (De Silva et al., 2007; Kurukulasuriya & Ajwad, 2007). They found that the impact on wet season paddy would be negative for many parts of the country except in the extreme south (De Silva et al., 2007). Another study found regional variation in the profitability of smallholder farmers where the farmers in the wet high latitude areas benefited while the farmers in the north western and south eastern lowlands were adversely affected (Kurukulasuriya & Ajwad, 2007).

Perennial cropping systems are thought to be more vulnerable to climate change because they are long established (Lobell, et al., 2006); however, there are few studies conducted for plantation agriculture. A study conducted on the tea industry found that the impact on mid and lowland

grown tea was more negative than that on highland grown tea (Wijeratne, et al., 2007).This classification was based on the topography of the lands from sea level.

Coconut (*Cocos nucifera L*) is a rain fed perennial crop important in Sri Lankan culture, food consumption and the economy. It is the second most important food in the Sri Lankan diet after rice. An analysis of the economic impact of climate variability on the coconut industry conducted using 1971-2001 data showed that 60 percent of the variation in coconut production can be explained by climatic factors and it can incur an economic loss of US$32 million to US$73 million in extreme shortages while gaining an income of US$42 million to US$87 million in crop gluts (Fernando et al., 2007). This study emphasized the potential benefits that can be gained through adaptation strategies. Coconut production forecasting studies have shown that annual coconut production is particularly sensitive to rainfall during January to March in the main coconut growing regions (Peiris et al., 2008). Further, maximum ambient temperature and relative humidity in the afternoon are the most significant variables in nut production (Peiris & Thattil, 1997). Another study showed that coconut production will be lower by 2040 under six climate change scenarios (Peiris et al., 2004).

However, none of the studies cited were conducted to simulate and determine the impact of future climate change and future adaptation strategies on coconut production, or to calculate the economic welfare effects for different stakeholders in the coconut sector. As a first step towards assessing the impact of climate change and adaptation on coconut production in Sri Lanka and to quantify the subsequent effects on different stakeholders of the industry, this paper examines the current status of the coconut industry in Sri Lanka in terms of its structure, performance, policies and economic issues, and the prospects for adaptation to a future climate.

## 2. Coconut in the Sri Lankan Society and Economy

The coconut tree benefits the people of Sri Lanka in numerous ways due to its multiple uses. The coconut tree is often termed the “Tree of Life” or “Kapruka” because of its substantial contribution to the wellbeing and livelihood of people as well as to the economy of the country. It is internationally recognized as one of the most important tree crops in the world, providing food and shelter for millions of people in developing countries (Ministry of Plantation Industries, 2007). It can provide about 20 percent of the daily calorie intake of a person, as fresh nuts, coconut oil, desiccated coconut and copra. Further a coconut tree provides fronds which can be used as temporary roofing material and cultural decorations. Its stem provides rafters and every dried part of the tree is a source of fuel wood. Partial ribs of a coconut frond are called ‘ekel’ which is used in making ornaments and sweeping tools for gardens or compounds. Coconut inflorescence sap is used to make coconut toddy, arrack, honey and jaggery (sugar blocks made of concentrated sap). Tender coconut water is used as a drink and water from mature nuts is processed as a sports drink and vinegar.

According to the most recently available data, coconut occupies about 20 percent of the arable lands in Sri Lanka (Department of Census and Statistics, 2002), almost 400,000 hectares. The number of holdings under coconut cultivation is more than 2,175,000 which is the highest among all food crop sectors. The current contribution to Sri Lankan GDP is 1.1 percent (Central Bank of Sri Lanka, 2013) and the contribution to Sri Lankan export earnings is nearly 4 percent, including both kernel and non-kernel products (Coconut Development Authority, 2012). The coconut industry in Sri Lanka is estimated to provide employment for some 6.5 million people (Ministry of Plantation Industries, 2007).

This contemporary picture is somewhat different to that of the plantation era in the early 1970s, when the **c**ontribution of the coconut sector to GDP was around 5 percent and almost half the coconut production was processed for export. While average nut production during these two periods remained nearly the same, domestic fresh nut consumption increased from 1269 to 1919 million nuts over the period, thus halving the nuts directed towards export processing (now just 22 percent). The population of Sri Lanka increased from 10 million to 17 million during the same time, showing the increase in demand for coconuts for culinary consumption.

## 3. Economic Structure of the Coconut Industry

Following land reforms of the early 1970s (Department of Census and Statistics, 2002; Karunanayake, 1976) the structure of the landholding size has shifted dramatically from plantation to small scale (now 82 per cent of the total). The main coconut growing area consists of three administrative districts within the "Coconut Triangle": Kurunegala, Puttalam and Gampaha (as shown in Figure 1). This region contains 57 percent of the total coconut lands. The Southern Province is identified as the "Mini-Coconut Triangle" and comprises the Galle, Matara and Hambantota administrative districts. The Southern Province contains around 12 percent of the coconut cultivated lands. The remainder is distributed throughout the country except for the central upcountry where coconut is not grown.

The coconut processing sector comprises two distinct sub-sectors: kernel and non-kernel products. The major kernel products are coconut oil, desiccated coconut, copra, coconut cream, and coconut milk powder. Up until the mid-1970s, coconut oil was the major export commodity which utilized 28 percent or 683 million nuts of output processed for export, followed by desiccated coconut (15 percent or 380 million nuts) and then by copra (180 million nuts annually).

The value chain map of the coconut kernel products sector is shown in Figure 2. Fresh coconut production requires input supplies such as seedlings, fertilizer and agrochemicals, extension services, management and labour (Pathiraja & Weerahewa, 2013). The output is received by the processors with the involvement of different chain actors. Direct sales to the processors are not very common. Estate level plantations and contract basis cooperative societies are examples of chain actors that deal directly with processors. Generally the longest chain is through village level primary collectors, secondary collectors, wholesalers and brokers to the processors (Samarajeewa & Fernando, 2004).

The non-kernel sector products are based on the husk and the shell of the coconut. Husk products include bristle fibre, mattress fibre, coir pith and other value added products for example coir yarn, coir twine, Tawashi brushes, coir brooms, brushes, rubberized coir pads, mattress for bedding, coir mats, rugs, fibre pith, husk chips, geo textiles and moulded coir products used in horticulture. The greater part of these value added products are exported.

The value chain map of the coir sector is shown in Figure 3. Coconut husk is a by-product of fresh coconuts. This husk is primarily collected from coconut growers when they sell the husked coconuts to buyers or from the remaining nuts kept for household consumption. Generally the fresh nuts are sold with the husk to the collectors. These husks are a raw material for fibre processing industries and purchased by the coir processors. These husks are cut into chips at village level and sold to the manufacturers who sell to export market. There are coir millers who process the husks using different technologies. Three fibre types are produced according to particle size or the length.

Coir pith or dust is the finest and dried by village level contractors and then sold to the exporters. Markets for bristle fibre and mattress fibre are mainly the export market followed by local market. Value addition is prominent in export fibre market.

Shell products constitute activated carbon, charcoal and shell powder. Shells are the raw material mainly collected from processors. The rest is collected through village level collectors. The value chain map of the shell products sector is shown in Figure 4. Coconut shell is a by-product of coconut which is the outer layer of a husked nut (endocarp). These are collected from consumers or kernel processors of fresh nuts. Processors sell the produce to the next chain actors. Charcoal manufacturers and activated carbon processors sell their produce to the export market mainly through direct sales to an overseas buyer.

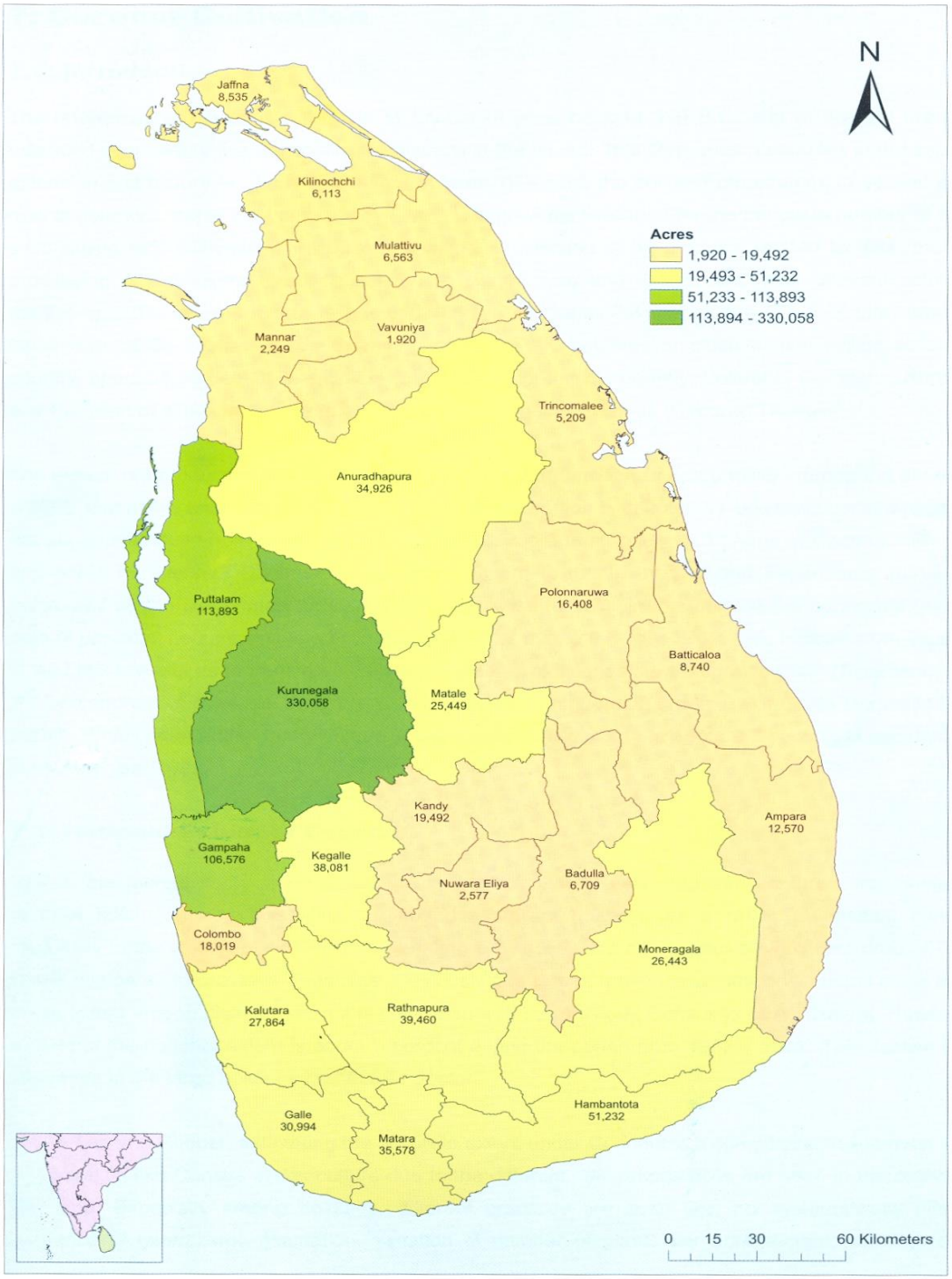


**Figure 1: Land under coconut cultivation in Sri Lanka (2002)**
*Source: (Department of Census and Statistics, 2002)*

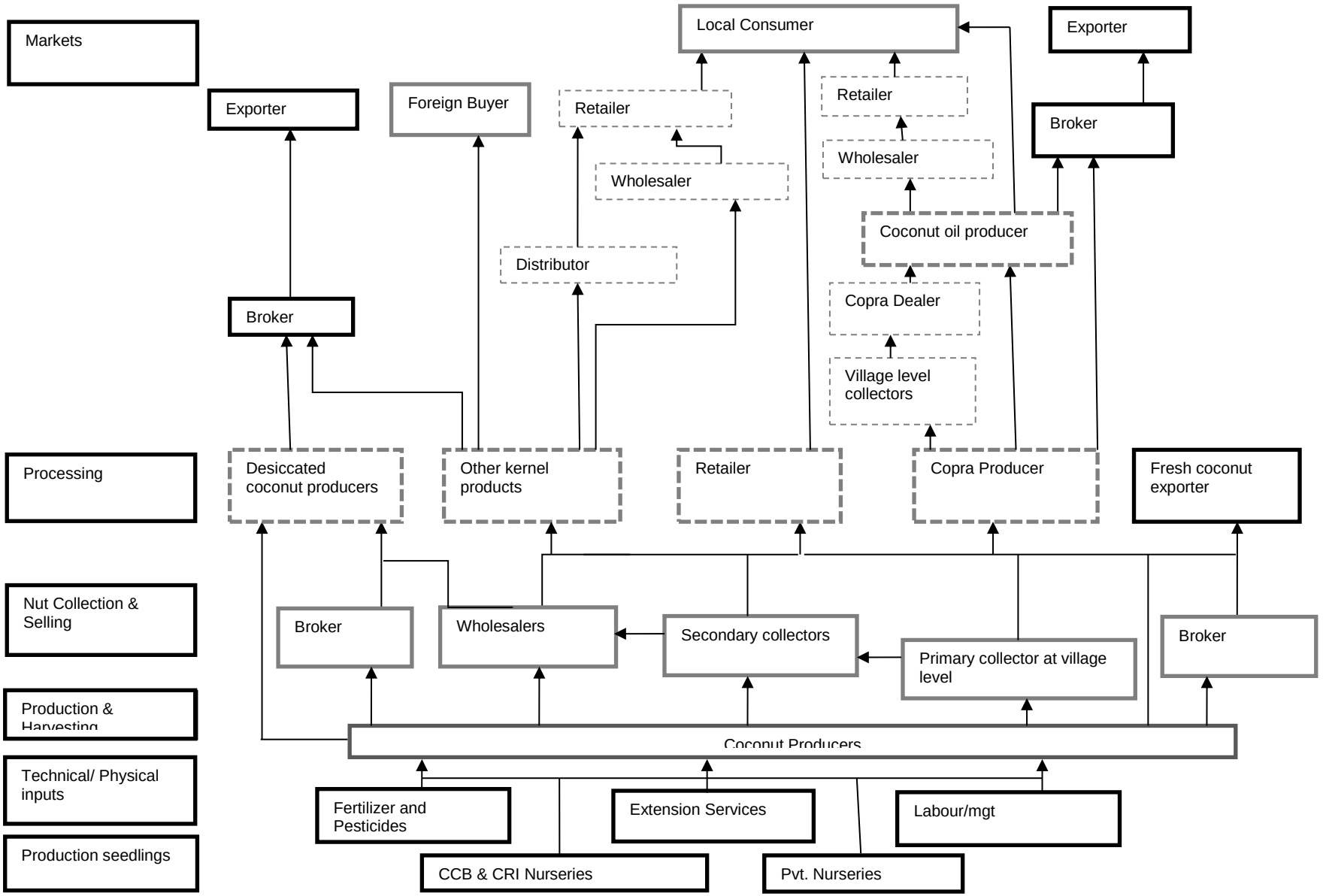


**Figure 2: Value chain map of coconut kernel product sector**
*Source: Pathiraja & Weerahewa (2013)*

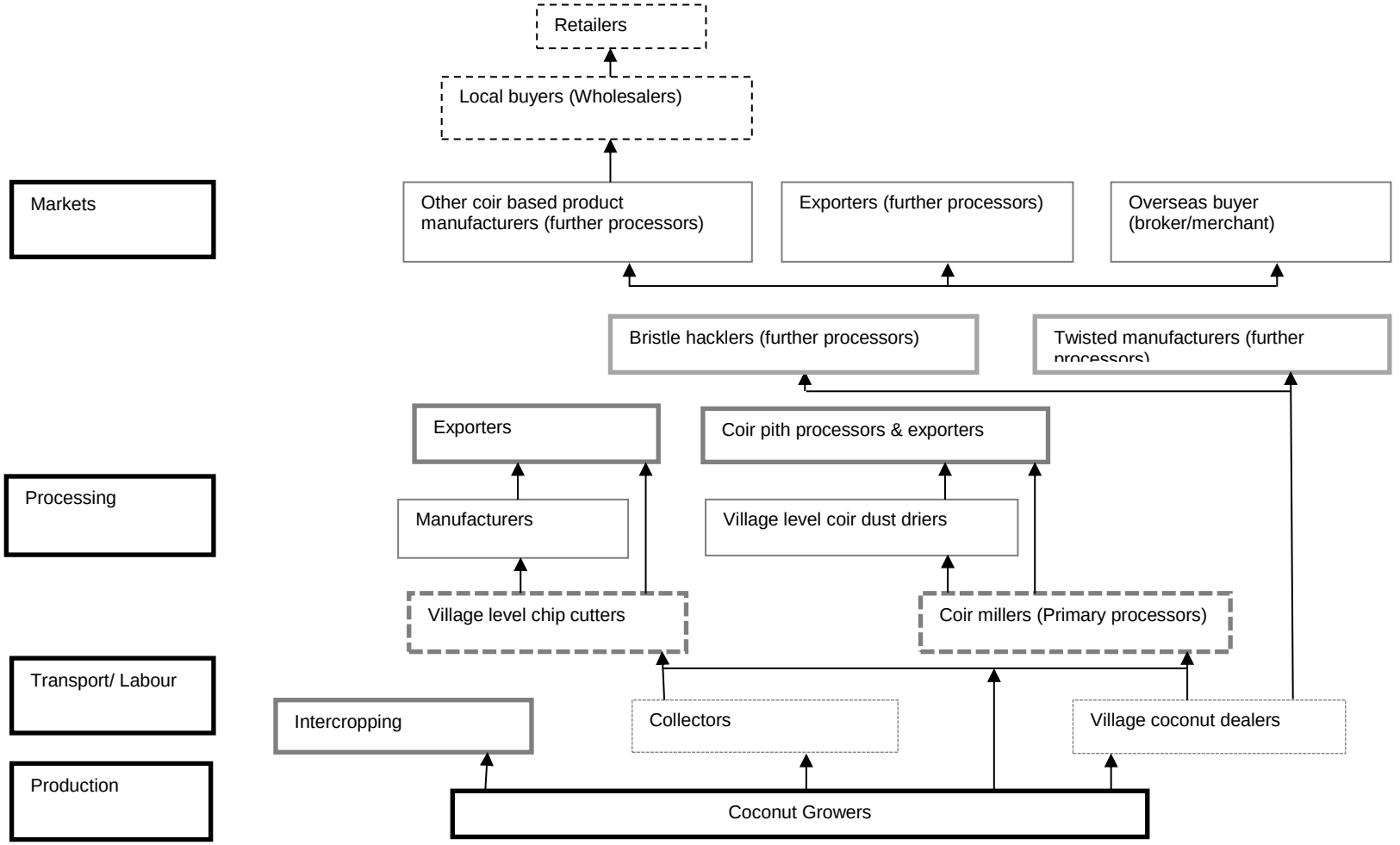


**Figure 3: Value chain map of coconut fibre sector**
*Source: Pathiraja & Weerahewa (2013)*

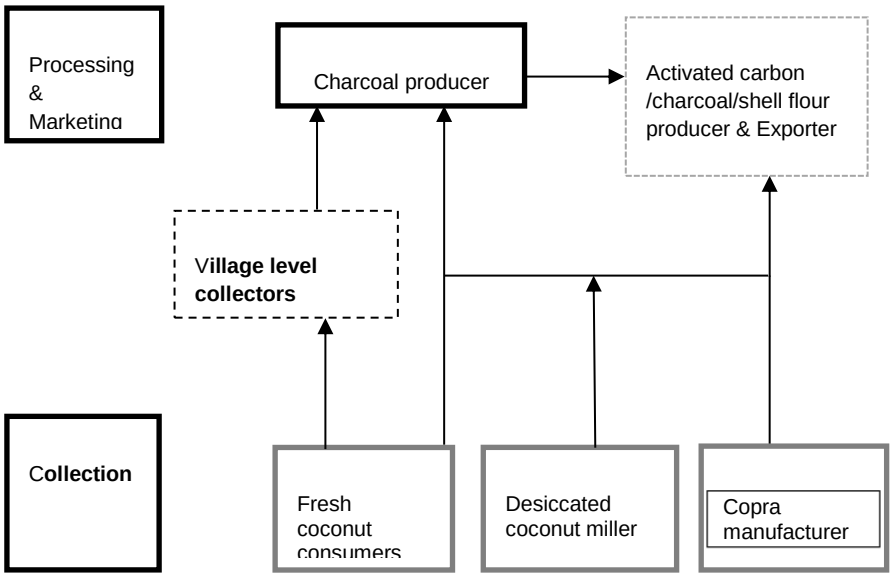


**Figure 4: Value chain map of shell products sector**
*Source: Pathiraja & Weerahewa (2013)*

## 4. Recent Economic Performance of the Sri Lankan Coconut Industry

### Nut production

Average annual nut production was around 2,649 million nuts from 1992 to 2012, although it has fluctuated between 2,164 and 3,096 million nuts over this period. Of the total production nearly 70 percent is domestically consumed as culinary nuts. Per capita annual consumption is around 121 nuts (including coconut oil). Consumption has risen steadily with population growth. The combination of increasing demand through population growth and stagnating coconut production has meant that the processing sector is facing stronger competition for raw material and it may affect the future of industry (Figure 5).

Coconut is harvested at bimonthly intervals. The general distribution of production throughout a year is shown in Figure 6 (Mahindapala & Pinto, 1991). Coconut production is closely tied to the distribution pattern of rainfall in previous years (Figure 7). Therefore, considering rainfall as the most important yield determining factor, lagged rainfall is often used in coconut yield prediction studies (Peiris et al., 2008; Peiris et al., 2000). A model including lagged quarterly rainfall of the previous year was capable of predicting yield 15 months ahead (Peiris et al., 2008). Prolonged droughts affect coconut production and the impact lasts for nearly four years due to the 44 month development cycle of an inflorescence. Depending on the degree of severity of a drought, its impact may affect the palms in different degrees. Initially it affects seedlings, then young palms followed by adult palms. Yield is affected by button nut fall, immature nut fall and even mature nut fall. Growth retardation or complete cessation of adult palms may occur in prolonged droughts (Liyanage, 1987). Due to the high dependency of yield on climatic factors, the performance of the coconut industry under climate change to date has been challenging.

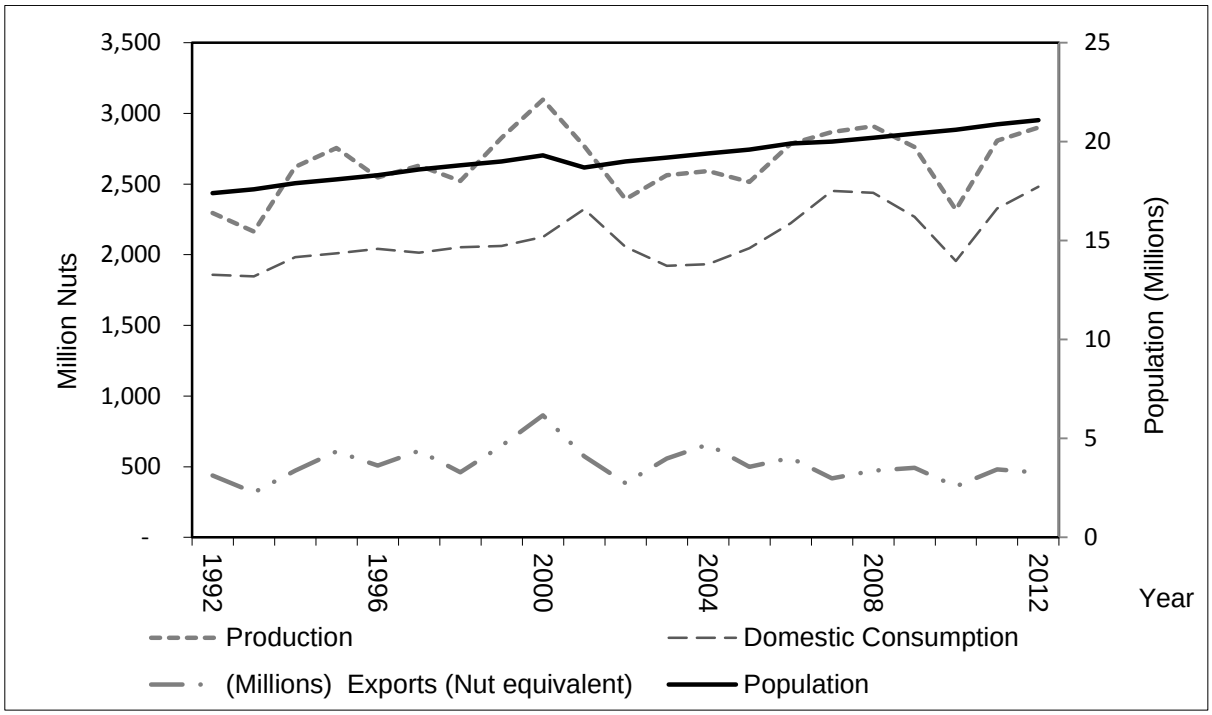


**Figure 5: Production, exports and domestic consumption of coconuts with population increase**
*Data source: (Coconut Development Authority, 1970-2013)*

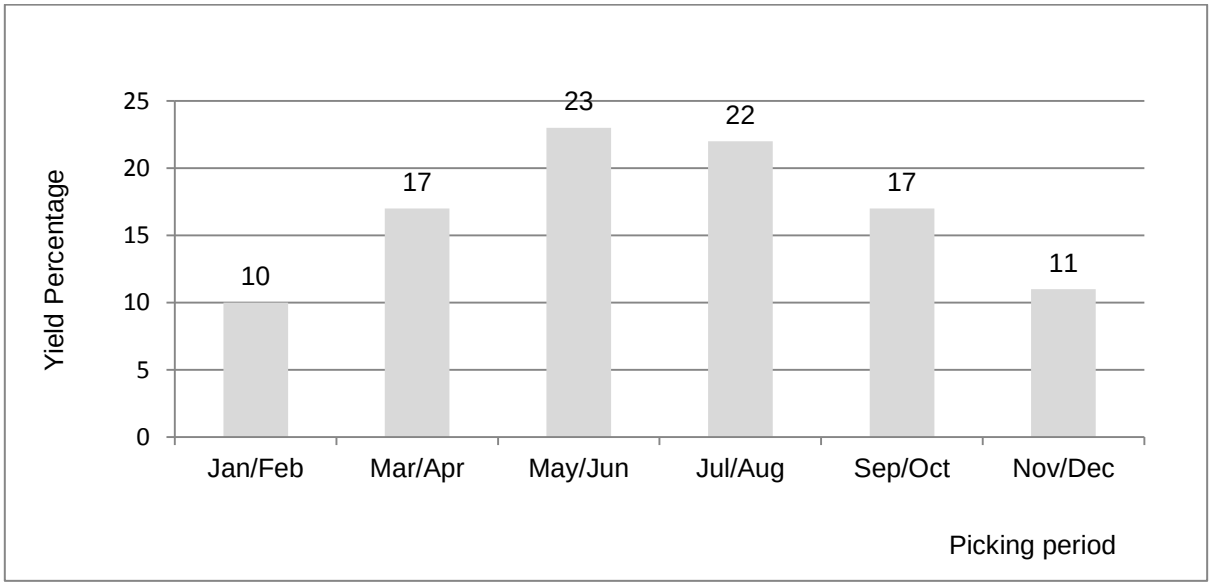


**Figure 6: Intra-annual variation of coconut production**
*Data source: (Mahindapala & Pinto, 1991)*

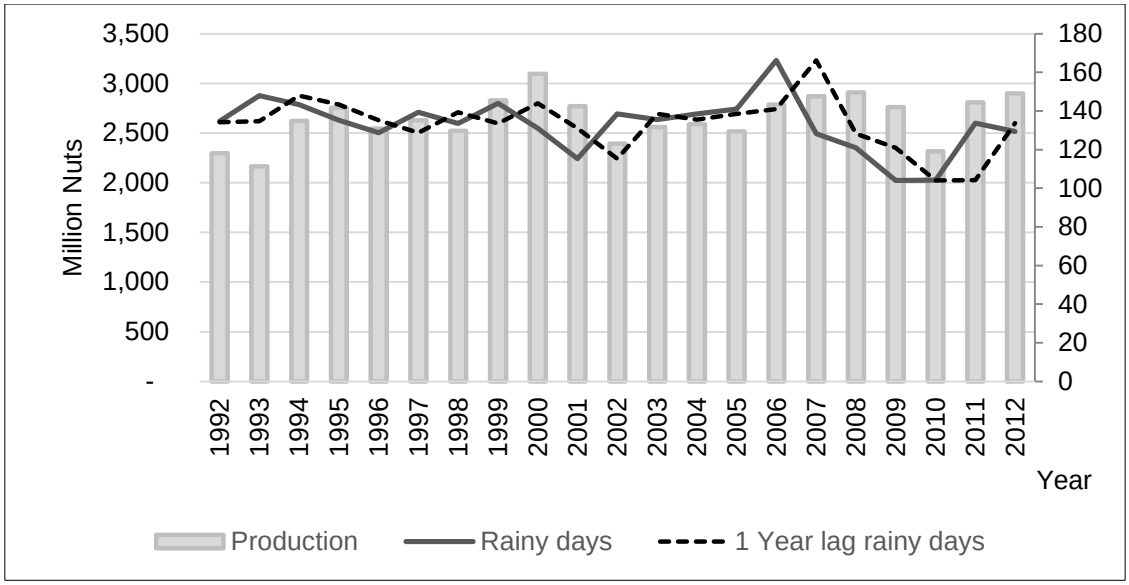


**Figure 7: Production of coconut over time and average rainfall**
*Data Source: (Coconut Development Authority, 1970-2013)*

**Nut processing**

Around 30 percent of production goes for industrial processing. The utilisation of nuts among processing industries has changed over time (Figure 8). However, after fresh nut consumption, coconut oil and desiccated coconut industries are the main processing industries. Other value added products operate at a comparatively small scale.

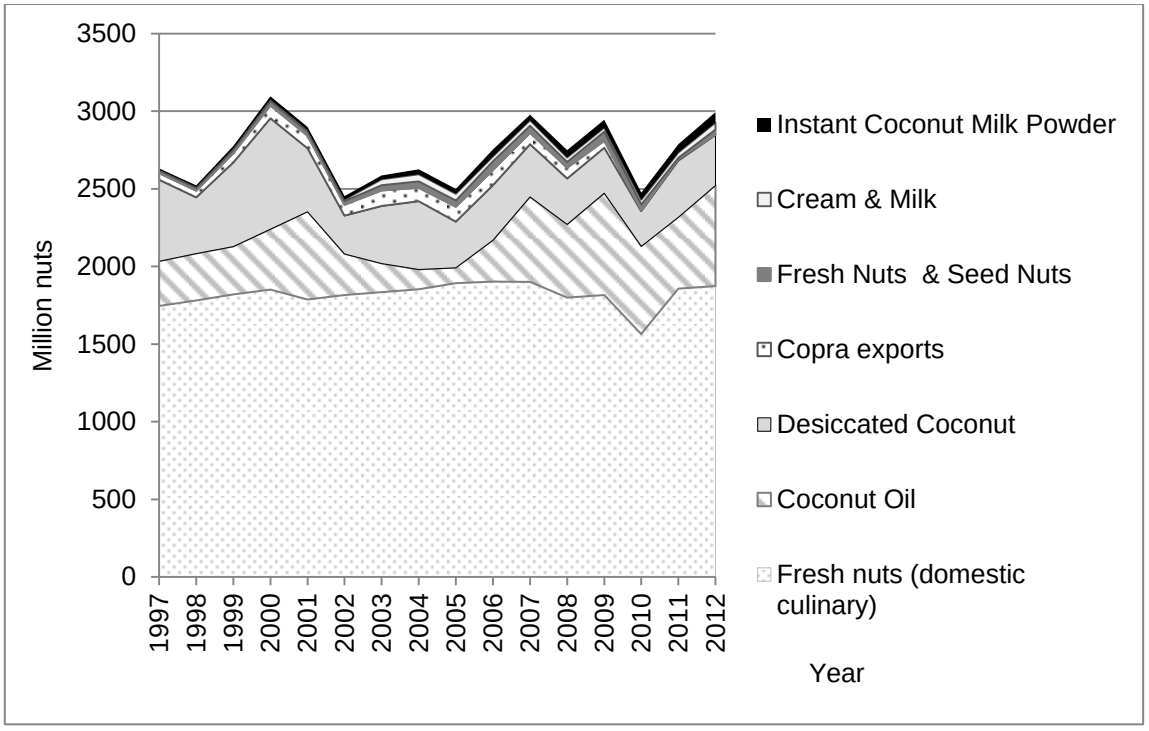


**Figure 8: Pattern of utilisation of coconut production**
*Data source: (Coconut Development Authority, 1970-2013)*

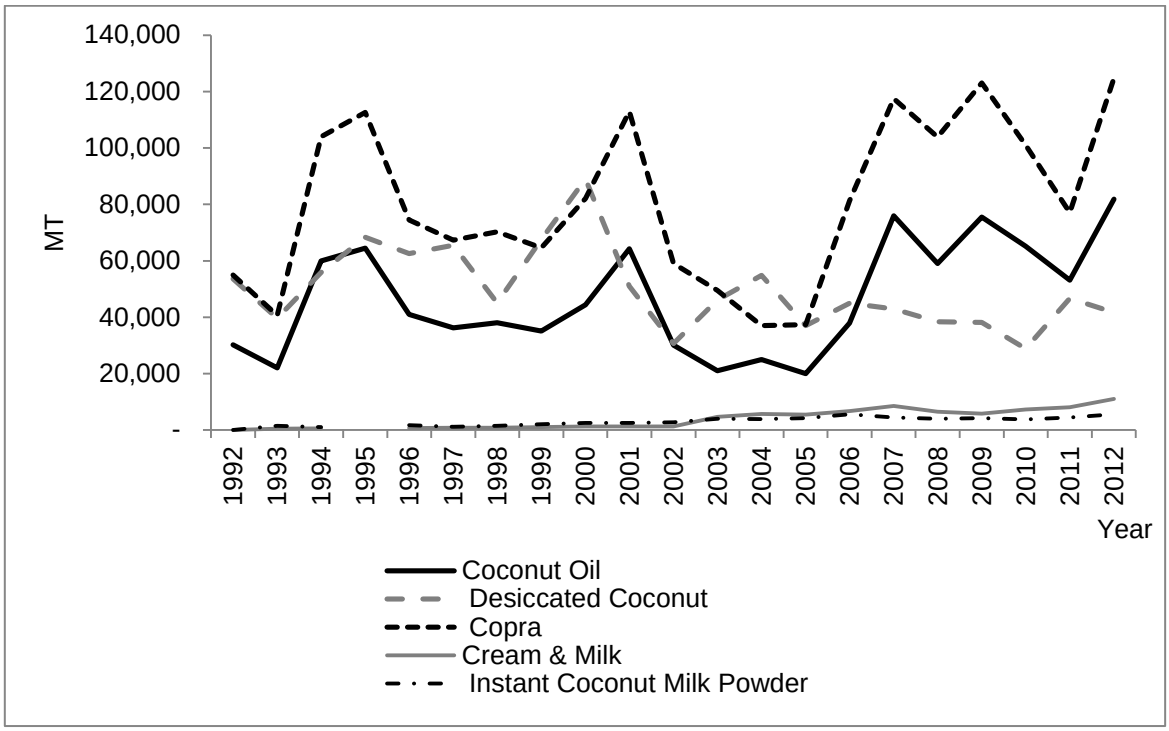


**Figure 9: Production volume of coconut kernel products over time**
*Data Source: (Coconut Development Authority, 1970-2013)*

Coconut oil and desiccated coconut production volumes generally exhibit an opposite direction of volume flows over time (Figure 8). During low coconut production years (2002-2006, 2010), coconut oil production tended to decrease, and in crop gluts production volumes tended to increase. However, the year 2010 was an exception in that nut production volume and culinary consumption declined but processing volumes held up (Figure 9).

**Local market prices**

Domestic prices of kernel products show a slightly increasing trend over time in real terms (Figure 10). The wholesale and retail price of fresh nuts both increased throughout the period and moved closely together. While the prices of all products showed the same year to year variability, the price of coconut oil showed an increasing trend compared to the prices of desiccated coconut and copra.

**Export earnings from coconut products**

The total value of export earnings from coconut products was nearly 46.7 billion rupees (US $ 0.37 billion) in 2012. Coconut kernel products contributed approximately 36 percent of the earnings while the rest was from the non-kernel sector. Figure 11 shows the value of each sector in export earnings over time. It shows the expansion of fibre value added products during the last ten year period.

Figure 12 shows the composition of kernel products in export earnings. Desiccated coconut is the main export product which contributed 45 percent of the earnings on average.

Export prices declined up to 2007 and thereafter increased except for copra and coconut milk powder (Figure 13).

In export volumes, desiccated coconut declined slightly while other products increased, particularly fresh nuts. However, both copra and fresh nut exports declined rapidly in 2010, when a lean crop occurred and exports of fresh nuts were banned (Figure 14). Since 1990,

coconut oil exports decreased dramatically with the appearance of substitute edible oils in the world market and the growth in local consumption.

Over the last two decades the contribution to export earnings from non-kernel products has increased. Value-added products mainly contributed to this increase. Among the shell products, activated carbon earned 94 percent of the earnings which was nearly 19 percent of the total export earnings of the coconut sector (Figure 15).

Fibre products contributed to 44 percent of the export earnings of coconut sector in 2012. Nearly 73 percent of this was from value added products (Figure 16).

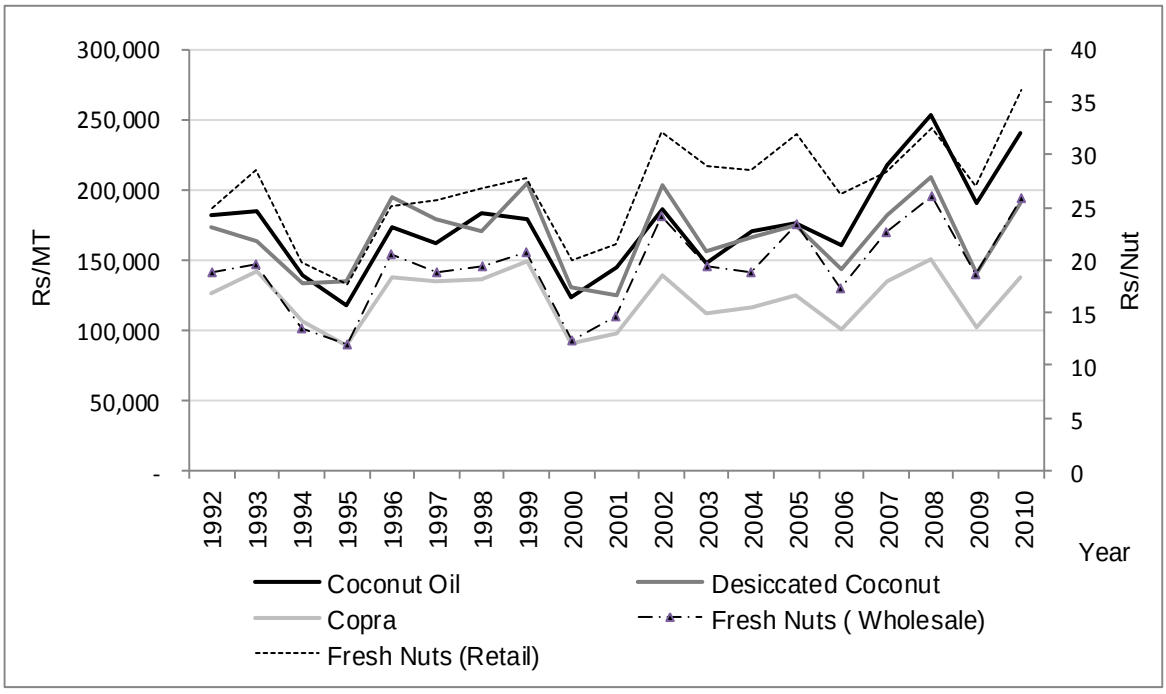


**Figure 10: Local market prices of coconut kernel products (in 2012 real terms) (I USD = 130 RS)**

*Data Source: (Coconut Development Authority, 1970-2013)*

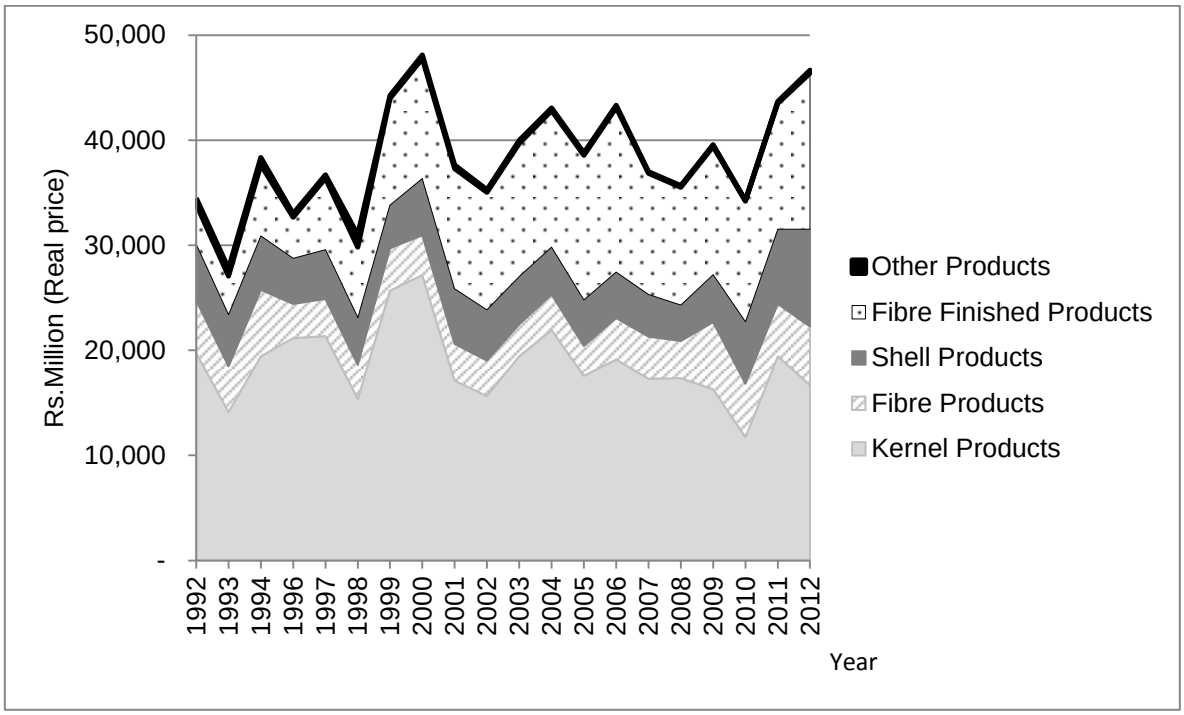


**Figure 11: Export earnings from coconut products**
*Data Source: (Coconut Development Authority, 1970-2013)*

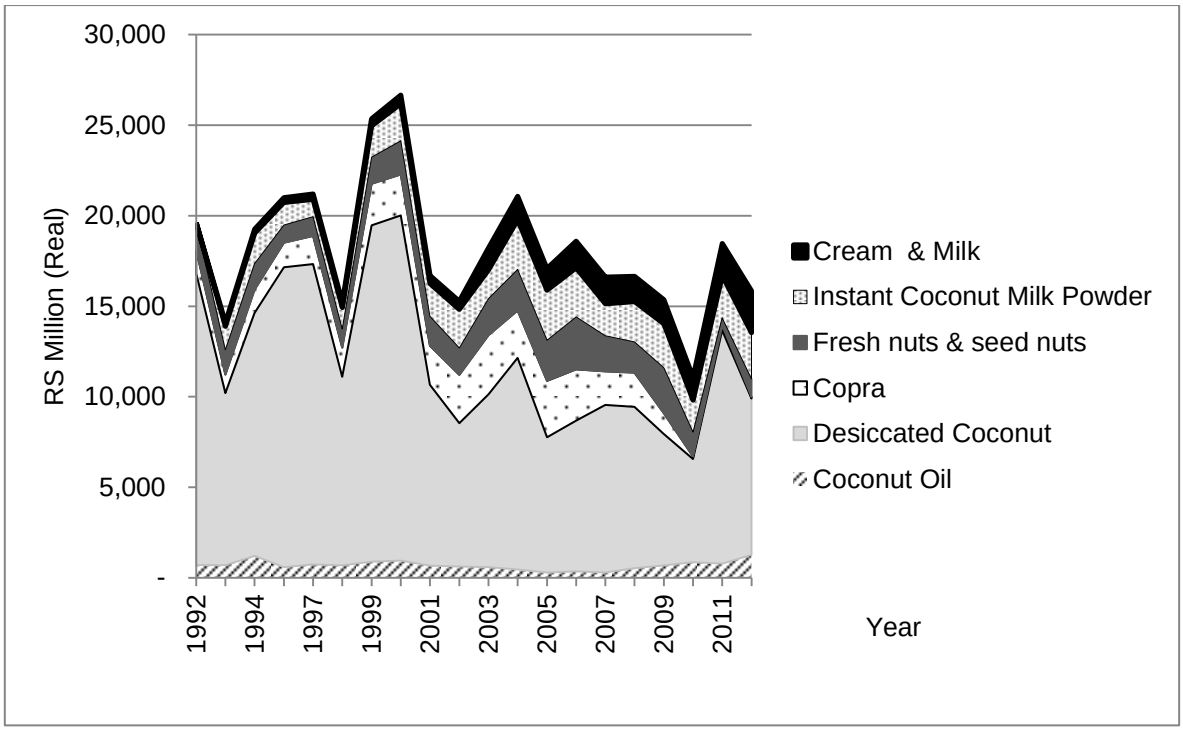


**Figure 12: Export earnings from different kernel products**
*Data source:(Coconut Development Authority, 1970-2013)*

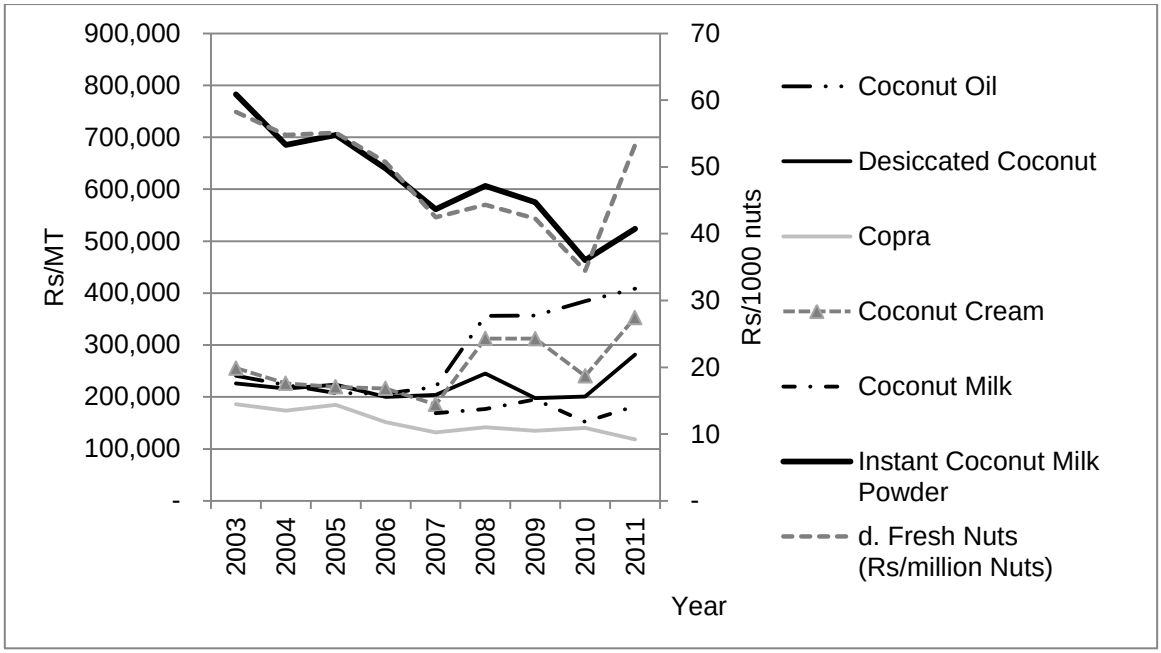


**Figure 13: Export prices of kernel products**
*Data source:(Coconut Development Authority, 1970-2013)*

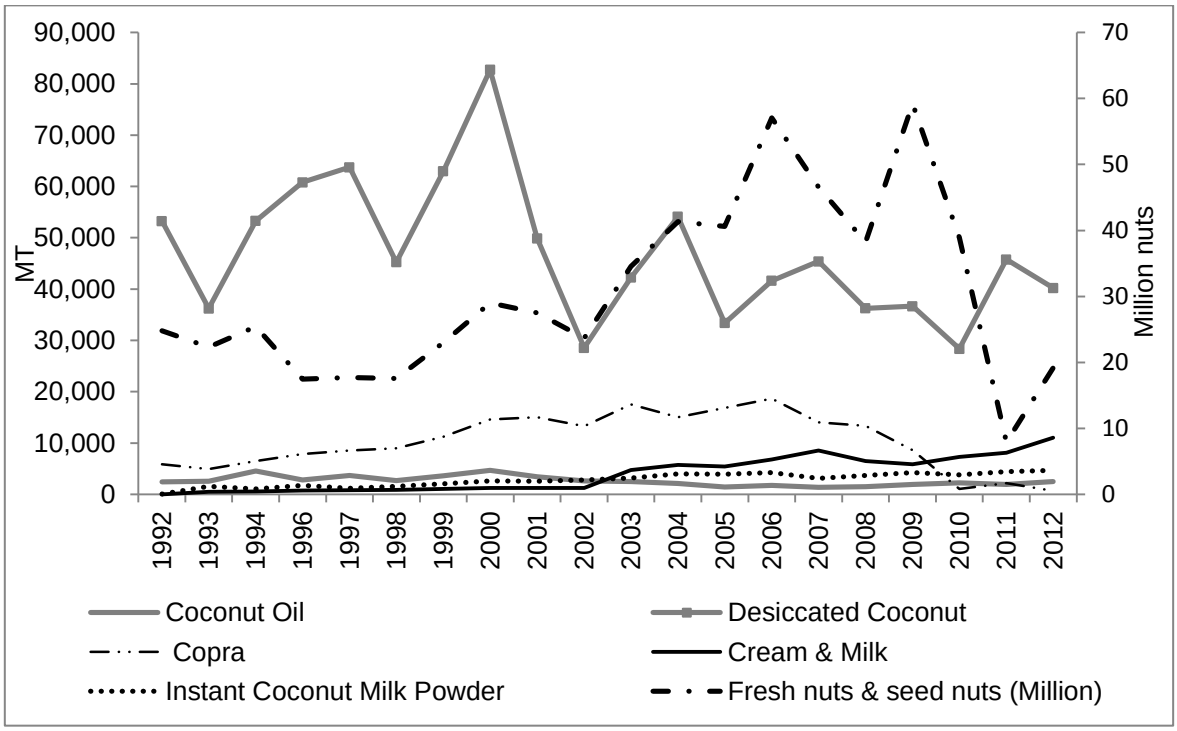


**Figure 14: Volume of exports of different kernel products**
*Data source: (Coconut Development Authority, 1970-2013)*

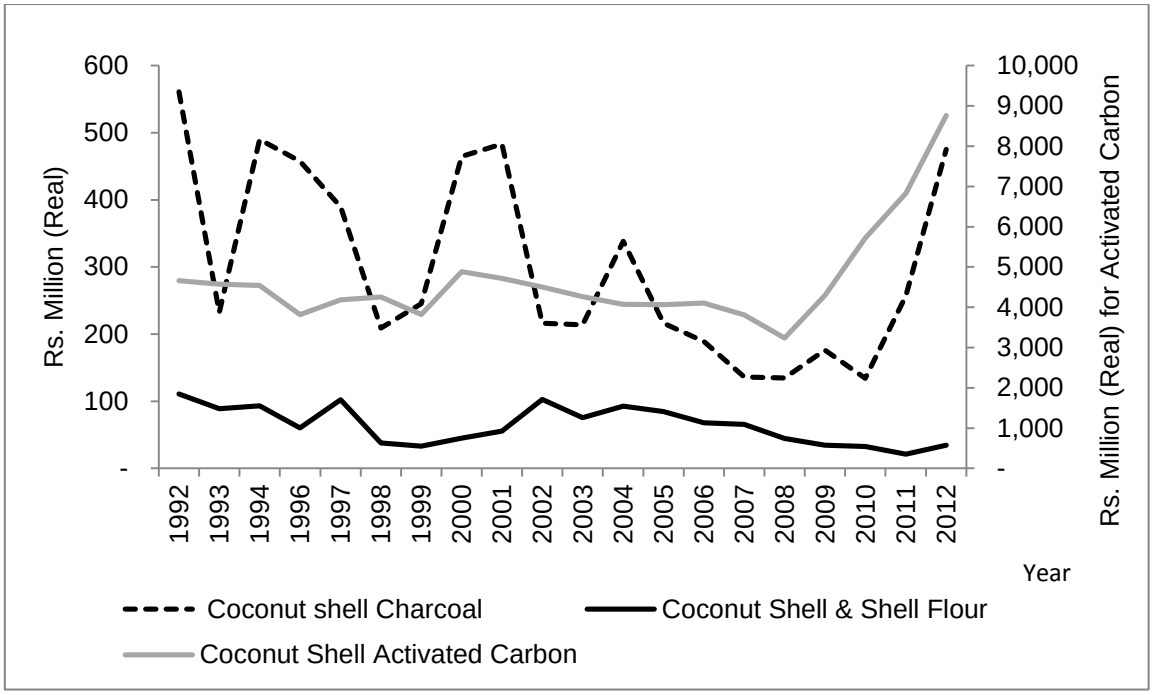


**Figure 15: Export earnings from shell products**
*Data source: (Coconut Development Authority, 1970-2013)*

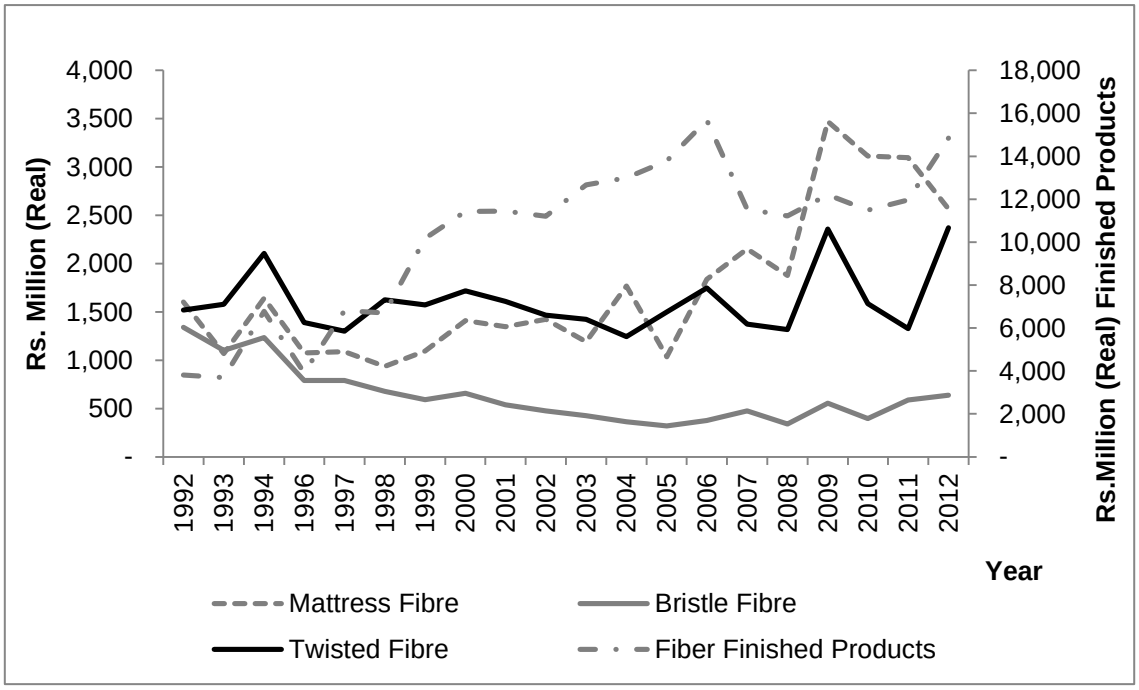


**Figure 16: Export earnings from fibre products**
*Data source: (Coconut Development Authority, 1970-2013)*

# 5. The Policy Framework

### Production and trade policies related to the coconut industry

The Government of Sri Lanka provides assistance to the coconut industry in numerous ways. The current government structure has a Ministry for Coconut Development and three institutions to carry out extension services, research, and export and domestic marketing matters (Ministry of Plantation Industries, 2007).

Several other policy schemes are operating. The Commodity Export Subsidy Scheme was introduced to provide incentives for coconut exports on the condition that the subsidies were reinvested into the development of the export sector. These funds are generally used in mill modernisation, mill development, and wage payment for workers during temporary production interruption periods especially in desiccated mills due to coconut production shortage (Coconut Development Authority, 1970-2013).

Government intervention in the coconut industry also occurs from time to time according to market conditions. For example, when nut production is below its long term average level, the government allows importation of edible oils into the country at lower tariff rates to safeguard consumers from high prices. This policy was first implemented in 1992 (Central Bank of Sri Lanka, (1950-2013 various issues); Samarajeewa et al., 2002). It makes available substitutes for domestic coconut oil demand. Nuts are released to other processing industries and for domestic fresh nut consumption, effectively dampening further price rises.

However, this policy affects the stability of the coconut oil industry. This sector faces considerable uncertainty about the quantity of nuts for processing. Moreover, the tariff release is not well controlled or planned for the shortage period. Therefore, excessive imports often lead to further nut price reduction, adversely affecting coconut growers. There are also instances of the adulteration of coconut oil with cheaper substitute oils. The branding of coconut oil and virgin coconut oil production is emerging as a measure to reassure coconut oil consumers about the quality of the product they are purchasing.

Copra imports are generally banned and only allowed in certain circumstances, and even then under quota restrictions. In certain periods, fresh nut exports are also banned to allow local consumption demand to be met. However, this leads to problems in the export markets for nuts and sometimes these markets are lost (Central Bank of Sri Lanka, 1950-2013 various issues).

### Climate change policy for the coconut industry

The Sri Lankan government developed a climate change policy in 2012 for the country across all sectors (thus, crop specific policies are not available). Its aim was “to provide guidance and directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively” (Climate Change Secretariat of Sri Lanka, 2012). The policy objectives were to make the community aware of vulnerability, adaptation, mitigation, sustainable consumption and production and knowledge management (Climate Change Secretariat of Sri Lanka, 2012). It aims to incorporate climate change aspects in development plans.

### Possible adaptation strategies

Coconut requires a well distributed rainfall throughout the year. However, there are two peaks and two stress periods in the intermediate zone due to the bimodal monsoon rainfall. In the dry zone, there is a longer dry period since rainfall is received from one monsoon. Therefore, soil moisture conservation is an already established adaptation strategy in coconut plantations. There is potential for further yield increases even in the presence of drought conditions when soil moisture conservation is practiced (Mahindapala & Pinto, 1991).

Mulching is one way of covering and protecting the soil in the manure circle (1.5m radius area from the base of the palm) from direct sunlight and wind. It helps in reducing weed growth and water loss. Materials used in mulching are coconut husks, coconut fronds, green matter and weed trash (Mahindapala & Pinto, 1991). Dead mulches are better than live mulches due to lack of competition for moisture during droughts (Vidhanaarachchi, 1998).

Incorporation of organic manure enhances the moisture retention of a soil. Sandy and clayey soils can be improved through organic matter (Mahindapala & Pinto, 1991).

The moisture retention period of a husk or dust pit varies from 45 to 60 days depending on the soil type and the severity of drought (Mahindapala & Pinto, 1991). The annual yield increase due to husk pits was found to be 19.7 percent (Liyanage, 1987). Further, a study conducted in different soil types recommends coir-dust pits for lateritic gravel soils and husk pits for sandy soils. In gravelly soils, the yield increase due to coir dust burial was 20 percent (Liyanage, 1988).These practices were found to be economically viable (Abeygunawardena et al., 1994-1995).

Cover crops prevent soil erosion, improve water intake of soil and reduce nutrient leaching and soil temperature. A good cover crop grows quickly and tolerates shade. Further it dries up during drought and does not compete with coconut for moisture (Mahindapala & Pinto, 1991).

Rainwater harvesting collects runoff water during the rainy season and these ponds can be used to irrigate the land for some period (Appuhamy, 2005).These moisture conservation practices can be used by growers, depending on resource availability and considering the severity of the drought in the area. They may use more than one of the above practices.

Irrigation during the water deficit or drought periods is identified as the most effective adaptation, having a potential to increase yield by 30 percent. However, this is restricted by the availability of water for irrigation during the drought. The other factors that determine water requirements are soil type, soil moisture availability, relative humidity, evaporation and transpiration and age of the plant. Water sources for irrigation are open wells, tube wells reaching deep underground water, and reservoirs or ponds. Sprinkler irrigation is identified as suitable for commercial scale nurseries. Drip irrigation is the most suitable method since it has advantages on efficient water use, fertilizer application (fertigation) and less labour cost. However both of above methods involves high capital investments (Mahindapala & Pinto, 1991). Pitcher irrigation (burying two clay water pots) is a traditional method of irrigating seedlings and young palms in dry and dry intermediate zones.

Identification of drought tolerant cultivars or developing drought tolerant varieties is a longer term solution and is only at an initial stage. Tall varieties and San Raman varieties are more capable of tolerating drought conditions than the hybrid varieties (Fernando, 1998-1999; Nainanayake & Morison, 2007). The majority of the coconuts grown are tall varieties.

## 6. Current Production and Marketing Issues

The Sri Lankan coconut industry is facing increased demand domestically for fresh nut consumption as a result of population growth (Figure 8). This demand for fresh nuts reduces the raw material available for processing industries. Increased demand for fresh nuts from both sectors has therefore increased the price to domestic consumers and exporters (Figure 10), increasing their cost of production and leading to declining competitiveness in the world market.

The industry is promoting coconut home gardening as a measure to increase output and partially satisfy the domestic culinary demand, as well as more efficient use of culinary nuts or the production of products such as coconut paste, coconut milk and milk powder that can be substituted for fresh nuts (Central Bank of Sri Lanka, 1950-2013 various issues; Pathiraja et al., 2007). However, the willingness of consumers to make or purchase these products is unclear.

The cost of production of coconut oil in Sri Lanka is high compared to imported edible oils. Palm oil is the main substitute oil which is in the market at lower prices due to a lower cost of production. The reasons for this low cost are palm's high efficiency as an oil crop, mechanisation and subsidies. Thus the coconut oil sector is affected by the world market situation in terms of edible oil prices. For example, the coconut oil industry functioned well when the demand for edible oils increased due to its use as a bio fuel. However, the media

focus on coconut oil adversely affecting human health has led to reduced world demand. Overall, the gradual increase of edible oil imports lead to a decline in the domestic coconut industry with the closure of oil mills (Central Bank of Sri Lanka, 1950-2013 various issues). Palm oil and palm kernel oil were comparatively cheaper substitutes for coconut oil, and adulteration of coconut oil sometimes occurred. Also, the lower farm gate price of fresh coconuts due to reduced competition for fresh coconut from the processing sector resulted in coconut cultivation becoming less attractive (Fernando et al., 2006).

Labour availability is another issue in both the plantation and processing sectors, for both skilled and unskilled work. Wage rates are increasing but still labour shortages persist. Increased mechanisation in the processing sector is possible. In the cultivation sector, pickers are the major issue (Pathiraja et al., 2010). Hybrid, dwarf varieties have been introduced for home gardening to reduce the need for pickers.

The breakup of coconut plantations into smaller blocks and the use of this land for alternative uses is known as coconut land fragmentation. Increasing population pressure has aggravated the situation so that the comparative profitability of keeping land in coconut production has been reduced. A law to control fragmentation was passed in 2005 in an effort to keep more land in coconut production and to address nut scarcity in the long term (Central Bank of Sri Lanka, 2005; Marawila et al., 2011; Weerawardana et al., 2013).

Coconut plantations are affected by different pests and diseases. Some major epidemics have been observed in recent years. For example in 2006, a leaf wilt disease (a phytoplasma disease) spread over the southern part of Sri Lanka (Wijesekara & Fernando, 2013). Nearly 336,000 coconut palms were affected by the disease (Pathiraja et al., 2013) and most of these palms were removed to prevent the spread of the disease to other parts of the country. This disease is still not eradicated from the area and coconut production is adversely affected.

Coconut mite attack is another disease in the dry and intermediate zones. The disease control measures are inadequate and difficult to practice in plantations. The nature of the damage is shrinking of coconut husk and small nuts. The estimated loss is 1-3 percent of the nut production (Peiris et al., 2003). Red weevil attack causes plants to die by boring into the stem and destroying the phloem tissues. This weevil attack is difficult to control.

## 7. Climate Change Issues for Sri Lanka

Farming systems in the dry and intermediate zones of Sri Lanka are predicted to be the most vulnerable to drought conditions in the future. Nearly 51 percent of the agricultural lands are paddy. Approximately 88,000 ha and 108,000 ha of coconut lands are in highly vulnerable and moderately vulnerable areas respectively (Ministry of Environment, 2011). These areas are located in Kurunegala and Puttalam districts which are major coconut growing areas.

Floods and landslides are the other conditions that would damage farming systems. Over 14,000 ha of coconut areas are in highly vulnerable areas with another 49,000 ha in moderately vulnerable areas. However, while coconut palms can withstand flood conditions for a few days, prolonged flooding may damage the palms. Increased soil erosion due to high intensity rainfall may increase soil degradation. The highly vulnerable area for landslides is in Nuwara Eliya district where the coconut cultivated area is nearly 2,400 ha. Moderately vulnerable areas to landslides consists of almost 52,000 ha of coconut (Ministry of Environment, 2011). Generally, coconuts are not well grown in these areas. Another climate related concern is sea level rise which may reduce the arable lands in coastal areas and increase soil salinity.

Fluctuations in yield and prices increase grower uncertainty with respect to farm income. However, increased prices due to reduced supply may help restore farmer income. These shocks are expected to transfer over the whole value chain. For example, some chain actors may be eliminated from the industry. Further, coconut fibre sector and shell sector value chains are expected to be influenced by the raw material flow deficits. This may cause a contraction in production volumes, exports and employment in the sector.

However, there is a potential for adaptation to a changing climate. As discussed above, adaptation at the plantation level is possible by mulching to reduce weed growth and soil water loss, incorporating organic matter, use of cover crops, rainwater harvesting, use of irrigation in water deficit periods, and development of drought tolerant cultivars or varieties (a longer term solution). It is important to identify the effectiveness of these adaptation strategies to withstand the changing climatic conditions.

The degree to which these adaptation measures would support the industry depends on future climatic conditions. A comprehensive climate change prediction considering the historic climate and future scenarios will provide the grounds for a detailed analysis of the above adaptations.

There are some other factors that may affect the yield in a changing climate. Examples are the impact of climate change on pest populations, performance of crops under elevated $CO_2$ levels, and impact on quality of the food. These are largely undiscussed or not yet understood. The influence of these uncertainties may enhance the current issues discussed in section 6.

Therefore, based on the available knowledge, a study of coconut industry adaptation in a credible climate change analysis will identify the biophysical impacts and economic effectiveness of adaptation. Such a study appears to be a requisite in future industry investment planning.

## 8. Conclusions

According to climatic change predictions, coconut yield reduction may occur with increasing ambient temperatures. Expected weather extremes may aggravate the situation leading to frequent production variations and price fluctuations. The irreversible impacts during prolonged droughts may cause permanent losses. The resulting supply uncertainty will be transferred to all the stakeholders of the industry. For instance, producers will be uncertain of their return on investment in coconut cultivation. Processing industries may face uncertainties on stability of supply of raw material both in quantity and price terms. Further, these instabilities will affect domestic consumers. Therefore, the role of adaptation strategies in sustaining yield under climate change scenarios becomes critical. The impact of potential climate change and adaptation strategies on the coconut industry value chain of Sri Lanka is an important issue for further research.

## 9. References

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[1]Sri Lanka is divided into three main climatic regions based on annual rainfall. Dry zone receives less than 1750 mm rainfall, intermediate zone receives 1750-2500 mm rainfall and wet zone receives more that 2500mm rainfall annually.