Anitha Karun, S Jayasekhar and
K Muralidharan

Coconut based cropping systems for enhancing profitability, ensuring sustainability and transcending towards nutritional security

Coconut is considered as one of the most important crops for the Asia and Pacific region, providing food, nutrition and livelihood to millions of coconut farmers in the region. Despite the economic importance of the coconut palm, coconut production continued to show stagnancy in production, productivity and trade in the recent decade. The coconut sector in the past has been dominated by copra and coconut oil, and the international coconut trade used to be driven by the demand for coconut oil. However, demand for coconut oil has witnessed a sharp decline during the last decades due to increased competition from other edible oils, such as palm oil and soybean. Furthermore, there is a changing trend wherein coconut is increasingly being processed into diversified value-added products in recent times. This emerging trend has influenced the current production, processing and trading system in coconut. To take advantage of these newfound opportunities in the world market, coconut growers must look into the trade patterns, performance and global competitiveness of coconut and coconut products. At present, the market trends indicate consumer choice and acceptance of the various products of coconut. Growth rates in export volumes continue to increase each year for Virgin Coconut Oil (VCO) by 30%, Coconut Water by 150%, Coconut Milk/Cream/ Powder by 50%, Desiccated Coconut by 30%, Coconut Flour by 115% and similar trends for other emerging products. Taking a cue from the changed scenario in the coconut sector, the Kalpa Agri-Business Incubator functioning under ICAR-CPCRI provides much-needed handholding to the startup entrepreneurs in the sector.

Production scenario

According to the latest production statistics brought out by the ICC, the coconut production in the world is estimated at 68,833 million nuts from an area of 12.08 million ha. The world productivity of coconut stands at 5,777 nuts/ha (Table 1). Notably, the world's area and production of coconuts are skewed by and large, wherein 70% of the total area and production is concentrated in India, Indonesia, and the Philippines. India is the largest producer of coconuts, with a share of 31% of the total production. In productivity, India is much ahead of the major coconut producers' with an average yield of 9,897 nuts/ha.

In India, coconut contributed about ₹ 10,707 crore in crop output in 2019-20, and the coconut industry directly or indirectly employs about 12 million people. Coconut is a major plantation crop of coastal regions of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh. These top-four producers accounted for 90% of total production and about 89.5% of total production acreage in the country in the year 2019-20 (Table 2). Other important coconut producing States in the country include West Bengal, Odisha, Gujarat, Maharashtra, Assam and Bihar, which account for nearly 8% of production. Among the four major coconut growing States, Andhra Pradesh had the highest productivity (14,019 nuts/ha), followed by Tamil Nadu with 12,291 nuts/ha. While Kerala, which accounts for the largest share in production in the country, had average productivity of 10,097/ha in 2019-20, marginally higher than the all-India yield of 9,897 nuts/ha. The productivity level in Karnataka (7,983 nuts/ha) was significantly lower than the all India average and other major producers.

The area under coconut has remained stagnant at around 2.1 million ha since 2011-12, with minor inter-year fluctuations. Coconut production and yield have been fluctuating in cycles of two years due to climatic and biological reasons. Overall, coconut production has increased at an annual growth rate of 3.3% during 2001-2020. The growth in coconut production was largely attributed to improvement in yield, reflecting the concerted efforts on coconut research, especially the popularization of improved varieties (Fig. 1 a,b).

Table 1. Area, production and productivity of coconut in the world

Country	Area ('000 ha)	% share	Production (million nuts)	% share	Productivity (nuts/ha)
Indonesia	3544	29.3	14356	20.9	4530
The Philippines	3612	29.9	14049	20.4	4196
India	2151	17.8	21288	30.9	9897
Sri Lanka	440	3.6	2450	3.6	6623
Brazil	216	1.8	2343	3.4	11923
Papua New Guinea	221	1.8	1483	2.2	6709
Thailand	179	1.5	666	1.0	4859
Others	1725	14.3	12198	17.6	5662
Total	**12053**	**100**	**68737**	**100**	**5777**

Source: Coconut Statistical Yearbook-2017.

Table 2. State-wise statistics: Coconut

State/UT'S	Area ('000 ha)	% share	Production (million nuts)	% share	Productivity (nuts/ha)
Tamil Nadu	436.94	20.31	5370.39	25.23	12291
Karnataka	619.78	28.82	4947.74	23.24	7983
Kerala	760.95	35.38	7683.55	36.09	10097
Andhra Pradesh	111.82	5.20	1567.6	7.36	14019
Others	221.40	10.29	1718.96	8.08	---
All India	2150.89	100.00	21288.24	100.00	9897

Source: CDB, 2020.

Demand and supply scenario

The projected coconut demand for 2050 is predicted to be about 45,000 million nuts. With the projected supply of around 36,000 million nuts, there would be a demand-supply gap of 9,000 million nuts by 2050. To meet the projected demand, the annual growth rate in production should be 3.20%. As a matter of fact, coconut in future may experience a paradigm shift from the oilseed label if promoted as food for nutrition, healthcare and environmental services to support the farming community. Moreover, the recent surge in the export of coconut products and the rising demand for tender coconut in the country is noteworthy. In such a scenario, by 2050, the demand for coconut would be certainly more than the estimated figure. Therefore, it would be a challenge to meet the futuristic coconut demand, especially because of the scarce land, labour, water and energy resources at disposal. An appreciable growth in total factor productivity and appropriate capital substitution are the possible alternatives. To achieve these, strengthening the traditional coconut-based farming system through modern research tools would be the starting point.

Fig. 1a. Kalparatna, the newly released multipurpose coconut variety (through selection) for copra, tendernut and 'neera'; 1b. Kalpajyoti coconut variety released for tendernut purpose.

Coconut products

Coconut palm is often called 'tree of life' as it ensures vibrant living, vitality, health and prosperity. Mature coconut fruit (nearly 10 to 12 months after fertilization) has solid and liquid endosperm referred to as the kernel (meat) and coconut water.

Kernel-based products: Fresh coconut kernel (i.e. gratings) is used for various culinary preparations. It has more fat (33%) than carbohydrate (15%) and is a rich source of dietary fibre (9%), potassium (355 mg) and manganese (1.5 mg). More than half the fat in coconut gratings is in the medium-chain category, absorbed directly at the

small intestine and rapidly used for energy. Some studies suggest that medium-chain fats promote loss of weight in people with obesity.

Fresh coconut kernel will have 50 to 55% moisture; on dehydrating, the desiccated coconut (DC) is obtained. It can be stored for more than six months. It may be noted here that the brown coloured testa, the thin layer separating the white coconut kernel from the shell, is removed while making the DC.

Another way of preserving coconut fruit is in the form of copra. The ball copra is obtained by allowing the whole fruit to dry (without removing its husk, i.e. exocarp) over 4 to 8 months; it will take a few months to obtain the ball copra. Once fully dried, there will be no water inside the fruit, and the entire kernel will be detached inside the shell. The milling copra (for oil) is produced by drying the split-opened nut (after removing the husk) to detach the kernel from the shell. The nutrient profile of copra is more or less similar to dried coconut gratings except for the constituents of testa, which is nearly 2% of copra weight. Testa has 40 to 50% fat.

In India, the milling copra is used for the extraction of edible oil, whereas in other countries, edible oil is obtained from the processing of coconut milk (extracted from fresh coconut kernel) or from instantly dried gratings. The nutrient profiles of coconut oil obtained in different ways show some variation. It has 92% saturated fats and 8% unsaturated fats. Because of the high concentration of saturated fats, many recommend avoiding or restricting coconut oil intake. But when examined critically, one can see that more than 80% of fat in coconut oil is of medium-chain fatty acids (Sl. No. 1 to 4 in Table 3). Further, 50% of the fat is in the form of lauric acid, making it the highest source among edible oils. As mentioned earlier, medium-chain fatty acids are easily absorbed and converted to energy instantly, unlike long-chain fatty acids. This advantage makes coconut fats a preferred choice for infant and sports person food recipes.

For direct consumption and culinary purposes, the Virgin Coconut Oil is most recommended. The VCO can be obtained by processing the coconut milk in three different ways: Centrifuge, hot processing or fermentation. ICAR-CPCRI has commercialized the protocol for hot and fermentation processing of VCO.

Coconut milk and milk powder are also used for many culinary purposes. While extraction of milk, 60 to 65% fat is removed from the kernel. These technologies are available with ICAR-CPCRI.

Beverages: More and more people now prefer natural drinks over soft drinks, which made the tender coconut a premium product across India in recent years. More than 15% of the production is consumed as tender coconut in India.

Another beverage from coconut is the inflorescence sap, popularly known as 'neera'. Technology for the collection of unfermented coconut sap has been developed by ICAR-CPCRI (Fig. 2a) and is referred to be Kalparasa®. The nutrient profile of coconut water, tender coconut water and Kalparasa® is provided in Table 4.

One of the value-added products from Kalparasa® is coconut sugar (Fig. 2b). As it is processed without adding any chemicals, it is most recommended for infants. Another product getting attention from the public is the vegan coconut delicacy with constituents as tender coconut pulp, coconut milk and coconut sugar.

Biodiversity support through system approach

By and large, the coconut lands in India are conducive to producing various annuals, biennials, and perennials. Secondly, since coconut is planted at a wider spacing due to its characteristic morphological features, the inter- and intra-row spaces in coconut gardens are adequate to provide the best forms of cropping system without adversely affecting the productivity of the palms. Several inter/mixed crops yield reasonably well because of their ability to tolerate coconut shade. On these accounts, the returns from the system offset the costs and ensure profits.

Crops identified as compatible ones with coconut include many tuber crops (cassava, elephant foot yam, yams, colocasia), rhizome-spices (ginger, turmeric), pulses (cowpea), oilseeds (groundnut, soybean), upland rice, fruit crops (banana, pineapple) and vegetables among the annuals and cocoa, black pepper, clove and nutmeg among perennials. Many intensive crop combinations

Table 3. Fatty acid profiles of different types of coconut oil

Sl. No.	Fatty acid	Oil from copra	Hot processing of coconut milk (VCO)	Fermentation of coconut milk (VCO)	Oil from dried gratings
	Saturated				
1	C12-lauric acid	50.44	50.39	51.09	51.35
2	C14-myristic acid	20.94	20.91	20.89	19.74
3	C8-caprylic acid	4.85	4.9	4.6	5.45
4	C10-capric acid	4.99	4.96	4.54	5.42
5	C16-palmitic acid	8.15	8.54	8.7	8.09
6	C18:0-stearic acid	3.01	2.53	2.64	2.49
	Unsaturated				
8	C18:1-oleic acid	5.83	6.1	6.12	5.62
9	C18:2-linoleic acid	1.45	1.15	1.15	1.11

Source: Arumuganathan T, Madhavan K, Mathew A C and Sugada Padmanabhan. 2011. Lipid profile of virgin coconut oil processed by different methods. *Journal of Plantation Crops* **39**(1): 247.

Table 4. The nutrient profile of mature- and tender- coconut water and Kalparasa®

Parameter	Mature coconut water	Tender coconut water	Kalparasa®
Total sugar, %	3.3	4.8	14
Reducing sugars, %	0.2	4.4	1.5
Minerals, %	0.5	0.6	0.32
Protein, %	0.1	0.01	0.17
Fat, %	0.1	0.01	0
pH	5.2	4.5	7.0
Potassium, mg%	247	290	175
Sodium, mg%	48	42	45
Calcium, mg%	40	44	4.5
Magnesium, mg %	15	10	0.5
Phosphorus, mg%	6.3	9.2	3.0
Iron, mg%	79	106	75.0

Source: Hebbar K B, Arivalagan M, Pavithra K C, Roy T K, Gopal M, Shivashankara K S and Chowdappa P. 2020. Nutritional profiling of coconut (*Cocos nucifera* L.) inflorescence sap collected using noval coco-sap chiller method and its value added products. *Journal of Food Measurement and Characterization* **14**: 2703-12.

Fig. 2. The 'coco-sap chiller' (2a) used for collecting unfermented coconut inflorescence sap; (2b) coconut sugar made from Kalparasa®.

that involve different annuals and perennials over time, such as multistoried cropping systems and high-density multi-species crop models (HDMSCs), have also been developed (Fig. 3a). Perennial intercrops such as cocoa (Fig. 3b), nutmeg, cinnamon and fruit trees are most compatible for commercial production under coconut. Mixed farming systems, which integrate other enterprises like dairying, provide higher employment and enhanced net income.

The comparative economic analysis of coconut monocropping, coconut-based compact cropping system and coconut-based mixed farming system (CMFS) categorically proved the advantages of the system approach. The system using multi-species cropping of coconut with pepper, banana, nutmeg, pineapple, ginger, turmeric and elephant foot yam generated a net income of ₹ 362,595/ha, which is 150% higher than that of coconut monocrop (₹ 141,505), while the CMFS wherein the components are coconut, pepper, banana, crossbred cows, poultry birds, goat, and pisciculture generated a net return of ₹ 550,214, which is 288% higher than that of coconut monocrop. However, there are cases of farmers who are highly successful in implementing multiple cropping/integrated farming in coconut. Similarly, some grama panchayats have successfully implemented the coconut-based farming system interventions under the peoples' campaign for decentralized planning programme. The potential to strengthen food and nutritional security by adopting appropriate coconut-based intercropping/mixed farming also needs to be effectively utilized.

Cocoa as a component crop

Cocoa is one of the most compatible intercrops in the coconut garden, evidenced from field experiments conducted in ICAR-CPCRI. The coconut-cocoa cropping system is one of the widely adopted cropping systems across coconut growing tracts in India.

Cocoa is grown in 58 countries on around 10 million ha with an estimated production of 4.7 million tonnes. Among the major countries, Côte d'Ivoire has the highest productivity of 660 kg/ha, while the world productivity is 504 kg/ha. The four West African countries viz. Côte d'Ivoire, Ghana, Cameroon and Nigeria contributed to 73.6% of worldwide cocoa production. India is a very small player with a production share of meagre 0.31%. In India, cocoa is cultivated mainly in Tamil Nadu, Andhra Pradesh, Kerala, and Karnataka. India produced 19,866t of cocoa from 88,515 ha with a 580 kg/ha productivity in the year 2020. Tamil Nadu has the highest area under cocoa (33%), followed by Andhra Pradesh (32%), and in cocoa production, Andhra Pradesh has the major share (41%), followed by Kerala (38%). The contribution of cocoa to the national income amounts to ₹ 2,000 million. The cocoa industry in the country has expanded to a considerable extent in recent years. At present more than

Fig. 3a. High-density multispecies cropping system model

Fig. 3b. Coconut and cocoa mixed cropping system

15 industrial entrepreneurs and firms existing in the field demanding nearly 40,000 t of cocoa beans, of which the present domestic availability is only about 42%.

Considering the present-day food consumption patterns and growth of the confectionery industry in India at around 20%, the demand for cocoa is likely to increase in the coming years. The import of cocoa and cocoa products to India has increased at a compound growth rate of 17% during the 10 years period (2009-19), which shows a surging domestic demand for cocoa and cocoa products and surplus processing capacity existing in the country. It is noteworthy that the import of cocoa in the year 2019 was 63,613 t while the export was meagre 25,700 t accounting for a negative trade balance of 37,913 t. The projected demand for cocoa in India by 2050 is 212 thousand tonnes against the estimated supply of 121 thousand tonnes. With the projected supply, there would be a demand-supply gap of 90 thousand tonnes of cocoa beans in 2050. To achieve this target, production should increase at an annual growth rate of 7.68%. There is a need to chalk out a logical and pragmatic strategy to achieve the desirable projected demand-supply equation. Growth in per capita consumption of cocoa in India is the motivating factor behind the projection of an optimistic supply-demand scenario. We have about 26 lakh ha area available in India under coconut, arecanut and oil palm gardens to cultivate cocoa plants (new area expansion), and around 35% of this land is under irrigation. Thereby, the total potential area for cocoa planting comes to around nine lakh ha. Availability of such areas in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Odisha will therefore offer ample scope for new area expansion of cocoa.

There are potentials and possibilities in the form of massive acreage wherein cocoa can be comfortably accommodated as an intercrop, an internal market with accelerated annual growth of the confectionery industry, and well-established research and development back up. In case of cocoa, the development of exclusive market yards and assembling places for cocoa beans and the adoption of high-quality food safety standards would be a proactive step for better realization of bean prices. Assured buy-back systems developed in the frame of contract farming under the government's stake (tripartite arrangement) can help in the sector's growth.

Recycling for sustainability

Recycling crop wastes in coconut and cocoa through vermicomposting and mushroom production helps in disposing of wastes, improving soil fertility, reduction in use of chemical fertilizers and sustaining the yield besides enhancing nutritional security. Coconut gardens of 1 ha area can generate up to 8 t of leaf biomass residues every year. Technology has been developed to utilize these wastes for the production of vermicompost, vermiwash, compost and mushrooms. From about 8 t of leaf residues, 3-4 t of vermicompost could be produced annually using the local isolate of *Eudrilus* sp. The coconut leaf vermicompost can also meet 50% of the nitrogen requirement of coconut palms grown in 1 ha, saving expenditure on inorganic fertilizers.

Coconut based ancillary industries

An off-shoot from the mainstay coconut sector, the coir industry in India contributes significantly to employment creation and the economy at large, mainly in Kerala and Tamil Nadu but also in other major coconut growing States and Union Territories, including Andhra Pradesh, Karnataka, Maharashtra, Goa, Odisha, Assam, Andaman and Nicobar, Lakshadweep and Puducherry. In the country, approximately seven lakh persons find employment, both direct and indirect, in this industry. The industry is also significant in terms of exports. In 2019-20, India exported 9.9 lakh MT of coir and coir products, earning ₹ 2,758 crore in export revenues. It is also noteworthy that, the exports of coir and coir products have increased at an annual growth rate of 11.1% during the last five years (2016-2020).

The domestic revenue earned is double the export revenue. India accounts for more than two-thirds of the global production of coir and coir products, including 60% of the total global supply of white fibre. Sri Lanka is the second-largest producer accounting for 36% of the total global supply of golden fiber. Currently, the global annual production of coir fiber is about 3.5 lakh metric tonnes.

The coir industry assumes significance because it

is agro-based, has a large presence in rural areas, and involves a large proportion of women workers (80%) and workers belonging to the economically and socially disadvantaged sections. India currently exports about 14 coir products, including coir pith, coir fiber, tufted mats, handloom mats, geotextiles, coir yarn, curled coir, handloom matting and rubberised coir. Currently, only 40% of the coconut husk is utilised by the coir industry, and there is potential for further development.

Coir pith: It is a by-product separated from the husk while extracting the fibre. Its capacity to hold moisture eight times its weight makes coir pith an excellent soil conditioner. With the ban on peat mining, the horticulture industry was in search of an alternative material from a renewable resource, and coir pith fits exactly into the slot. Coir pith has amazing water-retaining capacity. Thus, the fibre acts like mini-sponges, yielding astounding plant growth, which eventually makes it a great product. It is striking that coir pith contributes up to 49% of the value share in coir products exports from India.

Shell charcoal: India is amongst the top five exporters of coconut shell charcoal and activated carbon. Coconut based activated carbon is produced using coconut shell and coconut husks. Hardness required in coconut shells for manufacturing activated carbon, which are in high demand, is a rare feature in the shells sourced from southern India, therefore activated carbon from India has a high demand in international markets. Coconut shell-based activated carbon accounted for 67.2% of total exports of coconut products and stands as a promising and profitable enterprise for the aspirants

In India, the coconut sector has been inextricably linked to coconut oil, the most dominant product from the palm, from time immemorial. Such a strong dependency on a single product had indubitably made the sector vulnerable to supply and price shocks. It is also noteworthy that trade and market prices are increasingly playing a key role in sustaining the livelihood of those dependent on this sector. Hence, it is imperative to think beyond production and productivity, especially when many other issues plague the coconut sector. The potential area of the coconut sector is the agri-business, based on value-added products of coconuts.

Further, many rural youths from the country are interested in utilizing coconut value addition technologies such as virgin coconut oil, coconut chips, Kalparasa® and coconut sugar to start business ventures. The breakthrough products developed from the coconuts have export potential, and thereby in the long run, price stabilization in the domestic coconut sector is also possible. Further, to ensure the livelihood security of those dependent on the sector, it is of paramount importance to strengthen the value chain of the coconut through appropriate forward and backward integration of the chain.

For further interaction, please write to:
Drs Anitha Karun, S Jayasekhar and K Muralidharan, ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerela 671 124, India.