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REVIEW ARTICLE

COCONUT BASED CROPPING / FARMING SYSTEMS IN INDIA*

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INTRODUCTION

Coconut is an important perennial oil yielding crop of world, grown in an area of 11.919 m ha (APCC Statistical Year Book, 1998) in the tropical belt lying between 23.5°N and 23.5°S of the equator. Ninety per cent of the world's total area and production of coconut comes from the five major coconut producing countries *viz.*, India, Philippines, Indonesia, Sri Lanka and Malaysia. Millions of farmers in these countries are small holders and directly depend on coconut for their livelihood. The income derived from such small holdings is not sufficient to sustain even the small families. In addition, coconut as a monocrop provides employment only for about 150 mandays/ha/year under rainfed conditions (Nelliat and Krishnaji, 1976) and consequently the family labour remains unemployed for larger parts of the year. Coconut based cropping/farming systems, involving cultivation of compatible crops in the interspaces of coconut and integration with other enterprises like dairying offer considerable scope for increasing production and productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour.

In India, coconut is cultivated in about 1.8 m ha, and the average size of the holding is as low as 0.22 ha and 90 per cent of the five million coconut holdings are less than one ha (Thampan, 1988). Coconut based multiple cropping system is practiced in India, particularly in Kerala and Karnataka from the time immemorial. However, the traditional models used by the farmers are not systematic and scientific in selection and arrangement of crops (Rethinam, 1990). Research on coconut based cropping systems was initiated during thirties and intensified in the seventies with the establishment of Central Plantation Crops Research Institute (CPCRI) at Kasaragod and All India Coordinated Research Programme on Palms with centres in different coconut growing states. In recent years CPCRI has taken initiative to work out the labour requirements, nutrient recycling and budgeting and cash flow analysis of cropping system models.

Resource use in coconut

Perennial crops like coconut, which occupy the land continuously for several decades, utilize the natural resources only to a very limited extent producing less than 10 per cent of the potential for dry matter production in the tropics (Loomis and Williams, 1973; Nelliat *et al.*, 1974).

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Rooting pattern

A spacing of 7.5 m in the square system is recommended for coconut (175 palms/ha) for optimum production. Coconut palm like all monocots has a typical adventitious root system, under favourable conditions, as many as 4000 to 7000 roots are found in the middle aged palms (Patel, 1938). Kushwah *et al.*, (1973) reported that about 74 per cent of the roots produced by a palm under good management did not go beyond 2 m lateral distance and 82 per cent of the roots were confined to the 31 to 120 cm depth of soil. Recent studies have further confirmed that more than 80 per cent of the root activity was confined to a lateral distance of 2 m from the trunk (Anil Kumar and Wahid, 1988). Thus, the active root zone of coconut is confined to 25 per cent of the available land area (Darwis and Tarigans, 1990; Magat, 1990) and the remaining area could be profitably exploited for raising subsidiary crops.

Canopy structure and light utilization

The venetian structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed, but clumped around growing points. This non-random distribution will also lead to low extension coefficient of around 0.65 for PAR. Age, spacing, soil fertility, varietal characteristics, leaf area and time of the day influence the light penetration through the canopy (Nair and Balakrishnan, 1976; Liyanage, 1985).

The amount of light transmitted ranges from five per cent in a five to ten year old DxT hybrid at a density of 650 palms/ha to about 90 per cent in a 60-70 year old plantation at a density of 120 palms/ha (Reynolds, 1995). Nair and Balakrishnan (1976) estimated that as much as 56 per cent of the sunlight was transmitted through the canopy during the peak hours (10-16 hrs) in palms aged around 25 years. The diffused sunlight facilitates growing a number of shade tolerant crops in the interspaces.

The nature and amount of sunlight transmitted through coconut canopy and falling on the ground shows temporal as well as spatial variations. The angle of the sun rays (and thus the time of the day) influences the amount of light passing through the coconut canopy. With the movement of the sun and the movement of coconut fronds in the wind, the light and shade patterns under the palms are constantly changing. The distribution of light at different positions in the canopy zone of coconut varies much because of the non-random distribution of leaves. This causes differences in the growth and yield of intercrops at different positions of the plantation floor. Based on the growth habit of the palm and the amount of light transmitted through its canopy, the life span of coconut palm could be divided into three distinct phases from the point of view of intercropping (Nair, 1979).

1. Planting till full development of canopy (about 8 years): Good transmission initially; but decreasing with age; suitable for growing annuals/biennials; intercrops have minimal competition with coconut palm for ecological factors.
2. Young palms (8-25 years): Maximum ground coverage (80%) and low

canopy due to shorter trunk; poor light availability; not suitable for growing of other crops in the interspaces.

3. Gradual increase in the magnitude of light penetration to the ground; decrease in apparent ground coverage of canopy; taller trunk; ideal for raising annual and/or perennial crops.

The environment in irrigated coconut plantations favours luxuriant growth of grass and other vegetation throughout the year due to favourable microclimate of high humidity and favourable soil temperature. So, it is worth to have intercrops in such conditions rather than to invest labour in grass and clearing other vegetation.

Criteria for selection of subsidiary crops

The desirable characters of crops to be grown under or between a tree crop have been described by Allen (1955) and Hartley (1977):

1. Crops should be selected according to their shade tolerance and amount of solar radiation available.
2. Should not grow as tall as coconut.
3. Should not be more susceptible than the main crop to diseases they have in common.
4. Should not require harvesting or other operations that would damage the main crop or induce soil erosion or damage soil structure.
5. Should not have an economic life longer than the main crop.
6. Its root system exploit different soil horizons/zones.
7. Crops should be selected according to the soil type, rainfall pattern/ irrigation facilities and climatic conditions.
8. Availability of marketing/processing facility and labour availability.

Terminologies commonly used

Intercropping: Growing annuals/ biennials in the interspaces of coconut.

Mixed cropping: Growing perennial in the interspaces of coconut.

Multistoreyed cropping: Growing three or more crops having different morphological characteristics in the interspaces of coconut so as to intercept solar radiation at different level *viz.,* Coconut + black pepper + cocoa + pineapple (Nelliat *et al.,* 1974).

High Density Multispecies Cropping System: Growing a large number of crops species in unit area of coconut plantation at high plant densities to achieve maximum resource use efficiency and to meet the diverse needs of the farmer (Bavappa *et al.,* 1986; Rethinam, 1990).

Mixed farming: When other subsidiary enterprises such as livestock, poultry, rabbitary *etc.* are raised with the help of fodder or pasture grown in the coconut garden (Bavappa, 1990; Nair, 1993; Nair and Gopalasundaram, 1990).

Factors influencing cropping/ farming systems

Production systems range from raising of coconut in monoculture to single and multispecies cropping systems for subsistence, subsistence and cash, to the large plantations and small homestead gardens. On a regional basis, intercropping patterns, their intensity and species combination in non-irrigated areas are determined by the duration and amount of rainfall. A climate of tropical rain forest is more ideal for multistoreyed cropping. Sandy loam soil all along the coastal lines of the East and West Coast of the Peninsular India offers good scope for multistoreyed cropping with coconut (Nambiar, 1978). However, littoral sand, a soil type of very low fertility along the East and West Coast of India is unsuitable for crops such as black pepper and cocoa, whereas such soils could be profitably used for root crops, tobacco and vegetables especially the watermelons and cucumber.

Suitability of intercrops for coconut garden

Gopalasundaram and Nelliat, (1979); Nair, (1979); Dagar, (1990); Subramanian, (1990); Sharma and Gangawar, (1990) and Gopalasundaram *et al.,* (1993) have reviewed inter-cropping experiments with coconut in India. Among the intercrops are various food crops such as cereals, pulses, oil seeds, root crops, pasture legumes, grasses and vegetables (Nair, 1993; Nelliat and Krishnaji, 1976; Sahasranaman and Sethumadhava Menon, 1973); Other tree crops like cocoa (Bavappa, 1990a; Nair, 1993); spice crops like clove (Reddy *et al.,* 1998), nutmeg, cinnamon; pepper (Bavappa, 1990b); fruits like banana, pineapple, custard apple, papaya, lime, pomegranate, jack, mango, sapota and guava (Subramanian, 1990) and crops such as passion fruit (Anon. 1991) are suitable for inter/mixed cropping in coconut plantations. In Tamil Nadu, the popular intercrops were rice, sugarcane, sorghum, topioca and vegetables (Krishna Marar, 1964). There is also scope for floricultural intercrops in coconut plantations (Sharma and Gangawar, 1990; Sudha and Subramanyan, 1992). Problems and prospects associated with such an intensive systems have been enumerated and discussed by Krishna Marar (1964); Nelliat *et al.,* (1974); Nair and Bavappa (1975); and Nair and Thomas Varghese, (1976).

Cereals

One of the earliest reports on raising rice as an intercrop in coconut gardens from Nileshwar and Kasaragod was not encouraging (Anon. 1934) and the yield was very low, 160 kg/ha while upland variety was profitable at Pilicode (Anon. 1942). But, when summer showers were not adequate the yield of upland varieties *viz.,* PTB-29 and PTB-30 were low (Anon. 1960). The profitability of growing finger millet as an intercrop was brought out as early as 1931-32 (Anon. 1932). Intercropping trial with various millets *viz.,* thenai, finger millet, samai, jowar, kudiravalli, panivaragu, bajra and varagu showed that these millets gave equal or better yields under coconut shade compared to the yield in open (Anon. 1941, 42 & 43). However, in Thanjavur district, Tamil Nadu which lies on the East Coast, the performance of two finger millet varieties EC-4847 and EC-4849 was very poor (Anon. 1978b). Nambiar (1978) reviewed the work done on coconut based cropping systems and indicated *Panicum scrobiculatum* L. (varagu) performed better than upland rice and other millets. In semi arid Maidan tract of Karnataka, growing finger millet as an intercrop has increased the coconut yield by 19.3% compared to maize and wheat (Shanthamalliah *et al.,* 1982a).

Pulses

Suitability of growing pulse crops as green manure *viz.,* horsegram, redgram, soybean and black gram at

Kasaragod and black gram, dew gram, red gram, pillipesara, horse gram and cowpea at Pilicode were studied and found that redgram to be the better green manure at Kasaragod (Anon. 1934). The yield of redgram was good in the first year and poor in the next year at Pilicode (Anon. 1942). The experiments conducted during the seventies at Kasaragod showed that the yield of horsegram was higher (355 kg/ha) as an intercrop than blackgram (72 kg/ha) which was very poor (Anon. 1975). At Veppankulam in Thanjavur distrtict of Tamil Nadu, the performance of cowpea var C-152 was good compared to other pulses like cowpea var. PLS-370, redgram, blackgram, greengram and soybean (Anon. 1978a). Shanthamallaiah *et al.*, (1982a) reported that in the semi arid Maidan regions of Karnataka all the four pulses tried *viz.*, cowpea, bengalgram, soybean and groundnut performed better and increased the yield of coconut as well as income. However, the sowing time of pulses seems to have greater role for the failure or success of pulses as intercrops (Anon. 1976*a* and 1977). Soyabean varieties PK-472, MACS-13 and MACS-48 also were highly promising as intercrops in coconut gardens during post rainy season under irrigated conditions (Hegde and Yusuf, 1993).

Oilseed crops

The suitability of growing groundnut as intercrop at Kasaragod was established even during 1931-32 (Anon. 1932). Sahasranaman (1964) brought out the profitability of growing groundnut and its effect on suppressing the weed growth and maintaining soil tilth. Similarly Kannan and Nambiar (1976) and Leela and Bhaskaran (1978) showed that groundnut as an intercrop increased the coconut yield and income besides creating additional employment opportunities. Rajan *et al.*, (1988) reported the B:C ratio of 2.0 and 2.22 when groundnut was intercropped in coconut under rainfed and irrigation situations, respectively. The unsuitability of sunflower as an intercrop at Kasargod was also brought out (Anon. 1974).

Fruit crops

Banana is one of the common intercrops in coconut gardens. In Andhra Pradesh where irrigation facilities are available banana as an intercrop gave an yield of 1200 and 1300 bunches/ha with an average net profit of Rs. 500-700 (Anon. 1964). Kuttappan (1971) made a survey in the small holdings and found that 1000 banana plants could be raised in one hectare of coconut garden if coconut population is 125/ha. Krishnaji *et al.*, (1976) showed that banana as an intercrop gave a net profit of Rs. 2905/ha and provided an additional employment of 132 mandays and 6 woman days/ha/year. Similarly, Anil Kumar and Pillai (1989) also obtained highest net returns when interspaces in the coconut were used for raising banana. The nut yield increased by 145.4 percent and 400 per cent over pre-intercropping period with banana during the first and second year of post-intercropping, respectively (Reddy *et al.*, 1980). In Kerala, Palayamkodan, Robusta, BB Batheesa, Karpooravally and Poovan were identified as suitable varieties for intercropping (Nambiar *et al.*, 1988; Suma *et al.*, 1989) and gave mean yield ranging from 8 to 12.8 kg/bunch. The unsuitability of banana as a rainfed intercrop in coconut in laterite gravelly soil was brought out at Pilicode (Anon. 1979b).

Other fruits like papaya (Nair, 1993), pineapple (Das, 1990); sapota, guava, Assam lemon and mango (Anon. 1998) and passion fruit (Anon. 1991) were found to be profitable intercrops in coconut plantations.

Tuber crops and root crops

In a 50 year old coconut garden intercropping with tapioca, colocassia, and other cereal and pulse crops conducted during 1967-75 showed that the yield of coconut was increased by 30.3 per cent with colocassia. However, the tapioca gave highest net return (Kannan and Nambiar, 1976). The compatibility of tubers like *Dioscorea alata,* (greater yam), *Dioscrorea esculenta* (lesser yam), *Coleus parviflorus* (Chinese potato) and *Xanthosoma sagitifolium* (colocasia) as intercrops in coconut was brought out by Varghese *et al.*, (1978). In another experiment with six tubers carried out in a laterite gravelly soil at Pilicode, maximum profit was obtained from elephant foot yam (Anon, 1979b).

Greater yam when grown as intercrop in coconut garden recorded maximum yield with full dose of fertilizer, while lesser yam produced maximum yield with only 75 per cent of recommended fertilizer (Pushpakumari and Sasidhar, 1992).

Many workers have reported the higher yields of turmeric and ginger when grown as intercrops compared to open space (Ramanathan *et al.*, 1982; Satheesan, 1984; Satheesan and Ramadasan, 1988; Latha *et al.*, 1995; Jayachandran *et al.*, 1991). The coconut yield also increased from 120 nuts to 180 nuts/palm/year, when intercropped with turmeric (Nagarajan, 1988).

Menon and Nair (1978) revealed that tuber crops like tapioca, elephant foot yam and yam can be profitability grown as intercrops in the root (wilt) disease affected areas. They also revealed that coconut and tapioca H-165 gave the highest net return of Rs. 7415 followed by coconut and elephant foot yam (Rs. 5890) and coconut and yam (Rs. 5650), while coconut alone gave only Rs. 2520/ha. Das (1991b) while making the economic analysis of coconut + cassava intercropping reported that there was 190 per cent increase in net return by intercropping over coconut monocrop.

Medicinal and aromatic crops

In recent years, due to increased health consciousness of the people and carcinogenic hazards of synthetic drugs, there has been a rapid extension of the allopathic system of medical treatment in India. Similarly, there is a growing demand for aromatic crops from the Indian perfumery industries. However, as their availability from natural resources is limited, there is a scope to incorporate these crops in coconut based cropping systems. Of the different medicinal and aromatic crops, kacholam (*Kaempferia galanga* L.), arrowroot (*Maranta arundinacea* L.), greater galangal (*Alpinia galanga*), penikurkka (*Coleus aromaticus*), iruveli (*Coleus vetiveroides*), periwinkle (*Catharanthus roseus*), Ocimum (*Ocimum sanctum*), channakkuva (*Costus speciosus*), koduveli (*Plumbago rosea*), sarpaganda (*Rauvolfia serpentina*), mango ginger (*Curcum amada*), *Andrographis peniculata, Sida retusa,* and patchouli (*Pogostemon cablin*) are well suited to grow under shaded conditions (Sen, 1956; Pandarakalam, 1956; Rajagopalan *et al.*, 1992; Nair *et al.*, 1991; Viswanathan *et al.*, 1992; Viswanathan *et al.*, 1993; Lalitha Bai *et al.*, 1996; Maheshwarappa, 1997).

In kacholam and arrowroot, number of tillers, chlorophyll "a" and "b", carotenoid content and fresh rhizome yield were higher (21.4 per cent in kacholam and 34.1 per cent in arrowroot) under intercrop in coconut garden compared to open space (Maheswarappa, 1997).

Vegetable crops

Only limited work has been done on intercropping vegetables in coconut. Vegetable cultivation is possible with high amount of labour input and family involvement. Sahasranaman (1961) showed the profitability of growing chilli as an intercrop. Shanthamallaiah *et al.*, (1982a) indicated that french bean recorded the highest increase (26.78%) of coconut yield followed by chilli (18.75%) and potato (14.51%). Raising of chillies, potato, french beans (Rethinam, 1989), dolicos bean, tomato, knolkhol, capsicum and brinjal (Patil *et al.*, 1992) was found to be profitable as intercrops in coconut gardens. Recent experiments at Kasaragod have indicated vegetables like snake gourd, bottle gourd, amaranthus, coccinia, brinjal and bitter gourd as compatible crops with coconut. Intercropping with vegetables helped to generate additional employment to the tune of 215 to 365 man days/ha/year. Among the different sequences tried snake gourd - ridge gourd - amaranthus was found to be the most remunerative (Rs 22217/ha/year) followed by amaranthus - bottle gourd - brinjal (Rs 20920/ha/year) Hegde *et al.*, (1993). In the Konkan region of Maharastra, it was found that ridge gourd is the best vegetable followed by cucumber to grow as intercrop in coconut plantation under rainfed conditions (Nagwekar *et al.*, 1997).

Rotation of intercrops in coconut

The advantage of growing crops in sequence is a well known fact and being adopted all over India. Similarly in coconut based cropping systems also crop rotations have yielded beneficial effects by way of increasing the income as well as enhancing soil fertility status. Varghese *et al.*, (1978) reported that elephant foot yam or tapioca grown continuously every year lowered the coconut yields, while a rotation of elephant foot yam alternated with tapioca yielded more. Tapioca - elephant foot yam, tapioca - ginger, elephant foot yam - ginger appears to be good rotations under Kerala conditions. Elephant foot yam yield increased from 6.4 t/ha (continuous crop) to 11.8 t/ha in rotation with topioca. Shanthamalliah *et al.*, (1982a) tried six double cropping practices with coconut and found that potato - wheat gave the maximum net income of Rs. 12801/ha followed by french beans - wheat (Rs. 12760/ha) ragi - wheat (Rs. 9208/ha) chillies - wheat (Rs. 9100/ha), maize - wheat (Rs. 8864/ha) and cowpea - wheat (Rs. 8646/ha), while coconut alone gave only Rs. 3373/ha.

Coconut based mixed cropping

The practice of growing perennials in the interspaces of other perennials otherwise known as mixed cropping was also in vogue for a long time particularly in homestead gardens of Kerala for increasing the productivity over an unit area. As components of mixed cropping with coconut, cocoa, pepper, cinnamon, clove, nutmug, coffee, betelvine, vanila and mulberry were tried in many locations. Nair *et al.*, (1975) reported the profitability of growing cocoa as single and double hedge planting over pure stand. The increase in coconut productivity by following mixed cropping of cocoa has been reported (Nair, 1977; Abdul Khader *et al.*, 1984). The average increase in the yield of coconut over pre-treatment yield was 68 per cent and 115.9 per cent respectively in single hedge and double hedge cocoa (Nair *et al.*, 1975). Mixed cropping with cocoa had a buffering effect against drastic fluctuations in micro-climate (Nair and Balakrishnan, 1977; Varghese *et al.*, 1978). Higher net return was obtained by adopting mixed cropping of coconut with pepper or coffee or cocoa compared to monocropping of coconut (Das, 1984; Mathes, 1986).

Nelliat *et al.*, (1979) reported the beneficial effect of growing cocoa, pepper, clove, nutmeg and cinnamon. The yield of cinnamon was 30-35 g quills and 15-20 g chips in 1974 and increased to 82 g quills and 30 g chips in 1978 (Anon. 1975 and 1979a). Panniyur - 1 pepper planted in 1971-72 as mixed crop in coconut yielded 2 kg dried berries/vine and the maximum yield was 5 kg/vine (Anon. 1977). Potty *et al.*, (1979) evaluated the performance of six varieties of pepper in the multistoreyed cropping system and suggested that Karimunda and Panniyur-I perform better under mixed cropping situations.

Shanthamallaiah *et al.*, (1982b) reported that mulberry as a mixed crop increased the yield of coconut by 920 nuts/ha and net income by Rs. 7379/ha and doubled the employment potential. Reddy *et al.*, (1998) reported the successful cultivation of clove as mixed crop in an adult coconut garden aged over 20 years and spaced atleast 7.5 m apart. At Ratnagiri, coconut mixed cropping with spice crops such as cinnamon, clove, nutmeg, black pepper, garcinia and allspice was found to increase the coconut yield considerably compared to pre-treatment yield (Anon. 1998; Patil *et al.*, 1991). The net profit from monocrop of coconut was Rs. 30,475/ha. Coconut mixed cropped with spice crops especially nutmeg and cinnamon gave a net return of Rs. 82,355/ha and Rs. 62,475/ha, respectively. (Anon. 1998). In recent years farmers of Karnataka State are cultivating coffee var. Cauvery successfully in coconut plantations even in non-traditional coffee growing areas.

Coconut based multistoreyed cropping

In the light of the successful growing of a number of annuals and perennials in coconut stand, multi-storeyed cropping system was conceived and put to practice in 1970-71 with the main objective of greater utilization of solar energy and soil resources. The most productive and remunerative combination under the West Coast conditions was found to be coconut, pepper (trained on the coconut trunk), cocoa and pineapple (Nelliat *et al.*, 1974). Between two rows of coconut, 350-600 cocoa seedlings are planted (in one hectare) in the North-South direction in one or two rows, adopting a spacing of 2.7 m along the row. Pepper rooted cuttings (175 numbers) are planted 2 m away from coconut base on the Northern side and the vines are trailed on the ground up to the palm and then wound round the base of the trunk. In the alleys between coconut palms and cocoa rows, 3500 pineapple suckers are planted. These crops develop their canopies at varying heights, simulating the features of a 'multistoreyed' building. Coconut with its canopy at 10-30 m from ground forms the top floor, while black pepper trained on coconut trunk up to 5-6 m height forms the second floor. Cocoa with a canopy height of 2-4 m and pineapple having a low stature of 1 m constitute the first and ground floor crops respectively (Nelliat *et al.*, 1974). In this trial, the mean yield of coconut increased by 33 per cent. The output from the four crops were 17,000 coconuts, 300 kg cocoa (dried beans), 60 kg dry pepper and 4,000 kg of pineapple/ha/year (Nelliat, 1979).

Coconut based high density multi-species cropping system (HDMSCS)

High density multispecies systems for high biomass production and high income generation have been designed and planted in Sri Lanka for lower elevations with 13 crop species such as jack, breadfruit, avacado, mango, coconut, nutmeg, clove, papaya, arecanut, lime, banana, pepper and coffee (robusta) and for high elevations with coffee, pepper, coconut and other crops (Bavappa and Jacob, 1982). Models for homesteads with crops having different root and canopy architecture and ability to stand varying moisture conditions have also been developed (Bavappa and Jacob, 1982). In an experiment carried out at Kasaragod, nearly 17 species at a high density of 14,976 planting points per ha of coconut plantation were studied. The crops included in the model were tapioca, elephant foot yam, colocasia, banana, pineapple, mango, bread fruit, jack fruit, nutmeg, clove, sapota, acid lime, guava, pepper, papaya, San Ramon coffee and subabul. The annual crops, except banana were withdrawn from the system in stages as the perennials grew and utilized more and more space and sunlight. Some perennials also were withdrawn from the system as their performance was not satisfactory. Now, the system is left with clove, nutmeg, bread fruit, jack fruit, banana and pineapple as component crops in coconut. The coconut yield increased by 176 per cent as compared to pre-experimental yield due to the practice of HDMSCS (Anon. 1995).

The cash flow analysis for coconut based HDMSCS under optimum management conditions for the period 1983-84 to 1996-97, involving banana, clove and pineapple indicated that the variable capital requirement for adoption of system ranged between Rs. 8,200/ha during 1984-85 to Rs. 40,570/ha during 1996-97. The gross margin realized ranged between Rs. 1,750/ha during 1983-84 to Rs. 92,230/ha during 1996-97 (Sairam *et al.,* 1999). In Assam, the nut yield during experimental period per palm increased by 109.8 per cent and 83 per cent in HDMSCS models involving coconut+ black pepper + banana + Assam lemon + pineapple + ginger and coconut + betelvine + banana + Assam lemon + turmeric + colocasia, respectively over pre-experimental nut yield (Choudhury and Deka, 1997).

Besides this, many high density crop models as listed below are being evaluated in different coordinating centres in India under All India Co-ordinated research projects on Palms (Anon. 1998).

1. Arsikere (Karnataka)	: Model-1	: Coconut+pepper+sapota+ banana+clove+lime+ pineapple
	Model-II	: Coconut+pepper+nutmeg+ mango+guava+curry leaf + potato
2. Kahikuchi (Assam)	: Model-I	: Coconut+black pepper+ banana+Assam lemon+ pineapple+ginger
	Model-II	: Coconut+betelvine+banana +Assam lemon+colocasia +turmeric
3. Veppankulam: (Tamil Nadu)	Model-I	: Coconut+nutmeg+banana (poovan)+seedless lime+ elephant foot yam+ bittergourd
	Model-II	: Coconut+clove+betelvine +banana+curry leaf+ colocassia
	Model-III	: Coconut+mango+pepper+ banana+seedless lime+ bhendi+sirukizhangu

Of the above models, model-1 at Arsikere (Karnataka) and Kahikuchi (Assam) and models II and III at Veppankulam (Tamil Nadu) were found promising in terms of total harvest and net returns/ha/year (Anon. 1998).

Coconut based mixed farming

As in the case of HDMSCS, experiments on mixed farming have also produced encouraging results. Mixed farming studies were started in 1972 at Kasaragod and Kayangulam in healthy and root (wilt) affected coconut growing areas. Sahasranaman and Pillai (1976) screened the fodder crops suitable for mixed farming and found that Guatemala (*Tripsacum laxum*), hybrid napier (Pusa giant and NB-21), and guinea grass (*Panicum maximum*) gave an yield of 50-60 t of green fodder/ha/ year under coconut shade and legumes, Brazilian lucerne (*Stylosanthes gracillis*) and cowpea (*Vigna unguiculata*) yielded 30 t/ha. With a cutting interval of 30-40 days and a feeding rate of 30-40 kg of green fodder in the ratio of 3:1 grasses and legumes per animal/day, an area of one hectare could support four milch cows. Jacob Mathew and Mohamed Shafee (1979) had indicated the incremental benefit of coconut + dairy over coconut alone as Rs. 22763/year/ha. The total output from 1.04 ha mixed farming model in 1994-95 was 19,125 coconuts, 9275 litres milk, 526 kg poultry (live weight), 50 number quail birds, 3500 hen eggs, 1100 qual eggs and 400 kg fish. Economic analysis revealed that total variable cost for the system was Rs 1,59,989. The gross return from the system was Rs 2,07,168 with net returns of Rs. 66,679/year for the family (Anon. 1996).

An integrated model for farmers with very small (0.2 ha) coconut-based homesteads developed for Southern Kerala using linear programming, comprising 43 enterprises and with a cropping intensity of 161.84 per cent provides a net profit of Rs. 37,426 on investing Rs. 25,000 and has a benefit : cost ratio of 2.5 (John and Nair, 1998), while a coconut based mixed farming involving 14 activities and integrating the crop and livestock systems was found to provide a net return of Rs. 12,628 with a benefit-cost ratio of 1.64 from 0.2 ha model (Salam *et al.*, 1991).

The crop-livestock components selected in the models interact synergistically to increase the productivity and to generate higher net returns. Various coconut based cropping/farming systems have been evaluated on the basis of their economic viability (Das, 1991a). It is concluded that it is more profitable to integrate a number of subsidiary crops and animal components with coconut than to grow it as a monocrop.

Sahasranaman *et al.*, (1976) showed 28 per cent increase in nut yield in the root (wilt) affected area by adopting mixed farming practice over a peirod of five years. They have also indicated that the foliar yellowing of root (wilt) disease affected palms are ameliorated due to mixed cropping. Regeneration of roots in the diseased palms of the mixed farming area with grass and irrigation was also brought out (Anon. 1976b) besides increased income (Anon. 1976a) and additional employment generation from 150 days/ha to 1000 man-days/ha by mixed farming (Sahasranaman *et al.*, 1976). In healthy coconut plantations at Kasaragod, Jacob Mathew and Mohamed Shafee (1979) showed an increased coconut yield, satisfactory milk yield and employment potential for about 800-850 days as against 150 days for pure coconut as indicated by Nelliat and Krishnaji (1976).

Nutrient management in coconut based cropping systems

The importance of intensive cropping lies in the nutrient economy as the extensive cover in the plantation floor increases the plant cycling fraction of nutrients (Khanna and Nair, 1977). The crop combination as in coconut based farming system, therefore serves as a buffer against drastic changes in ecoclimate which will have considerable effect on the various biological processes occuring in the rhizosphere of crops (Nair and Balakrishnan, 1977; Varghese *et al.*, 1978). The direct percolation loss of 113.8 kg K/ha in a pure stand of coconut is reduced to 54.5 kg/ha in the case of crop combinations. The better exploration of the soil volume by roots in crop combination may possibly reduce the loss of nutrients through percolating water (Khanna and Nair, 1977).

The practice of growing large number of crops in the interspaces of coconut would add lot of biomass to the soil and indirect addition of nutrients. This, makes it necessary to rationalise the fertilizers to the crops in the system. Pushpa Kumari and Sasidhar (1992) reported that the fertilizer recommendation can be reduced to half of the recommended dose when amorphophallus was intercropped in coconut garden. The results of HDMSCS model studied under differrent levels of recommended fertilizers for ten years at Kasaragod indicated that there was no marked yield difference of crops in the full and two-third levels of recommended fertilizers. This indicates the scope for scaling down of the recommended fertilizer dose of different crops in the system (Anon. 1995). Annual nutrient budget and balance of N, P, K and Mg was worked out for three consecutive years in HDMSCS experiment indicated that while there has been no build up of N and Mg, the levels of P and K doubled by the third year. In fact there was a depletion of N and Mg (Bavappa *et al.*, 1986). However, there appears to be displacement of Mg from its exchange site due to heavy input of K^+ and NH_4^+ fertilizers resulting in leaching of Mg (Ochs and Ollangnier, 1977).

The microbial biomass, the organic C, total N, P and K were higher in the root region soils of the multistoreyed cropping system than in the coconut monocropping (Bopaiah and Shetty, 1991b).

Similarly in case of coconut-cocoa system, it was observed that N budget decreased from 788 kg/ha in 1985 to 589 kg/ha during 1988 under pure stand of coconut while in single and double hedge system, the N budget declined from 849 and 872 to 698 and 787 kg/ha respectively after a lapse of four years. Almost a similar trend was observed for N-balance also. However, in case of P and K, both budget and balance steadily increased from 1985 to 1988 in all the three systems of culturing. But in case of secondary nutrients like Ca and Mg, budget and balance showed a progressive decline (Biddappa *et al.*, 1988, Unpubl.). Nutrient export and recycling studies in coconut based HDMSCS revealed that the annual nutrient export on kg/ha basis ranged from 93.37 to 149.31, 12.94 to 20.79 and 119.09 to 183.62 for N, P and K respectively under various levels of recommended fertilizers. The extent of annual nutrient recycling on per ha basis in terms of dried leaves, inflorescence waste and husk was estimated to range from 45.99 to 81.88, 5.36 to 10.63 and 79.39 to 127.34 kg for N, P and K respectively (Subramanian *et al.*, 2000). This shows that a substantial saving in terms of fertilizer input can be achieved through efficient recycling of the waste available in the field.

In case of coconut-vegetable system, the nitrogen budget and balance studies showed that the N-removed was highest for cowpea followed by chilli and snake gourd. At the end of third season, the N balance was observed to be highest in the plot cultured with amaranthus, bottle gourd and brinjal (937.3kg/ha) and lowest (785.5 kg/ha) for cowpea, bhendi and chilli cultured plot (Anon. 1990).

Nair and Rao (1977) found that there was intense microbial activity in the rhizosphere of coconut with which cocoa was planted as a mixed crop. The other benefits of intercropping/mixed cropping in coconut are control of weeds, soil conservation and regulated temperature. It was reported that the average soil loss was 0.5 to 7.5 t/ha in coconut based mixed cropping with spices and grasses, which is much less than the normal rate of soil erosion (10-15 t/ha) in the Andaman and Nicobar Islands (Pramanik *et al.*, 1998). The total sugars in the root zone soil of coconut-pepper-elephant grass mixed cropping and total sugars, amino acids and phenols in coconut-pepper-cocoa-pineapple multistoreyed cropping system were significantly higher (Bopaiah *et al.*, 1990).

Studies of soil properties carried out in a mixed farming experiment consisting of cultivation of fodder grasses in the interspaces of coconut, maintaining milch animals, poultry birds and recycling of farm yard manure and poultry manure showed that there was an increase in maximum water holding capacity and porosity and decrease in bulk density. The build up of organic carbon, N, P, K and Fe status was also noticed. However, secondary nutrients like available Ca, Mg, Mn, Cu and Zn status in soil reduced. Leaf nutrient status of coconut palms was better in mixed farming plot resulting in increased nut yield (Maheswarappa *et al.*, 1998). The soil microbial biomass and the concentration of N and available P and K were higher in the rhizosphere of coconut and elephat grass mixed cropping than in coconut monocropping (Bopaiah and Shetty, 1991a).

New research areas

* Studies on requirement of cultural operation such as tillage, irrigation, weeding and plant protection of the entire system as a whole needs to be considered.
* In view of development of large number of varieties and hybrids in crops, there is, need for screening the crops/varieties and select the best suited crops/varieties for getting profitable income.
* In the development of a fertilizer programme for a multispecies system a rational approach will be to develop a single fertilizer schedule for the whole system considering the nutrient input and exhaust ratios. Besides, the enormous addition of organic matter (carbon dynamics) and indirect addition of nutrients to the system also need to be considered.
* Since variety of crops with different crop canopies, rooting pattern, and yielding capacities are tried in the inter/mixed cropping, it is essential to workout the complementary, competitive and supplementary effect of these crops over a period of time.
* Due to involvement of many crops in the system there will be always continuous addition of biomass that is being recycled in the soil system which will have definite bearing on the physico-chemical and the biological properties of soil. This has to be studied for the different systems.
* Inter and mixed cropping will cause marked changes in the microclimate of a coconut plantation. Their effect on the soil moisture relationship, nutrient availability and uptake, and pest and disease incidence need a critical study.
* A co-ordinated collaborative inter disciplinary approach by agronomists, plant breeders, physiologists, soil scientists, pathologists and microbiologists alone will solve the problem. Agronomy in this new Millennium is looking ahead for an integrated approach of all the above scientists particularly for plantation crops based farming system.

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