



Review Article

MULTI STORIED CROPPING SYSTEM IN HORTICULTURE-A SUSTAINABLE LAND USE APPROACH

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Abstract- There are three major components including nutritional security, ecological restoration and economized productivity for sustainable production. Intensification of agricultural land use has led to the development of multi-storied cropping system and crop mixtures. The introduction of multi-storied cropping system ensures the use of best combination of crop-tree intercropping to reduce the impacts of floods, landslides and droughts. Also, it ensures a regular income and employment throughout the year from harvest of different tree crops in different seasons. A multi storey cropping system accommodates crops of different heights, canopy patterns and rooting systems to maximize the sunlight, nutrients and sustainable land use. Land cultivated in this way can maintain an ecological balance and facilitates the judicious and efficient use of all natural resources. In addition to this, multi-storied cropping systems are more amicable for horticultural crops as they include tree species, shrubs, climbers, annuals and shade loving or tolerant species. Such multi-storied cropping systems are predominantly practiced in Coastal regions of India.

Keywords- Multi-storied cropping, Ecological balance, Coastal regions and Canopy patterns

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Introduction

Seventy per cent of the world small farms are in China and India. China and India accounts for 193 (47 %) and 93 million (23 %) small farms out of 404 million small farms in the world. Small farms are more diversified in nature. Out of 92 million farm households falling under marginal farm category having < 1 ha as operational holding size, 70 % of the farmers are having the area of below 0.5 ha. The average size of marginal holdings varies from 0.13 ha in Kerala to 0.61 ha in Punjab with only 8 states having the mean holding size of > 0.50 ha. As per estimates, in India, more than 95 % holdings will be under the category of small and marginal holders by 2050[1]. In future, the availability of land for cultivation will be a major impendent due to rapid urbanization, hydroelectric projects, dams and rivers, highway roads and also there is a degradation of fertile land due to soil erosion (120.72 million ha), soil salinity and water logging (8.4 million ha) [30,18]. Under this situation, multi-storied cropping system will be a viable option to provide food, nutrition and income security to people [5]. The available arable land could be effectively utilized for production of field and horticultural crops to achieve nutritional security for the growing population and sustainable income for the farming community. Increasing food production with limited natural resource is a great challenge to the scientific community.

Diversified cropping system could be one of the solution to realize sustainable productivity and maximum income per unit area of land besides maintaining soil fertility by the recycling of byproducts of crops since land being a renewable resource, must be put to maximum use for increased crop production. These systems are crucial to Western Ghats because of space constraints in most of the farms. A multi-storied approach is often viewed as a sustainable alternative farming system particularly on small and marginal lands and it can provide greater economic return per unit area. Land cultivation through this system can maintain sustainable ecological balance besides efficient use of all natural resources [35]. Agriculture/ Horticulture/ Silvi culture based cropping systems especially Horti-Horti and Horti-Agri based cropping system plays a potential role in realizing more

sustainable productivity and income [Table-1]. The future of Indian agriculture/ horticulture depends on the development of appropriate farming system suitable to poor agrarian families of different agro-ecological zones. Growing of intercrops, mixed crops, multiple crops and multistoried crops in perennial fruits (Mango, Sapota, Banana etc.) and plantation crops (Coconut, Areca nut, Coffee etc.) produces more food products, ensuring sustainable income besides employment generation. According to [36] perennial fruit tree based production system have been found successful under semi-arid and dry land conditions, as it ensure high returns from the underutilized and stressed lands and also improve the soil characteristics. This system is usually practiced in agro-climatic regions of Western Ghats, North-East India and South Asian countries, where tropical and humid climate is predominant.

The Multi-Cropping System

Multi storied cropping system is a perspective modern approach for sustainable productivity in horticulture crops in general and plantation crops especially in Coconut, Areca nut and Coffee in particular. The system is more adaptable in tall growing perennials with compatible semi-perennial and annual crops [42]. The practice of multi storied cropping system is highly successful in plantation crops especially in Coconut, Areca nut, Coffee and Cashew for enhancing sustainable productivity and realizing higher income per unit area. The basic principles of multi-storey cropping system include (i) Opportunities for crop diversification on scientific, ecological & economic principles; (ii) Maximize system productivity; (iii) Utilization of resources with higher efficiency; (iv) Intensive input use and (v) Sustainability of farm resources & environment on long term perspective. This system mainly comprises an over story of trees or shrubs with an understory of economic or forage crops. Tree-to-tree distance would be wide enough to let sufficient light through to understory crops. Therefore, "Forest Farming" is also a form of multistory cropping. Multistoried cropping systems are more amicable for horticultural crops as they include tree species, shrubs, climbers, annuals and

shade loving or tolerant species. Such multistoried cropping systems are very commonly practiced in Coastal areas of India and also elsewhere in the world, mostly comprising of horticultural crops [10].

Table-1 List of fruit crop based system with their intercrops (Horti-Agri System).

Horti-Agri System			
No.	Crop	Main crop with intercrops	References
1.	Aonla	Aonla + Fenugreek + chick pea + mustard + cumin (Rabi season); Moth bean (Kharip season)	[4]
		Aonla + Ber + Karonda + Cluster bean + Brinjal; Aonla + Ber + Karonda + Mothbean + Mustard	[3]
2.	Ber	Ber (Jharber and Bordi) + Mung, Clusterbean, Pearl millet, Mothbean, gram, Vegetable crops	[14]
		Ber (<i>Zizyphus mauritiana</i>) + Green gram	[16]
		Ber (Cv. Gola) + Clusterbean+ Mustard + Indian aloe; Wheat + Groundnut	[38]
		Ber + Wheat; Ber + Chick pea; Ber + Kulthi	[33,32]
3.	Mango	Mango + <i>Phaseolus acutifolius</i> Genotype "Frijol Escumite" + <i>Cajanus cajan</i> (Pigeon Pea) + <i>Phaseolus vulgaris</i> Genotype "Frijol de Vara"	[2]
		Mango + Guava + Cowpea	[30]
		Guava + Ground nut + Black gram	
4.	Mandarin	Mandarin + Ginger	[34]
		Mandarin + Pea	[15]
5.	Lemon	lemon + French bean	[19]
6.	Passion fruit	Passion fruit+Bean (<i>Phaseolus vulgaris</i>)	[24]
7.	Banana	Banana + Sweet potatoes	[7]
8.	Fig	Fig+ Strawberry	[27]

Feasibility of Multi Storied Cropping System in Horticultural Crops

- Horticultural crops especially fruits and plantation crops are perennial in nature and long pre-bearing period (Mango, Coconut, Areca nut, Cashew).
- Crops have wider spacing and are tall growing eg: Coconut (7.5X7.5m, 15-20m ht.), Areca nut (2.7X 2.7m, 15-20m ht.), Oil palm (9X9m, 10-15m ht.).
- Canopy cover (Occupation of space) is very slow, took years together and more than 60-70% inter space is not effectively utilized (Mango, Sapota, Coconut, Areca nut).
- Crop geometry and rooting pattern among perennials, semi-perennials and annual crops could be compatible without any adverse effect on main crops (Areca nut, Cocoa, Banana, Ginger, Turmeric, Pineapple).
- Crops are shade loving and tolerance to dripping of rain drops and high humidity (Banana, Cocoa, Turmeric, Ginger, Pineapple, Pepper).
- Crops are the good source of bio-mass and byproducts which are easily recyclable and decomposable (Cocoa, Coconut, Areca nut, Cashew, Tree spices, Turmeric, Ginger, Mango, Guava).
- Crops having different harvesting time and period which facilitates for sustainable income (Banana, Cocoa, Coconut, Areca nut, Pineapple, Ginger, Turmeric).
- Suitability / tolerance to prevailing micro – climatic condition (Black pepper, Cocoa, Pineapple, Tree spices, Heliconia, Marigold, Jasmine) (Source: [18]).

Structure of the Multi-Layer Cropping System

In Philippines, under the multi-storey cropping system, perennial crops (Coconut, Banana, Coffee, Papaya, Pineapple) and annuals/biennials (Root Crops: Taro, Yam, Sweet Potato etc) are inter planted to maximize productivity and income. This is most applicable where farms are small and the system needs to be intensive. In this particular area, Cavite, coconuts are usually planted first. When they reach a height of 4.5 meters (after 3-4 years), bananas, coffee and/or papaya are planted underneath. Black pepper may also be part of the system. After sufficient space, has developed at ground level in about three to four years, root crops are planted. At full establishment, the system develops different layers [Fig-1]: coconut (tallest) followed by) banana, coffee, papaya (middle), root crops and pineapple (lowest).

Different Multi-Storied Cropping Systems

Coconut Based Cropping System

Studies conducted at ICAR-CPCRI, Kasargod have shown that in the coconut gardens spaced at 7.5 X 7.5 m apart, the space available for each palm is 56.25m², of which the maximum concentration of roots lies in 12.57m², which in turn is only 22.2% of the total area. Thus, it provides about 77.8 % of the land available for growing other crops. The pattern of crop canopy coverage and solar energy utilization of sole coconut plantation indicates that about 45 – 50 % of the sunlight is infiltrated on to ground without interception by the coconut. In order to utilize the natural resources like light, soil and water efficiently for sustainable production, the practice of inter/mixed cropping has to be practiced through scientific management. Growing various suitable crops as intercrops in coconut gardens not only increases the productivity per unit area but also ensures additional income, employment and enhancement of soil properties. Thus, several spice crops, tuber crops, medicinal and aromatic plants, flowers and vegetable crops can be successfully grown as mixed / intercrops in coconut gardens. In the initial 5 years of plantation, suitable inter crops of short and medium duration with crop rotation recommended are banana-turmeric-ginger-pineapple-vegetables-papaya, sorghum-legumes, sunflower, tapioca, elephant foot yam, sweet potato, guava etc., profitably grown with the enhancement of 20 – 30 % coconut productivity [6]. After 20-25 years, more than 40 % of light falls on the ground and also have efficient shade. Therefore, shade loving crops could be grown in the multistoried cropping pattern eg: Coconut + Black pepper + Cocoa + Pineapple/ Turmeric / Ginger [25].

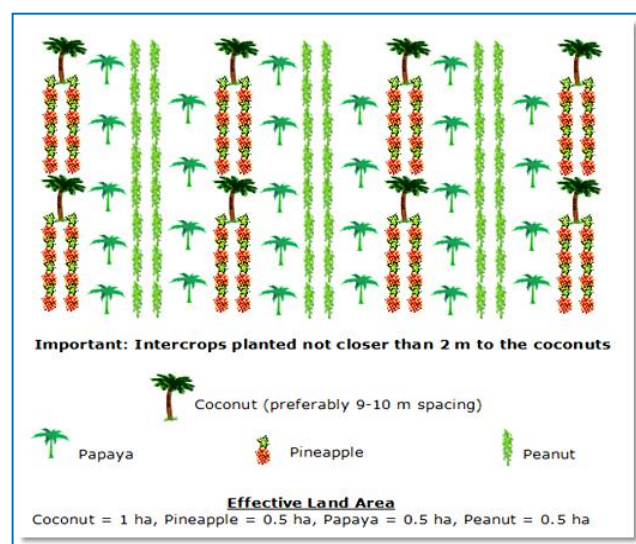


Fig-1 Field arrangement of mixed cropping model for coconut+pineapple+peanut cropping system

[Source: Department of Agriculture Philippine Coconut Authority, Philippines]

The Coconut based cropping system model Coconut + Cocoa + Banana + Moringa + Pineapple with integrated nutrient management at AICRP Aliyarnagar revealed that the cropping system with 75 % NPK + organic recycling with vermicompost recorded highest nut yield of 182 per palm and highest net income (Rs. 3.80 lakhs per ha) and B:C ratio (2.71) compared to monocrop coconut with recommended NPK + FYM which recorded 150 nuts /palm, Rs. 1.31 lakhs / ha and B:C ratio of 2.00 respectively. In this cropping system, the maximum earth worm population in coconut basin (12 no./m²), cocoa basin (12 no./m²), banana basin (9 no./ m²) improved with vermicompost, vermi wash, green manuring, coir-pith compost and mulching with coconut leaves, similar pattern was observed with Bacteria (65.4 10⁴ CFU/g), Fungi (10³ CFU/g), *Actinomycetes* (16.3 x 10⁵ CFU/g) and least in mono crop with RD NPK + FYM (46.6;10.1;14.2/g soil respectively) [23]. The CBCS model – coconut + cocoa + lime + banana + drumstick in AICRP, Arasikere revealed that the number of functional leaves (32), number of inflorescence (13), number of female flowers (241), nut yield (104) and copra yield (16.2 kg) per palm increased compared to mono-crop for the same traits

(30,12,230,97 and 14.6 respectively). Similarly, net income obtained was Rs. 2,94,810 per hectare compared to mono crop (Rs. 68,200/ha) [37]. Studies at AICRP Ambajipeth in CBCS model cocoa + banana + pineapple + tomato + heliconia revealed that the system provided with 75 % recommended NPK + organic recycling with vermicompost recorded maximum nut yield per palm (124.8) compared to mono-crop with recommended NPK + FYM (108 nuts per palm) [41]. The cropping system comprising of coconut + black pepper + nutmeg + cinnamon + banana + pineapple provided with 50% recommended NPK + organic recycling with vermicompost + bio fertilizer and green manuring reported significantly higher yield of nuts per palm (126), Rs. 6.29 lakhs/ha compared to mono-crop of coconut (102 nuts/palm) and Rs. 1.57 lakhs net returns/ha. The most popular and compatible multi storied cropping system in coconut under coastal region in an area of 1 ha 150 coconut (7.5 X 7.5 m) + black pepper (1.25 m away from coconut base -150 vines) + cocoa (2.5 m between 2 rows of coconut - 525 plants) + pineapple (1-2 m in the rows, two rows of pineapple-4900 plants). This model recorded higher yield of coconut (20%) and net returns compared to mono cropping of coconut, besides enhancing soil fertility due to recycling of byproducts [20].

Areca nut Based Cropping System

Studies under coastal Karnataka conditions (Uttara Kannada) on intercropping in areca nut plantation comprising of seven crops namely - *Amorphophallus*, Chinese potato (*Coleus rotundifolius*), colocasia (*Colocasia esculenta*), ginger (*Zingiber officinale*), sweet potato (*Ipomoea batatas*), tapioca (*Manihot esculenta*) and turmeric (*Curcuma longa*) revealed that all the intercropping systems recorded higher mean yields of arecanut than the sole cropping of arecanut. The highest LER of 1.76 was recorded in arecanut+ginger with the highest benefit: cost ratio (3.3:1) closely followed by arecanut+colocasia (3.15:1), while the lowest LER value (1.13) was recorded in arecanut+tapioca. Among the intercrops, the highest contribution to LER was by ginger (0.52), closely followed by Chinese potato (0.51), *Amorphophallus* (0.50) and colocasia (0.48). The lowest contribution to LER was by tapioca (0.09). All the intercropping systems were superior to the control, with an increased net profit over the control from 9.3% in areca nut+tapioca to 61.2% in arecanut+ginger [17]. Similarly, complementary benefits were observed at Sirsi in Karnataka when crops such as pepper, banana and cardamom were mixed in arecanut plantation. Mixed cropping enhanced yield of areca nut in arecanut+cardamom+pepper and arecanut+cardamom+ banana+pepper cropping models (3.12 and 3.05 kg/palm, respectively) when compared to mono-cropping of areca nut (2.95 kg). The yield of pepper was the highest under arecanut+pepper and arecanut+cardamom+pepper (25.47 and 22.22 q/ha, respectively). All the mixed cropping systems were found economically better with an elevated net profit per hectare ranging from Rs 169539/- (arecanut+pepper) to Rs 352858/- (arecanut+cardamom+pepper) respectively. This recorded 15.94 and 141.30% more profits than the sole crop [40].

Black Pepper Based cropping System

Intercropping of pepper gardens with ginger, turmeric, colocasia and elephant foot yam is advantageous. Banana as an intercrop in yielding gardens reduces pepper yield. Therefore, this is not recommended beyond three to four years after planting of pepper vines. However, in the early years, banana provides shade to the young plants and protects them from drying up during summer months [22]. It is also intercropped with arecanut, coffee and coconut [21]. In multiple cropping based system the maximum advantage was observed with combination of coconut+black pepper+ pineapple+cocoa [11]. The incidences of *Fusarium* disease in Brazil was reduced in mixed cropping system of rubber +black pepper+pineapple+clove [12].

Coffee Based Cropping System

In the present scenario of global production and declining price in the international market, diversification of coffee with compatible crops like, pepper, orange, banana has been found to be practiced on a large scale, in the high ranges of Western Ghats. Cultivation of these associate crops is sure to improve the cash inflow of the coffee growers, thereby overcoming the total dependence on monoculture of coffee. In the erratic rainfall years (drought) when coffee yields are

not economical, the subsidiary crops will come to the rescue of farmers, which could be clearly illustrated, from 1983 crop season [28]. Sustainable cropping systems in coffee plantations should involve successful management of natural resources like soil moisture and solar radiation to satisfy changing needs of increasing number of small and marginal farmers (below 2.0 ha) who constitute majority. It is also quite imperative to maintain or enhance the very basic quality of environment and conserve natural resources in the high ranges of coffee growing tracts of Western Ghats in South India. Productivity of coffee plantations should be increased by intensive cultivation of coffee and resorting to diversification with suitable mix crops to improve and sustain high income [39].

Cashew based cropping system

In the initial years, the great scope for inter cropping in cashew as the crops reduces the weed growth and helps in maintaining fertility of plantation. Annual crops such as sweet potato, sesame, peanut, maize, pigeon pea etc., in coastal areas and tapioca, elephant foot yam, turmeric, black pepper/ vanilla and tree crops like jackfruit, mango and fuel wood trees are grown in association with cashew in Karnataka [8,31].

Cropping System Performance Evaluation Tools

Sustainability of any cropping system, including multistory cropping system, lies in the fact that how much diversified the agro-eco production system is and the positive interaction among the diverse components of the system.

Land Equivalent Ratio

Land Equivalent Ratio (LER) is an important tool for the evaluation of intercropping systems. The LER is calculated using the formula $LER = \sum (Y_p/Y_m)$, where Y_p is the yield of each crop in the polyculture, and Y_m is the yield of each crop in the sole crop or monoculture. A LER value of 1.0 indicating no difference in yield between the intercrop and the cultivation of monocultures. Any value greater than 1.0 indicates a yield advantage for intercrop. A total LER of higher than 1.0 indicates the presence of positive interaction among the crop components of the mixture, and also means that any negative interspecific interaction that exists in the mixture is not as intensive as the intraspecific interaction that exists in the monocultures [9, 1, 23].

Relative Yield Advantage

The most important index of biological advantage is the relative yield total (RYT) that can be used to quantify the yield advantages in a replacement series. The equation for RYT, when two species are intercropped: $RYT = X_{mix}/X_{sole} + Y_{mix}/Y_{sole}$, where X_{mix} and Y_{mix} are yields of species X and Y in mixture, and X_{sole} and Y_{sole} are yields of species X and Y as sole crops. Values of $RYT > 1$ indicate that the species make different demands on resources or avoid competition in some way, while values of $RYT < 1$ imply mutual antagonism. RYT values of 1 indicate that the components fully share the same limiting resource, i.e. compete fully and show no antagonism. [26].

Summary and conclusion

Multi-tier cropping system involved combination of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity. Horticulture crops particularly fruit and plantation crops have self-sustainable system where solar energy can be harvested at different heights, soil resources are used efficiently and can increase cropping intensities. The system consists of three main components viz. main crops, filler crop and intercrops which occupy three different tiers in space of the production system. To ensure sustainable productivity and high returns from underutilized and stressed lands and to improve the soil characteristics multi-storey cropping system have been found successful in tropical rain forest, semi-arid and dry land conditions. Multi storied cropping system in horticulture is found to be a perspective approach for sustainable productivity in fruit crops (Mango, Ber, Amla, Pomegranate) and Plantation crops (Coconut, Areca nut, Coffee, Cashew) by which natural resources are utilized efficiently to enhance productivity of main crops (15-20%) and high revenue realization per unit area (50-90%)

besides maintaining soil health and balancing environment. This modern approach is boon to small and marginal farmers who are major stakeholders in Indian Agriculture/ Horticulture system in present and future days.

Abbreviations: ICAR-Indian Council of Agricultural Research; CPCRI-Central Plantation Crops Research Institute; CBCS- Coconut based cropping systems; FYM-Farm yard manure; NPK-Nitrogen Phosphorus Potassium; LER-Land Equivalent Ratio; RYT-Relative yield total.

Conflict of Interest: None declared

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