

Diversified multitier cropping systems

for west coast of India

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Exponential increase in human population exerts pressure on the fixed land area and demand for agricultural innovations to enhance food production to feed them with balanced diets. Multitier cropping system is a land saving technique that offer solutions to the challenges of food production by growing more crops in the same piece of land. Most fruit and vegetable crops fit suitably in several multitier cropping systems hence augment nutritional security. To assist the sustainable management of different crops on several levels, the multitier cropping system permits modification of plant species, composition, structure, and canopy cover to create or maintain a desired plant community. The success of a multitier cropping system depends on the choice of crops, soil, and availability of critical inputs such as light, nutrients, and space. It improves species diversity, helps in soil building, preserving and improving ecological conditions essential to achieve sustainability. It increases species variety, aids in soil formation, and preserves and enhances ecological conditions, all of which are necessary for long-term sustainability. It also improves soil nutrient cycling and reduces insect multiplication. Multitier cropping with location-specific methods provides meaningful employment and is extremely profitable and sustainable in all ecosystems. In this case, the large interspace between plantation crops may be effectively used to produce a range of crops, sustaining farmer revenue while reducing the risk of crop failure and market volatility.

Keywords: Homestead farming system, Multitier cropping system

SUSTAINABLE agriculture is to conserve and maintain the natural resources and ecosystem protection. The agricultural system is a set of agro-economic activities that are connected and interact with each other in a given agro eco-system. To assist the sustainable management of different crops on several levels, the multitier cropping system permits modification of plant species, composition, structure, and canopy cover to create or maintain a desired plant community. The success of a multitier cropping system depends on the choice of crops, soil, and availability of critical inputs such as light, nutrients, and space. It improves species diversity, helps in soil building, preserving and improving ecological conditions essential to achieve sustainability. It

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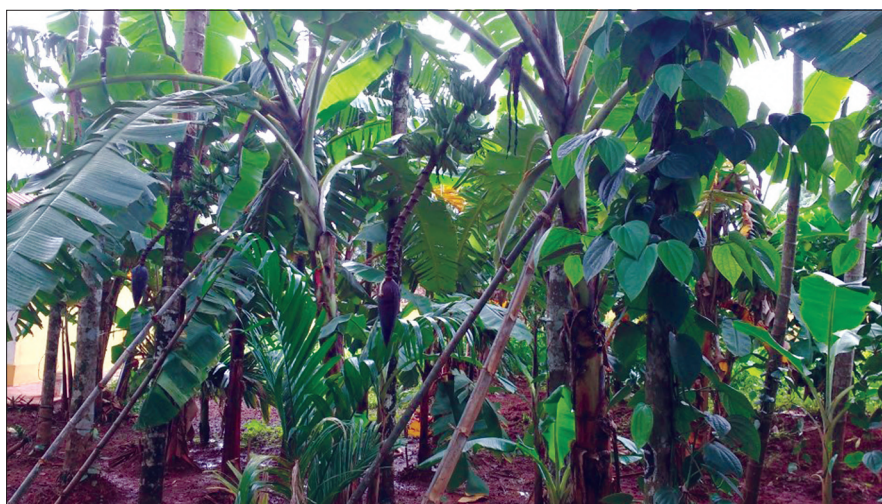


Fig. 1. Areca + pepper + banana intercropping system at Goa.

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Multitier cropping systems enhance resource use efficiency by harnessing the light, water, and nutrients per unit area. The system also enhances employment generation due to year-round labor requirements, fewer weeds due to intensive cropping. The system also enhances the ecosystem services and generates additional revenue and ensures income during variable climate and price fluctuations. Component crops or crop cultivars for multitier cropping systems need to be chosen carefully to suit the available light, water, and nutrient status of the soil, agro-climatic suitability, and consumer preference and marketability. Labor availability vis-à-vis requirements, compatibility to other enterprises if grown with crop-livestock mix systems, food and nutritional requirement of grower and his/her family need consideration.

The tree and understory crops grown at multitier systems compete for light, water, nutrients, and space. Low interception of light is a major reason for the low productivity of banana in shaded perennial cropping systems. Canopy of an adult arecanut or coconut garden intercepts one-third to half of the incident light depending on the age, spacing. About 3/4th of the root system of the coconut palm is occupied in 2 m lateral distance and within 30 -120 cm depth of soil. Research conducted across multiple locations identifies suitable intercrop models and the economics of the systems. Although the yield of intercrops is low and even half compared to the crop grown as sole crop, farmers continue to choose intercrop due to the attractive net returns. Banana is one such intercrop whose yields are low in multi-tier cropping systems and preferred as mid-tier intercrop in coconut, arecanut based cropping systems.



Fig. 2. Multi-tier cropping system (coconut + pineapple + passion fruit) at Goa.

Harvest of palms is difficult due to obstruction of vines while climbing whenever the pepper vines are trailed on the trunks of coconut/arecanut palms. A telescopic ladder is used in such cases to harvest coconut/arecanut palms as well as with minimal damage to pepper vines. Banana cultivars Saldatti, Amti (Mysore/Poovan), Grand Nain are found suitable for coconut/arecanut based multi-tier cropping systems. Pineapple cultivars Kew, Giant Kew are suitable for cultivation as intercrops (Fig. 2).

Key design consideration for multitier cropping system

- Select plants that provide multiple benefits.
- Use plants that provide short and long-term products.
- Avoid plants that compete for same resources.
- Utilize the light in different canopy layers
- Utilize the water and nutrients by efficient and well spaced root systems

Multi-Story Cropping can include a wide variety and types of plants and products

- Medicinals
- Fruits and vegetables
- Plantation and spice crops
- Food
- Ornamentals

- Wildlife habitat
- Fuelwood
- Fodder
- Green leaf manures

The common crops that can be included in the multitier cropping system are;

Plantation crops: Coconut, arecanut, Cashewnut, Oil palm, Cocoa.

Fruits: Mango, Jack fruit, Banana, papaya, Pineapple, Kokum (in Konkan coast), Sapota, Annona, minor fruits.

Spices: Black pepper, Turmeric, Ginger, Cinnamon, Nutmeg, Hog plum, Tamarind.

Medicinal and aromatic plants: Tulsi, lemongrass, Coleus, Aloe vera, Asparagus, Ashoka, Thippali.

Flowers: Hibiscus, Jasmine, Nerium, Ixora, Heliconia, Crossandra, Marigold, Golden champa.

Purpose of multi-tier cropping system

- To produce wood or tree products in addition to agronomic crops or forage;
- To improve crop or forage quality and quantity by enhancing microclimatic conditions;
- To improve utilization and recycling of soil nutrients for crop or forage use;
- To reduce excess subsurface water or control water table depths;

- To provide favorable habitat for species beneficial to crops or forage.

Homestead-based farming system

The Homestead-farming system is an age-old production system. The traditional homestead-farming system in the coastal ecosystem with its highly diverse crop and animal components has been a low-input sustainable system evolved with nature, socio-economic, ecological and cultural aspects of the people. Homestead farming may be defined as an operational unit, which is adjacent or surrounds the farmer's home with a wide array of crops/trees with or without livestock and other subsidiary income-generating activities for subsistence and marketable surpluses. The major constraints in homestead farming are its complex entity, which varies according to the taste of the farmers. It is a form of low-input management subsistence model and the situations within a small area differ considerably. Homesteads are thus a unit of polyculture of perennials, annuals, and livestock for the nearly full exploitation of solar energy. It fulfills the strategies of agroforestry and is a rich source of biodiversity. Scrutiny of features of homestead farming system of Kerala reveals that the system has several attributes of globally important agricultural heritage system. Homestead systems increase the productivity of the system and net returns by 23% if properly planned and laid out.

Coconut based systems

Coconut palms are planted at 7.5 m × 7.5 m or wider spacing. Coconut palms being monocot plants with branchless stems provide filtered light through the canopy, and sufficient space, and resources for intercrops. Multitier cropping systems provide scope to grow more than three crops that grow to different heights to harness the light available at different levels. The upper storey usually involves coconut palms where black pepper vines are trained on the stems. The second level storey is suitable for growing one of the tree spices such as kokum, cinnamon, nutmeg, clove. The middle tier is



Fig. 3. Traditional farming system (Kulagar) of Goa.

usually grown with any one of these fruit crops banana, lemon, papaya, guava, soursop. The ground storey is suitable for any of the following crops, viz. pineapple, turmeric, elephant foot yam, mint, and African marigold. The Lakhbag (one lakh net returns per acre) concept developed at BSKKV Dapoli at Coastal Maharashtra allows earning high income from the unit area by growing multiple crops in the interspaces of coconut (Table 1). High-density multistoried system in the coconut plantation with nutmeg, cinnamon, banana, black pepper, and pineapple contributed very high returns.

Coconut palms based on their age group (<7 years), (8-25 years) (>26 years) could be considered for intercrop options. Juvenile gardens (<7 years) with lot of light and space available for any kind of intercrop. Profitable annual crops are grown in interspaces to augment the income in the pre-bearing period. Mid-age palms provide scope for multitier systems whereas gardens above 26

years of age are reaching the replanting phase if productivity declines hence intercrops could be chosen in a way that they can be replanted. Shade affects the growth rate and productivity hence component intercrops are chosen judiciously. Labor requirements of intercrops and main crop are worked out and chosen in such a way that employment generation and available manpower in the farm is engaged throughout the year. Coconut based cropping systems increase productivity by 6,000-8,000 coconut equivalent yields and high net returns (₹ 0.39 - ₹ 4.0 Lakhs) per hectare.

Arecanut based systems

Arecanut palms are planted at 2.7 m × 2.7 m or wider spacing. Areca palms with branchless stems provide scope for the cultivation of intercrops. Multitier cropping systems involve arecanut palms where black pepper/betel vine plants are trained on the stems. The middle tier is usually grown with banana and lemon (Fig. 1). The ground storey is suitable for



Fig. 4. Medicinal crops growing under coconut crop.

pineapple, medicinal plants. Areca-based cropping systems require recycling organic matter to reach the target yields. Kulagar systems are common in the Konkan region (Goa/Maharashtra) where arecanut based multitier cropping systems are practiced in irrigated midland systems. Kulagar is a system of land development and management that adopts the principle of gainful coexistence of the owner's and the labors depicting characteristic traditional Goan village culture. In the past, certain people acquired virgin land on the slopes of hillocks having the natural source of water and constructed houses. They terraced the land around the houses, planned the irrigation system, and planted trees. The major plantation in Kulagar is betel nut and banana. But every betel nut tree is holding a mounting creeper of either pepper or betel leaf. Besides, a variety of other fruit-bearing plants like coconut, mango, jack-fruit, Torand, Bimbel, Karmal, Aambade, and many more; at the flower side, Sonchamfa, Surangi, variety of hibiscus, Aaboli, Shanker, Nantan, etc are also cultivated. Vegetables like Suran, Aalum, Terem, Mashing etc., coffee, and medicinal plants like Brahmi, Aagado; all such plants traditionally cultivated together. The upper portion of the arecanut based system (Kulagar) (Fig. 3) wherein regular watering is not required. This part is full of cashew, bamboo, pineapple, grafted mango varieties, tamarind, etc. The crops of such items changed the entire agricultural

scenario of Goa. Most of them are utilizing the farmyard manure for maintaining crop productivity and are also managing the soil flora and fauna. Areca based systems accomadating suitable intercrops at appropriate density saves land area when grown as monocrops and are highly productive and remureative (130 per cent higher net returns).

Cashew based systems

Cashew (*Anacardium occidentale* L.) is one of the largest plantation crops in west coast of India. They are grown on hilly sides, mixed with other vegetation or scattered on open pastures. Since cashew is grown on hill slopes and most of the plantations are rainfed, intercrops can be grown only in rainy season. It is very common to grow leguminous intercrops like cowpea, green gram, black gram, pigeon pea and groundnut in rotation with the vegetables like okra, amaranthus, chillies, cucurbits, etc., to get income during the juvenile period of cashew plantation. Ragi, tapioca, and local varieties of pineapple are also be

grown successfully as intercrops in cashew orchards. At later stages of crop growth (5th year onwards), turmeric can be introduced as an intercrop to boost the system's productivity and profitability. As a border crop, Gliricidia can be introduced to supply nutrients to the cashew crop. Intercropping cashew gardens with pineapple, black pepper, and vegetables increase the system productivity by 1.5 to two fold and add ₹ 20,000 - ₹ 40,000 additional net returns.

Medicinal crops as a component crop in the multitier cropping system

Medicinal plant as understorey crop/as creeper can be included in the multitier cropping system in arecanut, coconut, and cashew system (Fig. 4). As their crop nutrient requirement is vey less, they are very much suited as intercrop. Medicinal plants suited for cultivation under multitier system are given in Table 2.

SWOT analysis of multitier cropping system

Strengths

- Land, labor, and resource-saving
- Ensure additional income
- Biodiversity conservation
- Enhancement of soil fertility

Weakness

- Overcrowding leading to competition for light, water and nutrients
- High Labour requirements
- Difficult to apply mechanization and crop management practices

Opportunities

- Increased ecosystem services
- Year round income and employment

Suitable multitier cropping systems with a high benefit-cost ratio

Location	Crop combination	Benefit-cost ratio	Net returns (₹ Lakhs/ha)	University/ICAR
Goa	Coconut-Passion fruit-pineapple	2.16	1.42	ICAR-CCARI Old Goa
Vellayani Kerala	Coconut-cassva- elephant foot yam- ginger-vegetable cowpea	1.74	0.69	Kerala Agricultural University
Arsikere Karnataka	Coconut-okra Coconut-tomato	2.0	4.03	University of Horticultural Sciences, Karantaka

Table 2. Botanical classification of common medicinal plants found in multi-tier cropping system of coastal India based on its growth habit

Growth habit	Common name	Scientific name
Herbs	Aloe vera	<i>Aloe barbadensis</i>
	Centella	<i>Centella asiatica</i>
	Citronella	<i>Cymbopogon nardus</i>
	Coleus	<i>Coleus aromaticus</i>
	Ginger	<i>Zingiber officinale</i>
	Insulin Plant	<i>Costus igneus</i>
	Kalanchoe	<i>Bryophyllum pinnatum</i>
	Lemon grass	<i>Cymbopogon citratus</i>
	Long pepper	<i>Piper longum</i>
	Turmeric	<i>Curcuma longa</i>
	Vetiver	<i>Vetiveria zizanioides</i>
Shrubs	Adulsa	<i>Adhatoda vasica</i>
	Calotropis	<i>Calotropis gigantea</i>
	Henna	<i>Lawsonia inermis</i>
	Holy basil	<i>Ocimum sanctum</i>
	Serpent wood	<i>Rauvolfia serpentina</i>
Climbers	Asparagus	<i>Asparagus racemosus</i>
	Gymnema	<i>Gymnema sylvestre</i>
	Tinospora	<i>Tinospora cordifolia</i>
	Betel vine	<i>Piper betle</i>

Threats

- Low productivity
- The emergence of pests and diseases

Guidelines for enhancing productivity/ profitability of main and component crops

1. Provide optimum or wide spacing for the main crop to allow space

2. Ensure water conservation structures and land management strategies to harvest rainwater and use it during water shortage.
3. Choose intercrop cultivars that complement the main crop in terms of root distribution, nutrient uptake patterns.

4. Plant elite high yielding varieties of main and intercrop.
5. The application of nutrients of both main and intercrops as per their requirements.
6. Choose few (3-4) complementary species at different storey levels at suitable spacing.

SUMMARY

The multitier system can become a complementary enterprise, saves land, labor, and resources, enhances income, biodiversity conservation, and soil fertility under coastal region of the country. The selection of component crops for the multitier cropping system should be based on the location, soil, and climate suitability, market demand, family requirement, available farm resources, etc. Besides the yield and income, the multitier system also addresses partially the nutritional security and the issue of unemployment and has the potential to produce around the year income.

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Cropping system in Peninsular region

Intercropping of maize +cowpea (1:1) was most effective with higher grain yield of maize (66 q/ha) compared to that in maize–chickpea system (63.90 q/ha). On liquid fertilizer supplementation, highest grain yield of cowpea DC-15 was recorded in water soluble complex fertilizer applied (1%) at flowering stage (60 DAS) in the peninsular India.



Maize + Cowpea (1:1) intercropping at Dharwad (Peninsular India). (Source: ICAR Annual Report 2020)

Efficient cropping system

Maize-tobacco cropping system is recommended as remunerative cropping system in terms of tobacco leaf equivalent yield (2,380 kg/ha) and net returns (₹ 13,9285) for enhancing the farmers' income in FCV tobacco growing Vertisols of Andhra Pradesh.



Maize–tobacco cropping system in Vertisols of Andhra Pradesh. (Source: ICAR Annual Report 2020).