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# Optimizing agricultural productivity: Insights into efficient cropping systems of plantation crops

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**Abstract**
Cropping systems are a fundamental aspect of agricultural practices, representing the specific patterns of crop cultivation employed on a farm and their interactions with other farm operations, available technology, and resources. In certain cropping systems, multiple crops are grown in the same field either simultaneously or in quick succession. Given that a farm operates as a well-organized economic entity, the efficient functioning of its cropping systems relies on the effective utilization of its resources, businesses, and technology. These resources include land, labor, water, capital, and infrastructure, all of which are crucial for successful farming. Intensive cropping methods are tailored to maximize the use of available water and manpower, particularly in situations where land availability is limited. Additionally, plantation crop interspaces provide ample opportunities for mixed and intercropping, with approximately 70-75% of the plantation land being suitable for cropping systems.

**Keywords:** Cropping systems, plantation crops, optimizing agricultural productivity

## Introduction
Over the past few years, significant progress has been made in the field of cropping systems for plantation crops. Plantation crops, such as tea, coffee, rubber and oil palm, play a crucial role in the global agricultural economy. The adoption of innovative cultivation practices has led to improved yields, sustainability, and economic viability in these crops. The implementation of agroforestry systems within plantation crops has gained much interest among stakeholders. Intercropping trees or other complementary crops between plantation crops enhances biodiversity, soil health and ecosystem resilience. These systems not only improve environmental sustainability but also diversify income sources for farmers. This also involves optimizing inputs, such as water, fertilizers and pesticides, to achieve higher yields while minimizing environmental impact. Integrated pest management and organic farming practices are being integrated to reduce reliance on synthetic chemicals.

## Advances in plantation crop management
Plantation crops are vulnerable to climate change impacts. Research efforts are made to develop climate-resilient varieties with improved temperature and drought tolerance to overcome stress due to climatic conditions. Similarly, innovative irrigation technologies, such as sensor-based irrigation and drip systems are being employed to ensure precise water delivery, reducing water wastage and increasing water use efficiency. Digital platforms and mobile applications are being utilized to provide real-time information and advisory services to plantation farmers. These platforms offer weather forecasts, disease alerts, market prices and best practices, enabling farmers to make timely decisions. Advanced soil testing and nutrient analysis methods help in tailoring fertilizer applications according to the specific needs of each crop, enhancing nutrient use efficiency. Recent advances in cropping systems for plantation crops encompass a range of innovative approaches aimed at enhancing productivity, sustainability, and resilience. The integration of precision agriculture, agroforestry, sustainable intensification, climate-resilient varieties, smart irrigation, digital platforms, and improved nutrient management collectively contribute to the evolution of modern plantation agriculture. These advancements not only address current challenges but also pave the way for a more efficient and sustainable future for the cultivation of plantation crops.

## Intercropping
Intercropping, a system of growing two or more crops on the same land within a cropping year offers benefits such as better resource utilization, time and space efficiency, weed suppression,

protection against crop failure, improved soil fertility, ecological stability, increased per-area output, additional revenue, provision of daily requirements for farmers and pest and disease management. Conversely, the demerits encompass labor intensity, challenges with differential maturity and harvesting, potential for hosting pests and pathogens, difficulties in weed management, disease and pest control, challenges with mechanization, agricultural competition among component crops and potential allelopathic effects.

Intercropping is recommended as a strategy to address uncertainties and risks in agricultural production while ensuring income stability for farmers. This approach has gained popularity in various regions, such as cocoa-plantain intercropping in Ghana and tea-arecanut intercropping (Anjaneyulu and Bhattacharjee, 2019) [1]. The concept of intercropping medicinal and aromatic plants with arecanut has also been proposed to boost soil organic carbon levels and provide additional benefits to growers.

Drawing from the insights of Nath *et al*. (2019) [9], it is suggested that gerbera, tuberose, gladiolus and marigold can be cultivated profitably as flower crops within established coconut gardens. This can be achieved without compromising the yield, performance or economic viability of the primary coconut crop. Integrating flower crops into coconut gardens has shown minimal impact on the growth and productivity of coconut trees. Prior studies in the arid region of Karnataka have also indicated that intercropping coconut with various crops like banana, French bean, ladies' finger, drumstick, red gram, aromatic and medicinal plants can maintain or enhance coconut nut yield.

The practice of intercropping not only contributes to weed management in plantations but can also boost coconut yields. Research comparing weeded and un-weeded coconut plantations revealed that intercropping coconut with Gliricidia led to increased coconut yields. Moreover, the utilization of diverse weed control techniques influenced yield consistency (Nuwarapaksha *et al*., 2022) [12], potentially contributing to substantial income gains for farmers. Additionally, adopting a coconut-fodder grass-legume cropping system has shown the potential to significantly increase net returns in coconut-based systems, generating Rs 2,06,000/ha/year compared to Rs 44,720/ha/year realized from the mono-cropping system. The suitable intercrops for coconut gardens are mentioned below.

**Stage 1 (age 0−5 years):** Passion fruit, Cassava, Guava, Banana, Ginger, Pineapple, Turmeric

**Stage 2 (age 5−20 years):** Lemon, Chili, Capsicum, Yam, Ginger, Pasture, Turmeric

**Stage 3 (age >20 years):** Pepper, Cocoa, Coffee, Vanilla, Avocado, Gliricidia, Wild sunflower

**Source:** Nuwarapaksha *et al.* 2022 [12]

**Table 1:** Suitable intercrops for other plantation crops

| Categories | Crops |
|---|---|
| Plantation crops | Cocoa, Coffee |
| Flower crops | Heliconia, Anthurium, Jasmine. |
| Fruit crops | Areca Palm, Banana, Drumstick, Guava, Lemon, Papaya, Pineapple |
| Vegetable crops | Amaranthus, Bottle Gourd, Bitter Gourd, Brinjal, Chilli, Capsicum, Cluster Beans, Coccinia, Cucumber, Dolichos Bean, French Bean, Knolkhol, Ridge Gourd, Snake Gourd, Tomato, etc. |
| Spice crops | Ginger, Clove, Cinnamon, Nutmeg, Turmeric, Black Pepper Vanilla. |
| Medicinal and aromatic crops | Arrow Root, Chittadalodakam, Galanga, Indian Long Pepper, Karimkurinji, Nagadanthi, Noni, Patchouli, Snap Ginger, Vetiver |
| Green manure and cover crops | Calopo, Centro, Giant Sensitive Plant, Gliricidia, Hairy Indigo, Kolinji, Subabul, Sunhemp, Tropical Kudzu |
| Tuber crops | Sweet Potato, Taro, Tannia, White Yam, Cassava, Elephant Foot Yam, |
| Fodder crops | Hybrid Bajra Napier, Fodder Cowpea, Guinea Grass. |

**Source:** Mohan Kumar and Kunhamu (2022)

**Mixed cropping and multi-storied cropping**

Mixed cropping is an agricultural practice that involves cultivating multiple crops simultaneously within the same field. This approach is particularly prevalent in regions such as Assam, Meghalaya, Mizoram, Tripura and Nagaland in North Eastern India. An intriguing example of mixed cropping is the combination of coconut and cocoa cultivation. Studies have revealed that integrating cocoa with coconut not only enhances soil fertility but also promotes the proliferation of beneficial microorganisms in comparison to coconut cultivation alone. The objectives driving mixed cropping systems encompass a wide array of goals. These systems are designed to achieve higher crop yields, ensuring consistent production even amidst varying weather conditions. Additionally, they aim to fulfil domestic consumption needs, generate employment opportunities, manage pest pressures effectively, ensure equitable distribution of resources and harness soil resources within the realm of organic farming.

Another innovative approach in sustainable agriculture is the multi-storey cropping system. Within this framework, diverse crops are cultivated with distinct morphological and root behaviours. This strategic cultivation optimizes the utilization of natural resources for sustainable production. The multi-storey cropping approach involves the intercropping of lucrative crops during the initial stages of a plantation's development. As the plantation matures, shade-tolerant crops are introduced, leading to increased coconut yield and enriched soil fertility. The foundation of a successful multi-storey cropping system rests on key principles which include diversifying the crop portfolio, maximizing the overall productivity of the system, efficiently utilizing available resources, intensifying input management and ensuring long-term sustainability. An interesting aspect of this approach is the implementation of a high-density multi-species cropping system within coconut-based agriculture. This strategy has demonstrated notable benefits, including heightened crop yield, improved net returns, and enhanced soil fertility.

Moreover, integrated nutrient management techniques are

seamlessly integrated with the high-density multi-species cropping system. This holistic approach has shown promising outcomes, particularly in gardens affected by root wilt. Studies have reported positive results in terms of both yield and soil fertility. For instance, the work of Maheswarappa *et al.* (2020) [7] highlights the efficacy of this approach in addressing challenges posed by root wilt in coconut-based systems.

**Coconut based high density multi species cropping system with high value intercrops**

| Main crop | Intercrop combination 1 | Intercrop combination 2 |
|---|---|---|
| Coconut | Sweet corn, Baby corn, Brinjal and Pumpkin | Black pepper (Panniyur 1), Banana |

| Crops | Spacing (m) | Plants/ha | Crops | Spacing (m) | Plants/ha |
|---|---|---|---|---|---|
| Coconut | 7.5 X 7.5m | 150 | Cocoa | 2.5 x 2m | 525 |
| Black pepper | 1.25m | 150 | Pineapple | 1-2 m | 4900 |

## Conclusion

The cultivation of plantation crops presents a range of benefits, particularly through the well-suited cropping systems, like intercropping and mixed cropping. These systems not only ensure year-round employment opportunities but also bolster financial and nutritional security. Additionally, they play a pivotal role in promoting sustainable resource utilization. One of the most noteworthy outcomes of these cropping practices is the steady and augmented revenue generation. The integration of various crops in close proximity enables the utilization of available resources to their fullest potential. This, in turn, leads to a substantial increase in overall yield and income. Furthermore, these practices promote optimal utilization of soil nutrients and organic matter, thereby bolstering soil health and fertility. In contrast to monoculture practices, the diversity of crops in these systems disrupts the proliferation of pests and diseases, reducing the reliance on chemical interventions. By providing extended benefits in terms of employment, stability, revenue generation, and ecological resilience, these systems emerge as pivotal components of a sustainable and thriving agricultural future.

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