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REVIEW ARTICLE

Cultivating arecanut in India: challenges, opportunities and sustainable practices

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ABSTRACT

Arecanut cultivation faces numerous challenges and opportunities. Key issues include vulnerability to climatic variations, declining soil fertility, and pest infestations, which negatively affect crop yield and quality. Traditional farming methods and limited access to modern agricultural knowledge exacerbate these problems. Additionally, fluctuating market prices contribute to the financial instability of areca nut farmers. However, there are promising prospects for arecanut cultivation. Diversified farming practices, such as intercropping with pepper, banana, and cocoa, and integrated farming systems combining crop production with livestock and fish farming can enhance productivity and sustainability. Adopting modern agricultural techniques and improving market access can increase yield quality and economic returns. This study emphasizes the need for a holistic approach to arecanut farming, integrating modern technology, diversified farming practices, and strong support systems to address challenges and seize opportunities for a sustainable future in India.

Keywords: *Arecanut; Climate; Diversified farming; Integrated farming System; Marketing; Challenges*

INTRODUCTION

Areca nut (*Areca catechu*), a tropical crop, is popularly known as betel nut, as its common usage in the country is for mastication with betel leaves. It is a palm tree species under the family of Arecaceae (Rangaswami, 1977; Ramappa, 2013). The crop is mainly grown in Karnataka, Kerala, Tamil Nadu, Assam, West Bengal, Meghalaya, Maharashtra and Andaman & Nicobar group of Islands. The economic produce is the fruit called betelnut or 'supari' used mainly for mastigatory purposes (Schoneman, 2010; Balanagouda *et al.,* 2021). Areca nut is an essential ingredient of 'gutka' and 'pan masala.' It is consumed as a raw/ripe nut (adaka or kacha tamul), as dried ripe nut (chali supari) and as semi-mature, cut and processed varieties `Bateldike' or `Kalipak'. In India, it is extensively used and linked to religious practices (Nair and Nair, 2021; Palanna *et al.,* 2020).

India is the largest producer of arecanut and, at the same time, the largest consumer also. Major states cultivating this crop are Karnataka (40 per cent), Kerala (25 per cent), Assam (20 per cent), Tamil Nadu, Meghalaya and West Bengal (Bhat *et al.,* 2024). Areca nut production in India is dominant in the coastal region within 400 kilometres (250 mi) from the coast line and also in some other non-coastal states of India. Its production in India is the largest in the world, as per the Food and Agriculture Organization of the United Nations (FAO) statistics for 2017, accounting for 54.07% of its world output and is exported to many countries. Within India, as

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of 2013–14, Karnataka produces 62.69% of the crop, followed by Kerala and Assam; all three states together account for 88.59% of its production. In the other states of Meghalaya, Tamil Nadu and West Bengal, where it is also consumed, the crop is grown in a very small area. In Karnataka, the Uttara Kannada District , and Shivamogga District , the crop is grown extensively.

Factors influencing the production and productivity of areca

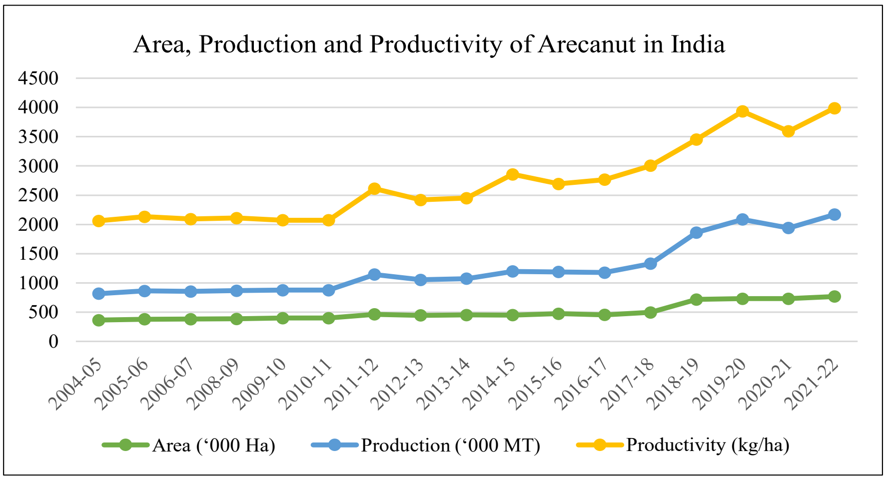
Climate action

Weather conditions plays an important role in development and productivity of the crops. As we know arecanut can be grown in varying climatic conditions, but its productivity is highly influenced by weather factors mainly during critical stages of the crop (Jose et al., 2019). About 66 per cent of the crop production is dependent on weather conditions. Change in the climate, mainly during inter and intra annual, causes a negative impact on the productivity of the crop (Nellemann et al., 2009). Sujatha *et al.* (2018) reported that the productivity of the crop is highly dependent on weather, which can affect both the quantity and quality of the nut and showed differential response

Table 1: Area, production and productivity in India

Year	Area ('000 Ha)	Production ('000 MT)	Productivity (kg/ha)
2004-05	364	453	1245
2005-06	381	483	1268
2006-07	382	473	1238
2008-09	387	481	1243
2009-10	400	478	1195
2010-11	400	478	1195
2011-12	464	681	1468
2012-13	446	609	1365
2013-14	452	622	1376
2014-15	450	747	1660
2015-16	474	714	1506
2016-17	455	723	1589
2017-18	497	833	1676
2018-19	718	1144	1593
2019-20	732	1353	1848
2020-21	731	1209	1654
2021-22	770	1400	1818

Fig 1: Statiscal analysis of area production and productivity of arecanut in India

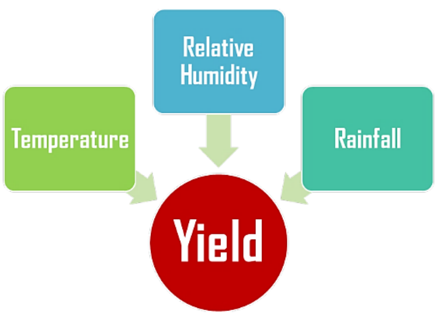


of arecanut to weather variability. The relationship between the yield of areca and weather parameters like temperature, relative humidity, and rainfall was critical. Particularly during the flowering stage*, i.e., January to March, an increase in temperature, relative humidity, and rainfall had a significant positive effect on nut yield, whereas* the rainfall during the nut development stage (from June to July) adversely affected the crop productivity (Sunil *et al.,* 2011).

Areca production is sensitive to daily temperature, relative humidity, annual rainfall and sunshine hours. Heavy rainfall, high relative humidity and low temperatures are the major constraints in arecanut production mainly in coastal regions of Karnataka. Meanwhile, in other regions, low rainfall and high temperatures are major constraints on crop production. High rainfall in malnad regions lead to leaching of nutrients (potassium and calcium) and high relative humidity is responsible for pests and diseases. Heavy rainfalls during the fruit development period and evening relative humidity had a significant negative effect on the yield of areca nut (Sujatha et al., 2017).

Temperature

The maximum temperature during November (31-34 ºC), December (32.3-34.4 ºC), January (32.8 -34 ºC) and May (32.9 -36.2 ºC) of the previous year and July (27 -30 ºC) and September (29-32 ºC) of the current year shows the significantly positive correlation with flowering and fruit setting of areca. In contrast, a minimum temperature of 25 ºC during May directly influenced the areca nut yield, whereas yield declined when the minimum temperature reached more than 25 ºC (Jose *et al.,* 2019).



Rainfall

Rainfall has shown a significant negative correlation with annual areca yield. In particular case, heavy rainfall during November effects the flowering period of the crop and high rainfall during May and July affects the fruit setting period of areca which indirectly affects the productivity. On average, rainfall of 175->1100 mm reduces the yield and marketing value of the crop (Jose *et al.,* 2019).

Humidity

High relative humidity has a negative impact on the areca nut yield. In case, high relative humidity during September (94-97 %), November (91-97 %), and February to May (90-93 %) adversely affects the following year's yield whereas high relative humidity during July, September and October of the current year also had negative impact on yield. Vise versa, decreased RH cent showed increased yield for next year. In the case of summer months (February to May), increased RH of more than 93 percent increased the rate of yield reduction.

Soil

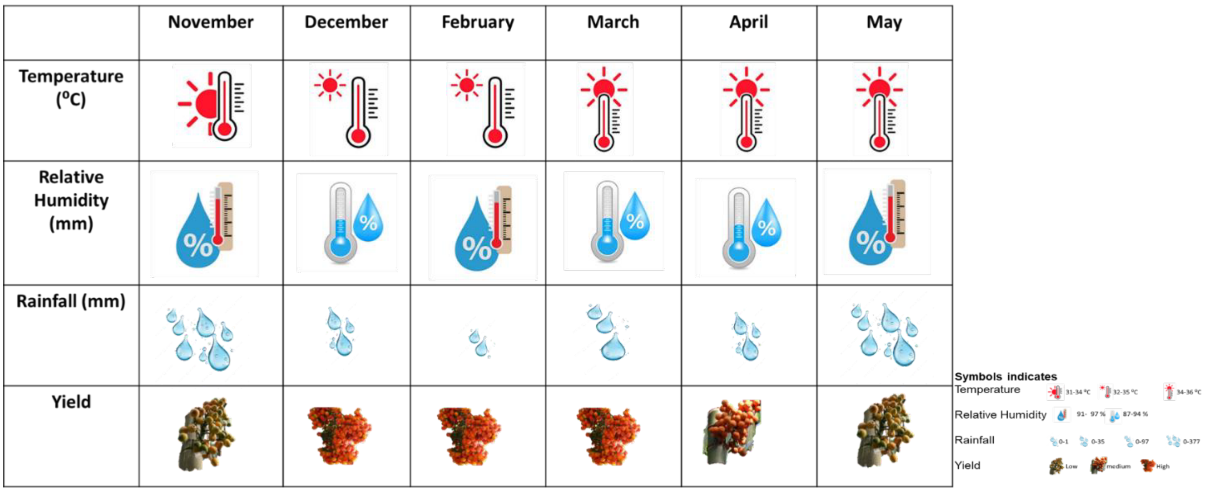
Areca nut grows well within the temperature range of 14ºC and 36ºC and is adversely affected by temperatures below 10ºC and above 40ºC. Extremes of temperature and wide diurnal variations are not conducive to the healthy growth of the palms. It can be grown in areas receiving annual rainfall of 750 mm to 4,500 mm. In areas where there is a prolonged dry spell, the palms are irrigated. Due to its susceptibility to low temperatures, a good crop of areca nut cannot be obtained at an altitude of more than 1000 m MSL. The largest area under the crop is in gravelly laterite soils of red clay type. It can also be grown on fertile clay loam soils. Sticky clay, sandy, alluvial, brackish, and calcareous soils are unsuitable for areca nut cultivation.

Diversified farming

Diversified farming is a strategy that integrates various agricultural practices and crops within a single farming system to enhance productivity, sustainability and profitability. It mainly includes functional biodiversity at multiple spatial or temporal scales through the practices developed *via* traditional or agroecological scientific knowledge (Zhang *et al.,* 2007).

Diversified farming in areca plantations is a sustainable and profitable agricultural practice that addresses the challenges of traditional monoculture farming. In arecanut cultivation, diversification plays a

Table 2: Impact of temperature, relative humidity, and rainfall on yield of areca nut



crucial role in optimizing resource use, improving soil health, increasing biodiversity and providing multiple sources of income (Sujatha *et al.,* 2016: Sujatha *et al.,* 2011a). Though arecanut is capable of surviving in diverse climatic conditions and its productivity is directly affected by weather factors like rainfall, relative humidity and temperature. Crop diversification in arecanut garden is essential for areca farmers as there are facing the recurring problems (Sunil *et al.,* 2011; Sujatha *et al.,* 2006). Doubling farmer's income is possible through proper planning and adoption of an advanced package of practices in which new technologies like high-yielding and disease-resistant varieties, marketability, and post-harvest technological support are provided. Farmers can optimize resource use, enhance soil health, increase biodiversity, and achieve economic stability by integrating various crops and farming practices. As global agricultural practices evolve, diversified farming offers a promising pathway towards resilient and sustainable arecanut cultivation (Ray *et al.,* 2011).

Important methods of diversified farming in arecanut

Arecanut is predominantly grown in India and Southeast Asia. Traditional monoculture farming of arecanut can lead to several issues, including soil nutrient depletion, increased vulnerability to pests and diseases and economic risks associated with market fluctuations. Diversified farming addresses these challenges by promoting a more resilient and sustainable agricultural system. The brief information regarding diversified farming in arecanut has been described below.

Intercropping

Previous studies reported by Vishwanathan *et al.* (1992) revealed that the availability of congenial microclimate and minute utilization of resources for intercropping in arecanut plantations is critical. The scope for intercropping in plantation crops mainly arecanut crop is well documented (Sujatha *et al.,* 2011). Intercropping mainly involves growing multiple crops alongside the areca palms. Common intercrops include pepper (*Piper nigrum*), betel vine (*Piper beetle*), banana, cocoa (*Theobroma cacao*) and coffee (Kumar *et al.,* 2016). These crops are compatible with areca is due to their similar shade and water requirements. For instance, pepper vines can climb areca nut palms, while bananas can be planted in between the rows and are represented in figure 2. This approach maximizes the use of available space, sunlight, and soil nutrients, leading to higher overall productivity (Rajaseger et al., 2023; Crews *et al.,* 2018).

Agroforestry

Agroforestry integrates trees and shrubs into areca nut farming systems. Planting valuable timber species like teak (*Tectona grandis*) and mahogany (*Swietenia macrophylla*) within or around arecanut plantations can provide long-term income from timber sales (Arunachalam, 2022; Vinodhini *et al.,* 2023). Additionally, these trees offer shade, reduce wind erosion, and enhance biodiversity, contributing to a more stable and healthy ecosystem (Barrios *et al.,* 2018).

Sequential Cropping

Sequential cropping involves growing different crops in succession within a year on the same land (Gliessman, 1985). Farmers can plant seasonal vegetables such as tomatoes, brinjal, and chili, legumes like cowpea and green gram, and tuber crops like yam and sweet potato after harvesting areca nut. This practice helps in maintaining soil fertility, improving soil structure, and breaking pest and disease cycles (Thomas *et al.,* 2018; Alexander *et al.,* 2009).

Cover Cropping

Cover crops are grown primarily to cover the soil rather than for harvest (Baggs, 2000). Leguminous cover crops like cowpea, sun hemp (*Crotalaria juncea*) and green gram are commonly used in arecanut plantations. These plants improve soil fertility through nitrogen fixation, prevent soil erosion and add organic matter to the soil, enhancing its structure and health (Pokharel *et al.,* 2023).

Fig 2: Cropping systems in arecanut plantation

Alley Cropping

Alley cropping involves planting rows of trees or shrubs with alleys of crops between them. In arecanut plantations, various annual or perennial crops can be planted in the alleys. This system improves microclimates, enhances biodiversity, and provides additional sources of income to the farmers (Mohamad Ashraf *et al.,* 2019).

Integrated Farming Systems

Integrated farming systems combine crops with livestock and fish farming. For example, poultry, goats, dairy cows and fish ponds can be integrated into arecanut farms (Walia *et al.,* 2019). This enhances farm resilience, provides multiple sources of income, and makes efficient use of resources like water and feed (Paramesh et al., 2022) and is represented in Figure 3.

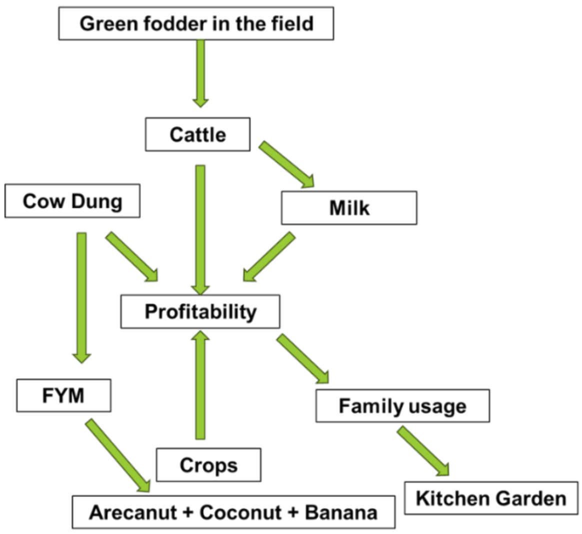
Organic Farming

Organic farming emphasizes the use of natural inputs and processes. The practices include composting, green manuring and using biofertilizers and biopesticides (Gamage *et al.,* 2022; Rao *et al.,* 2010). This approach improves soil health, reduces dependence on chemical inputs and can command premium prices in the market.

Benefits of diversified farming in arecanut

- Diversified farming provides multiple income streams, reducing the economic risks associated with price fluctuations and crop failures (Kurdys-Kujawska *et al.,* 2021; Duffy *et al.,* 2021). Farmers can earn from various sources such as pepper, bananas, timber, and livestock, ensuring a more stable and reliable income.
- The inclusion of legumes and cover crops in arecanut plantations improves soil fertility through nitrogen fixation and organic matter addition. Sequential cropping and organic farming practices further enhance soil structure and nutrient availability, leading to healthier and more productive soils (Pandey *et al.,* 2024; Kebede, 2021).
- It enhances biodiversity by introducing various plant and animal species into the farming system (Bengtsson *et al.,* 2005; Scherr *et al.,* 2008). This contributes to a balanced ecosystem, promoting natural pest control and reducing the incidence of diseases.
- By integrating multiple crops and farming practices, diversified farming makes efficient use of available resources such as land, water and sunlight. Intercropping and sequential cropping ensure that no space is wasted and that resources are utilized throughout the year (Yang *et al.,* 2020).
- Farming practices, such as agroforestry and organic farming, promote environmental sustainability by reducing reliance on chemical inputs, enhancing soil and water conservation, and maintaining ecological balance (Kumar and Singh, 2024).

Fig 3: Profitability through integrated farming systems



Integrated agro-ecosystem was explained below in brief to know their importance in areca plantations.

Integrated agro-ecosystem

Integrated agro-ecosystem in arecanut farming involves incorporating various sustainable agricultural practices to optimize production while minimizing environmental impact. Here are some components of an integrated agro-ecosystem in arecanut farming

- Crop Diversity: Intercropping arecanut with compatible crops such as cocoa, pepper, banana, or pineapple can enhance soil fertility, reduce pest pressure, and provide additional income for farmers.
- Organic Farming Practices: Implementing organic farming techniques like composting, mulching and biofertilizers reduces reliance on synthetic inputs, improves soil health and enhances the overall sustainability of the farming system.
- Water Management: Efficient water management practices such as drip irrigation or rainwater harvesting can help conserve water resources, especially in regions prone to water scarcity.
- Agroforestry: Integrating trees within areca nut plantations, such as nitrogen-fixing trees or fruit trees, contribute to biodiversity and soil fertility and provides additional sources of income.
- Biological Pest Control: Encouraging natural predators and beneficial insects, practicing crop rotation and using botanical extracts or biopesticides can effectively manage pests and diseases while minimizing chemical usage.
- Soil Conservation: Employing techniques like contour bunding, terracing and cover cropping helps prevent soil erosion, improves moisture retention and maintains soil structure.
- Integrated Nutrient Management: Balancing nutrient inputs through the use of organic amendments, green manures and mineral fertilizers based on soil testing optimizes nutrient availability for arecanut plants while minimizing nutrient runoff.
- Community Involvement: Engaging local communities in sustainable farming practices through training programs, farmer cooperatives and knowledge-sharing initiatives fosters collective action and promotes the adoption of integrated agro-ecosystems.
- Agro-ecological Zoning: Considering local ecological conditions, including climate, soil types and topography, helps tailor farming practices to specific agro-ecological zones, optimizing resource use and resilience to environmental stressors.
- Market Diversification: Exploring diverse markets for arecanut products, including value-added products like processed nuts or extracts, enhances market resilience and provides additional income streams for farmers.

By integrating these practices, farmers can develop resilient and sustainable arecanut farming systems that promote both environmental conservation and economic viability.

Integrated farming system in arecanut plantation

In recent years, several factors such as climate change, degradation of natural resources, declining factor productivity, shrinking landholdings and reduced profitability have increased vulnerability to biotic and abiotic stresses in the agriculture sector (Behera and France, 2016; Tuo misto *et al.,* 2017; Agovino *et al.,* 2019). Additionally, traditional monocropping practices have led to reduced farm productivity, degradation of ecosystem functions, deterioration of soil health, loss of biodiversity (Clark *et al.*, 2017; Yang

Fig 4: Representing the different integrated ecosystems

a. Coconut, arecanut and cocoa

b. Arecanut intercropped with coffee

C. Arecanut intercropped with coffee and black

d. Intercropping of vegetable and flower crops in arecanut garden

et al., 2020; Panklang *et al.*, 2022) and altered soil food web interactions (Pervaiz *et al.*, 2020). To address these challenges, crop diversification is essential, as it enhances profitability, soil fertility and resilience to climate change (Nunes *et al.*, 2018; Mishra *et al.*, 2022).

The Integrated Farming System (IFS) involves integrating crop production with livestock, fish, poultry, plantation crops and other systems in a sustainable and holistic manner and is presented in figure 3. This approach improves soil fertility, enhances synergies among components and recycles resources, leading to higher crop production and economic returns (Paramesh *et al.*, 2021; Palsaniya *et al.*, 2022).

IFS models are more resilient to extreme weather conditions, reduce dependence on external inputs, utilize natural resources efficiently, and exhibit favorable crop-livestock interactions while also providing employment, food, and nutritional security (Paramesh *et al.*, 2019; Sneessens *et al.*, 2019; Walia *et al.*, 2019). Furthermore, IFS involving agroforestry, agri-silvi-horti-pastoral or horticultural components reduces soil erosion, sustains soil health and ensures food security (Choudhury *et al.*, 2022). IFS also aids in biodiversity conservation through the integration of diversified crops, indigenous livestock breeds and regional bird species, ultimately contributing to food and nutrition security (Ranganathan *et al.*, 2008; Paramesh *et al.*, 2022).

The west coast region of India, rich in natural resources and home to the Western Ghats, a global biodiversity hotspot, has been under cultivation for over 2000 years (Ranganathan *et al.*, 2008). In this region, plantation crops such as arecanut and coconut dominate. The arecanut-based farming system, prevalent in this area, typically includes perennial plantation crops like arecanut and coconut, mixed with banana, nutmeg, black pepper, betel leaf, other spices, vegetables, flowers and forest trees, integrated with a dairy component. However, the risk associated with arecanut cultivation has increased due to fluctuating prices and reduced profitability (Jaya sekhar *et al.*, 2012; Manjunath *et al.*, 2017). Diversifying income sources by integrating multiple components into the arecanut-based farming system can ensure income security (Sujatha and Bhat, 2015; Paramesh *et al.*, 2022). Studies by Aditya *et al.* (2017) found that the arecanut-based farming system is economically viable, improving the economic status of farmers and reducing poverty. Bhargavi and Behera (2020) concluded that the income of small and marginal farmers can be improved by diversifying the IFS system compared to conventional systems.

Impacts of illiteracy and lack of technical knowledge on scientific cultivation

Many farmers rely on traditional methods passed down through generations. These methods may not be efficient or sustainable in the long term (Hamadani *et al.,* 2021; Sekhar *et al.,* 2024). Without knowledge of modern techniques, farmers may not optimize inputs such as water, fertilizers and pesticides, leading to lower yields and poor-quality produce (Melash *et al.,* 2023). Illiteracy and lack of technical knowledge hinder the use of technological tools like mobile apps, online resources and digital platforms that provide valuable information on farming practices (Bai *et al.,* 2023; Zondi *et al.,* 2024). Farmers may not be able to interpret and apply findings from scientific research on crop management, pest control, and disease prevention (Jena *et al.,* 2023).

Limited understanding of market dynamics can prevent farmers from accessing better markets or getting fair prices for their produce (Magesa *et al.,* 2014; D'souza, 2020; Bizikova *et al.,* 2020). Illiteracy can lead to poor financial management, making it difficult for farmers to take advantage of credit facilities, insurance and subsidies offered by the government. Without knowledge of sustainable farming practices, farmers might overuse chemical inputs, leading to soil degradation, water pollution, and a decline in biodiversity. Farmers may lack the knowledge to adapt to changing climate conditions, making their crops more vulnerable to extreme weather events (Ahsan *et al.,* 2021; Dhanaraju *et al.,* 2022; Gamage *et al.,* 2023).

These can provide hands-on training in scientific cultivation techniques, pest management, and sustainable practices (Waddington *et al.,* 2014). Initiatives to improve basic literacy among farmers can empower them to access and utilize agricultural information effectively (Yang *et al.,* 2008; Tamo *et al.,* 2022). More extension officers should be deployed to rural areas to provide personalized guidance and support to farmers (Singh *et al.,* 2014; Mungai et al., 2018). Setting up model farms where farmers can see the benefits of scientific cultivation practices firsthand (Rai *et al.,* 2023).

Developing and promoting user-friendly mobile applications that provide information in local languages and through audio-visual means for illiterate farmers (Patel and Patel, 2016; Rege and Nagarkar, 2010). Leveraging local media to broadcast educational programs on modern farming techniques and market information (Razaque and Sallah, 2013). Providing financial incentives for farmers to adopt new technologies and practices (De Vries *et al.,* 2005; Alimohammad *et al.,* 2022). Collaborations between the government, private sector, and NGOs to fund and implement training and support programs. Encouraging the formation of farmer cooperatives to facilitate shared learning, collective bargaining and easier access to resources. Promoting peer-to-peer learning where experienced farmers mentor others in their community (Ramberg, 2020; Bose *et al.,* 2017).

CONCLUSION

Arecanut cultivation signifies the challenges and promising opportunities for farmers. The key issues identified include climatic vulnerabilities, such as temperature fluctuations and heavy rainfall, which adversely affect crop productivity. Soil fertility degradation and pest infestations further exacerbate these problems. Farmers' reliance on traditional methods, coupled with limited access to modern agricultural techniques and market information, hinders their ability to maximize productivity and profitability. The volatile market prices of arecanut also contribute to financial instability among farmers, creating a precarious economic environment. However, the prospects for arecanut cultivation are encouraging. Embracing diversified farming practices, such as intercropping and integrated farming systems, can significantly enhance productivity and sustainability. Integrating compatible crops like pepper, banana and cocoa within arecanut plantations can optimize resource use, improve soil health, and provide additional income streams. Moreover, the adoption of modern agricultural technologies and improved market access can lead to higher yields and better-quality produce, ultimately improving the economic viability of arecanut farming. To achieve a sustainable and profitable future for arecanut cultivation, a comprehensive approach is essential. This includes enhancing farmers' knowledge through training and extension services, promoting diversified and integrated farming practices and ensuring better access to markets and modern technologies. By addressing these challenges and leveraging the opportunities, arecanut farmers can achieve greater resilience, economic stability and long-term sustainability in their farming practices.

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