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Promoting Karonda (*Carissa carandas*) cultivation through agricultural extension: Pathways for rural development and income security

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Abstract

Karonda (*Carissa carandas*), an underutilized fruit crop indigenous to South Asia, holds immense potential as a sustainable solution for rural development and livelihood security. Despite its nutritional richness, medicinal value, and resilience to drought and poor soils, Karonda remains largely confined to subsistence and boundary plantings rather than being integrated into mainstream horticultural or commercial systems. This paper explores the pathways through which agricultural extension can play a transformative role in promoting Karonda cultivation and value addition, thereby enhancing income opportunities and resilience among rural households. Drawing on scientific evidence, government reports, and ethnobotanical studies, the paper highlights Karonda's adaptability to marginal agro-ecological zones, its wide range of pharmacological and nutritional benefits, and the diverse avenues for product diversification into pickles, syrups, nutraceuticals, and herbal preparations. By developing farmer-oriented extension strategies such as training modules on propagation and processing, establishment of community nurseries, facilitation of value-chain linkages, and policy advocacy for inclusion in horticultural development schemes Karonda can be repositioned as a "climate-smart" crop. The analysis further emphasizes the socio-economic impacts of scaling up Karonda cultivation, including livelihood diversification, empowerment of women through micro-enterprises, and the strengthening of local agro-economies. The study concludes that effective extension interventions, coupled with supportive policies, can transform Karonda from a neglected fruit into a catalyst for rural income security and sustainable development in semi-arid regions.

Keywords: Karonda cultivation, agricultural extension, rural development, income security, *Carissa carandas*

Introduction

Agricultural diversification has become a central pillar of rural development policies in South Asia, where climate variability, land degradation, and economic vulnerabilities continue to threaten smallholder farmers' livelihoods. Underutilized fruit crops, which often combine ecological hardiness with high nutritional and medicinal value, represent a largely untapped resource for achieving both food security and income generation. Among such crops, Karonda (*Carissa carandas*), a thorny, evergreen shrub native to India and neighboring countries, stands out for its remarkable resilience to drought, salinity, and poor soils, as well as its wide range of nutritional and therapeutic properties. Traditionally valued in Ayurvedic, Unani, and folk systems of medicine for treating ailments such as anemia, skin disorders, and digestive problems, Karonda also serves as a dietary supplement rich in iron, vitamin C, and antioxidants. Despite these attributes, Karonda cultivation remains largely neglected in policy frameworks, research programs, and market-oriented agricultural systems.

The fruit's inherent adaptability to arid and semi-arid regions makes it particularly suitable for marginal farmers who lack access to irrigation and high-input technologies. In addition to ecological resilience, Karonda offers multiple avenues for value addition through processing into pickles, jams, chutneys, syrups, juices, and herbal nutraceuticals.

These products hold growing market potential in both local and global health-conscious consumer segments. Furthermore, the plant's thorny, dense growth habit provides additional ecosystem services by functioning as a natural hedge, preventing soil erosion, and supporting biodiversity. Yet, the absence of organized cultivation practices, standardized propagation protocols, and established value chains has constrained its widespread adoption.

In this context, agricultural extension emerges as a crucial instrument for unlocking the latent potential of Karonda. Extension systems can serve as a bridge between scientific knowledge and rural communities by introducing improved propagation techniques, offering training in post-harvest handling and processing, facilitating collective marketing, and promoting Karonda-based enterprises. Moreover, extension programs can advocate for policy incentives, such as subsidies on planting material and credit access, while encouraging community participation in nursery development and cooperative processing. Through such initiatives, Karonda cultivation can evolve from its current role as a subsistence hedge crop into a cornerstone of rural economic empowerment and climate-resilient farming systems.

This paper critically examines the agronomic, nutritional, and socio-economic dimensions of Karonda cultivation and proposes extension-driven pathways for enhancing its role

in rural development. By situating Karonda within broader discourses on food security, livelihood diversification, and sustainable agriculture, the study argues that promoting this underutilized fruit through targeted extension strategies can not only secure incomes but also strengthen rural resilience against environmental and economic uncertainties.

Botanical Profile and Ecological Adaptability

Karonda (*Carissa carandas* L.), belonging to the family Apocynaceae, is a perennial, evergreen, spiny shrub or small tree widely distributed across India, Nepal, Sri Lanka, Bangladesh, and Southeast Asia. It grows naturally in scrub forests, wastelands, and semi-arid zones, thriving even under adverse soil and climatic conditions. The plant, known by various vernacular names such as “Karonda” in Hindi, “Kalakai” in Tamil, and “Koromcha” in Bengali, has long been integrated into traditional farming systems as a hardy hedge plant and a supplementary fruit source. Despite its resilience and versatility, it has not received due recognition in mainstream horticulture, resulting in its current categorization as an “underutilized fruit crop.” Karonda is a hardy shrub that usually reaches a height of 2-4 meters, though it can occasionally grow taller under favorable conditions. Its dense, thorny branches make it an effective live fence. The plant produces simple, opposite leaves that are oval to oblong, leathery in texture, and dark green in color. The flowers are small, fragrant, and white, borne in terminal clusters, which later give rise to berry-like fruits. The fruits are initially green, turning pink, red, and eventually deep purple or black when fully ripe. Depending on the stage of maturity, the taste varies from sour to sweet, lending itself to a range of culinary and processing uses. Taxonomically, the plant is classified as follows:

- **Kingdom:** Plantae
- **Order:** Gentianales
- **Family:** Apocynaceae
- **Genus:** *Carissa*
- **Species:** *C. carandas*

The natural distribution of Karonda is primarily in tropical and subtropical regions. In India, it grows abundantly in the Western Ghats, Central India, and arid tracts of Rajasthan, Gujarat, and Bundelkhand. It is well adapted to high temperatures (tolerating up to 45°C), prolonged dry spells, and degraded soils with minimal fertility. Karonda also shows tolerance to salinity and alkalinity, making it a suitable candidate for cultivation in areas affected by soil degradation. Its natural ability to withstand drought and thrive in rainfed conditions positions it as a climate-resilient crop suitable for sustainable agriculture in marginal areas. Karonda is remarkably versatile in its soil preferences. It performs well in sandy, lateritic, and rocky soils where most conventional fruit crops fail. The plant is not demanding in terms of soil fertility and can even grow on shallow soils with minimal organic matter. Rainfed cultivation during the monsoon season is the most common practice, but the crop benefits from light irrigation during prolonged dry periods. Its deep-root system enables it to tap sub-surface moisture, ensuring survival in drought-prone regions. This ecological adaptability reduces the need for intensive management and makes Karonda a cost-effective option for small and resource-poor farmers.

Karonda typically flowers twice a year, during spring (March-April) and post-monsoon (September-October). The fruiting period extends from May to July in the summer season and again during the winter months in regions with a second flowering flush. Fruits mature in about 90-100 days after flowering. Propagation occurs through both seeds and vegetative methods. While seed propagation is common and simple, it results in considerable variability in fruit quality. Vegetative methods such as stem cuttings, air layering, and budding are increasingly being recommended to ensure uniformity and faster bearing. Research has also demonstrated the effectiveness of using Indole-3-butyric acid (IBA) treatments to improve rooting success in cuttings, providing opportunities for nursery development as part of extension programs.

Apart from its role as a fruit crop, Karonda contributes significantly to agro-ecosystem sustainability. Its dense, thorny canopy makes it an ideal live fence, protecting crops from grazing animals and demarcating boundaries. The plant is also effective in soil conservation, as its root system stabilizes eroded slopes and prevents further land degradation. Moreover, Karonda flowers attract pollinators, supporting biodiversity in rural landscapes. These multifunctional attributes reinforce its value in integrated farming systems and agroforestry models.

Nutritional, Medicinal, and Ethnobotanical Value

The nutritional and therapeutic importance of *Carissa carandas* has been well documented in scientific literature, with particular attention to its role as a source of micronutrients and bioactive compounds. A biochemical analysis reported by Sarkar (2024, International Journal of Agriculture and Food Science, 6(2):156-158) provides standardized values of the fruit’s composition. According to this study, Karonda is exceptionally rich in vitamin C and iron, in addition to containing valuable amounts of calcium, phosphorus, and dietary fiber. The findings confirm its status as a functional food with applications in combating anemia, enhancing immunity, and supporting bone health.

Table 1: Nutritional composition of Karonda (*Carissa carandas*) fruit (per 100 g edible portion)

Component	Amount per 100 g
Moisture (%)	82.0
Protein (g)	1.1
Fat (g)	0.5
Carbohydrate (g)	10.8
Fiber (g)	2.9
Energy (kcal)	44
Vitamin C (mg)	200
Iron (mg)	39
Calcium (mg)	21
Phosphorus (mg)	18
Potassium (mg)	192
Pectin (%)	2.6

Source: Sarkar T. Karonda: An underutilized fruit crop, promise as a significant asset for rural economies. Int J Agric Food Sci. 2024;6(2):156-158.

This profile highlights the dual nutritional advantage of Karonda: a very high concentration of vitamin C that enhances immunity and aids iron absorption, and an unusually high iron content that directly addresses rural

dietary deficiencies. Together, these two components explain why Karonda has historically been used in folk medicine for treating anemia and general weakness. Beyond nutrition, phytochemical analyses have identified alkaloids such as carissone and carindone, triterpenoids like carissin and ursolic acid, and flavonoids including quercetin and rutin. These compounds have been associated with antioxidant, anti-inflammatory, antimicrobial, and cardioprotective properties. Experimental studies demonstrate that fruit and leaf extracts inhibit bacterial pathogens, reduce oxidative stress, and lower blood glucose levels in animal models. The anthocyanins found in ripe fruits are particularly valued for their free radical scavenging capacity and potential applications in natural cosmetics and anti-aging formulations.

The ethnobotanical role of Karonda further reinforces its importance. Rural households in India traditionally use the sour unripe fruits in pickles and chutneys, while ripe berries are processed into syrups, preserves, and candied products. Women in several communities sustain small-scale enterprises by preparing Karonda-based foods for local markets, thereby generating supplementary income. The plant's thorny hedges also serve ecological purposes, acting as live fences, preventing soil erosion, and conserving biodiversity.

In essence, Karonda represents a rare convergence of nutritional excellence, medicinal efficacy, and cultural relevance. Its scientific validation as a nutrient-dense and pharmacologically active fruit provides a strong foundation for promoting it through agricultural extension and value-chain development.

Agronomic Practices and Propagation Techniques

The cultivation of *Carissa carandas* has traditionally been confined to hedgerows and home gardens, yet its adaptability to marginal soils and climate-stressed regions

makes it suitable for systematic horticultural promotion. Agronomic investigations, including the work of Sarkar (2024), confirm that Karonda is not a demanding crop in terms of inputs and can be successfully grown under rainfed conditions. Its resilience and low maintenance requirements make it an ideal option for resource-poor farmers in semi-arid regions.

Soil and Climate Requirements

Karonda thrives best in tropical and subtropical climates, performing well in regions with annual rainfall between 750 and 1,200 mm. It tolerates extreme summer temperatures up to 45°C, making it suitable for semi-arid and drought-prone environments. Unlike most fruit crops, Karonda adapts to a wide variety of soils ranging from sandy to lateritic and rocky substrates. It also shows tolerance to saline and alkaline soils, with a pH range of 5.5 to 8.5 considered optimal. Its deep root system enables the plant to survive prolonged dry periods, which reduces dependency on irrigation and positions the crop as climate-resilient.

Propagation Methods

Traditionally, Karonda has been propagated through seeds, but this method often results in significant genetic variability and non-uniformity in fruit quality. Plants raised from seed generally take three to four years to begin fruiting. To achieve uniformity and faster establishment, vegetative propagation is recommended. Stem cuttings treated with indole-3-butyric acid (IBA) have shown rooting percentages as high as 65-70 percent, while air layering and budding techniques have also been successfully employed in experimental trials. Grafting on related species within the *Carissa* genus has further improved survival rates in nurseries, providing an effective pathway for the development of quality planting material.

Table 2: Performance of propagation methods in *Carissa carandas*

Propagation method	Time to bearing (years)	Success rate (%)	Remarks
Seed	3-4	80-85	High variability in fruit quality
Stem cuttings (IBA treated)	2-3	65-70	Uniform plants, nursery-friendly
Air layering	2-3	60-65	Useful for small-scale nurseries
Budding/Grafting	2-3	55-60	Ensures true-to-type plants

Source: Sarkar T. Karonda: An underutilized fruit crop, promise as a significant asset for rural economies. *Int J Agric Food Sci.* 2024;6(2):156-158.

Crop Management

Karonda requires minimal crop management once established. Regular weeding during the initial years helps young plants establish more vigorously. The crop is responsive to organic manures, and a basal application of farmyard manure at the time of planting is recommended to improve soil structure. While the plant is tolerant of dry conditions, supplementary irrigation during flowering and fruit development stages enhances yield and fruit quality. Pruning after harvesting is beneficial for maintaining plant structure and encouraging new growth. Pest and disease incidence in Karonda is generally low, though fruit borers and mealy bugs have been reported in isolated instances; these can be managed through integrated pest management practices.

Yield Potential

The yield of Karonda depends on age, propagation method, and environmental conditions. Plants raised from vegetative methods begin bearing earlier and are more uniform in yield. A mature shrub under rainfed conditions produces on average 5 to 8 kilograms of fruit annually, though higher yields up to 10 kilograms have been recorded under managed cultivation with supplemental irrigation. The fruiting season typically occurs twice a year, with a major harvest during May-July and a secondary harvest after the monsoon in September-October.

Karonda's agronomic characteristics its ability to grow in marginal soils, low requirement for fertilizers and irrigation, tolerance to heat and salinity, and dual harvests make it a promising crop for inclusion in horticultural extension programs. With the establishment of nurseries that supply

vegetatively propagated, true-to-type seedlings, farmers can adopt Karonda as a reliable fruit crop capable of contributing both to household nutrition and local market supply.

Value Addition, Market Potential, and Livelihood Opportunities

The economic potential of *Carissa carandas* extends far beyond its role as a subsistence fruit. While it is often consumed fresh or preserved at the household level, systematic processing and marketing can transform it into a profitable commodity for rural communities. Sarkar (2024) emphasizes that the fruit's high content of vitamin C, iron, and pectin makes it particularly suitable for a variety of processed products with both nutritional and therapeutic appeal.

Value Addition and Processing

Unripe fruits, with their characteristic sour taste and high acid content, are widely used in the preparation of pickles, chutneys, and spicy condiments. Ripe fruits, which are sweeter and rich in anthocyanins, lend themselves to processing into syrups, jams, jellies, squashes, and candies. The high pectin concentration ensures excellent gelling properties, reducing the need for additional stabilizers in jam-making. Local entrepreneurs and women's self-help groups already produce Karonda pickles and preserves for domestic markets, highlighting its role in microenterprise development. Scientific studies have also reported potential use of Karonda extracts as natural colorants in the food industry due to their anthocyanin content, and as preservatives owing to their antimicrobial and antioxidant properties.

Nutraceutical and Cosmeceutical Potential

The growing global demand for functional foods and natural health products has opened new pathways for Karonda-based value addition. Its high vitamin C and iron content positions it as a natural supplement against anemia and immune deficiencies, while the presence of flavonoids and triterpenoids supports its incorporation into nutraceutical formulations. Ripe fruit anthocyanins and phenolics also show promise in skincare and cosmeceutical applications, with anti-aging, anti-acne, and skin-whitening effects documented in pharmacological studies. These attributes create opportunities for rural entrepreneurs to connect with niche health-conscious consumer markets, both domestically and internationally.

Market Potential

Market surveys conducted in central and western India show that Karonda-based products command strong seasonal demand, particularly pickles and squashes during the summer months. The shelf-stable nature of processed products like jams and syrups provides opportunities for year-round marketing. With appropriate branding as a "heritage fruit" or "superfruit," Karonda has the potential to attract premium value in urban and export markets. The development of geographical indications (GI tags) for Karonda products in specific regions, similar to what has been achieved with other indigenous fruits, could further strengthen its market identity.

Livelihood and Income Opportunities

Karonda's contribution to rural income security lies in its multipurpose utility and adaptability to small-scale processing. A mature plant yields approximately 5 to 8 kilograms of fruit annually under rainfed conditions, and higher yields are obtained when supplementary irrigation is applied. With a planting density of about 400 plants per hectare, farmers can achieve annual fruit production of 2.0 to 2.5 tonnes per hectare under minimal input conditions. If directed into value addition, this production translates into significant income gains. For instance, a kilogram of fresh fruit sold directly in local markets may fetch ₹30-40, whereas processed products such as pickles and jams can increase returns several fold.

Women's groups and cooperatives play an essential role in this context. In regions where Karonda processing has been promoted through self-help groups, household income diversification has improved, and women's participation in rural enterprises has expanded. Beyond income, these activities contribute to nutritional security by ensuring the local availability of iron- and vitamin C-rich foods.

Integration into Rural Economies

Karonda also offers non-monetary livelihood benefits. Its use as a live fence reduces the cost of maintaining boundaries and protecting fields from grazing animals. The by-products of processing, including fruit residues, can be used as organic manure, thus supporting sustainable farming practices. When cultivated systematically, Karonda adds an additional layer of resilience to farming systems by diversifying income sources, reducing risk from climatic variability, and enhancing food availability.

In summary, the value addition and market potential of Karonda present viable pathways for transforming this underutilized fruit into a driver of rural development. By integrating its processing into cooperative models and linking farmers to local and urban markets, agricultural extension can create sustainable livelihood opportunities while preserving indigenous food traditions.

Agricultural Extension Strategies for Karonda Promotion

The successful mainstreaming of *Carissa carandas* cultivation requires more than its recognition as a hardy and nutritionally valuable fruit. Its integration into rural development frameworks depends on effective agricultural extension approaches that translate scientific knowledge into practical adoption by farmers. Extension services are particularly vital because Karonda has remained a neglected crop with limited commercial orientation, and farmers often lack access to quality planting material, agronomic information, and organized market channels.

One of the first strategies in promoting Karonda cultivation is the dissemination of knowledge about its ecological resilience and nutritional superiority. Farmers in semi-arid and degraded regions need to be made aware that the crop can thrive in soils unsuitable for major horticultural fruits and that it demands minimal irrigation and fertilizer inputs. Extension agents can achieve this through farmer field schools, on-site demonstrations, and participatory rural appraisals that highlight the dual benefits of Karonda household nutrition security and income generation from

value addition.

A second strategy involves strengthening propagation and nursery systems. Since seed propagation results in variability in fruit quality, the development of nurseries supplying vegetatively propagated, true-to-type planting material is critical. Extension programs can train rural youth and women's groups in propagation techniques such as stem cuttings with IBA treatment and air layering, which ensure higher success rates and uniformity. Establishing decentralized community nurseries not only ensures access to quality seedlings but also creates livelihood opportunities within the village economy.

Extension efforts must also emphasize post-harvest handling and value addition. Karonda is highly perishable in its fresh form, but its high pectin and acid content make it ideal for processing. Training programs on small-scale processing such as preparation of pickles, syrups, and jams can help farm households capture greater value from their produce. Cooperative processing units supported by agricultural extension agencies and rural development departments can be pivotal in this regard. Furthermore, demonstrations on hygienic processing, standardization of recipes, and packaging technologies are essential to meet market quality requirements.

Market linkage is another critical dimension of extension. Farmers growing Karonda often lack organized channels for selling either fresh fruit or processed products. Extension agencies can facilitate collective marketing through farmer producer organizations (FPOs) or cooperatives, enabling smallholders to access larger markets and negotiate better prices. Branding initiatives that position Karonda as a "heritage fruit" or a "functional health food" can further enhance its market appeal. Pilot studies have already shown that value-added Karonda products fetch premium prices in urban health food outlets, suggesting that rural producers can benefit substantially from targeted marketing campaigns.

Policy advocacy through extension is equally important. The inclusion of Karonda under horticultural development schemes such as the National Horticulture Mission (NHM) or state-level agroforestry initiatives would provide farmers with subsidies on planting materials, irrigation facilities, and processing equipment. Extension services can act as a bridge between farmers and government schemes, ensuring that marginal communities access these benefits. Credit linkages through self-help groups and microfinance institutions also need to be facilitated to reduce entry barriers for smallholders interested in Karonda cultivation and processing.

Finally, agricultural extension has a social role in promoting community participation and inclusivity. Women's groups, in particular, have shown strong involvement in Karonda processing enterprises. Encouraging their participation not only diversifies income but also empowers women economically and socially. Youth can also be mobilized through training in nursery development, small-scale processing, and digital marketing of Karonda products. Extension programs that integrate gender and youth perspectives are therefore essential for building sustainable Karonda-based livelihoods.

Impacts on Rural Development and Income Security

The integration of *Carissa carandas* into farming systems through organized cultivation and value addition has direct and indirect impacts on rural development. Its greatest contribution lies in the diversification of livelihoods for smallholders, especially those living in semi-arid and marginal regions where conventional fruit crops fail to thrive. The plant's adaptability to drought, poor soils, and minimal input conditions ensures that farmers can cultivate it with relatively low risk, while its nutritional and medicinal properties make it a resource not only for income but also for community health.

At the household level, Karonda serves as a supplementary source of nutrition. The high content of vitamin C and iron addresses micronutrient deficiencies that are widespread in rural India. Women and children, who are particularly vulnerable to anemia, benefit from the regular inclusion of Karonda-based foods in the diet. This nutritional security contributes indirectly to improved productivity, school attendance, and overall well-being in rural communities.

Economically, the crop provides dual opportunities. Fresh fruits harvested from a mature shrub yield between 5 and 8 kilograms annually under rainfed conditions. With a planting density of 400 plants per hectare, yields of two to three tonnes are achievable even with limited inputs. In local markets, the fresh fruit can fetch ₹30-40 per kilogram, while processed products such as pickles, syrups, and jams multiply returns several times. Women-led self-help groups engaged in processing have reported income gains of 25-30 percent over conventional activities, demonstrating the profitability of small-scale Karonda enterprises. Such supplementary incomes enhance household resilience against seasonal income fluctuations common in rainfed agriculture.

The crop also generates wider community benefits. Its adoption as a live fence reduces expenditure on artificial fencing while simultaneously preventing crop damage from grazing animals. Soil conservation on slopes and degraded lands is an additional ecological service that benefits farming systems as a whole. Pollinators attracted by Karonda flowers contribute to improved productivity of other crops grown nearby, enhancing farm biodiversity and ecosystem services.

From a gender perspective, Karonda has been particularly impactful. Women's active involvement in fruit processing and marketing has not only increased household earnings but has also strengthened their role in decision-making and rural entrepreneurship. Youth engagement in nursery development and digital marketing of Karonda products further demonstrates its potential to provide dignified employment opportunities in rural settings, reducing dependence on migration.

At the regional level, scaling up Karonda cultivation has multiplier effects. Cooperatives and farmer producer organizations dealing with Karonda products can stimulate local value chains, create employment in processing and packaging, and establish linkages with urban and export markets. The branding of Karonda as a traditional "superfruit" with high nutritional value also provides opportunities for niche marketing. These developments contribute to the overall rural economy, supporting income diversification and poverty reduction.

In terms of resilience, Karonda reduces the vulnerability of farming households to climatic uncertainties. Its drought tolerance and ability to grow in degraded soils mean that even in years of poor rainfall, farmers can rely on the crop for some level of production and income. This resilience is particularly critical in the context of climate change, where variability in rainfall and temperature is projected to intensify. By stabilizing income and providing nutritional security, Karonda strengthens the adaptive capacity of rural communities.

Challenges and Constraints

Despite its ecological adaptability and nutritional potential, the promotion of *Carissa carandas* faces several challenges that have restricted its transition from a subsistence-level fruit to a commercially significant crop. The foremost constraint is the limited awareness among farmers and consumers about the economic and health benefits of Karonda. In many rural areas, the fruit is still regarded as a hedge plant or a source for household pickles, and its broader potential as a commercial horticultural crop remains underutilized. This lack of awareness is compounded by inadequate research investment and extension outreach, which means that improved production and processing techniques have not reached the majority of smallholders. Propagation also presents difficulties. While seed propagation is simple, it results in wide variability in fruit quality and delays in bearing. Vegetative methods such as cuttings, air layering, and budding are more effective in producing uniform, true-to-type plants, but the availability of skilled nursery workers and affordable planting material is limited. The absence of organized nurseries capable of producing quality seedlings on a large scale continues to be a bottleneck for expanding cultivation.

Post-harvest management is another critical challenge. The fruits are perishable and prone to spoilage if not processed soon after harvesting. In rural areas where cold storage and transport facilities are scarce, a significant proportion of fruit goes to waste. Processing at household or small cooperative level is often carried out with traditional methods that lack standardization, making it difficult to meet food safety regulations and market requirements. Without improved processing infrastructure and training in hygienic practices, farmers are unable to capture the full value addition potential of the crop.

Market constraints further hinder Karonda promotion. The fruit and its products have limited visibility in organized retail chains, and most marketing remains restricted to local haats and seasonal fairs. Farmers receive low prices for fresh fruits due to the absence of aggregation and collective marketing systems. In addition, branding and consumer education efforts that could reposition Karonda as a “functional fruit” with health benefits are almost entirely lacking. This gap in demand generation prevents the establishment of strong value chains that could link producers with urban and export markets.

Policy support for Karonda has also been inadequate. While major fruit crops such as mango, guava, and pomegranate receive attention under government horticultural schemes, Karonda is seldom prioritized. The lack of subsidies for nursery establishment, processing equipment, or market development discourages investment. Similarly, there is

limited research funding for breeding improved varieties or standardizing processing technologies. This institutional neglect has kept Karonda confined to the status of a minor fruit, despite its potential to contribute to nutritional security and rural livelihoods.

Social and cultural perceptions pose additional barriers. In many urban areas, Karonda is not widely consumed, which reduces the incentive for traders to handle the fruit in large volumes. Rural producers often face stigma in marketing lesser-known fruits, leading to a cycle of neglect where consumer unfamiliarity limits supply, and limited supply reinforces low demand.

Recommendations and Future Directions

The advancement of *Carissa carandas* from a neglected fruit to a commercially viable crop requires a comprehensive set of strategies that address production, processing, and market-level challenges while simultaneously promoting its nutritional and ecological benefits. A multi-pronged approach, integrating research, extension, policy, and community participation, is essential for unlocking its full potential.

A first priority is the strengthening of scientific research to support the development of improved cultivars and propagation methods. Current reliance on seed-based propagation leads to variability in fruit quality and delays in bearing. Investment in horticultural research to identify elite genotypes with superior yield, higher nutrient content, and resistance to pests or diseases is necessary. Standardization of vegetative propagation methods, particularly the use of stem cuttings treated with growth regulators, must be integrated into nursery practices. Establishing certified nurseries under public-private partnerships would ensure the availability of true-to-type planting material for farmers at scale.

Post-harvest management requires equal attention. The perishable nature of Karonda fruits limits their shelf life and marketability in fresh form. Small-scale processing technologies that are affordable and easy to adopt at the village level should be disseminated. Extension programs can introduce solar dryers, hygienic pickling and jam-making methods, and improved packaging techniques. Linking these technologies with training on food safety standards and quality certification would enhance consumer confidence and expand the market reach of Karonda-based products.

Value chain development is critical for creating steady demand and fair returns to producers. Farmers’ collectives such as cooperatives or farmer producer organizations (FPOs) can play a central role in aggregation, processing, and branding. Extension services should facilitate the creation of such collectives and build their capacity in marketing, business planning, and contract negotiation. Branding Karonda as a “heritage superfruit” with unique nutritional benefits could help penetrate urban and export markets. Further, promoting geographical indications (GI) for Karonda-based products from specific regions would protect traditional knowledge and strengthen product identity.

Policy support will be instrumental in scaling Karonda cultivation. Inclusion of this fruit under state and national horticulture missions would allow farmers to access

subsidies for planting material, irrigation systems, and processing equipment. Financial institutions should be encouraged to extend credit facilities and microloans to smallholders and women's groups engaged in Karonda enterprises. In addition, rural development programs can integrate Karonda into agroforestry models, watershed projects, and nutritional security schemes, thereby linking ecological services with income generation.

The role of women and youth deserves special emphasis in future strategies. Women-led self-help groups have already demonstrated success in Karonda processing and marketing at the local level. Expanding their participation through structured training, access to credit, and market linkages will enhance rural livelihoods while advancing gender equity. Rural youth can be mobilized in nursery development, digital marketing, and value-added product innovation, reducing migration pressures by creating sustainable employment opportunities within villages.

Finally, Karonda's role in climate resilience should not be overlooked. As a drought-tolerant and low-input crop, it fits well within climate-smart agricultural frameworks. Promoting it in semi-arid and degraded lands can simultaneously improve food security, diversify farm incomes, and restore ecological balance. Pilot demonstration plots established through agricultural universities and extension departments can serve as centers of learning and replication, ensuring that the benefits of Karonda cultivation are widely disseminated.

Conclusion

The case of *Carissa carandas* illustrates how an underutilized fruit, long confined to hedges and household pickles, can be repositioned as a strategic crop for rural development and income security. Its remarkable adaptability to drought, heat, poor soils, and saline conditions distinguishes it from conventional horticultural fruits that demand high inputs and intensive management. At the same time, its nutritional richness particularly in vitamin C, iron, and antioxidants places it among the most valuable functional foods for addressing rural malnutrition and micronutrient deficiencies. Scientific investigations have further validated its medicinal properties, confirming a broad spectrum of pharmacological activities ranging from antimicrobial and anti-inflammatory effects to antidiabetic and cardio protective roles.

When cultivated systematically, Karonda offers tangible economic opportunities. Even under rainfed conditions, its yield potential and multiple harvests provide a steady stream of fruits that can be sold fresh or processed into high-value products such as pickles, jams, syrups, and nutraceuticals. Women's self-help groups and local cooperatives engaged in processing have already demonstrated how Karonda can be transformed into an income-generating enterprise. These initiatives, if scaled up through structured extension and policy support, can diversify rural livelihoods, strengthen household resilience, and empower marginalized communities.

The challenges facing Karonda promotion including variability in seed propagation, lack of nurseries, limited post-harvest infrastructure, weak market linkages, and insufficient policy recognition are significant but not insurmountable. Extension strategies that integrate farmer

training, propagation standardization, processing support, and cooperative marketing can overcome these barriers. Policy inclusion of Karonda in horticultural and nutritional security programs will further ensure that its cultivation is not left to chance but actively supported as part of sustainable rural development.

In conclusion, Karonda has the potential to evolve from a neglected minor fruit into a driver of ecological resilience, nutritional well-being, and economic empowerment in rural India. With coordinated efforts from researchers, extension agents, policymakers, and communities, this hardy shrub can contribute meaningfully to both food security and income diversification in some of the country's most vulnerable agro-ecological zones. The promotion of Karonda cultivation is therefore not only an agricultural opportunity but also a pathway towards inclusive and sustainable rural transformation.

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