Mechanized Coconut Farming: A Pathway to Resilient and Gender-Responsive Agro-Systems

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ABSTRACT

Coconut (*Cocos nucifera L.*) is a vital perennial crop grown in tropical regions, offering significant socio-economic and ecological benefits. However, traditional cultivation practices in coconut farming are increasingly unsustainable due to labor shortages, declining productivity, and gender disparities. Mechanization presents a promising avenue for sustainable coconut cultivation by reducing drudgery, improving operational efficiency, and fostering inclusive development. This paper explores the current mechanization technologies in coconut farming, evaluates their impact on sustainability and gender equity, and offers policy and research recommendations for scaling mechanization in tropical agriculture.

INTRODUCTION

Coconut palms are cultivated extensively across tropical Asia, Africa, and Latin America. India alone contributes over 30% of the world's coconut production, employing more than 10 million people (FAO, 2020). Despite its importance, coconut farming suffers from low productivity and high labor dependence. The average productivity in India is about 9,346 nuts per hectare compared to 13,000–15,000 in countries like the Philippines (CPCRI, 2022). Labor-intensive operations, especially harvesting, de-husking, and transportation, contribute significantly to the production bottlenecks.

Mechanization—the use of machines to perform agricultural operations—has

revolutionized other sectors of agriculture. Its adoption in coconut farming has been relatively slow due to the perennial nature of the crop, tall tree height, and fragmented land holdings. Nonetheless, recent innovations are making it increasingly feasible and accessible.

UNIT OPERATIONS IN COCONUT CULTIVATION:

Unit operations in coconut cultivation cycle are pre-planting, planting and maintenance, harvesting, and post-harvest operations:

1. **Pre-Planting Operations:** In the first stage of establishing a coconut orchard land Clearing is done by removal of weeds, shrubs, and old or unproductive palms. It is followed by soil Preparation through ploughing, levelling, and digging pits for transplanting seedlings. It is also recommended that soil testing and amendment should be done by application of lime or organic matter based on soil analysis.

2. Planting and Maintenance

- **Seedling Production:** Nursery preparation, selection of quality nuts, raising seedlings in polybags or nurseries.
- **Transplanting:** Placement of seedlings in prepared pits at recommended spacing.
- **Manure and Fertilizer Application:** Scheduled application of FYM (farmyard manure), NPK, and micronutrients.
- **Irrigation:** Manual, basin, drip, or micro-irrigation systems depending on location and infrastructure.
- **Weed Management:** Manual weeding or mechanized intercultural operations using tillers or weeders.
- **Mulching:** Application of coconut leaves, husk, or plastic mulch to conserve soil moisture.
- **Pest and Disease Management:** Use of integrated pest management (IPM) strategies including spraying, pheromone traps, and biocontrol.
- **Intercropping and Cover Cropping:** Cultivation of compatible crops like banana, cocoa, or legumes.

3. Harvesting

- **Climbing and Harvesting:** Using traditional climbers or mechanical/electromechanical devices for climbing and sickles, telescopic handles for harvesting coconut.
- **Coconut Collection:** Gathering nuts from the field, either manually or using nut collection trolleys or baskets.

4. Post-Harvest Operations

- **De-Husking:** Removal of husk using traditional iron spike or mechanized de-husking machines.
- **Sorting and Grading:** Based on size, maturity, or intended use (tender, mature, seed nuts).
- **Copra Making:** Drying nuts either using sun drying, smoke kilns, or solar/biofuel hybrid dryers.
- **Oil Extraction:** Using mechanical expellers or traditional bullock-powered setups.
- **Value Addition:** Processing into products like virgin coconut oil (VCO), coconut milk, coir, activated carbon, etc.

- **Waste Utilization:** Conversion of shell, husk, and coir into value-added products like coir mats, pith blocks, or biomass fuel.

Optional (Advanced/Mechanized Systems)

- **Digital Monitoring:** Use of IoT and sensors for irrigation, fertigation, or pest alerts.
- **Precision Farming Tools:** GIS mapping, drone-based nutrient monitoring.

DRUDGERY IN THE TRADITIONAL PRACTICES OF COCONUT CULTIVATION:

Traditional coconut cultivation involves significant drudgery, characterized by hard work, monotony, and time-consuming tasks often performed with traditional tools and inappropriate working postures. This leads to various health hazards and reduced work efficiency for farmers

Harvesting and Climbing: Harvesting coconuts traditionally involves climbing tall trees, a task that is highly labour-intensive and dangerous, leading to human drudgery (Kolhe, 2015; Kerure, 2016). This activity requires significant muscular effort and can result in physical discomfort and injuries (Nayak M.M., 2021). The use of equipment like local sickles and knives for cutting tender coconuts is not suitable and can create calluses in the hand palm (Nayak, 2021). Older farmers, in particular, face difficulties with these manual methods, highlighting the need for drudgery reduction tools or equipment (Kumari A.P, 2013).

Husking: Coconut husking is considered one of the most difficult post-harvest operations (Varghese A. R & Jacob J., 2014). Traditionally, it is done manually using a machete or crowbar, which demands substantial human drudgery, skill, training, and endurance (Varghese A. R & Jacob J., 2014). This process is labour-intensive and time-consuming (Adedipe, 2024).

Processing: Beyond husking, many traditional processing activities are also arduous and time-consuming. For instance, the traditional processing of coconut for virgin coconut oil (VCO) needs to be mechanized to reduce drudgery and enhance efficiency, especially for women's self-help groups involved in this work (Beegum *et al*., 2022). Similarly, the manual grinding of coconut shell, though it can be done, is inefficient compared to mechanical methods that reduce manual labor (Dong, 2013).

Other Labor-Intensive Practices: Overall, many traditional coconut cultivation practices are labour-intensive. This includes tasks that involve significant manual effort and time, contributing to the overall drudgery experienced by farmers (Jaganathan *et al*., 2016). The reliance on traditional methods, particularly in downstream processes like producing black copra and coconut oil, signifies a management approach that has remained largely unchanged (Asthutiirundu *et al*., 2022). The lack of awareness regarding improved tools further exacerbates the drudgery in farming activities.

MECHANIZATION IN COCONUT CULTIVATION

1. **Tree Climbing Devices:** Traditionally coconut is harvested by climbing on the tree without any safety gear, but in recent times various manual coconut climber are introduced. Standing type coconut climber, sitting type coconut climber. Coconut are also harvested by using tactor operated hydraulic powered lifts (Kolhe K. P, 2015). Research is also conducted to develop

motorized coconut tree climber, which reduces the risk for traditional climbers and enables women to participate in harvesting activities. (Kumar *et al*., 2019).

Standing type coconut climber

TNAU Sitting type coconut climbers

Motorised coconut climber

Hydraulic lift

2. **De-husking Machines:** India has developed a range of coconut dehuskers to address the labour-intensive and hazardous nature of traditional dehusking. These include both manual and power-operated machines, each designed to improve efficiency, safety, and ease of use.

- **Manual/Pedal-Operated Dehuskers**: These use levers, pedals, or foot-operated mechanisms to open blades or teeth that grip and peel the husk. They are designed for safety, require less skill, and can process up to 100 coconuts per hour.

- **Bicycle-Based Dehuskers**: Use pedal power to rotate spiked rollers, offering a low-cost, energy-efficient solution.

- **Power-Operated Dehuskers**: Typically use single-phase or three-phase electric motors to drive spiked rollers or cylinders. These machines can process 200–2000 coconuts per hour, with high efficiency and reduced operator fatigue.

Manual and pedal-operated machines are affordable, portable, and suitable for small-scale farmers, but require some physical effort. Power-operated machines offer high capacity, consistent performance, and significant reduction in drudgery, making them ideal for commercial or cooperative use.

3. **Post-harvest Operation**: India offers a variety of machines for oil extraction and copra-making in the coconut value chain, designed to improve efficiency, product quality, and accessibility for both small-scale and commercial producers. Key technologies include mechanical dryers for copra production and a range of oil extraction machines, from compact expellers to integrated processing units.

- **Machines for Copra-Making**: Mechanical copra dryers use indirect heating (agricultural waste, electric, or forced convection); they improve drying speed and copra quality, especially in adverse weather. The electric handy copra dryers are portable, suitable for small-scale/household use; it achieves higher moisture removal than sun drying.

- **Machines for Oil Extraction**: Power-operated oil expellers screw-type expellers for copra is optimized for high oil recovery (up to 84.8% efficiency), it gives low cost per kg. The compact, portable oil extractors small is easy to operate, suitable for small businesses and households and can process small batches. Integrated oil processing machines combines cutting, heating, and pressing thus is low-cost, time-saving, suitable for small-scale operators. Virgin

Coconut Oil (VCO) Cookers are specialized for hot-process VCO extraction, they are standardized by ICAR-CPCRI for quality and export. The optimized VCO extraction machines are designed for rural use; optimized for temperature, pressure, and yield; energy-efficient

- **Supporting Technologies:** Moisture sensors (NIRS) are used for real-time, online monitoring of copra moisture, improving oil yield and process control.
- **Copra Dryers and Oil Expellers:** CPCRI's hybrid solar dryers and TNAU's biomass-fueled copra dryers reduce drying time while maintaining nut quality. Coimbatore industries offer turnkey solutions combining dryers with oil expellers, allowing decentralized processing and higher farmer incomes.
- **Nut Collection and Transport Tools:** Coconut collection trolley and low-volume nut hauler reduce manual lifting. These innovations improve safety and are ideal for smallholder plantations with dense canopy cover.
- **Intercultural Operations:** Rotary tillers and power weeders suited for operation between coconut palms are commercially available. Lightweight mini-tillers available commercially can perform soil aeration, weeding, and mulching, significantly reducing labor cost and drudgery.

GENDER DIMENSIONS IN COCONUT FARMING

Women play a critical role in coconut farming, particularly in post-harvest operations such as de-husking, copra processing, and coir making. Gender-disaggregated data indicates that women constitute approximately 80% of the labor force in coir industry. However, they have limited access to training, equipment, and decision-making processes.

1. Barriers to Mechanization for Women

- Lack of ergonomic design in machines
- Limited financial resources
- Social norms restricting mobility and participation
- Inadequate access to extension services and credit

2. Way Forward for Gender Equity

- Develop women-friendly, lightweight tools and ergonomic machines.
- Gender-sensitive training programs and extension services.
- Special credit lines for women-led cooperatives and SHGs.
- Incentivize adoption through subsidies and recognition for women farmers and innovators.

CONCLUSION:

Coconut cultivation involves a series of labour-intensive unit operations ranging from climbing and harvesting to dehusking, processing, and value addition. Many of these tasks are traditionally performed using manual methods that are physically demanding, time consuming, and often unsafe. The persistent challenges of labour scarcity, increasing production costs, and occupational drudgery highlight the urgent need for appropriate mechanization across different stages of coconut farming.

Mechanization offers a practical pathway to improve operational efficiency, reduce physical strain on workers, and enhance productivity in coconut-based production systems. Tools such as improved coconut climbers, dehusking devices, processing equipment, and small-scale value-addition machines can significantly reduce the

workload associated with traditional practices. By minimizing drudgery and improving work ergonomics, mechanization can make coconut farming more attractive, particularly for younger generations.

Equally important is the need to integrate gender-responsive strategies in the design, dissemination, and adoption of these technologies. Women contribute substantially to several post-harvest and processing activities in the coconut value chain, yet many existing tools and machines are not designed considering their ergonomic needs and working conditions. Developing lightweight, safe, and user-friendly technologies, along with providing skill training and institutional support, can enhance women's participation and productivity in coconut enterprises.

In the long term, the adoption of inclusive and context-appropriate mechanization will strengthen the sustainability and resilience of coconut agro-systems. By addressing labour constraints, reducing drudgery, and promoting gender equity, mechanization can transform coconut farming into a more efficient, profitable, and socially inclusive enterprise for farming communities.

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