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### Assessment of Biomass residues from Arecanut and Eucalyptus Plantations in Uttara Kannada District

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#### Abstract

Biomass, a key renewable energy source, derives significant contributions from industrial, agricultural and forestry residues. In Uttara Kannada district, Arecanut and Eucalyptus plantations generate substantial amounts of biomass waste, with only a small portion being utilized for mulching and composting, while most is burned for disposal. Arecanut plantations yield between 3.77 to 8.04 tons of waste per acre annually, comprising husks, leaves, poles, and sheaths. sheaths are utilized to greater extent of 66.67 to 69.23 per cent, with the remainder disposed of through a combination of burning (25-28%), composting (25.49-32.14%), mulching (14.28-25%) and construction uses (18.75-28%). In Eucalyptus plantations, poles are primarily used for the paper industry, other residues such as leaves, bark, branches, and twigs are often left unused or burned. It generates 3.16 to 5.28 tons of waste per acre annually. Small twigs are nearly fully utilized (93.72-100%), but bark and leaf usage remains more variable. Bark utilization ranges from 13.41 to 65.31 per cent, while leaves are underutilized at 4.09 to 12.96 per cent. Burning remains the predominant method of disposal, particularly for bark and leaves, with rates ranging from 53 to 68.24 per cent. The underutilization of biomass residues, particularly Eucalyptus and Arecanut residues offered a significant opportunity for improved resource management and alternative energy use in the district.

**Keywords:** Biomass residues, waste utilization, resource efficiency, eucalyptus, arecanut

#### Introduction

India remains a predominantly agro-based nation, with about 70 percent of its rural households depending on agriculture for their livelihood (Prasad *et al.*, 2020) <sup>[15]</sup>. Biomass, a renewable energy source, is generated from various human and natural activities. It includes materials such as industrial waste, agricultural byproducts (e.g., paddy straw, rice husk, groundnut shells, and sugarcane bagasse), and forestry residues like leaves, bark, and wood remnants (Thorenz *et al.*, 2018) <sup>[18]</sup>. The biomass left over from agricultural and forestry operations are often referred to as agroforestry waste (Nunes, 2020) <sup>[14]</sup>. Improper disposal of these residues has become a significant environmental issue globally (Gupta *et al.*, 2022) <sup>[9]</sup>. Conventional waste management methods, including thermal treatment, landfills, and composting, can lead to adverse effects such as the emission of CO, CO<sub>2</sub>, NOx,

SOx, ash, unpleasant odours, and groundwater contamination (Ferronato and Torretta, 2019) <sup>[7]</sup>. Furthermore, as waste accumulates, disposal costs rise, highlighting the need for sustainable waste-to-resource conversion methods.

Biomass is not only renewable and widely available but also carbon-neutral, with the potential to generate substantial employment opportunities in rural areas. Biomass currently accounts for approximately 32 per cent of India's total primary energy consumption. To leverage this potential, the Ministry of New and Renewable Energy, Government of India has initiated several programs to promote the adoption of efficient technologies across various sectors, aiming to maximize benefits (Anon., 2021) <sup>[11]</sup>.

Eucalyptus belongs to the family Myrtaceae and comprises more than 700 species, most of which are native to Australia, with a few species occurring naturally in Indonesia, Papua

New Guinea and the Philippines. Due to their fast growth, adaptability to diverse climatic conditions and high productivity, Eucalyptus species have been widely introduced and cultivated in tropical and subtropical regions across the world. In India, Eucalyptus is extensively planted in states such as Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Kerala, Punjab, Haryana, and Uttar Pradesh for timber, pulpwood, fuelwood and industrial raw material purposes. Among the commonly cultivated species are *Eucalyptus tereticornis*, *Eucalyptus camaldulensis*, *Eucalyptus grandis*, and *Eucalyptus pellita*. The species are valued for their rapid biomass accumulation and ability to meet the growing demand of the pulp and paper industry Doughty (2000) <sup>[6]</sup>, Coppen (2002) <sup>[4]</sup>. In Uttara Kannada district, West Coast Paper Mills in Dandeli has established Eucalyptus plantations to meet the raw material needs of the pulp and paper industry. While the debarked round wood logs are used for pulping, other residues such as leaves, bark, branches, and twigs are often left unused or burned. According to De Souza *et al.* (2016) <sup>[5]</sup>, a commercial Eucalyptus clone consists of approximately 12 per cent roots, 8 per cent bark, 2–5 per cent leaves, and 4–8 per cent branches. Additionally, around 23 per cent of a harvested Eucalyptus tree is classified as waste, including bark (12%), branches (6%), and leaves (5%). Bhadake (2019) <sup>[2]</sup> conducted a survey documenting Eucalyptus biomass residue utilization pattern. The study revealed that beyond using poles, farmers in the area predominantly use twigs, branches, and bark waste as firewood, with most of the biomass waste being burned post-harvest without further repurposing. Harvest residues from Eucalyptus plantations, including bark, leaves, branches, and twigs, represent an important source of biomass that can be utilized for bioenergy production and nutrient recycling. Retention and proper management of these residues can improve soil fertility, enhance nutrient cycling, and increase plantation productivity over successive rotations. However, in many plantation systems, a large proportion of these residues remains underutilized or is disposed of through burning, leading to resource losses and environmental concerns. Therefore, efficient residue management practices are essential for improving the sustainability of Eucalyptus-based production systems Rocha *et al.* (2016) <sup>[16]</sup>, Gonzalez *et al.* (2023) <sup>[8]</sup>.

The Areca palm (*Areca catechu* L.) produces the widely used Arecanut, also known as betel nut. This nut is a vital commercial crop in Southeast Asia, with cultivation practices dating back to Vedic times and historical applications in Ayurvedic and veterinary medicine. Arecanut, or supari, is cultivated across several countries, including India, China, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, the Philippines, and Sri Lanka. India is the global leader in Arecanut production, with major cultivation centred in Karnataka, Kerala, and Assam. Other regions, such as Tamil

Nadu, West Bengal, Maharashtra, Andhra Pradesh, Meghalaya, Goa, Tripura, Puducherry, Mizoram, and the Andaman and Nicobar Islands, also grow Arecanut, though to a lesser extent. Karnataka, Kerala, and Assam together account for about 83 per cent of the total cultivation area and production, with Karnataka being the top producer, followed by Kerala and Assam. Notably, the area dedicated to Arecanut cultivation has expanded more rapidly in Shivamogga district compared to Dakshina Kannada and Uttara Kannada districts. Arecanut cultivation generates significant biomass residues, including husks, leaves, poles and sheaths. While a portion of these residues is utilized for practices like mulching, composting, and construction, a majority are often burned, leading to inefficient use of resources (Ramappa, 2013). These residues can be utilized in the production of bio composites, biodegradable packaging materials, biochar, briquettes and organic manure. Wet Arecanut sheaths are commonly used as cattle fodder, while dry sheaths serve as fuel for heating water, cooking, and producing manure (Shashikumar *et al.*, 2016) <sup>[17]</sup>. Effective utilization of arecanut biomass not only reduces environmental problems associated with open burning and improper disposal but also contributes to resource conservation and sustainable rural development. The conversion of arecanut residues into bioenergy products offers an eco-friendly waste management strategy while providing additional income opportunities for farmers. Recent studies have emphasized the importance of promoting circular bioeconomy approaches through the efficient utilization of agricultural biomass residues Madyaratri *et al.* (2025) <sup>[11]</sup>, Nizori *et al.* (2026) <sup>[13]</sup>.

Documentation of biomass availability will enable better planning and management, supporting initiatives to integrate these residues into renewable energy production. This approach can reduce dependency on conventional resources, mitigate environmental impacts, and unlock the full potential of biomass as a sustainable resource for the district.

## Materials and Methods

The study was conducted in Mundgod, Sirsi and Siddapur village of Uttara Kannada district during the year 2023 to 2024 within already existing Eucalyptus and Arecanut plantations. A comprehensive list of all biomass residues generated in these plantations, along with their disposal systems, was compiled. The survey was conducted using semi-structured questionnaires, personal interviews, and physical observations. Data were collected from 30 respondents, categorized based on landholding size into four groups: large (above 5 acres), medium (3 to 5 acres), small (1.5 to 3 acres) and marginal (up to 1 acre). The primary focus of the survey was to identify the types of wastes generated by the plantations, determine the volume/quantity of biomass produced, and examine waste management practices, including any reuse or recycling efforts.

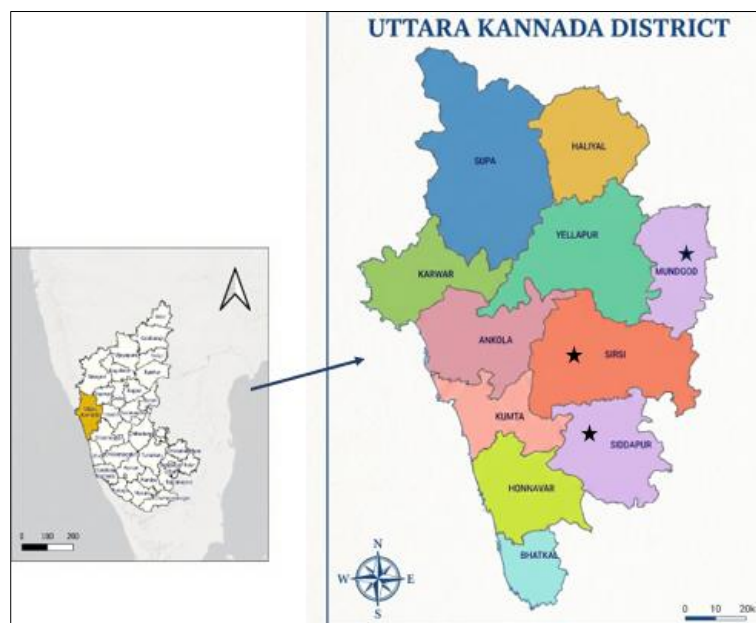


Fig 1: Map of the study area

## Results and Discussion

### Arecanut plantation biomass waste availability and its usage pattern

Table 1 illustrates the availability of Arecanut biomass residues in relation to varying landholding sizes, detailing the annual generation of residues in tons per acre. The residues are categorized into four types: husks, leaves, sheaths, and dead poles. The table also provides an overview of the utilization patterns and disposal methods for these biomass residues.

The average biomass waste generated in an Arecanut plantation range from 3.77 to 8.04 tonnes per acre per year. Small landholdings produce the most biomass residues at 8.04 tonnes per acre per year, followed by medium landholdings at 7.00 tonnes per acre per year. Large landholdings generate less at 3.98 tonnes per acre per year, while marginal landholdings have the lowest at 3.77 tonnes per acre per year. This may be due to higher crop density, as they maximize the use of limited space by planting crops closely together, resulting in more biomass produced per acre. Conversely, larger farms, which are often more mechanized, tend to produce lower biomass residues per acre due to their less intensive management approaches. Hussain *et al.* (2008) <sup>[10]</sup> reported that Arecanut biomass waste in small land holdings ranged from 12.54 to 15.51 tonnes per acre per year. This indicates a significantly higher biomass residue generation in smaller land holding compared to other land holding categories.

This study explores the primary types of waste encountered in Arecanut cultivation. Arecanut biomass residues are categorized into husk, leaves, sheath and poles. Leaves and husks are fully utilized 100 per cent across all landholdings. This may be due to easy utilization for composting, which helps improve soil fertility and manage waste effectively. Their high utility and ease of integration into various waste management practices ensure that they are fully used. Poles are also fully utilized in large, medium, and small holdings, this may be due to poles used for various purposes such as building frameworks and fencing, supporting plants. but

slightly less in marginal holdings at 88.89 per cent, due to less availability. The utilization of sheaths varies, with large holdings not using them at all, while medium and small holdings utilize them at 66.67 per cent and 69.23 per cent, respectively. Large landholdings were not collecting sheaths or other residues manually due to their mechanized farming methods. As a result, residues like sheaths were less utilized and the cost of processing sheaths is often higher than their benefits, leading to their disposal instead of being repurposed.

Composting is most prevalent in marginal holdings (32.14%) and large holdings (31.25%), followed by medium (28.00%) and small (25.49%) holdings. This suggests that farms often rely on composting to improve soil fertility and manage residues effectively. The percentage of residue use for composting varies across different landholdings; this may be due to differences in residue availability and waste management practices. Bhuyan *et al.* (2018) <sup>[3]</sup> examined the use of Arecanut sheaths for compost production and noted that a significant portion of the biomass was burned off.

Burning was consistently practiced across all holdings, with medium holdings burning 28.00 per cent of their residues, while large, small, and marginal holdings had a burning rate of 25.00 per cent. Burning is a quick, straightforward and inexpensive method for residue disposal that requires minimal labour and provides an easy solution for disposing of agro-waste. Shashikumar *et al.* (2016) <sup>[17]</sup> noted that Arecanut growers utilized biomass waste, such as sheaths, for manure and as fuel for water heating.

Mulching was most common in large holdings (25.00%), followed by small (23.52%), marginal (21.42%) and medium (14.28%) holdings. The variations in mulching practices may be due to differing priorities in residue usage or resource allocation.

Biomass for construction purposes was used most in medium holdings (28.00%), followed by small (25.49%), marginal (21.42%) and least in large holdings (18.75%). This may be due to large landholding farmers focusing on mechanized operations and streamlined processes, making them less

reliant on on-farm biomass for building purposes compared to smaller and medium-sized farms.

### Eucalyptus plantation biomass waste availability and its usage pattern

Table 2 illustrates the availability of Eucalyptus biomass residues across varying landholding sizes, detailing the annual generation of residues in tons per acre. The residues are categorized into leaves, bark, branches, and small twigs. The table also provides an overview of the utilization patterns and disposal methods for these biomass residues.

The average biomass residues per acre ranged from 3.16 to 5.28 tonnes per acre per year. Marginal holdings had the highest residues at 5.28 tonnes per acre per year, followed by small holdings at 4.33 tonnes per acre per year, large holdings at 3.83 and medium holdings with the lowest at 3.16 tonnes per acre per year. This may be due to higher crop density, as they maximize the use of limited space by planting crops closely together, resulting in more biomass produced per acre. Conversely, large and medium farms, which are often more mechanized, tend to produce lower biomass residues

per acre due to their less intensive management approaches. The study identifies four primary types of waste generated from Eucalyptus cultivation based on a survey of thirty Eucalyptus farmers: leaves, branches, dead poles and bark. Eucalyptus leaves are used less frequently, ranging from 4.09 per cent to 12.96 per cent across different landholdings. This lower utilization is attributed to the farmers in Uttara Kannada being less familiar with essential oil distillation from Eucalyptus leaves. As a result, leaves are underutilized compared to other parts of the plant, such as bark and sticks (Bhadake, 2019) <sup>[2]</sup>.

Eucalyptus sticks were used the most in marginal landholdings at 100 per cent, followed by large holdings at 97.35 per cent, medium holdings at 95.61 per cent and the lowest usage in small holdings at 93.72 per cent. This may be due to poles used for various purposes such as building frameworks and fencing, supporting plants. Eucalyptus bark had its highest usage in marginal landholdings at 65.31 per cent, followed by small holdings at 43.98 per cent, large holdings at 15.87 per cent and the lowest in medium holdings at 13.41 per cent.

**Table 1:** Documentation of Arecanut biomass residues in Uttara Kannada

| Category of land holdings (acre) | Average land holdings of farmer (acre) | Range of land holdings of farmer (acre) | Age of plantation (yrs) | Quantity of biomass residues generated (t/yr) | Biomass residues generated (t/acre/yr) | Arecanut tree parts usage (%) |        |       |        | Biomass residues disposal method followed by farmers (%) |            |              |          |
|----------------------------------|----------------------------------------|-----------------------------------------|-------------------------|-----------------------------------------------|----------------------------------------|-------------------------------|--------|-------|--------|----------------------------------------------------------|------------|--------------|----------|
|                                  |                                        |                                         |                         |                                               |                                        | Husk                          | leaves | Pole  | Sheath | Burning                                                  | Composting | Construction | Mulching |
| Large (>5)                       | 8.66                                   | 5-20                                    | 22.24                   | 8-50                                          | 3.98                                   | 100                           | 100    | 100   | 0.00   | 25.00                                                    | 31.25      | 18.75        | 25.00    |
| Medium (3-5)                     | 3.33                                   | 3-4                                     | 11.66                   | 8-15                                          | 7.00                                   | 100                           | 100    | 100   | 66.67  | 28.00                                                    | 28.00      | 28.00        | 14.28    |
| Small (1.5-3)                    | 1.73                                   | 1.5-2                                   | 28.15                   | 8-50                                          | 8.04                                   | 100                           | 100    | 100   | 69.23  | 25.49                                                    | 25.49      | 25.49        | 23.52    |
| Marginal (up to 1)               | 1.0                                    | Up to 1                                 | 17.33                   | 5-40                                          | 3.77                                   | 100                           | 100    | 88.89 | 66.67  | 25.00                                                    | 32.14      | 21.42        | 21.42    |

A similar study conducted by Bhadake (2019) <sup>[2]</sup>, who observed various types of residues, including twigs, branches, leaves, and bark, with average biomass waste ranging from 10.2 to 12.8 (t/acre/year). Beyond using the poles, farmers in the study area also use twigs, branches, and bark waste from Eucalyptus plantations as firewood. However, nearly all farmers burn the biomass waste after the harvest, without repurposing it for any other use. Nagar *et al.* (2017) <sup>[12]</sup> recommends that Eucalyptus leaf wastes is suitable for making vermicompost. De Souza *et al.* (2016) <sup>[4]</sup>

concluded that a commercial Eucalyptus clone has about 12 per cent of roots, followed by bark at 8 per cent, leaves at 2 to 5 per cent, and branches at 4 to 8 per cent. They also reported that in Eucalyptus spp., the roots represent 9.4 per cent of the tree, followed by branches at 9.0 per cent, bark at 5.6 per cent, and leaves at 4.5 per cent. Regarding the generation of residue after harvest, approximately 23 per cent of a Eucalyptus tree becomes waste, with bark accounting for a 12 per cent share, followed by branches at 6 per cent and leaves at 5 per cent.

**Table 2:** Documentation of Eucalyptus biomass residues in Uttara Kannada

| Category of land holdings (acre) | Average land holding of farmer (acre) | Range of land holding of farmer (acre) | Range of quantity of residues (t/yr) | Average biomass residues generated (t/acre/yr) | Eucalyptus tree parts usage (%) |       |       | Disposal method used by farmers (%) |         |          |
|----------------------------------|---------------------------------------|----------------------------------------|--------------------------------------|------------------------------------------------|---------------------------------|-------|-------|-------------------------------------|---------|----------|
|                                  |                                       |                                        |                                      |                                                | Bark                            | Leaf  | Stick | Burning                             | Dumping | Mulching |
| Large (5-7)                      | 6.58                                  | 5.0-6.5                                | 19-24                                | 3.83                                           | 15.87                           | 12.96 | 97.35 | 53.50                               | 35.08   | 20.00    |
| Medium (3-5)                     | 3.87                                  | 3.5-4.0                                | 12-15                                | 3.16                                           | 13.41                           | 5.17  | 95.61 | 59.32                               | 28.00   | 12.68    |
| Small (1.5-3)                    | 2.20                                  | 1.5-2.5                                | 7.0-12                               | 4.33                                           | 43.98                           | 7.39  | 93.72 | 53.00                               | 25.49   | 21.08    |
| Marginal (upto 1)                | 1.00                                  | Upto 1                                 | 5.38                                 | 5.28                                           | 65.31                           | 4.09  | 100   | 68.24                               | 19.14   | 12.41    |

### Conclusion

This investigation underscores the necessity for improved waste management practices in Arecanut and Eucalyptus cultivation, given the substantial biomass waste produced in both types of plantations. Briquetting emerges as a promising

method for enhancing the utilization of this abundant waste. Biomass energy remains a preferred alternative for meeting rural heating needs in many developing countries. This preference is attributed to its numerous benefits, including the potential to stimulate rural bio-economic activities by

creating new markets and job opportunities. It also offers environmental advantages such as carbon neutrality, improved waste management, and enhanced energy independence. Additionally, biomass energy promotes the efficient use of locally available resources, contributing to more sustainable living conditions.

The findings of the present study indicate that a considerable proportion of biomass residues generated from Arecanut and Eucalyptus plantations remains underutilized or is disposed of through open burning. Such practices not only lead to the loss of valuable biomass resources but also contribute to environmental pollution. Therefore, adopting appropriate technologies for biomass collection, processing, and utilization can significantly improve resource-use efficiency and provide additional income opportunities for farmers. Furthermore, the development of biomass-based enterprises such as briquetting, composting, biochar production, and value-added products can support rural livelihoods and promote sustainable agricultural and forestry systems. Effective utilization of plantation residues will contribute to the circular bioeconomy by transforming waste into valuable resources while reducing environmental impacts and enhancing the long-term sustainability of plantation-based production systems.

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