

## International Journal of Agriculture Extension and Social Development

Volume 9; Issue 8; August 2026; Page No. 104-108

Received: 24-05-2026  
Accepted: 28-06-2026

Indexed Journal  
Peer Reviewed Journal

### Farm waste management practices and knowledge on carbon emission and carbon sequestration among farming community

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DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i8b.3992>

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#### Abstract

The study aimed to document existing farm waste management practices adopted by farmers and assess their knowledge and awareness regarding carbon emission and carbon sequestration. A multistage purposive random sampling technique was employed to select 300 farmers from five villages. Primary data were collected using a structured interview schedule and analyzed using frequency, percentage, Weighted Mean Score, and Knowledge Index. The findings revealed that farming households generated diverse crop, livestock, biodegradable, and non-biodegradable wastes. Crop residues, particularly leaf litter, corn stalks, and cobs, were commonly generated, while livestock waste mainly comprised dung and urine. Among the existing farm waste management practices, mulching (29.13%) and the use of crop residues as animal feed (29.00%) were the most widely adopted, followed by manure preparation (27.13%) and composting (25.27%). Nevertheless, residue burning was practiced by 15.07 per cent of the respondents, indicating the continued use of environmentally harmful disposal methods. Farmers demonstrated comparatively better knowledge of conventional farm waste management practices, with a Knowledge Index of 64.48 per cent, whereas their knowledge of carbon emission and carbon sequestration in agriculture was low, with a Knowledge Index of 28.31 per cent. The overall Knowledge Index was 41.11 per cent, indicating limited awareness of the scientific and climate-related dimensions of farm waste management. The study highlights the need for targeted extension programmes, practical training, and location-specific awareness initiatives to strengthen farmers' understanding of sustainable waste utilization and promote climate-smart agricultural practices.

**Keywords:** Farm waste management, carbon emission, carbon sequestration, knowledge and awareness, intervention

#### Introduction

Agriculture is the backbone of India's rural economy, providing livelihoods to millions of farming households. Along with food production, agricultural activities generate large quantities of organic and inorganic residues, collectively known as farm waste, including crop residues, livestock waste, and other agricultural by-products. Improper management of these wastes has become a major environmental and resource management concern, affecting sustainability and efficient resource utilization (Koul *et al.*, 2022) <sup>[8]</sup>. Farm waste includes crop residues, livestock waste, bedding materials, food scraps, and processing residues (Mishra and Kameswari, 2025) <sup>[10]</sup>. Crop residues, which are the plant parts remaining after harvest, constitute one of the largest agricultural waste streams worldwide (bikkannavar *et al.*, 2024) <sup>[3]</sup>. In India, rapid population growth and agricultural intensification have significantly increased the generation of bio-waste, while waste-management systems

have not expanded proportionately, creating serious environmental challenges (Rao *et al.*, 2024) <sup>[11]</sup>.

Farm waste management plays a critical role in environmental quality and carbon dynamics. Unsustainable disposal methods such as open burning, indiscriminate dumping, and uncontrolled decomposition contribute to air, soil, and water pollution and increase greenhouse gas emissions (Lackner and Besharati, 2025) <sup>[9]</sup>. Crop residue burning, particularly in north-western India, has been associated with severe air pollution, depletion of soil organic matter, and reduced soil productivity. Crop residue burning is a major contributor to greenhouse gas emissions and environmental pollution, highlighting its significant role in increasing carbon emissions (Venkatramanan *et al.*, 2021) <sup>[15]</sup>. Likewise, stubble burning, although a quick method of field clearance, destroys beneficial soil microorganisms and releases substantial quantities of carbon dioxide and methane (Singh *et al.*, 2025) <sup>[13]</sup>. Intensive use of chemical inputs

further increases the carbon footprint when crop residues are poorly managed, while residue incorporation can improve soil fertility and carbon stocks, although its effectiveness depends on residue quality and management conditions (Komorowska *et al.*, 2024) <sup>[7]</sup>.

Sustainable farm waste management offers an effective alternative by converting agricultural waste into valuable resources. Composting and farmyard manure improve soil fertility, enhance soil structure, reduce dependence on chemical fertilizers, and promote soil carbon sequestration (Zainudin *et al.*, 2024) <sup>[16]</sup>. Practices such as residue incorporation, reduced tillage, residue-based nutrient recycling, and biogas production further improve soil organic carbon, enhance resource-use efficiency, and support circular economy approaches in agriculture (Koul *et al.*, 2022) <sup>[8]</sup>. Similarly, in-situ residue incorporation, surface retention, and ex-situ composting have been recognized as sustainable strategies for improving soil health while reducing residue burning and greenhouse gas emissions (Shinde *et al.*, 2022) <sup>[12]</sup>.

Despite these benefits, the adoption of sustainable farm waste management largely depends on farmers' awareness and understanding of carbon emission and carbon sequestration. Information on farmers' knowledge of these climate-related concepts remains limited, particularly in developing countries. Therefore, assessing existing farm waste management practices alongside farmers' knowledge of carbon emission and carbon sequestration is essential for designing effective extension programs and promoting climate-smart agriculture. Against this background, the present study documents farm waste management practices, assesses farmers' knowledge regarding carbon emission and carbon sequestration, and evaluates the effectiveness of educational modules in improving awareness and encouraging environmentally sustainable farming practices.

## Objectives

1. To document the existing farm waste management practices adopted by the farmers.
2. To study the level of knowledge and awareness regarding carbon emission and carbon sequestration.

## Methodology

The present study was conducted in Dharwad Taluk of Dharwad district, Karnataka. A multistage purposive random sampling technique was adopted for the selection of respondents. Five villages, namely Timmapur, Pudakalakatti, Mangalagatti, Mandihal, and Karadigudda, were selected for the study, and 60 farmers were randomly selected from each village, resulting in a total sample of 300 respondents. For intervention, a sub-sample of 30 farmers was selected from the total respondents to assess the effectiveness of the educational modules developed to improve farmers' knowledge regarding carbon emission, carbon sequestration, and sustainable farm waste management practices. Primary data was collected from the selected respondents. The collected data was analysed using appropriate statistical techniques, including frequency, percentage, Weighted Mean Score (WMS), Knowledge Index (KI), and the paired *t*-test, in accordance with the objectives of the study.

## Results and Discussion

**Table 1:** Demographic profile of the respondents (n=300)

| Sl. No. | Variable              | Category               | Frequency   |
|---------|-----------------------|------------------------|-------------|
| 1.      | Age                   | Below 30               | 104 (34.67) |
|         |                       | Middle 31-50           | 142 (47.33) |
|         |                       | Above 50 old           | 54 (18.00)  |
| 2.      | Education             | Illiterate             | 28 (9.33%)  |
|         |                       | Primary education      | 75(25.00%)  |
|         |                       | Middle school          | 67(22.33%)  |
|         |                       | High school            | 77(25.67%)  |
|         |                       | PUC / Higher secondary | 33(11.00%)  |
| 3.      | Marital status        | Graduate and above     | 20 (6.67%)  |
|         |                       | Married                | 203 (67.67) |
|         |                       | Unmarried              | 96 (32.00)  |
|         |                       | Widow                  | 1 (0.33)    |
|         |                       | Nuclear                | 126 (42.00) |
| 4.      | Type of family        | Joint                  | 123 (41.00) |
|         |                       | Extended               | 51 (17.00)  |
|         |                       | Agriculture            | 292 (97.33) |
| 5.      | Main occupation       | Business               | 5 (1.67)    |
|         |                       | Private job            | 3 (1.00)    |
|         |                       | Agriculture & allied   | 151(50.42)  |
| 6.      | Subsidiary occupation | Business               | 120 (40.00) |
|         |                       | Private job            | 29 (9.58)   |
|         |                       | Low                    | 80 (26.67)  |
| 7.      | Income                | Medium                 | 178 (59.33) |
|         |                       | High                   | 42 (14.00)  |
|         |                       | Landless               | 0 (0.00)    |
| 8.      | Landholding Category  | Marginal Farmers       | 92 (30.67)  |
|         |                       | Small Farmers          | 136 (45.33) |
|         |                       | Large Farmers          | 72 (24.00)  |
| 9.      | Experience in Farming | No Experience          | 0 (0.00)    |
|         |                       | Less than 2 years      | 8 (2.67)    |
|         |                       | 2-4 years              | 25 (8.33)   |
|         |                       | 4-6 years              | 63 (21.00)  |
|         |                       | More than 6 years      | 204 (68.00) |

**Note:** Figures in Parenthesis represents percentage

The socio-economic profile of the respondents is presented in Table 1. The results showed that 47.33 per cent respondents belonged to the middle-age group, followed by the 34.67 per cent respondents below 30 years and 18.00 per cent respondents above 50 years. The higher proportion of middle-aged respondents indicated that farmers in their active working age played a major role in farming and household decision-making. Similar findings were reported by Gondali and Bose (2019) <sup>[4]</sup>.

With respect to education, 25.67 per cent respondents had completed high school, followed by 25.00 per cent with primary education and 22.33 per cent with middle school education. This indicated that most respondents had basic formal education, which could help in understanding and adopting sustainable farm waste management practices. Similar findings were reported by Arvind *et al.*, (2025) <sup>[2]</sup>, while Angadi and Belli (2020) <sup>[1]</sup> reported that education had a positive influence on the adoption of climate-smart agricultural technologies, whereas the majority of the respondents 67.67 per cent were married. Regarding family type most of the respondents 42.00 per cent belonged to nuclear families, followed by 41.00 per cent from joint families.

About 97.33 per cent respondents' main occupation is agriculture, while 50.42 per cent respondents had agriculture and allied activities as their subsidiary occupation. This showed that agriculture was the major source of livelihood and that farm waste management formed an important part of the farming system. Similar observations were reported by Bikkannavar *et al.*, (2024) <sup>[3]</sup>.

The majority of the respondents 59.33 per cent belonged to the medium-income category. Further, 45.33 per cent Respondents belonged to the small farmer category and 68.00 per cent respondents had more than six years of farming experience. This indicated that the respondents had good practical farming experience; however, continuous technical guidance and extension support would still be necessary to promote climate-friendly farm waste management practices. Similar findings were reported by Jamanal *et al.*, (2020) <sup>[5]</sup>.

**Table 2:** Seasonal cropping pattern of the selected respondents

| Crops      | Kharif Season (%) | Rabi Season (%) |
|------------|-------------------|-----------------|
| Sugarcane  | 10.33             | 0               |
| Cotton     | 10.33             | 0               |
| Paddy      | 7.33              | 0               |
| Soybean    | 9.33              | 0               |
| Jowar      | 13.67             | 20.67           |
| Maize      | 60                | 8.67            |
| Wheat      | 0                 | 24.67           |
| Onion      | 0.67              | 0               |
| Chickpea   | 0                 | 45.67           |
| Cowpea     | 1                 | 0               |
| Green pea  | 1.67              | 0               |
| Black gram | 38.33             | 1.33            |
| Horse gram | 0                 | 3.33            |
| Green gram | 24.33             | 6.33            |
| Groundnut  | 23.67             | 0               |
| Vegetables | 2.67              | 0               |
| Moth bean  | 0                 | 0.67            |

The seasonal cropping pattern of the respondents is presented in Table 2. The results showed that maize (60.00%) was the major crop grown during the Kharif season, followed by black gram (38.33%), green gram (24.33%), groundnut (23.67%), jowar (13.67%), cotton (10.33%), sugarcane (10.33%), soybean (9.33%), and paddy (7.33%), while the remaining crops were grown by a smaller proportion of respondents. During the Rabi season, chickpea (45.67%) was the predominant crop, followed by wheat (24.67%), jowar (20.67%), and maize (8.67%), whereas the other crops occupied comparatively smaller areas. The predominance of the maize–chickpea cropping system reflected the typical cropping pattern of the Northern Transition Zone of Karnataka under rainfed conditions. The cultivation of cereals, pulses, oilseeds, and commercial crops indicated that the respondents followed a diversified farming system, which helped reduce production risk and improve resource-use efficiency, as reported by Felix and Ramappa (2023). This diversified cropping pattern also generated a wide variety of crop residues, such as stalks, cobs, leaf litter, and pulse haulms, creating greater opportunities for residue recycling, composting, mulching, and soil incorporation. Therefore, promoting crop-specific farm waste management practices could improve the resource utilization while reducing environmental pollution.

**Table 3:** Different type of waste generated by the selected respondents (n=300)

| Sl. No. | Type of Farm Waste      | Farm Waste Component | Percentage |
|---------|-------------------------|----------------------|------------|
| 1.      | Crop Waste              | Leaf litters         | 85.00      |
|         |                         | Corn stalks          | 68.67      |
|         |                         | Husk                 | 7.33       |
|         |                         | Cotton sticks        | 10.33      |
|         |                         | Sugarcane trash      | 10.33      |
|         |                         | Wheat straw          | 24.67      |
|         |                         | Cobs                 | 68.67      |
|         |                         | Others               | 64.00      |
| 2.      | Livestock Waste         | Dung                 | 73.33      |
|         |                         | Urine                | 73.33      |
|         |                         | Poultry litter       | 24.67      |
|         |                         | Other                | 29.33      |
| 3.      | Biodegradable Waste     | Vegetable waste      | 100.00     |
|         |                         | Fruits waste         | 92.00      |
|         |                         | Paper waste          | 60.33      |
|         |                         | Other                | 7.67       |
| 4.      | Non-Biodegradable Waste | E-waste              | 4.33       |
|         |                         | Plastic waste        | 78.33      |
|         |                         | Other                | 6.00       |

The findings revealed that the respondents generated a diverse range of crop, livestock, biodegradable, and non-biodegradable waste. Among the crop waste, leaf litter 85.00 per cent was the most commonly generated waste, followed by corn stalks 68.67 per cent, cobs 68.67 per cent, other crop residues 64.00 per cent, and wheat straw 24.67 per cent, whereas cotton sticks 10.33 per cent, sugarcane trash 10.33 per cent, and husk 7.33 per cent was generated by a relatively smaller proportion of respondents. The predominance of leaf litter, corn stalks, and cobs could be attributed to the widespread cultivation of cereal crops and the generation of residues during harvesting and post-harvest operations. With regard to livestock waste, dung and urine 73.33 per cent were the major wastes generated, while poultry litter 24.67 per cent and other livestock waste 29.33 per cent were reported by comparatively fewer respondents, reflecting the importance of livestock as an integral component of farming systems. Among biodegradable waste, vegetable waste was generated by all the respondents 100.00 per cent, followed by fruit waste 92.00 per cent and paper waste 60.33 per cent, which may be attributed to their regular generation from household consumption and farm-related activities. In the category of non-biodegradable waste, plastic waste 78.33 per cent was the predominant waste generated, whereas e-waste 4.33 per cent and other non-biodegradable wastes 6.00 per cent were relatively low. The high generation of plastic waste could be due to the extensive use of plastic materials such as fertilizer bags, pesticide containers, and packaging materials in agricultural operations. Similar findings were reported by Varghese *et al.*, (2023) <sup>[14]</sup> who observed that farm waste primarily consisted of crop residues, livestock waste, and household biodegradable materials. The availability of these organic residues provides considerable opportunities for sustainable waste utilization through composting, mulching, bioenergy production, and other circular economy approaches, whereas improper management may contribute to environmental pollution and greenhouse gas emissions, as reported by Koul *et al.*, (2022) <sup>[8]</sup>.

The crop waste utilization practices adopted by the respondents are presented in Figure 1. Mulching 29.13 per cent was the most widely adopted practice, followed by animal feed 29.00 per cent, manure making 27.13 per cent, and composting 25.27 per cent, whereas throwing away crop residues 8.47 per cent was the least preferred practice. The predominance of mulching, composting, and manure making indicated that farmers recognized the value of recycling crop residues for improving soil health and enhancing resource utilization. These findings were consistent with the observations of Shinde *et al.*, (2022) [12]. However, the continued practice of residue burning 15.07 per cent suggested the need for greater awareness and extension efforts to promote sustainable residue management practices and reduce carbon emissions.

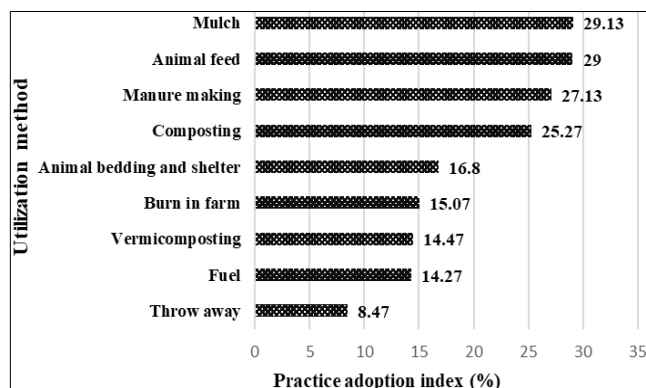


**Fig 1:** Existing farm waste utilization and management practices adopted by farmers (n=300)

**Table 4:** Knowledge on carbon emission and carbon sequestration (n=300)

| Knowledge domain                                        | Fully aware% | Partially aware% | Not aware% | Mean score 0–2 | Knowledge Index (%) | Knowledge level | Rank |
|---------------------------------------------------------|--------------|------------------|------------|----------------|---------------------|-----------------|------|
| Farm waste management                                   | 52.18        | 24.58            | 23.23      | 1.29           | 64.48               | Medium          | 1    |
| Household carbon emission and carbon sequestration      | 35.10        | 40.53            | 24.37      | 1.11           | 55.37               | Medium          | 2    |
| Farm Machinery and Domestic vehicle                     | 31.58        | 37.27            | 31.15      | 1.00           | 50.21               | Medium          | 3    |
| Indigenous technical knowledge                          | 16.44        | 38.97            | 44.58      | 0.72           | 35.93               | Medium          | 4    |
| Utilization and products made from specific crop waste  | 21.99        | 26.22            | 51.79      | 0.70           | 35.10               | Medium          | 5    |
| Carbon Emission and Carbon Sequestration in Agriculture | 11.27        | 34.08            | 54.65      | 0.57           | 28.31               | Low             | 6    |
| Overall                                                 | 26.62        | 28.99            | 44.39      | 0.82           | 41.11               | Low             | —    |

The knowledge of respondents regarding carbon emission and carbon sequestration across different domains is presented in Table 4. Among the six domains, the respondents exhibited the highest knowledge in farm waste management, with a Knowledge Index of 64.48 per cent, followed by household activities 55.37 per cent and farm machinery and domestic vehicles 50.21 per cent, all of which were categorized under a medium awareness. In contrast, comparatively lower levels of knowledge were observed in indigenous technical knowledge 35.93 per cent and specific crop-waste product utilization 35.10 per cent, whereas agricultural carbon emission and carbon sequestration recorded the lowest Knowledge Index of 28.31 per cent and was the only domain classified under a low level of Knowledge. Consequently, the respondents attained an overall Knowledge Index of 41.11 per cent, indicating a low level of knowledge regarding carbon emission and carbon sequestration. The findings suggested that farmers possessed better knowledge of practical farm waste management practices than the scientific concepts of carbon emission and carbon sequestration. Similar observations were reported by Jantke *et al.*, (2020) [6] who noted that farmers generally demonstrated greater familiarity with practical farm management practices than with the underlying scientific aspects of climate change mitigation. These findings underscored the need for targeted extension program and practical training to enhance farmers' understanding of climate-smart agricultural practices and carbon mitigation strategies.

### Conclusion

The study concludes that the selected farm families were predominantly small and marginal farmers with considerable farming experience and diversified cropping systems, resulting in the generation of a wide range of crop, livestock,

biodegradable, and non-biodegradable farm wastes. Farmers commonly adopted traditional and locally available farm waste utilization practices, such as mulching, composting, manure preparation, and the use of crop residues as animal feed. However, the continued practice of residue burning by a section of the respondents indicates the need to promote improved and environmentally sustainable farm waste management practices. The findings further revealed that farmers had comparatively better awareness of conventional farm waste management practices that provide immediate agricultural benefits. In contrast, awareness regarding advanced and climate-smart technologies, including biochar production, biogas generation, carbon credit programmes, and other carbon sequestration strategies, was relatively low. This highlights the need to strengthen farmers' understanding of the relationship between farm waste management, carbon emissions, soil organic carbon, and carbon sequestration. The study therefore emphasizes that farm waste should be recognized not merely as an agricultural by-product but as a valuable resource with the potential to improve soil health, recycle nutrients, reduce carbon emissions, and enhance carbon sequestration. Strengthening extension services, improving access to scientific information, and promoting practical, location-specific farm waste utilization technologies are essential to encourage the wider adoption of sustainable and climate-smart agricultural practices.

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