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Socio-economic, psychological and institutional determinants of farm mechanization adoption in sugarcane cultivation

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Abstract

Farm mechanization has become a critical intervention in sugarcane cultivation in India in response to persistent labour shortages, rising wage rates, and the need to enhance productivity and operational efficiency. Adoption of mechanized technologies in sugarcane farming, however, remains uneven and influenced by a complex interaction of socio-economic, psychological, and institutional factors. This review synthesizes empirical evidence from studies conducted across major sugarcane-growing regions of India to examine the determinants shaping farmers' awareness, knowledge, and utilization of farm machinery. The findings reveal that education, farm size, income, farming experience, and access to information significantly influence mechanization adoption, while psychological attributes such as innovativeness, risk orientation, scientific orientation, and economic motivation play a crucial role in farmers' decision-making behaviour. Institutional factors, including availability of machinery, custom hiring services, training exposure, extension support, and credit access, further condition the extent and intensity of mechanization. Although mechanization has improved timeliness of operations and reduced labour drudgery, its adoption remains largely confined to selected operations, with limited penetration in planting, harvesting, and ratoon management. The review underscores the need for a holistic mechanization strategy that integrates appropriate technology, capacity building, and institutional support to promote inclusive and sustainable mechanization in sugarcane cultivation. Addressing these determinants is essential for improving productivity, reducing production costs, and ensuring the long-term viability of the sugarcane sector in India.

Keywords: Farm, mechanization, sugarcane, cultivation, socio-economic, labour

1. Introduction

Empirical research conducted across different regions of India has consistently highlighted the socio-economic and behavioural characteristics of sugarcane growers as key determinants influencing farm mechanization adoption. Age distribution patterns reported across multiple studies indicate that sugarcane cultivation is predominantly managed by middle-aged farmers, who represent the most active group in adopting improved farm technologies (Kanavi, 2000; Shashidhar, 2014) [31, 59]. However, studies focusing specifically on mechanized cultivation systems have reported a higher representation of older farmers, particularly in sugarcane and other commercial crops, suggesting that accumulated experience, capital ownership, and decision-making authority play a significant role in mechanization adoption (Ghosh, 2014; Pauline, 2022; Karunthadankanni, 2022) [30, 34, 32]. Younger farmers were comparatively fewer, reflecting limited participation of youth in labour-intensive agricultural enterprises unless supported by mechanized interventions.

2. Socio-Personal Characteristics of Sugarcane Growers

Age has been widely reported as an important socio-personal factor influencing the adoption of farm mechanization in sugarcane cultivation.

Several studies observed that the majority of sugarcane growers belonged to the middle-aged category, which represents the most economically active and decision-making segment of the farming population (Kanavi, 2000; Shashidhar, 2014) ^[31, 59]. In contrast, studies focusing on mechanized sugarcane systems reported a comparatively higher proportion of older farmers, indicating that experience, land ownership, and capital availability strongly influence mechanization decisions (Ghosh, 2014; Pauline, 2022; Karunthadankanni, 2022) ^[30, 34, 32]. The limited participation of younger farmers reflects the declining interest of rural youth in labour-intensive agriculture unless supported by mechanized interventions.

3. Economic and Farm-Related Characteristics

Occupation patterns revealed that agriculture remained the principal source of livelihood for most sugarcane growers, either as a sole occupation or in combination with allied activities (Deepa, 2013; Sathyachitradevi, 2016; Mande and Thombre, 2019) ^[21, 46, 33]. Farmers engaged exclusively in agriculture were more inclined toward mechanization due to the need for timely operations, whereas diversification into non-farm occupations was common among small and marginal farmers as a risk-coping strategy (Pauline, 2022; Karunthadankanni, 2022; Shanthi and Muthusamy, 2022) ^[34, 32, 37]. Farm size consistently emerged as a decisive factor influencing mechanization intensity. Medium and large farmers dominated sugarcane cultivation in several regions and demonstrated higher adoption of mechanized practices (Kanavi, 2000; Mande and Thombre, 2019) ^[31, 33]. However, other studies reported a significant proportion of small and marginal farmers, reflecting regional variation in landholding patterns (Sathyachitradevi, 2016; Persis, 2017; Pauline, 2022) ^[46, 35, 34]. The expansion of custom hiring services has enabled smallholders to access machinery without ownership, thereby promoting inclusive mechanization (Ghosh, 2020; Din, 2021) ^[26, 24]. Farming experience of sugarcane growers was predominantly medium to high, indicating sustained engagement in agricultural activities (Vanetha, 2016) ^[77]. Farmers with greater experience demonstrated higher confidence in adopting mechanized practices, particularly when such technologies complemented traditional knowledge systems (Persis, 2017; Pauline, 2022; Karunthadankanni, 2022) ^[35, 34, 32].

4. Cropping Pattern and Income Characteristics

Area under sugarcane cultivation was generally reported to be medium to high, especially in irrigated and commercially oriented regions (Vijayalan, 2021; Pauline, 2022; Karunthadankanni, 2022) ^[84, 34, 32]. Farmers cultivating sugarcane on a larger scale exhibited greater dependence on mechanization to manage labour-intensive operations efficiently and to ensure timeliness. Income level significantly influenced machinery adoption behaviour. Most sugarcane growers fell into the medium income category, though both low- and high-income groups were also represented (Rosaiahyluri, 2000) ^[39]. Higher income farmers showed greater capacity for machinery ownership, whereas low-income farmers relied predominantly on hired services and traditional implements (Ghosh, 2014; Mande and Thombre, 2019; Shanthi and Muthusamy, 2022) ^[27, 33, 37].

5. Psychological and Behavioural Attributes

Psychological characteristics such as innovativeness, economic motivation, risk orientation, and scientific orientation were reported to have a significant influence on mechanization adoption. Most studies documented medium levels of innovativeness and economic motivation, indicating cautious but progressive attitudes towards new technologies (Chandra and Shiraj, 2021; Jayabalan, 2012; Ghosh, 2014) ^[19, 30, 27]. A medium level of risk orientation was also consistently reported, suggesting selective adoption of mechanization rather than complete technological transformation (Pauline, 2022) ^[34].

Scientific orientation was predominantly medium, with higher levels observed among farmers adopting advanced technologies such as precision farming and drip irrigation systems (Floralavanya, 2017; Thiyagarajan, 2021; Karunthadankanni, 2022) ^[25, 74, 32]. These findings highlight the importance of strengthening farmers' scientific outlook through extension and capacity-building initiatives.

6. Information Access and Social Participation

Information source utilization and social participation were generally reported at medium levels, reflecting moderate interaction with extension agencies, mass media, and farmer organizations (Suganya, 2000; Vanetha, 2016; Persis, 2017; Pauline, 2022) ^[67, 77, 35, 34]. Farmers with higher levels of social participation and better access to information sources exhibited greater awareness and utilization of farm machinery (Banumathy, 2013; Karunthadankanni, 2022) ^[16, 32]. However, gaps in timely and location-specific information dissemination continued to constrain mechanization adoption.

7. Availability of Farm Power, capital power and Machinery

Availability of farm power and machinery remained uneven across regions. Ownership of tractors and advanced implements was limited, particularly among smallholders, leading to a high dependence on hiring services for critical operations (Subramanian, 2000; Ghosh, 2020; Din, 2021) ^[65, 26, 24]. These findings underline the importance of strengthening custom hiring centres and cooperative mechanization models to improve access. Labour availability emerged as one of the most critical constraints influencing mechanization adoption. Acute shortages of skilled labour during peak agricultural seasons, combined with rising wage rates, were widely reported across sugarcane-growing regions (Santhi, 2016; Dhanasekaran, 2017; Pauline, 2022) ^[42, 23, 34]. Labour scarcity acted as a major driving force accelerating the adoption of mechanized operations in sugarcane cultivation.

8. Training Exposure and Capacity Building

Training participation related to farm implements and machinery was found to be low to moderate. Several studies reported that a majority of sugarcane growers had not attended formal training programmes, while only a small proportion participated in multiple training sessions (Pauline, 2022; Karunthadankanni, 2022) ^[34, 32]. Limited training exposure constrained effective utilization, maintenance, and optimization of machinery.

9. Awareness, Knowledge and Utilization of Farm Machinery

Awareness, knowledge, and utilization levels of farm implements and machinery were predominantly medium among sugarcane growers. High adoption was observed for

basic implements, while advanced machinery related to precision agriculture and resource conservation remained underutilized (Ghosh, 2014; Persis, 2017; Pauline, 2022) ^[27, 35, 34]. Education, farm size, extension contact, scientific orientation, innovativeness, and training participation were consistently reported to have significant positive relationships with awareness, knowledge, and utilization behaviour (Pauline, 2022) ^[34].

10. Conclusion

Farm mechanization has emerged as an indispensable component of sustainable sugarcane cultivation in India, particularly in the context of persistent labour scarcity, rising wage rates, and increasing pressure to enhance productivity and cost efficiency. The reviewed studies collectively demonstrate that mechanization adoption in sugarcane farming is not merely a technological choice but a multifaceted process shaped by socio-personal, economic, psychological, and institutional factors. Characteristics such as education, farm size, income level, farming experience, scientific orientation, and access to information and training consistently influence farmers' awareness, knowledge, and utilization of farm machinery.

Despite the recognized benefits of mechanization in improving timeliness of operations, reducing drudgery, and enhancing labour and land productivity, its adoption in sugarcane cultivation remains uneven and largely partial. Mechanization is still predominantly confined to land preparation and limited intercultural operations, while critical stages such as planting, harvesting, and ratoon management continue to rely heavily on manual labour. This partial mechanization reflects structural constraints including small and fragmented landholdings, limited machinery ownership, inadequate training exposure, and uneven availability of farm power across regions.

The findings also underline the growing importance of institutional mechanisms such as custom hiring centres, cooperative models, and extension services in promoting inclusive mechanization, particularly among small and marginal farmers (Persis, 2017) ^[35]. Labour scarcity has emerged as a dominant driver accelerating mechanization; however, without adequate capacity building and context-specific machinery solutions, the full potential of mechanization in sugarcane systems cannot be realized. Strengthening farmer-oriented training programmes, improving access to credit, and promoting region-specific, cost-effective machinery are therefore essential to enhance adoption intensity.

Overall, this review highlights that future progress in sugarcane mechanization must move beyond tractorisation towards a holistic, system-based approach that integrates appropriate machinery, skilled human resources, and supportive institutional frameworks. Addressing existing gaps through targeted research, policy support, and technology dissemination will be critical for improving productivity, ensuring economic viability of sugarcane farming, and sustaining the competitiveness of the Indian sugar industry in a rapidly changing agricultural landscape.

10.1 Declaration of Generative AI and AI-assisted technologies

The authors take complete responsibility of the information presented in the manuscript and has not used Artificial Intelligence (AI) tools or bots in drafting the review paper.

10.2 Data Availability Statement

The article is purely drafted from thorough literature study, there is no data available for the submitted manuscript.

10.3 Authors Contributions

Dr. Krishna, had gathered various research articles, arranged, aligned, sequenced, and drafted the manuscript. Co-authors have conceptualised the data, provided additional information about sugarcane cultivation, later, validated and visualized the information in the manuscript. Finally, Dr. Krishna has reviewed and edited the manuscript before final submission.

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10.5 Competing Interests

As part of declaration, the authors have no financial or personal interest/relationships regarding the information present in the manuscript. "I have not submitted my manuscript to a preprint server before submitting it to this journal.

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