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Socio-economic determinants of crop residue burning practices among farmers in Telangana

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Abstract

Crop residue burning continues to be a significant challenge in Telangana despite increased awareness of its environmental and agronomic impacts. The study examines the socio-economic determinants influencing farmers' residue burning behaviour, focusing on key variables such as age, education, land holding, cropping pattern, irrigation sources, labour availability, extension contact, training exposure, credit access, market accessibility and availability of crop residue management (CRM) technologies. Primary data were collected from farmers across selected districts, and appropriate analytical methods were used to derive meaningful insights.

The findings indicate that although a majority of farmers are aware of the harmful effects of residue burning and related government initiatives, the adoption of CRM practices remains limited. Borewells were identified as the most reliable irrigation source, while traditional sources like tanks were largely insufficient. Labour availability was found to be moderate to low, particularly during peak periods, which constrains the adoption of labour-intensive CRM practices and encourages burning as a quick alternative. Extension contact was strong with state department officials and progressive farmers, but interaction with scientists, financial institutions, and emerging stakeholders such as FPOs and agripreneurs was minimal. Training programs mainly focused on awareness creation and basic skills, with less emphasis on digital advisory services, entrepreneurship, and value addition.

The study also revealed that commercial banks were relatively effective in providing formal credit, though many farmers relied on informal sources like relatives and fellow farmers. Market accessibility showed spatial disparities, with machinery largely available at the mandal level, while outputs like biomass and briquettes were concentrated at the district level. Furthermore, advanced CRM technologies such as shredders and balers were largely unavailable.

Overall, residue burning is driven by labour shortages, limited mechanization, weak institutional linkages and inadequate market and credit support. A comprehensive strategy integrating improved access to machinery, strengthened extension services, enhanced credit systems, and promotion of decentralized CRM enterprises is essential for sustainable residue management.

Keywords: Crop residue burning, Crop residue management, socio- economic determinants, market accessibility, sustainable agriculture

1. Introduction

Crop residue burning (CRB) has emerged as a major environmental and agricultural concern across many parts of the world, particularly in developing countries where intensive farming systems generate large quantities of agricultural residues. Crop residues, which include straw, stalks, leaves, husks and other plant remains left after harvesting, are valuable resources that can be utilized for soil enrichment, livestock feed, composting and bioenergy production. However, due to the increasing pressure of intensive cropping systems and the need for rapid land preparation for the next cropping cycle, farmers often resort

to open-field burning as a quick and cost-effective method for residue disposal. Globally, several hundred million tonnes of crop residues are generated every year and a significant proportion of these residues are burned in open fields, resulting in environmental degradation and contributing to climate change (FAO, 2023; Bhuvaneshwari *et al.*, 2019; Gupta *et al.*, 2022) [4, 1, 5].

In India, crop residue burning has become a recurring issue associated with the intensification of agriculture, increased mechanization and the expansion of cereal-based cropping systems. Recent estimates indicate that India generates nearly 650-700 million tonnes of crop residues annually, of

which a substantial proportion remains underutilized or is disposed of through burning (Jain *et al.*, 2023; Pathak *et al.*, 2020) ^[6, 11]. This practice is particularly common during harvesting seasons when farmers face a limited time window between successive crops and lack affordable alternatives for residue management. Burning residues enables farmers to clear fields quickly and reduce labour requirements; however, the environmental and agronomic consequences are severe. Crop residue burning releases significant quantities of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), along with particulate matter and other harmful pollutants that contribute to air pollution and global warming (Shyamsundar *et al.*, 2022; Singh *et al.*, 2022) ^[12, 15]. Furthermore, burning residues leads to the loss of valuable plant nutrients, including nitrogen, phosphorus, potassium and sulphur, which adversely affects soil fertility and long-term agricultural productivity (Kumar *et al.*, 2021; Lohan *et al.*, 2023) ^[8, 10].

The environmental consequences of crop residue burning have received increasing attention in recent years due to its role in deteriorating air quality and increasing atmospheric pollution. Open-field burning emits large quantities of fine particulate matter (PM_{2.5} and PM₁₀), carbon monoxide, volatile organic compounds and other pollutants that pose serious risks to human health and environmental sustainability (Cusworth *et al.*, 2023; Tiwari *et al.*, 2021) ^[2, 17]. Studies have shown that agricultural residue burning contributes significantly to seasonal smog events and regional air pollution in several parts of India, particularly during the post-harvest period (Jain *et al.*, 2023; Singh *et al.*, 2020) ^[6]. Apart from air pollution, residue burning also negatively affects soil health by destroying beneficial soil microorganisms, reducing soil organic carbon content, and altering soil physical and biological properties, thereby reducing long-term crop productivity and sustainability (Lohan *et al.*, 2023; Kumar and Sharma, 2022) ^[15, 10]. Consequently, promoting sustainable crop residue management practices has become a priority for researchers, policymakers and agricultural extension agencies.

Although several alternative residue management practices such as mulching, composting, in-situ incorporation and the use of mechanized technologies like the Happy Seeder and Straw Management System have been developed, their adoption remains limited among farmers. Evidence suggests that the availability of technologies alone is insufficient to bring about behavioural change among farming communities (Singh *et al.*, 2023; Kumar and Sharma, 2022) ^[15, 7]. Farmers' decisions regarding residue management are influenced by a complex interplay of socio-economic, institutional and psychological factors. Variables such as farm size, access to agricultural machinery, labour availability, cost of residue management technologies, awareness of environmental impacts, and access to extension services significantly affect farmers' choices between burning residues and adopting sustainable management practices (Dube *et al.*, 2024; Singh *et al.*, 2023) ^[3, 15]. In addition, farmers' attitudes, risk perceptions, and social norms play an important role in shaping their residue management behaviour.

The socio-economic characteristics of farmers are particularly important in understanding the persistence of

crop residue burning. Small and marginal farmers often face financial and resource constraints that limit their ability to adopt improved residue management technologies, while larger farmers may prioritize rapid field preparation in order to maintain high cropping intensity (Kumar *et al.*, 2023) ^[9]. Similarly, education level, access to information, and exposure to agricultural extension services significantly influence farmers' awareness and perception of environmentally sustainable agricultural practices. This has demonstrated that farmers with better educational status and greater access to extension support are more likely to adopt eco-friendly residue management practices compared to those with limited resources and information (Jain *et al.*, 2023; Lohan *et al.*, 2023) ^[6, 10].

While a substantial body of research has examined crop residue burning in northern India, particularly in the Indo-Gangetic Plains where rice-wheat cropping systems dominate, relatively limited attention has been given to this issue in other agricultural regions such as southern India. In states like Telangana, rapid agricultural development, increasing mechanization, and the cultivation of residue-intensive crops such as paddy, maize, cotton, and chilli have led to the generation of large quantities of crop residues. In many cases, farmers resort to burning these residues due to labour shortages, limited awareness of sustainable management practices, and lack of locally appropriate residue management technologies. Moreover, socio-economic conditions, institutional support and extension interventions in this region may differ significantly from those in northern India, highlighting the need for region-specific research.

Understanding the socio-economic determinants of crop residue burning in Telangana is therefore essential for developing effective policy interventions and extension strategies aimed at promoting sustainable residue management practices. Identifying the factors that influence farmers' decisions can help policymakers design targeted programmes, improve technology dissemination, and strengthen agricultural extension services. Such insights can also contribute to the formulation of environmentally sustainable agricultural policies that balance productivity with ecological conservation. In this context, the present study aims to analyse the socio-economic determinants of crop residue burning practices among farmers in Telangana, with the objective of generating empirical evidence to guide policy interventions and promote sustainable agricultural practices in the region.

2. Material and Methods

2.1 Study Area

The present study was conducted in the Telangana, which is one of the major agricultural regions in southern India characterized by diverse cropping systems and increasing agricultural mechanization. In recent years, the problem of crop residue burning has been observed in several districts due to labour shortages, limited availability of residue management technologies and time constraints between successive cropping seasons. Therefore, Telangana provides a suitable context for examining the socio-economic determinants influencing farmers' decisions regarding crop residue burning practices. Among three agro-climatic zones are selected as depicted in Table.1 which is grown as Paddy and cotton as their major crop in the cropping system.

Table 1: Selection of Agro-climatic Zones along with districts, mandals and Villages

S. No.	District	Mandal	Villages	No. of respondents
Northern Telangana Zone				
1.	Kumuram Bheem Asifabad	Dahegaon	Hathni	10
			Kalawada	10
		Kagaz Nagar	Kagaz nagar	10
			Bhutpally	10
2.	Mancherial	Chennur	Sundharshala	10
			Kistampet	10
		Kotapalle	Kotapalle	10
			Mallampet	10
Central Telangana Zone				
1.	Khammam	Kusumanchi	Kusumanchi	10
			Thurkagudem	10
		Thirumalaya palem	Thallacheruvu	10
			Erragadda	10
2.	Jangoan	Ghanpurstn	Meedikonda	10
			Raghavapur	10
		Palakurthi	Palakurthi	10
			Bammera	10
Southern Telangana Zone				
1.	Nalgonda	Gurrapode	Gurrapode	10
			Amloor	10
		Narketpalle	Kondapakagudem	10
			Choudampally	10
2.	Nagarkurnool	Tadoor	Medipur	10
			Indrakal	10
		Bijinapally	Manganur	10
			Waddemanu	10
Total	6	12	24	240

2.2 Research Design

An *Ex-post facto* research design was employed for the study since the phenomenon of crop residue burning had already occurred and the variables influencing farmers' behaviour could not be manipulated by the researcher. This design is widely used in agricultural extension research to analyze relationships between socio-economic characteristics and farmers' behavioural practices.

2.3 Sampling Procedure

A multistage sampling technique was adopted to select the respondents for the study. In the first stage, districts with a higher prevalence of crop residue generation and burning practices were purposively selected. In the second stage, two mandals from each selected district were chosen purposively based on the extent of agricultural activity and cropping intensity. In the third stage, villages were selected randomly from each mandal. Finally, a proportionate random sampling method was used to select the respondents from each village.

A total sample of 240 farmers was selected for the study to ensure adequate representation of different farm categories such as small, marginal and large farmers. Primary data were collected from the selected farmers using a structured and pre-tested interview schedule. The interview schedule was designed to capture information on farmers' socio-economic characteristics, residue management practices, awareness levels and factors influencing crop residue burning. Prior to the final survey, the interview schedule was pre-tested with a small group of farmers outside the study area to ensure clarity and reliability of the questions. Necessary modifications were made based on the feedback

received during the pre-testing stage. Statistical tools to be used for the study are standard deviation, arithmetic mean, class interval.

3.Results and Discussion

The socio-economic characteristics of farmers play a crucial role in influencing their behaviour towards crop residue burning (CRB) and adoption of alternative crop residue management (CRM) practices.

1.Age

The majority of respondents (83.33%) belonged to the middle age group (40-60 years), followed by young (9.17%) and old farmers (7.50%) as shown in table.2

Middle-aged farmers are typically more active in farm decision-making and are responsible for timely field preparation. Due to time pressure between cropping seasons, middle age group is more likely to practice crop residue burning as a quick and cost-effective method of field clearance. Younger farmers, although fewer, may be more open to adopting sustainable alternatives, while older farmers may rely more on traditional practices.

2. Education

More than half of the respondents (52.08%) had education up to high school, while 20.42 per cent were illiterate. Very few had higher education as shown in table.2.

This indicates that although basic awareness about the negative effects of residue burning may exist, deeper understanding of long-term environmental and soil health impacts may be limited. Farmers with lower education levels may find it difficult to access or interpret technical

information about alternative CRM technologies. This highlights the need for simple, demonstration-based and locally adapted extension approaches to discourage burning practices.

3. Family size

A majority (67.50%) of respondents had small family sizes (2-5 members) as shown in table.2.

Smaller family size implies limited availability of family labour, which can encourage farmers to adopt quicker methods like residue burning instead of labour-intensive residue management practices such as incorporation or mulching. This indicates that labour scarcity is a contributing factor to CRB.

4. Annual Income

An overwhelming majority (93.33%) of respondents belonged to the low-income category as shown in table.2.

Low income is one of the most significant factors influencing crop residue burning. Farmers with limited financial resources are less capable of investing in machinery such as happy seeders, rotavators, or other CRM equipment. Burning is often perceived as the cheapest and

fastest option, making it a preferred practice among economically weaker farmers.

5. Occupation

The majority (90.42%) of respondents were solely dependent on agriculture as shown in table.2.

Farmers relying primarily on agriculture tend to prioritize immediate economic returns and timely operations. Due to tight cropping schedules, especially in rice- cotton systems, they may opt for residue burning to save time and reduce operational costs. Lack of alternative income sources also reduces their risk-bearing capacity to experiment with new technologies.

6. Farming Experience

A large proportion (73.33%) of respondents had high farming experience (35-50 years) as shown in Table no.2

Highly experienced farmers often rely on conventional methods, including residue burning, due to familiarity and perceived effectiveness. While experience can enhance knowledge, it may also lead to resistance in adopting new CRM technologies unless strong evidence, demonstrations, and incentives are provided.

Table 2: Categorization of respondents based on the profile characteristics

S.No.	Variable	Category	Class interval	F	%
1.	Age	Young	20-40	22	9.17
		Middle	40-60	200	83.33
		Old	60-80	18	7.50
2.	Education	Illiterate		49	20.42
		Primary school		4	1.67
		Middle school		32	13.33
		High school		125	52.08
		Intermediate		22	9.17
		Diploma		2	0.83
		Graduation		4	1.67
		Post graduation		2	0.83
3.	Family size	Low	2 - 5	162	67.50
		Medium	6 - 7	71	29.58
		High	8 - 10	7	2.92
4.	Annual income	Low	10,000- 3,40,000	224	93.33
		Medium	3,40,000-6,70,000	14	5.83
		High	6,70,000-10,00,000	2	0.83
5.	Occupation	Agriculture		217	90.42
		Business		23	9.58
6.	Farming Experience	low	2-18	31	12.92
		medium	19-34	33	13.75
		high	35-50	176	73.33

7. Land holding

The distribution of respondents based on landholding size reveals that a majority (52.08%) belonged to the semi-medium category (2-4 hectares), followed by medium farmers (18.75%), small farmers (15.00%), large farmers (10.42%), and marginal farmers (4.17%) as shown in table.3.

This indicates that most farmers in the study area operate under moderate landholding conditions, with relatively fewer farmers at the extreme ends (marginal and large categories).

Landholding size plays a significant role in influencing

farmers' decisions regarding crop residue burning and adoption of alternative management practices.

The predominance of semi-medium (52.08%) and medium farmers (18.75%) suggests that a large section of farmers manages substantial cropped area.

As a result, they are more likely to adopt crop residue burning as a convenient and time-saving method. However, compared to small farmers, they may have relatively better access to machinery, making them potential adopters of crop residue management (CRM) technologies if adequate support is provided.

Table 3: Categorization of respondents based on their landholding

S.No.	Category	Range (Acres)	Frequency	Percentage
1	Marginal	Up to 1 hectare (>2.47 acres)	10	4.17
2	Small	1 - 2 hectares (2.47 - 4.94 acres)	36	15.00
3	Semi-medium	2 - 4 hectares (4.94 - 9.88 acres)	125	52.08
4	Medium	4 - 10 hectares (9.88 - 24.71 acres)	45	18.75
5	Large	Above 10 hectares (> 24.71 acres)	25	10.42
	Total		240	100.00

8. Cropping pattern

The data presented in the table.4 reveals the distribution of cropping patterns among sampled farmers (n = 80 per district) across six districts, namely Asifabad, Mancherial, Khammam, Jangoan, Nalgonda, and Nagar Kurnool. The analysis indicates a clear dominance of paddy and cotton cultivation across all districts, with relatively smaller proportions allocated to other crops such as maize, red gram, groundnut, chillies, millets, pulses, and oilseeds.

Paddy emerges as one of the principal crops cultivated in all districts. Its highest representation is observed in Nalgonda district (30%), followed by Khammam (27.50%) and Asifabad (25%). Comparatively lower proportions are seen in Mancherial and Nagar Kurnool (22.50% each). This variation may be attributed to differences in irrigation facilities, water availability, and agro-climatic suitability, as paddy is a water-intensive crop.

Cotton is another major crop grown extensively across all districts, with percentages ranging from 25% to 27.50%. The highest cultivation is reported in Asifabad and Nalgonda (27.50% each), followed by Jangoan (26.25%), while Mancherial, Khammam, and Nagar Kurnool each recorded 25%. The consistent presence of cotton across districts highlights its economic importance as a cash crop and its adaptability to varied soil conditions in the study area.

Maize cultivation shows moderate distribution, with the highest percentage in Mancherial (17.50%) and lowest in Nagar Kurnool (8.75%). Similarly, red gram is cultivated to

a lesser extent, with Nagar Kurnool showing relatively higher participation (11.25%) compared to other districts (ranging from 6.25% to 8.75%). This indicates the role of pulses in dryland farming systems, particularly in regions with limited irrigation.

Groundnut cultivation is modest across districts, ranging from 5% in Mancherial to 8.75% in Jangoan and Nagar Kurnool. Chillies, though a commercially important crop, occupy a smaller share (3.75% to 6.25%), with slightly higher concentration in Nalgonda. Millets show limited but notable presence, especially in Nalgonda (7.50%) and Mancherial/Nagar Kurnool (6.25%), indicating their role in climate-resilient agriculture.

Other pulses and oilseeds are grown in smaller proportions, reflecting diversification in cropping systems. Pulses (other than red gram) range from 2.50% in Nalgonda to 8.75% in Mancherial, while oilseeds vary between 3.75% and 7.50%, with relatively higher values in Nagar Kurnool.

Overall, the findings suggest that the cropping pattern in the selected districts is largely dominated by paddy and cotton, indicating a trend toward monocropping or limited diversification. However, the presence of secondary crops such as maize, pulses, millets, and oilseeds reflects efforts toward diversification based on resource availability and risk management strategies. The variation across districts highlights the influence of agro-ecological conditions, irrigation infrastructure, and market demand on crop choices.

Table 4: Categorization of respondents based on their cropping pattern

S.No.	Crop	Asifabad	Mancherial	Khammam	Jangoan	Nalgonda	Nagar Kurnool
1	Paddy	20 (25%)	18 (22.5%)	22 (27.50%)	19 (23.75%)	24 (30%)	18 (22.50%)
2	Cotton	22 (27.50%)	20 (25%)	20 (25%)	21 (26.25%)	22 (27.50%)	20 (25%)
3	Maize	12 (15%)	14 (17.50%)	10 (12.50%)	11 (13.75%)	8 (10%)	7 (8.75%)
4	Red gram	5 (6.25%)	6 (7.50%)	7 (8.75%)	5 (6.25%)	5 (6.25%)	9 (11.25%)
5	Groundnut	6 (7.50%)	4 (5%)	6 (7.50%)	7 (8.75%)	5 (6.25%)	7 (8.75%)
6	Chillies	3 (3.75%)	4 (5%)	3 (3.75%)	4 (5%)	5 (6.25%)	4 (5%)
7	Millets	4 (5%)	5 (6.25%)	3 (3.75%)	4 (5%)	6 (7.50%)	5 (6.25%)
8	Pulses (other)	3 (3.75%)	4 (8.75%)	5 (6.25%)	4 (5%)	2 (2.50%)	4 (5%)
9	Oilseeds (other)	5 (6.25%)	5 (6.25%)	4 (5%)	5 (6.25%)	3 (3.75%)	6 (7.50%)
	Total	80 (100%)	80 (100%)	80 (100%)	80 (100%)	80 (100%)	80 (100%)

9. Farm machinery availability

9.1 Farm implements

The distribution of respondents according to possession and usage level of farm implements reveals a clear dominance of low-level ownership for most traditional and basic implements, while selective tools show moderate to high adoption.

A very high proportion of respondents belonged to the low category in the use of hand hoe (85%), wooden plough

(82.92%), diesel pump set (82.12%), drip irrigation kit (81.25%), and wheel hoe (80%), indicating that these implements are either minimally available or underutilized among the farmers. Similarly, electric pump sets (77.50%) and cultivators (67.50%) also recorded a majority under the low category. The limited mechanization and continued dependence on traditional or manual farming practices in the study area as shown in table.5.

Table 5: Categorisation of respondents based on their farm machinery availability (N=240)

S.No.	Category	Farm Implements								
		Wooden plough	Cultivator	Hand hoe	Wheel hoe	Diesel pump set	Electric pump set	Drip irrigation kit	Knapsack sprayer	Sickles
1	Low	199 (82.92%)	162 (67.5%)	204 (85%)	192 (80%)	197 (82.12%)	186 (77.50%)	195 (81.25%)	20 (8.33%)	33 (13.75%)
2	Medium	21 (8.75%)	25 (10.42%)	13 (5.42%)	18 (7.50%)	20 (8.33%)	22 (9.17%)	23 (9.59%)	149 (62.08%)	22 (9.17%)
3	High	20 (8.33%)	53 (22.08%)	23 (9.58%)	30 (12.50%)	23 (9.58%)	32 (13.33%)	22 (9.17%)	71 (29.58%)	185 (77.08%)
S.No.	Category	Farm machinery								
		Tractor	Rotavator	Puddler	Combined harvester	Cono weeder				
1	Low	181 (75.42%)	17 (7.08%)	201 (83.75%)	189 (78.75%)	212 (88.33%)				
2	Medium	10 (4.17%)	194 (80.83%)	28 (11.67%)	23 (9.58%)	18 (7.50%)				
3	High	49 (20.42%)	29 (12.08%)	11 (4.58%)	28 (11.67%)	10 (4.17%)				

In contrast, certain implements showed relatively higher levels of adoption. Notably, knapsack sprayers had a majority of respondents in the medium category (62.08%), followed by 29.58 percent in the high category, indicating their widespread use due to their importance in plant protection measures. Likewise, sickles exhibited a dominant high-level usage (77.08%), reflecting their essential role in harvesting operations and their affordability and accessibility to farmers.

The presence of moderate to high usage of cultivators (22.08% high) and electric pump sets (13.33% high) indicates gradual adoption of improved implements, though not yet widespread. Overall, the findings suggest that while essential and low-cost tools are commonly used, adoption of improved and mechanized implements remains limited due to factors such as cost, farm size, and access to resources.

9.2 Farm machinery

The distribution pattern of farm machinery further highlights the low level of mechanization among the respondents.

A majority of farmers fell under the low category for Cono-weeders (88.33%), puddler (83.75%), combined harvesters (78.75%) and tractors (75.42%), indicating that these machinery types are not widely owned or accessible. This may be due to their high initial investment cost, lack of custom hiring services or unsuitability for small and fragmented landholdings.

However, a contrasting trend was observed in the case of rotavators, where a significant proportion of respondents (80.83%) belonged to the medium category, followed by 12.08 percent in the high category. This indicates that rotavators are relatively more accessible, possibly through

custom hiring centres or shared usage and are increasingly preferred for land preparation due to their efficiency and time-saving advantages.

A smaller proportion of respondents reported high usage of tractors (20.42%) and combined harvesters (11.67%), suggesting that while ownership may be limited, some farmers are gradually adopting mechanization either individually or through rental services.

10. Source of Irrigation

The distribution of farmers based on the sufficiency of different sources of irrigation tanks, canals, borewells, and rainfed conditions reveals clear variations in reliability and dependence patterns.

The results indicated in table.6 that borewells are perceived as the most reliable source of irrigation, with a majority of respondents (65%) reporting them as *fully sufficient*. Only 18.75% considered borewells moderately sufficient, and a relatively smaller proportion (16.25%) reported them as not sufficient. This revealed that groundwater-based irrigation plays a dominant role in ensuring water availability, particularly in regions where surface irrigation systems are inconsistent or inadequate. The high dependence on borewells may also reflect increased investments in private irrigation infrastructure by farmers.

In contrast, canal irrigation shows a mixed level of sufficiency. While 17.92% of farmers reported canals as fully sufficient, a substantial proportion (60.42%) considered them moderately sufficient, and 21.67% reported them as not sufficient. This indicates that canal systems provide a significant but somewhat unreliable water supply, possibly due to irregular water release, maintenance issues or unequal distribution across command areas.

Rainfed agriculture is predominantly categorized as moderately sufficient (69.17%), followed by 22.08% as fully sufficient and 8.75% as not sufficient. This pattern suggests that rainfall contributes meaningfully to crop water

requirements but remains uncertain and inconsistent. Farmers relying on rainfed systems may experience variability depending on monsoon performance, which influences their perception of sufficiency.

Table 6: Categorisation of respondents based on their source of irrigation

S.No.	Category	Source of Irrigation			
		Tanks	Canals	Borewells	Rainfed
1	Fully sufficient	9 (3.75%)	43 (17.92%)	156 (65%)	53 (22.08%)
2	Moderately sufficient	18 (7.50%)	145 (60.42%)	45 (18.75%)	166 (69.17%)
3	Not sufficient	213 (88.75%)	52 (21.67%)	39 (16.25%)	21 (8.75%)
Total		240 (100%)	240 (100%)	240 (100%)	240 (100%)

11.Extension Contact

11.1 Personal Extension Contact

The findings show in the table.7 that farmers maintain strong regular contact with State Department Officials (91.67%) and Progressive Farmers (92.08%), making them the most trusted and accessible sources of information. This highlights the continued importance of local institutional support and peer learning in agricultural decision-making. Progressive farmers, in particular, serve as informal opinion leaders, facilitating the diffusion of innovations at the grassroots level.

In contrast, contact with Scientists is very limited, with only 3.33% of respondents interacting regularly and a majority (93.75%) doing so only occasionally. This suggests a gap between research institutions and farmers, possibly due to limited outreach mechanisms or accessibility issues.

Similarly, Bankers show minimal engagement, with 84.17% of farmers reporting no contact, indicating a weak linkage between farmers and formal financial advisory services. This could affect farmers' access to credit-related information and financial planning.

Similarly, Bankers show minimal engagement, with 84.17% of farmers reporting no contact, indicating a weak linkage between farmers and formal financial advisory services. This could affect farmers' access to credit-related information and financial planning.

Contacts with NGOs (80% never), FPOs (80% never), Agripreneurs (92.08% never), and Input Dealers (75.83% never) are also notably low. Although some farmers

reported occasional contact with NGOs (15.42%) and FPOs (14.58%), these institutions have not yet established strong, regular engagement with the majority of farmers. This reflects underutilization of alternative extension channels and emerging agricultural service providers.

11.2 Impersonal Extension Contact

In contrast to personal sources, impersonal channels show significantly higher levels of regular engagement, particularly through social media (91.76%), Television (90%), and Mobile Apps (88.33%). These platforms have emerged as dominant sources of agricultural information due to their accessibility, real-time updates, and wide reach. Radio also remains relevant, with 66.25% of farmers using it regularly and 26.25% occasionally, indicating its continued importance, especially in rural areas with limited internet connectivity.

Newspapers are moderately utilized, with 45.42% of respondents accessing them occasionally and 21.25% regularly, suggesting that print media still contributes to information dissemination, though less prominently than digital platforms.

On the other hand, Podcasts (81.67% never) and Magazines (25% never, 69.58% occasionally) have relatively low adoption rates. The limited use of podcasts may be due to lack of awareness or technological familiarity, while magazines may be constrained by accessibility and timeliness of information.

Table 7: Categorisation of respondents based on their extension contact

S.No.	Category	Personal Extension Contact							
		Scientists	State department Officials	Bankers	Progressive farmers	NGOs	FPO	Agripreneurs	Input dealers
1	Regularly	8(3.33%)	220(91.67%)	20(8.33%)	221(92.08%)	11(4.58%)	13(5.42%)	15(6.25%)	24(10%)
2	Occasionally	225(93.75%)	09(3.75%)	18(7.50%)	08(3.33%)	37(15.42%)	35(14.58%)	04(1.67%)	34(14.17%)
3	Never	7 (2.92%)	11 (4.58%)	202 (84.17%)	11 (4.58%)	192 (80%)	192 (80%)	204 (92.08%)	182 (75.83%)
Impersonal Contact									
S.No.	Category	Radio	Social media	Mobile apps		Newspaper	Podcasts	Television	Magazines
1	Regularly	159(66.25%)	220(91.76%)	212(88.33%)		51(21.25%)	17(7.08%)	216(90%)	13(5.42%)
2	Occasionally	63 (26.25%)	9 (3.75%)	10 (4.17%)		109 (45.42%)	27 (11.25%)	05 (2.08%)	167 (69.58%)
3	Never	18 (7.50%)	11 (4.58%)	18 (7.50%)		80 (33.33%)	196 (81.67%)	19 (7.92%)	60 (25%)

12. Trainings undergone

The analysis of trainings on crop residue management (CRM) reveals that most farmers were primarily exposed to awareness-oriented and policy-related programmes, with the highest participation in training on environmental impacts of residue burning (82.50%) and government schemes and subsidies (77.92%), indicating strong institutional focus on sensitization and support mechanisms as indicated in table.8. A considerable proportion of respondents also received practical and skill-based trainings, including in-situ residue management practices (73.33%), skill development and field demonstrations (71.67%), and operation of CRM machinery (68.75%), reflecting efforts to promote hands-on learning and adoption of sustainable practices. Moderate coverage was observed in areas such as composting and bio-decomposition techniques (65.83%) and soil health and

nutrient management (62.08%), suggesting some emphasis on long-term soil sustainability. However, comparatively fewer farmers were trained in value addition and safety aspects, such as bioenergy (50.42%) and health and safety measures (55.83%). Notably, the lowest participation was found in digital and entrepreneurial domains, with only 40.00% trained in ICT-based advisory services and 36.67% in entrepreneurship in CRM, highlighting a critical gap in modern and market-oriented competencies. Overall, the findings indicate that while current training programmes effectively address awareness and basic technical skills, there is a need for a more balanced and comprehensive approach that integrates digital literacy, entrepreneurship, and value addition to ensure sustainable and economically viable adoption of CRM practices.

Table 8: Categorization of respondents based on their training undergone for CRM.

S.No.	Name of Training	Frequency	Percentage
1	Awareness on environmental impact of residue burning	198	82.50
2	In-situ crop residue management (Mulching and Incorporation) practices	176	73.33
3	Ex-situ crop residue management (Compost, fodder, bioenergy) practices	142	59.17
4	Operation of CRM machinery (Happy Seeder, SMS, Bailer, Shredder etc.)	165	68.75
5	Composting and bio-decomposition techniques (Pusa decomposer)	158	65.83
6	Soil health and nutrient management	149	62.08
7	Bioenergy and value addition of residues	121	50.42
8	Government schemes and subsidy awareness	187	77.92
9	Skill development and field demonstrations	172	71.67
10	Health and safety measures	134	55.83
11	Digital/ICT-based CRM advisory	96	40.00
12	Entrepreneurship in crop residue management	88	36.67

13. Labour availability

The availability pattern across paddy and cotton crop residue management (CRM) practices reflects significant labour constraints, particularly for labour-intensive and mechanization-dependent operations. Practices represented in table.9 such as manual collection and removal (57.08% fully available), fodder usage (60.83%), and composting (67.50%) show higher levels of full availability, indicating that farmers rely more on activities that can be managed with existing or family labour. Mulching is largely moderately available (67.50%), suggesting partial dependence on labour that may not always be sufficient or timely. In contrast, operations like soil incorporation (77.92% not available) and zero tillage (78.33% not available) reflect low labour availability, possibly due to

their higher labour or skill requirements combined with limited access to machinery. Similarly, very high unavailability is observed for shredders (83.33%), choppers (89.58%), baling (95.42%), and biochar/biofuel units (99.17%), indicating that labour alone is insufficient without mechanized support. The low availability of labour for household fuel usage (82.5% not available) also suggests declining reliance on traditional practices. Overall, the findings highlight that while basic CRM practices are sustained through available labour, there is a serious shortage of labour for advanced and efficient residue management techniques, emphasizing the need for mechanization, custom hiring services, and labour-saving technologies to ensure timely and effective CRM adoption.

Table 9: Categorization of respondents based on their labour availability for CRM.

S.No.	Category	Fully available	Moderately available	Not available
1	Soil incorporation	10(4.17%)	43(17.92%)	187(77.92%)
2	Mulching	31(12.92%)	162(67.50%)	47(19.58%)
3	Manual collection & removal	137(57.08%)	89(37.08%)	14(5.83%)
4	Fodder usage for CRM	146(60.83%)	85(35.42%)	09(3.75%)
5	Composting	162(67.50%)	59(24.58%)	19(7.92%)
6	House fuel	23(9.59%)	19(7.92%)	198(82.5%)
7	Zero till	21(8.75%)	31(12.92%)	188(78.33%)
8	Shredder	19(7.92%)	21(8.75%)	200(83.33%)
9	Chopper	7(2.92%)	18(7.5%)	215(89.58%)
10	Baling	2(0.83%)	9(3.75%)	229(95.42%)
11	Bio char/ bio fuel units	0(0.00)	2(0.83%)	238(99.17%)

14. Credit availability for CRM technologies

The analysis of credit availability for crop residue management (CRM) technologies reveals a contrasting pattern between formal and informal financial sources. Among formal institutions, results depicted in table.10 that commercial banks emerge as the most reliable source, with a majority of farmers (92.08%) reporting credit as fully sufficient, indicating strong institutional support and accessibility. Similarly, Grameen banks show moderate effectiveness, with 58.75% of respondents perceiving credit as moderately sufficient and 30.42% as fully sufficient. In contrast, Primary Agricultural Cooperative Societies (PACS) are largely rated as moderately sufficient (93.75%), suggesting limited but somewhat consistent support. However, Self-Help Groups (SHGs) and NABARD-linked credit sources are perceived as largely insufficient, with 95% and 85% of farmers respectively reporting inadequate access, indicating weak outreach or limited engagement in

CRM financing.

On the other hand, informal sources show a different trend, where relatives (89.58%) and fellow farmers (90.83%) are considered highly sufficient, highlighting the importance of social capital and trust-based lending in meeting immediate financial needs. Conversely, money lenders (92.50% not sufficient), input dealers (85.83% not sufficient), and output buyers (95.42% not sufficient) are largely viewed as unreliable or inadequate sources of credit for CRM technologies. Overall, the findings suggest that while formal banking institutions, particularly commercial banks, play a crucial role in providing sufficient credit, farmers still heavily depend on informal social networks for financial support. The limited effectiveness of cooperative and development-oriented institutions indicates a need to strengthen their role, simplify credit procedures, and enhance awareness to ensure broader and more equitable access to finance for CRM adoption

Table 10: Categorization of respondents based on their credit availability for CRM.

S.No.	Category	Formal sources				
		PACS	SHGs	Grameen banks	Commercial banks	NABARD
1	Not sufficient	10 (4.17%)	228 (95%)	26 (10.83%)	06 (2.50%)	204 (85%)
2	Moderately sufficient	225 (93.75%)	10 (4.17%)	141 (58.75%)	13 (5.42%)	24 (10%)
3	Fully sufficient	5 (2.08%)	02 (0.83%)	73 (30.42%)	221 (92.08%)	12 (5%)
S.No.	Category	Informal sources				
		Relatives	Fellow farmers	Money lenders	Input dealers	Output buyers
1	Not sufficient	16 (6.67%)	06 (2.50%)	222 (92.50%)	206 (85.83%)	229 (95.42%)
2	Moderately sufficient	09 (3.75%)	16 (6.67%)	13 (5.42%)	20 (8.33%)	05 (2.08%)
3	Fully sufficient	215 (89.58%)	218 (90.83%)	05 (2.08%)	14 (5.83%)	06 (2.50%)

15. Market Accessibility

The analysis of market accessibility for crop residue management (CRM) inputs and outputs indicates a clear spatial variation across village, mandal, and district levels, with distinct patterns for different commodities as shown in table.11. In terms of input market access, machinery is predominantly available at the mandal level (53.33%), followed by village level (35.83%), suggesting that farmers often need to travel beyond their villages to access CRM equipment, which may limit timely adoption. Regarding output markets, biomass (58.33%) and briquettes (82.08%) are largely accessible at the district level, indicating that these value-added products are linked to more distant and possibly organized markets, creating challenges for small farmers in terms of transportation and market linkage.

Compost markets are mainly available at the mandal level (59.58%), with moderate presence at village and district levels, reflecting relatively better local demand and accessibility. In contrast, fodder markets are highly localized at the village level (71.25%), highlighting their immediate utility and strong local demand within farming communities. Overall, the findings reveal that while essential outputs like fodder are easily accessible locally, high-value and processed CRM products depend on distant markets, and machinery access is concentrated at intermediate levels, emphasizing the need to strengthen local market infrastructure, improve supply chains, and promote decentralized CRM enterprises to enhance accessibility and farmer participation.

Table 11: Categorization of respondents based on their market accessibility.

S.No.	Category	Input market access	Output market access			
		Machinery	Biomass	Compost	Briquettes	Fodder
1	Village level	86 (35.83%)	10 (4.17%)	44 (18.33%)	10 (4.17%)	171 (71.25%)
2	Mandal level	128 (53.33%)	90 (37.50%)	143 (59.58%)	33 (13.75%)	35 (14.58%)
3	District level	26 (10.83%)	140 (58.33%)	53 (22.08%)	197 (82.08%)	34 (14.17%)

16.Awareness on Government policies/schemes related to residue burning

The analysis of farmers' awareness regarding various approaches to crop residue management (CRM) reveals a high level of awareness for general policy measures and incentive-based interventions, while awareness of regulatory and advanced institutional approaches remains notably low as shown in table.12. A vast majority of respondents were aware of banning crop residue burning (92.92%), subsidies on agricultural implements (90.42%), and crop diversification incentives (85.42%), indicating effective dissemination of commonly promoted government initiatives. Similarly, awareness campaigns on CRM practices (83.75%) have reached a large proportion of farmers, reflecting the success of extension efforts in creating basic awareness. However, awareness drops sharply for more specific or enforcement-oriented measures, with only 4.17% aware of penalties imposed by the National

Green Tribunal (NGT) and just 1.67% aware of the imposition of Section 144 under the Civil Procedure Code, suggesting limited communication of legal enforcement mechanisms. Additionally, awareness of market-oriented and advanced interventions, such as establishing marketplaces for CRM products (20.42%), biomass-based power projects (10.42%), and exposure visits to briquette units (6.67%), is relatively low. Awareness of detection and prevention through physical enforcement (11.25%) is also minimal, indicating that such measures are either not widely implemented or poorly communicated. Overall, the findings suggest that while farmers are well-informed about general awareness campaigns, subsidies, and diversification strategies, there is a significant gap in understanding regulatory, market-driven, and advanced technological approaches, highlighting the need for more comprehensive and targeted extension strategies to improve awareness and adoption of diverse CRM interventions.

Table 12: Categorization of respondents based on their Awareness on Government policies/schemes related to residue burning.

S.No.	Approaches	Aware		Not aware	
		F	%	F	%
1	Banning Crop Residue Burning	223	92.92	18	50
2	Penalty is being imposed on any offending farmer (The National Green Tribunal (NGT) has imposed fines ranging between Rs 2,500 and Rs 15,000 on farmers to prevent them from burning paddy fields)	10	4.17	231	96.25
3	Detection and prevention through physical force	27	11.25	214	89.17
4	Establishment of a marketplace for crop residue managed products	49	20.42	192	80.00
5	Organising awareness campaigns on CRM practices	201	83.75	36	15.00
6	Subsidy on Agri-implements	217	90.42	20	8.33
7	Crop Diversification/ Bonus on MSP through crop diversification	205	85.42	32	13.33
8	Establishment of a larger number of biomass-based power projects utilising greater amounts of paddy straw and cotton stalks	25	10.42	216	90.00
9	Imposing the Section 144 of the Civil Procedure Code (CPC) to ban burning of paddy and cotton residues	4	1.67	237	98.75
10	Organising exposure visits to crop residue management product units like briquettes manufactured units	16	6.67	225	93.75

Conclusion

The study on socio-economic determinants of crop residue burning practices among farmers in Telangana clearly demonstrates that residue burning is influenced by a combination of institutional, economic, and infrastructural factors rather than mere lack of awareness. The findings across variables indicate that although farmers possess high awareness of CRM approaches and government initiatives, adoption is constrained by limited labour availability and poor access to appropriate machinery and technologies, particularly for advanced practices such as shredding, baling, and bioenergy utilization. The analysis of source of irrigation highlights a heavy dependence on borewells, reflecting individual resource investment but also pointing to regional disparities in resource availability. Further, extension contact patterns reveal strong reliance on state department officials and progressive farmers, while linkages with scientists, financial institutions, and emerging actors like FPOs and agripreneurs remain weak, limiting the flow of specialized and market-oriented information.

The study also shows that while training programs are largely focused on awareness creation, subsidies, and basic technical skills, there is insufficient emphasis on digital advisory services, entrepreneurship, and value addition, which are crucial for sustainable CRM adoption. In terms of

credit availability, formal institutions such as commercial banks play a significant role, but gaps persist in cooperative and development-based financing, leading farmers to depend on informal sources like relatives and fellow farmers. Moreover, market accessibility analysis reveals that while fodder markets are localized, high-value CRM outputs such as biomass and briquettes are concentrated at distant district-level markets, creating logistical and economic barriers for farmers.

Overall, the persistence of residue burning is primarily driven by labour shortages, inadequate mechanization, weak institutional convergence, limited market access, and financial constraints, despite reasonable awareness levels. Therefore, addressing this issue requires a comprehensive and integrated strategy that strengthens local-level machinery access, improves labour-saving technologies, enhances institutional credit delivery, promotes decentralized markets for residue-based products, expands capacity-building in advanced and entrepreneurial aspects, and reinforces extension systems for better coordination among stakeholders. Such a holistic approach is essential to ensure the large-scale adoption of sustainable crop residue management practices and to effectively reduce residue burning.

Conflict of Interest: Nil

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