

## PREVALENCE OF STUBBLE BURNING IN PUNJAB: EXPLORING DRIVERS AND THE EMERGING ROLE OF MOTORWAY POLICE

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DOI:<https://doi.org/10.5281/zenodo.17291676>

### Keywords

Roadside stubble burning, Traffic hazards, Role of Motorway Police, Stubble burning alternatives, Awareness campaigns

### Article History

Received: 11 August 2025

Accepted: 21 September 2025

Published: 08 October 2025

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### Abstract

Rice harvest seasons in Punjab are characterized by severe smog and elevated air quality index levels, with roadside stubble burning posing particular risks by reducing visibility and increasing traffic accidents. Despite its significance, research examining roadside burning practices, traffic disruptions, and motorway police interventions remains limited. Employing a cross-sectional mixed-methods design, this study surveyed 181 farmers across five districts along major motorways and highways within the rice-wheat cropping zone to investigate farmers' perceptions of roadside stubble burning impacts and the emerging role of National Highways and Motorway Police in mitigation efforts. Findings reveal that farmers possess considerable awareness of stubble burning's detrimental effects but continue the practice due to unaffordable and inaccessible alternatives rather than conservative attitudes. Respondents demonstrated high awareness of roadside burning's traffic hazards, citing multiple fatal accidents caused by smoke, while Motorway Police actively patrol highways, educating farmers and enforcing regulations. However, approximately half the respondents perceived penalties as unjust, arguing that enforcement without viable alternatives constitutes an unsustainable approach. The study recommends policy interventions extending beyond awareness campaigns and punitive measures to incorporate farmer training, financial support, and multi-stakeholder collaboration for sustainable stubble burning solutions.

### INTRODUCTION

The practice of setting fire to crop residues after harvest is widespread in Punjab, Pakistan (Azhar et al., 2019; Lin and Begho, 2022). Every year, millions of tons of crop residues are set on fire in fields, sending hazardous smoke into the atmosphere. While it offers a quick and cheap way to clear fields, it poses serious environmental, public health, and economic issues (Majumder et

al., 2023). It is considered a significant contributor to smog in the Indo-Pak gigantic plains (Singh et al., 2017; Sawlani et al., 2019; Singh et al., 2023). According to FAO (2019), stubble burning contributes 20% to smog. The issue is especially severe during the rice harvesting season as the winter temperature triggers pollutants to stay longer in the atmosphere,

obstructing visibility (Gupta, 2019; Abdurrahman et al., 2020).

One significant concern associated with this practice is the substantial production of the pollutant black carbon (Zhu et al., 2019). These particles contribute to air pollution, adversely impacting both the environment and human health. Black carbon is known to have detrimental effects on respiratory health and plays a significant role in climate change by absorbing sunlight and contributing to global warming (Highwood and Kinnersley, 2006; Ramanathan and Carmichael, 2008). Furthermore, the burning of crop residues leads to a decrease in soil fertility, reducing the long-term sustainability of agricultural systems. By burning organic matter that could otherwise be incorporated back into the soil as nutrients, the practice diminishes the soil's capacity to support healthy crop growth and productivity (Ladha et al., 2004; Reddy and Chhabra, 2022). The destruction of habitats through stubble burning can lead to a decline in biodiversity, posing health risks to wildlife, including animals, birds, and insects (Kohli et al., 2021; Singh, 2024).

Stubble burning releases pollutants such as PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, CH<sub>4</sub>, and NO<sub>x</sub>, contributing to smog and poor air quality (Rashid et al., 2025). A study by Raza (2025) shows a 36% rise in respiratory infections in affected regions. Heavy smog in the harvesting season leads to severe Air pollution. The issue becomes particularly acute along highways, where smoke impairs visibility, increases accident risks, and contributes to regional air pollution. A study by the Pakistan Environmental Protection Agency (Pak-EPA, 2020) found that visibility on major highways in Punjab dropped by up to 70% during peak burning periods (Khan et al., 2025).

Over the past few years, many cities in Punjab have witnessed alarmingly high AQI levels. Considering this, the Punjab government declared an environmental emergency and devised an Air Quality Policy. Under the "Punjab Environmental Protection Act" and "policy on controlling smog 2017", a ban was imposed on stubble burning with penalties of FIR and fines on farmers involved in burning. Further, it was

decided to raise farmers' awareness and provide them with alternatives to stubble burning. Various government departments were assigned responsibilities on this, including the Motorway Police, who launched an organized anti-smog awareness campaign and monitoring activities.

Numerous studies (Pathak et al., 2025; Krishnapriya et al., 2024) have investigated the causes of stubble burning and government efforts with respect to providing subsidies to buy machinery. Others (Kumar et al., 2015; Ahmed et al., 2015; Goyal et al., 2025; Singh et al., 2023) focus on the severe impact of stubble on health and socio-economic dimensions. In addition, Howes et al. (2017) and Criscuolo et al. (2022) evaluated broader policy frameworks, such as government bans, and the role of the agriculture department towards awareness campaigns. However, there is no study available that explored the special dimensions of roadside stubble burning and the role of National Highways and Motorway Police in dealing with it. This study is therefore designed to answer the question: What do farmers perceive about the specific impacts of roadside stubble burning? And how do National Highways and Motorway Police play their part in curbing roadside stubble burning and managing traffic?

### Methodology

The study employed multi-stage random sampling to achieve representativeness. First, five districts: Kasur, Sialkot, Hafizabad, Sheikhupura and Nankana Sahib were selected from the rice-wheat cropping zone (highly prevalent area for stubble burning), while

considering their location along motorways and highways. The population for the study was farmers located near motorways and highways within the selected districts. These farmers were involved in and also the direct effectees of stubble burning near roads, making them pivotal to comprehend the phenomenon of stubble burning alongside roads and their consequences. At the second stage, villages adjacent to major roads were identified. From these, 4 villages were

randomly selected from the territory of each district. In the next step, 9 farmers from each selected village, whose farms were in proximity to the motorway or major highways, were randomly selected for data collection. The sample size of 181 is determined through Yamane's formula by keeping the confidence level and margin of error at 95% and 7% respectively.

A cross-sectional research design was adopted to reach respondents for data collection. The study incorporates both qualitative and quantitative components. The questionnaire includes closed-ended survey questions along with open-ended ones to provide in-depth comprehension of the issue Creswell and Clark, 2018).

The questionnaire, first made in English, was translated into the local language (Urdu) to ensure accessibility and clarity for respondents. Validity of the questionnaire was ensured through expert review. Further, a pilot survey of 8 farmers (other than the respondents of the main study) was conducted to check the reliability of the instrument. Cronbach's alpha value was 0.807, indicating that the internal consistency of the questionnaire is acceptable (Nunnally & Bernstein, 1994).

Quantitative data were analyzed through SPSS, and descriptive statistics were used to summarize the findings of the study. Qualitative responses were thematically analyzed using the approach of Braun and Clarke (2006). Finally, findings from both sections were used to get insights and a

deeper understanding of the study's objectives (Curry et al., 2009).

### Result and Discussion

Table 1 presents the results of the socio-demographic characteristics of the respondents. The result shows the distribution of respondents based on age. From the result, those 36-45 years old have the largest percentage of 34.3%, followed closely by those 26-35 years (28.7%). Together, these two groups make up 63% of the respondents. Only 4.4% are 25 years or younger. In relation to educational level, the majority (61.3%) have a "Matric or less" level of education. Only 24.3% have an FA (intermediate) or higher qualification. However, some (14.4%) are illiterate. The result also indicates that most of the farmers are smallholders. 61.3% have farms of 10 acres or less. Only 11% have farms larger than 20 acres. In addition, over one third (37.0%) have direct access from a road (within 100m). 56.3% (37.0% + 19.3%) are within 200m. This indicates high proximity of the farms to the road. In relation to experience, the result indicates that 33.1% have 6-15 years of experience, and a further 56.9% (23.2% + 19.9% + 13.8%) have 16 years or more of experience. Nearly half (48.6%) of the farmers have their land within 1 km of their home. The majority (69.6%) have their farm land within 2 km. The most common pattern of crop cultivation is wheat and rice, followed by 87.3% of farmers.

**Table 1: Socio-Demographic Characteristics of the Respondents**

| Age                      | Frequency | Percentage |
|--------------------------|-----------|------------|
| 25 years or less         | 8         | 4.4        |
| 26 to 35 Years           | 52        | 28.7       |
| 36 to 45 Years           | 62        | 34.3       |
| 46 to 55 Years           | 43        | 23.8       |
| More than 55             | 16        | 8.8        |
| <b>Educational Level</b> |           |            |
| Matric or LESS           | 111       | 61.3       |
| FA and above             | 44        | 24.3       |
| Illiterate               | 26        | 14.4       |
| <b>Farm size</b>         |           |            |
| 5 or less than 5 acres   | 48        | 26.5       |
| 6 to 10 acres            | 63        | 34.8       |

|                                                     |     |      |
|-----------------------------------------------------|-----|------|
| 11 to 15 acres                                      | 35  | 19.3 |
| 16 to 20 acres                                      | 15  | 8.3  |
| More than 20 acres                                  | 20  | 11.0 |
| <b>Distance of farm land from home</b>              |     |      |
| 1 OR < 1 km                                         | 88  | 48.6 |
| Up to 2 km                                          | 38  | 21.0 |
| Up to 3 km                                          | 16  | 8.8  |
| Up to 4 km                                          | 9   | 5.0  |
| Up to 5 or more                                     | 30  | 16.6 |
| <b>Distance of farm edge from the road (meters)</b> |     |      |
| Up to 100 m                                         | 67  | 37.0 |
| Up to 200 m                                         | 35  | 19.3 |
| Up to 300 m                                         | 18  | 9.9  |
| Up to 400 m                                         | 9   | 5.0  |
| Up to 500 m                                         | 52  | 28.7 |
| <b>Years of farming experience</b>                  |     |      |
| 5 or less than 5 years                              | 18  | 9.9  |
| 6 to 15 years                                       | 60  | 33.1 |
| 16 to 25 years                                      | 42  | 23.2 |
| 26 to 35 years                                      | 36  | 19.9 |
| Above 35 years                                      | 25  | 13.8 |
| <b>Main Crop Grown</b>                              |     |      |
| Wheat and Rice                                      | 158 | 87.3 |
| Other                                               | 23  | 12.7 |

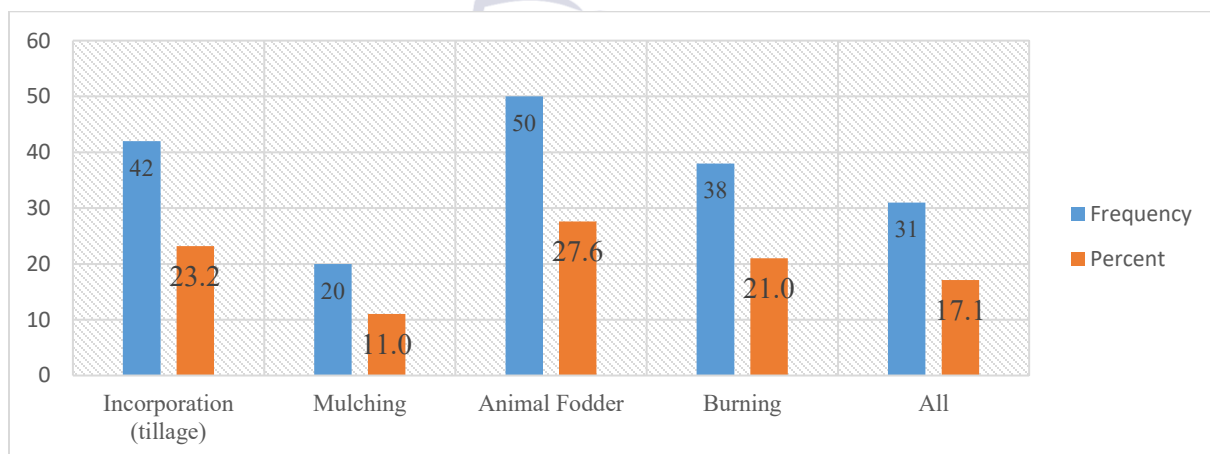


Figure 1. Various crop residue management practices followed by farmers

Figure 1 shows the disposal of stubble by farmers having fields along roadsides. The most common use of stubble, indicated by 27.6% of farmers, is as animal fodder. This is followed by the incorporation of stubble into soil, as indicated by

23.2% of farmers. Data showed that burning is a major issue, as 21.0% respondents reported that they fire stubble in the fields to get rid of it. Mulching is the least common practice among farmers, as only 11.0% respondents highlight the adoption of this practice. Further, many farmers (17.1%) indicated that they use a combination of

methods to manage stubble, considering its need and the resource availability.

**Table 2. Farmers' perception about the drivers of Stubble Burning**

| Statements                                                                                          | Mean | Std. Dev |
|-----------------------------------------------------------------------------------------------------|------|----------|
| Burning stubble is necessary to prepare the soil and sow the next crop on time                      | 3.35 | 1.43     |
| The high cost of alternative methods of residue management makes burning the only affordable option | 3.41 | 1.40     |
| Burning stubble is beneficial for soil fertility                                                    | 2.58 | 1.49     |
| Burning stubble is necessary to kill harmful insects/pests                                          | 2.54 | 1.38     |
| Field/soil preparation is incomplete without burning stubble                                        | 2.65 | 1.42     |
| I burn stubble because my neighbors do the same                                                     | 2.65 | 1.37     |

Scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

According to Table 2, the primary drivers for stubble burning are practical and economic. As most farmers agreed that stubble burning is practiced due to the high cost of alternatives (Mean=3.41) and to save time in soil preparation (Mean=3.35) due to shorter time in cultivation of

the next crop. Interestingly, traditional beliefs about stubble burning that it is necessary for soil fertility, pest control, and soil preparation are less strong motivators (Means ~2.6). Similarly, social influence is also a moderate factor, as farmers disagree with the statement that I burn stubble because my neighbors do it.

**Table 3. Farmers' awareness about the roadside hazards of stubble burning**

| Statements                                         | Mean | Standard Deviation |
|----------------------------------------------------|------|--------------------|
| Smoke from roadside burning makes it hard to drive | 4.49 | 0.90               |
| Smoke decreases visibility on the road             | 4.38 | 0.98               |
| I am aware that roadside burning causes accidents  | 4.28 | 1.02               |
| Stubble smoke exposes people to health problems    | 3.92 | 1.17               |

Scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

According to Table 3, there is a very high awareness among farmers of the hazards of roadside stubble burning, as most farmers strongly agree that it makes it hard to drive and

causes reduced visibility and accidents. Further, the awareness about health impacts is also high, as farmers agree that stubble smoke exposes people to health problems, with a mean value of 3.92.

**Table 4. Perceived barriers to adopting alternatives**

| Statements                                                                         | Mean | Std. Dev. |
|------------------------------------------------------------------------------------|------|-----------|
| I cannot easily access machines to manage stubble                                  | 3.61 | 1.56      |
| There are no government subsidies supporting farmers to adopt alternative measures | 3.91 | 1.32      |
| Alternate soil preparation methods are too labor-intensive                         | 3.94 | 2.82      |
| No demonstration trial of alternative methods, i.e., happy seeder                  | 3.49 | 1.52      |
| Alternate methods produce less yield                                               | 2.82 | 1.52      |

Scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

According to Table 4, the main perceived barriers by farmers in the adoption of alternative measures are systemic and economic: absence of subsidies, high labor requirement, and lack of access to machinery, with agree response of

farmers. While farmers' response is neutral on the absence of demonstrations of alternative methods and on the statement that alternative methods produce less yield, with a mean value of 3.49 and 2.82, respectively.

**Table 5. Farmers' Exposure to intervention by Motorway Police on stubble burning along the major highways**

| Questions                                                                                                        | Yes       | No        |
|------------------------------------------------------------------------------------------------------------------|-----------|-----------|
| Have you received educational/awareness messages from the Motorway Police?                                       | 118(65.2) | 63(34.8)  |
| Motorway Police educated us about the consequences of stubble burning on traffic                                 | 91(50.3)  | 90(49.7)  |
| Did the Motorway Police ever intervene to stop roadside burning?                                                 | 155(85.6) | 25(13.8)  |
| Motorway Police officers warn us about the legal actions and fines for stubble burning alongside the highway?    | 86(47.5)  | 95(52.5)  |
| I consider the intervention of the Motorway Police against stubble burning to be fair.                           | 92(50.8)  | 89(49.2)  |
| Motorway Police constantly patrol along the highway to vigilantly monitor any fire during the harvesting season. | 112(61.8) | 69(38.12) |

Table 5. indicates that the majority of farmers (65.2%) have received educational/awareness messages from Motorway Police. Around half of the respondents (50.3%) reported that the Motorway Police had educated them about the consequences of stubble burning on traffic. There is a vast majority of farmers (85.6%), indicating that Motorway Police intervened to stop roadside stubble burning. Further, nearly half (47.5%) of farmers highlighted that they

were provided with awareness about the legal consequences and the penalties of stubble burning by Motorway police, especially near the roads. Similarly, around half (50.8%) of respondents consider Motorway Police interference against stubble burning to be fair. At last, 61.8% of farmers manifest that Motorway Police constantly patrol along the highway to vigilantly monitor any fire during the harvesting season.

#### Qualitative results:

**Table 6. Thematic analysis**

| Major Findings             | Themes                        | Sub-Themes                                                                                                                                                               |
|----------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Drivers of stubble burning | Economic constraints          | <ul style="list-style-type: none"> <li>• Unaffordable alternatives</li> <li>• Rising input prices</li> <li>• No Subsidies</li> </ul>                                     |
|                            | Time and resource constraints | <ul style="list-style-type: none"> <li>• Short time for land preparation for the next crop</li> <li>• Unavailability of machinery</li> <li>• Expensive labour</li> </ul> |



| Major Findings             | Themes                           | Sub-Themes                                                                                                                                                         |
|----------------------------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Perceptions and Awareness  | Road safety awareness            | <ul style="list-style-type: none"> <li>• Reduced visibility for driving</li> <li>• Fatal Road accidents</li> </ul>                                                 |
|                            | Environmental & Health Awareness | <ul style="list-style-type: none"> <li>• Disturb soil fertility</li> <li>• Breathing problems</li> <li>• Causing smog</li> </ul>                                   |
| Actions of Motorway Police | Community Engagement             | <ul style="list-style-type: none"> <li>• Awareness campaigns</li> <li>• Farmers meetings</li> <li>• Promoting alternatives</li> </ul>                              |
|                            | Enforcement and Interventions    | <ul style="list-style-type: none"> <li>• Patrolling</li> <li>• Issuing warnings and Fines</li> <li>• Monitoring fires</li> <li>• Road safety management</li> </ul> |

Qualitative findings in Table 6 revealed drivers of stubble burning, farmers' awareness, and the role of the motorway police as the main domains. Stubble burning drivers were characterized by economic limitations, time, and resource constraints as themes. Farmers widely stated that alternatives to stubble burning given by the government were unaffordable due to high costs and the absence of subsidies. In addition, farmers highlighted the rising input prices, making farming tough. The short time span between the two crops, rice and wheat, is another driver of stubble burning mentioned by many farmers. Resource constraints include the inaccessibility of suitable machinery and the shortage/high cost of labor, leading to burning as the most accessible option.

Under the domain Perceptions and awareness of farmers, two themes, road safety concerns and environmental and health awareness, indicated that farmers were well aware of the negative consequences of stubble burning, both on road traffic and human health. In the domain of the role of motorway police, respondents highlighted community engagements through farmers' meetings and awareness campaign activities of the Motorway Police. Additionally, farmers explained law enforcement activities of motorway police through fines to farmers practicing stubble burning on their farms. The sub-themes patrolling, monitoring fires, issuing warnings,

and managing road safety indicated active involvement of motorway police in restricting fire to stubble near roads.

### Discussion

The demographic attributes of farmers indicate that the majority of farmers are under matric or literate. Illiteracy or less formal education among farmers may limit their exposure to knowledge of innovative farming practices, such as alternative methods of crop residue management. Various studies have mentioned that farmers' less formal education has an association with their dependence on traditional practices such as stubble burning, whereas educated farmers are more inclined towards mechanized or sustainable alternatives to stubble burning (Onphanhdala, 2009; Widijanto et al., 2024).

Results also found that most respondents are small landowners (as 61% owned less than 10 acres). Small farmers often have limited resources to invest in their farms and face severe financial constraints to adopt new technology. For these farmers, burning stubble is the low-cost practice of land preparation. As Bhuvaneshwari et al (2019) stated, small and marginal farmers often lack affordable/accessible replacements of stubble burning, which is a key driver for continued burning.

Another notable finding is that most farms were located within one to two kilometers of farmers'

homes, with proximity to roads. Although this proximity facilitates farmers' easy transportation of commodities, it also intensifies the road safety concerns during events of stubble burning. Roadside stubble burning causes reduced visibility and increases the risks of fatal traffic accidents.

Results in Table 2 challenge the assumption that stubble burning is mainly driven by farmers' mindset to stick with traditional practices, lack of awareness, and perceived usefulness of burning, i.e., better for soil fertility and pest management. The findings show that stubble burning exists mainly due to practical and economic constraints. Farmers are aware of the adverse effects of stubble burning, but economic barriers and limited access to resources compel them to continue the practice. Farmers highlighted that alternative methods, such as the use of the latest machinery for zero tillage and residue incorporation, are not only expensive but also inaccessible in their areas. The high rental costs of machinery and the issue of timely availability during the narrow window between rice harvest and wheat sowing make the adoption of sustainable practices difficult. These results are well supported by qualitative findings, as farmers stated that "Stubble burning is necessary to me because I don't have money to adopt alternate costly measures." Another farmer stated that "Farmers are already paying a heavy price due to the rising prices of fertilizers and pesticides, and the low value of our produce. Further, we are asked to pay for the heavy cost of managing stubble. We cannot afford".

Findings of the study showed that farmers believe, contrary to the argument presented in studies of Andrae (1991), Ekboir (2002), Korontzi et al. (2006), Pathak et al. (2011), and Huang et al. (2012), that burning is the cheapest and natural way farmers use for pest control and soil fertility. According to Ahmed et al. (2015), farmers believe that ash that comes through burning residue can help enhance soil fertility, which can subsequently promote healthier plant growth and higher yields. However, the current study results showed that farmers disagree that burning is beneficial for pest control or soil

health. Further, study findings are in line with Raza et al (2019), who discovered that farmers with awareness of high risks of stubble burning are willing to adopt sustainable residue management practices but are obstructed by economic, time, skills, and resource constraints. According to the study by Erbaugh et al (2024), farmers perceive government efforts subsidizing machines and enforcing legal sanctions against stubble burning to be ineffective and inequitable. Further, results indicate that farmers are aware of the negative consequences of burning stubble. They recognize that roadside burning severely compromises road safety (visibility, accident risk). However, this awareness has not translated into a change in practice because the perceived barriers to alternatives are too high. One farmer stated that "I know it is very dangerous, especially near road sides. Plus, it can lead to fire in other fields as well. I try not to burn, but then I have to harvest traditionally, by hand. It is time-consuming and also challenging due to a shortage of labor." The incidents of accidents are reported by many farmers in qualitative results. "Once, I traveled from Faisalabad to Lahore. Near Sheikhpura, an accident occurred due to a visibility problem caused by the smoke of stubble burning." "A few years back, a fatal road accident happened because of stubble smoke, resulting in the death of one passenger."

Further, results found the active and impactful involvement of the Motorway Police in both educating farmers and intervening in their stubble-burning action. It means they are broadening their responsibilities beyond traditional law enforcement on roads into organized educational campaigns for farmers to restrain stubble burning. The vast majority (85.6%) of farmers reported the direct intervention of Motorway Police in stubble burning occurrences, highlighting that burning stubble alongside roads/highways is not only an environmental issue but also a concern for the safety of travelers. Although these interventions provide an immediate response to minimize the risks, this approach cannot overcome the main drivers behind stubble burning. Therefore, around half of the farmers considered these



interventions by the Motorway Police to be unfair, indicating mixed, conflicting opinions of farmers. Half of the respondents had a realization of the duties of Motorway Police in ensuring road safety, while others might view these interventions as a punitive or unrealistic approach that denies the farmers' practical constraints. Chaudhary et al. (2022) and Mishra et al. (2024) found that farmers were aware of penalties for stubble burning but continued doing so because they considered it unfair. Demi and Sicchia (2021) reported that many farmers are aware of the health risks of stubble burning but continue the practice due to economic constraints and lack of viable alternatives. Awareness campaigns have had limited success due to cultural norms and skepticism about government interventions. Research by the Sustainable Development Policy Institute (SDPI, 2022) revealed that while 65% of surveyed farmers were aware of the health and environmental risks, only 22% considered alternatives to burning.

Besides, the majority of farmers accepted that the Motorway Police regularly patrol during the harvesting season for monitoring purposes to deter farmers from burning. Patrolling is crucial to find and take prompt actions against roadside fires, i.e., manage nearby traffic to avoid accidents and warn farmers.

Moreover, it is worth mentioning that it is primarily the role of agricultural extension workers to educate farmers and implement demonstrations of sustainable agricultural practice to drive broader adoption. Compelling farmers not to burn without providing them with practically feasible and economically viable alternatives is a flawed model. Many studies highlighted that Farmers often resort to stubble burning because they lack alternatives to manage it (Chongloi et al., 2021; Kaur et al., 2021). Provided that, Chambers' framework of "putting farmers first" and building practicable solutions considering local contexts and the needs of farmers is the way to curtail stubble burning.

#### **Alternatives to stubble burning:**

Farmers need to use a blend of on-farm and off-farm practices to manage stubble and avoid burning. On-farm practices that include no-till sowing, in-field incorporation, and mulching through machinery like Happy Seeder and straw-choppers, etc., have proved effective. These are not only cost-effective methods for timely wheat sowing but also beneficial for restoring soil health. Off-farm practices include collecting stubble for animal fodder, straw bedding, making compost, mushroom cultivation, and biogas production. Further, there is potential for its use in industries of paper and packaging, pellets and briquettes, biochar, bioenergy, and eco-friendly construction, such as Particleboard.

However, most of these alternatives are not accessible for farmers as farm machinery for on-farm usage is too expensive, and the absence of organized markets or infrastructure for farmers to sell their crop residue limits off-farm practices. This jeopardizes the opportunities for farmers to generate income and sustainably manage crop residue. So, farmers should be supported to streamline this transition at a large scale. Especially, straw collection and baler machines should be made accessible for farmers to swiftly and smoothly remove crop residue from the field instead of burning.

#### **Conclusion and Implications**

Stubble burning is a complex phenomenon driven by the interaction of multiple factors, in which farmers work under the burden of a ruthless system that offers them very limited viable alternatives. Findings suggest that farmers are aware of the harmful effects of burning stubble, especially near roadsides, as they rejected the notions that it is beneficial for pest control and soil health. However, they are compelled to continue due to a lack of affordable and accessible alternatives. Motorway Police is carrying out a strong, active role in not only enforcing laws but also educating the farmers around highways. They also intervene in the farmers' action of stubble burning in the immediate vicinity of highways to ensure the smooth flow of traffic. Farmers also pointed out

the patrolling of the Motorway Police on the highway to monitor stubble burning. However, these efforts are insufficient to address the root cause of stubble burning. Therefore, about half of farmers consider the penalties and intervention of the Motorway Police as unfair. Hence, to effectively reduce stubble burning, particularly the hazardous roadside burning, policy must move beyond mere awareness and penalties and focus on capping barriers in the adoption of alternatives, mobilizing the extension workforce to train farmers, and providing farmers with adequate financial support.

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