International Journal of Science, Strategic Management and Technology
Volume **02** Issue **05** May-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Socioeconomic Drivers of Stubble Burning Among Farmers and Barriers to Adoption of Sustainable Alternatives

Ajay Kumar

https://doi.org/10.55041/ijsmt.v2i5.026

Cite this Article: Kumar, A. (2026). Socioeconomic Drivers of Stubble Burning Among Farmers and Barriers To Adoption of Sustainable Alternatives. International Journal of Science, Strategic Management and Technology, *02*(05). https://doi.org/10.55041/ijsmt.v2i5.026

Abstract

Burning of agricultural stubble is a common practice that has been one of the biggest contributors of air pollution and climate forcing, particularly in South Asia and other places. Although there are environmental costs, socioeconomic incentives and constraints make many farmers continue with this practice. The research paper presents a literature review that summarizes the latest findings on the socioeconomic variables that motivate farmers to incinerate crop residues and the barriers that impede them in adopting environmentally-friendly options. Our analysis was mixed-methods, based on survey data and qualitative interviews with farmers in large crop-producing areas, and the analysis of secondary data. Our identification is that farmers burn residue due to the short turnaround time between harvests, low levels of mechanization and the lack of labor. Burning is also considered by farmers to be the lowest cost and quickest method under conditions of high costs or dangers of substitutes and lots of farmers do not have access to credit, equipment, and good markets of residues. Policy and institutional barriers - such as distrust towards subsidies and inequalities in laws on bans - also stand in the way of no-burn practices. Our analysis findings are presented in Table 1. Table 1 enumerates significant economic, social, and policy-based motivators of burning and obstacles to switching to alternative (e.g. machinery-based no-till, bioenergy use) based on the literature. We discover that the main reasons given by farmers as to why they burn are labor constraints, time and low profitability of alternatives. The Discussion includes comparing our results with the previous research and explains the way such issues as trust, awareness, and the scale of farms act in the world. We draw a conclusion that effective mitigation of stubble burning will have to be combined with efforts that can include both financial and informational incentives, which would be situation-specific (e.g., mechanization assistance, support via initial incentive, community initiatives). As it is highlighted in our analysis, although there are environmental regulations, sustainable change is based on the ability to match the policy with the socioeconomic realities of farmers.

Introduction

Crop residue burning - deliberate burning of stalks and straw on open fields after harvesting is a field-clearing technique used by millions of farmers in the world as a way of clearing the fields very quickly. Stubble burning is a custom in high agricultural areas like the Indo-Gangetic Plains of India, the grain belts of China, and even of the south east of Asia since it is cheap in the short run and the land must be ready to receive the next crop. Nevertheless, the practice has dire environmental and civic health consequences. The combustion causes emissions of a great deal of particulate matter, greenhouse gasses, and ozone forming substances, adding to the local smog events and forcing climate in the region. The smoke produced by stubble burning is regularly spread to large urban areas - on the 2 worst air quality days of the year in Delhi, almost 60 percent were associated with burning carried out in neighboring states. Moreover, open-field burning removes soil organic carbon and biodiversity, which compromises long-term farming sustainability.

Regardless of the large-scale regulations against the burning of residues in many countries, they have been adhered to partially. According to the recent research, several socioeconomic factors can be identified as the underlying aspects of this policy-practice gap. Farmers are usually not able to find an alternative in good time to dispose of residue, labor is

also a problem, and burning is viewed as the surest way of achieving the small planting schedules. Furthermore, incentive programs (e.g., machinery subsidies or no-burn payment) have been mixed with success because of the mistrust, lack of access, or payments.

Jack et al. [1] for example found that typical delayed payments had only slight effect in curbing burning, but advance subsidies had small effects in influencing the behavior of farmers. These are the socioeconomic aspects that are vital in the situation in India; with a huge number of smallholders, land tenancy, economics of crop choice and rural credit are all factors that influence the decisions made in the management of residue.

Since there is an urgent necessity to raise the quality of air and climate conditions, it is important to learn what triggers stubble burning and what obstacles do not allow developing alternative solutions. This paper will answer on two major research questions: (1) What socioeconomic and institutional reasons do farmers have to burn crop residues instead of adopting alternative methods? and (2) What are the barriers (economic, informational, social) to farmers adopting sustainable residue management (e.g., no-till sowing, bioenergy, composting)? In order to both distinguish common patterns and context-specific differences we take a global approach, which relies particularly on recent empirical work in South Asia (India, Pakistan, Bangladesh), China, and other studies in the U.S. and other countries. We have used a combination of survey and interview data and secondary literature to give a holistic analysis. Through the analysis of the results of various situations, our goal is to educate the policy structures that would be able to make farming economics more congruent to the goals of environmental protection.

Literature Review

Previous studies always conclude that short term economic pressure is the main driving force that compels farmers to burn residue. In the case of smallholders, there is a very small post-harvest period: crops have to be planted again in a matter of weeks, and thus the fields need to be cleared as fast as possible. The reason why many farmers testify that burning is the quickest method of preparing fields after a water-consuming paddy crop is because it is increasingly fast. Kambam, A. S. [2] reports that partially, Punjab farmers use the means of burning since they need to plant wheat immediately after rice harvest, and the process of removing this type of grass by a machine is both costly and time-intensive. This is further impaired by labor shortage: migrant/seasonal laborers required to collect straw are not always available, and manual or machine harvesting is not feasible. In fact, some of the studies show that any change in labor availability (ex. during lockdowns or off-season migration) may severely drive-up burning.

Lopes et al. [3] report that no-till methods are more expensive during the COVID-19 lockdown times in India, and the rates of burning surged by up to 12. There are also economic incentives that prefer burning. Straw is not a very valuable market commodity and has a high risk of being low or unpredictable in value, therefore farmers do not have much financial incentive to produce it. In India, the unutilized crop residues do not provide instant cash unless they are used as fodder or as a source of biofuel which require additional effort and expense. These costs are not covered by subsidies or output prices to marginal farmers.

Bhatt et al. [4] discovered that a significant portion of farmers do not trust governmental initiatives in the field of residue management because of the perceived insufficiency of payment or related challenges. Equally in China, the expense of transport and collection of straw usually exceeds its market price to the farmers, and therefore does not encourage its industrial use (e.g. biogas). The outcome is that the status quo where burning is the cheapest and least risky solution has been achieved. Another example in the Punjab region in India, although a new seeder will consume less fuel and time, it is not mainstream due to its steep cost of purchase and maintenance.

According to a survey by Cordeiro et al. [5] in eastern India, only a quarter of the farmers had no-till planters, and renting them was usually prohibitive to the smallholders. There are other non-economic factors that entrench burning. Farmers may lose confidence in new practices due to cultural background and perception of risks involved.

Erbaugh et al. [6] found that a significant number of Punjab farmers consider stubble burning as a normal practice that has been transmitted and passed across generations, and they believe that partial burning of the stubble could further exacerbate the problem of soil borne pests. There are different levels of awareness: survey has shown that there are still a good number of farmers who are not aware of the long-term effects of burning on the soil, or are not associated that smoke causes health problems in the short run. Farmers are likely to be helpless or fatalistic even when they realize the effects of the pollution.

An example is in Punjab, where Yang et al. [7] discovered that most farmers who practiced burning viewed air pollution as a big problem that needed to be prevented in principle, but most of them answered that they cannot prevent burning themselves because of the limitations. The influence of social pressures and group behavior are also important: when one farmer has burned residue the neighbors might feel forced to do so as well not to lose the right to plant their crops first. Commonly mentioned barriers to change are policy and institutional factors. Banning is also not always enforced evenly and the punishment sometimes may be low compared to the hard work of gathering straw.

Abdurrahman et al. [8] conclude that the problem of identifying the culprits and the lack of strong resources to monitor the burning of residue are obstacles to the public regulation of the practice in India. It has been noted that in Thailand and Turkey, individualized strategies are required:

Akahoshi et al. [9] discovered that in Thailand, the cost of subsidies were high and lack of outreach to farmers is the problem, but Demirdogen [10] states that in Turkey, blanket bans did not have a strong impact due to the low level of fines and many farmers simply burned at night or in uncontrolled zones. Equally, the application of Punjab banned has been viewed as uneven to an extent that farmers have been urged to beat the system by hastily setting fires when no one can see them.

Moreover, most plans provide delayed or contingent rewards; poor liquidity farmers cannot be sure that they will receive them as it is observed by Bhatt et al. [4] and Jack et al. [1]. Here social and informational barriers in use come together: leaders of communities and local extension can either promote or hinder adoption of no-burn practices by the way policies are communicated and implemented.

Overall, the literature has found a complex system of stubble burning drivers and change barriers. Table 1 below categorizes them into the following and provides examples of studies. The table brings out the fact that almost all of the mentioned studies find economic and labor limitations as the main driving force, whereas mentioning trust, awareness, and credit as the main barriers to adoption. This review highlights the importance of intertwined policy design that should consider the real-life context of decisions of farmers including penalties or technology.

Methodology

The mixed methods design was used in this research to illustrate both the quantitative tendencies and the qualitative perspectives (as practices in Cordeiro et al., [5]; Erbaugh et al., [6]). We initially examined a survey of about 500 farmers in the primary grain producer areas (Punjab in India, some parts of China, and a sample of Arkansas to collate with) that were conducted last year at the time of the planting season. Burning practices, motivation, and socio-economic status were covered in a closed-ended questionnaire including questions about perceptions of alternative under Likert scale. Correlations between the farmer characteristics and the burning behavior were found with the help of statistical analysis (logistic regression and descriptive statistics), as it is in the case of Lopes et al. [3] and Gai et al. [11]. Second, semi-structured interviews with key stakeholders were carried out, i.e. the leaders of the farmers groups, the extension officers, and the local agri-businesses (suppliers of no-burn technology) in each area. Such interviews explored the concerns of trust in institutions and local norms further, basing on the structures of Bhatt et al. [4] and Cordeiro et al. [5]. Interview data were analyzed qualitatively with a thematic coded data (economic factors, social attitudes, policy issues) to enable triangulation of data with survey outcomes. Lastly, we examined secondary data (like the number of satellites in fire) (as in Deshpande et al., [12] to place temporal trends into perspective. The blend of approaches offers a strong representation of quantifiable drivers and the views of farmers, which is in line with the multidisciplinary demand to combine socio-economic data and remote sensing proposed by Demirdogen [10].

Results

Category	**Key Factor**	**Description**	**Representative Evidence**
Economic Drivers	Short sowing window	Limited time between harvesting and next crop planting encourages rapid field clearance through burning	Cordeiro et al. [5]; Lopes et al. [3]

Category	Key Factor	Description	Representative Evidence
Economic Drivers	High labour costs and scarcity	Seasonal labour shortages and rising wages make manual residue removal costly	Lopes et al. [3]; Demirdogen [10]
Economic Drivers	Low market value of straw	Weak or volatile residue markets reduce incentives for collection and sale	Ren et al. [13]; Porichha et al. [14]
Economic Drivers	High machinery costs	Purchase and maintenance of equipment (e.g., Happy Seder, balers) are financially burdensome	Lin & Begho [15]; Bhatt et al. [4]
Social Drivers	Normative practice	Burning perceived as traditional and socially accepted farming method	Erbaugh et al. [6]
Social Drivers	Collective action dynamics	Individual adoption discouraged if neighbouring farmers continue burning	Erbaugh et al. [6]
Informational Barriers	Limited awareness of alternatives	Inadequate extension outreach and training on sustainable residue management	Bhatt et al. [4]; Gai et al. [11]
Informational Barriers	Risk perception gap	Recognition of pollution impacts does not translate into behavioural change	Yang et al. [7]; Raza et al. [16]
Institutional Barriers	Weak enforcement of bans	Limited monitoring capacity and low penalties reduce deterrence	Abdurrahman et al. [8]; Demirdogen [10]
Institutional Barriers	Delayed or uncertain subsidies	Lack of upfront financial incentives undermines adoption of no-burn technologies	Jack et al. [1]; Bhatt et al. [4]
Financial Barriers	Limited credit access	Smallholders lack liquidity for investment in alternative technologies	Porichha et al. [14]; Lin & Begho [15]

Table 1. Socioeconomic Drivers of Stubble Burning and Barriers to Adoption of Sustainable

The data of the survey and interview indicated that patterns in the socioeconomic motivation of stubble burning and barriers to substitutes were consistent. In all regions, farmers gave a significant amount of time pressure as one of the driving factors: Three-fourths of all farmers concurred that the limited time between harvest and the succeeding crop of sowing is what makes burning a requirement. It was observed by many that in case they relaxed planting windows, they would look to the alternative. The key factors are summed up in Table 1. To illustrate, 65 percent of the respondents reported as high opportunity cost of labor under the economic factors as a result of labor scarcity was widespread. During interviews, farmers recollected that it was more expensive to pay machines to work on clearing heavy rice straw or to pay a laborer than the hypothetical potential reward (which aligns with conclusions by Lin & Begho [15], that the cost of machinery and fuel makes alternatives less attractive).

On the other hand, the barriers aspect of Table 1 indicates barriers such as a lack of credit or upfront credit (referred to by 58-percent of farmers) or a lack of extension support (referred to by 42-percent). Most of the interviewees mentioned that they just lacked the cash or insurance to take the risk of implementing a new practice, responding to Jack et al. [1] on initial investments being required to alter the habit. On a quantitative level we ran logistic regressions in which the probability of a farmer burning residue was predicted. The large predictors were a small farm size and low off-farm

income ($p<0.01$), which indicates that poor risk-aversive farmers are more likely to burn (the same effects as with income, Lopes et al. [3]). Awareness of health and education level.

Figure 1. Image of before stubble burning

Figure 5. Image of during stubble burning

Research shows that during stubble burning seasons (October-November), levels of PM2.5 and PM10 increase dramatically, by up to 50-75% and 40-45% respectively, compared to non-burning periods. Stubble burning has a significant impact on soil fertility, often harming it by leading to nutrient loss and degrading soil health.

Nutrient Loss

- Burning crop residues destroys key nutrients like nitrogen, phosphorus, potassium, sulphur, calcium, and magnesium in the soil, making them less available for the next crop cycle.
- The intense heat causes nitrogen and other nutrients to evaporate instead of being reused in the soil.

Soil Microbial and Biological Damage

- High temperatures during burning kill beneficial soil microorganisms, earthworms, and microbes that are vital for nutrient cycling and maintaining soil structure.
- This disruption affects nutrient cycling, soil organic matter breakdown, and the overall resilience of the soil ecosystem.

Physical and Chemical Soil Changes

- Burning can increase soil pH temporarily because of ash deposition. However, it depletes soil organic carbon and nitrogen over time, leading to lower soil fertility.
- Burning may cause soil compaction, reduce moisture retention, and harm soil structure. These changes negatively affect aeration and root growth.
- Although some nutrients may increase right after burning due to ash, these effects fade as organic matter decreases.

Long-Term Implications

- The overall result is long-term damage to soil health and fertility. This makes soils less productive and leads to a higher reliance on chemical fertilisers.
- We need sustainable residue management practices to protect soil health and improve productivity.

The rise in pollutants degrades air quality, often reaching hazardous levels. These levels exceed national air quality standards and lead to public health emergencies in areas like Delhi and the Indo-Gangetic Plain. This visual evidence supports the observation that burning is highly localized in fertile grain zones during the designated harvest period, consistent with the 27% of Punjab's area burned in 2020 reported by Deshpande et al. [12].

We conducted logistic regressions, which were quantitative and predictive of a farmer obtaining a likelihood of burning residue. Smaller farm size ($p<0.01$) was a significant predictor together with less off-farm income, indicating that risk-averse farmers with lower income levels are more prone to burning (as was observed in the case of income effects by Lopes et al. [3]). The level of education and perception of health risks did not predict behavior significantly, although a significant number of respondents were aware of the risks of pollution (indicating that the same is relevant to Yang et al. [7] about the gap in knowledge and perception). No-till planters or balers were barely used (Adoption less than 10 percent) and were mainly prohibitive. The fact that structural barriers listed in Table 1 played a role was confirmed when farmers, once questioned why they did not explore alternatives, said in large numbers that they did not access credit (70%) or were unsure whether they would get any support at all (52%).

Discussion: The findings validate that the economic and logistical factors are the main factors propelling the choice of burning crop residue, which is aligned with previous research. The domination of our results by the reasons of labor and time is consistent with Lopes et al. [3] and Cordeiro et al. [5], who also report that lockdown- or seasonal-related labor shortages increase burning rates. On the same note, the economic aspect of machine prices is an established discouraging factor: Porichha et al. [14] and Lin & Begho [15] mention that even subsidies usually do not pay the entire cost of the equipment, and farmers may not be able to invest. Such relationship between burning and smaller and lower-income farms is consistent with the economic No-Till adoption theory (Cordeiro et al. [5]) - as reflected by our regression results of high poverty as one of the predictors of burning.

Our focus on mistrust and information gap is supported by Bhatt et al. [4] and Erbaugh et al. [6] on the barriers side. Most of the farmers in our sample were not very convinced that there would be realization of the promised incentives; some of them referred to the past where subsidized equipment is failing or payments are not received at the promised time. The qualitative interviews revealed another feeling that the government is not enforcing the laws consistently: some of the farmers confessed to burning at night or paying token fines because they know they would only be caught

violating the law every now and then. This is in line with the observation made by Demirdogen [10] in Turkey that the bans will be ineffective because penalty is low compared to the cost of re-plowing.

Interestingly, there are comparisons with other parts of the world with emphasis on universalities. The same situation was observed in Arkansas with Hyink et al. [17] reporting that producers consider burning something cost-effective, and the non-producers underestimate the agricultural constraints. Similar attitudes were observed in our Arkansas sample with many American rice farmers mentioning burning as less expensive than forage removal despite the fact that it is discouraged by the U.S. regulations. Similarly, Ren et al. [13] reported in China that the use of straw is not facilitated by sufficient market infrastructure - which is what we also experienced in the rural surveys where farmers are reluctant to use straw-based goods (mushroom substrate, briquettes) as the prices fluctuate and burning it becomes the least inconvenient option. Ravindra et al. [18] and Raza et al. [16] highlight the health and environmental costs, though they mention that they are not part of the immediate calculus of farmers. This is reflected in our data: although the awareness of health risks is mediocre, it hardly overcame the short-term farming demands when deciding.

These lessons have policy implications: it is not enough to declare burning illegal or give information. Interventions that are successful should decrease identified economic and informational barriers. Indicatively, Jack et al. [1] demonstrate that payments in advance may enhance adoption and hence subsidies should be front-loaded by aid schemes instead of reimbursed upon technology acquisition. Furthermore, community-level solutions might be required: when a farmer goes to no-burn, the adjacent lands can still blow the smoke, and this practice will not be encouraged. Sharing the investment in machinery and free-riding could be prevented in local cooperatives or networks of tenants. Literature on Thai (Akahoshi et al. [9]) and Chinese (Gai et al., [11]) policies indicates that burning can be less attractive by targeting crop systems that are specific to each area of China e.g. providing alternative varieties of crops with shorter maturation or establishing assured fodder markets.

All in all, our results support the argument in favor of combined solutions to reconcile environmental objectives and livelihood of farmers. Basic restrictions of top-down are not effective without targeting the underlying socioeconomic factors. Programs must aim at alleviating the short run pressure on farmers: ensuring price support of collected straw, temporary labor subsidies in peak seasons, and enhanced access to mechanical harvesters (rental programs or custom operators). Education and awareness programs are also significant but should be coupled with actual benefits. The trend is similar in all contexts: burning is a manifestation of resource strained economics and economic reasons will only allow the adoption of sustainable alternatives.

Conclusion

This study validates the socioeconomic factors that lead to stubble burning amongst farmers: the necessity to clear the fields as quickly and inexpensively as possible, the lack of labor and capital, and the social norms all support burning. No-till sowing, collecting residues, biomass conversion are seen by farmers as expensive and risky in the present circumstances as a sustainable alternative. Considerable obstacles to adoption are the large initial cost of equipment or storage, lack of confidence regarding market demand or subsidies on residues, and institutional support.

Policy implications are gained on these insights. Officials cannot be enlightened through enforcement of laws only because they need to take steps that mitigate the economic barriers and informational barriers that we have identified. As an example, the incentives may be changed through offering cheap machinery services using credit and advance payments to no-burn practices. Residue management may be distributed among community-based models (farmer cooperatives). Significantly, the establishment of trust is required: the perceived reliability of alternatives can be enhanced by transparent and prompt subsidy plans (as proposed by Jack et al.,[1]) and constant contact with the farmers (via extension agents).

To sum up, stubble burning should probably remain a regular until sustainable practices are economically positive and culturally accepted. The most promising one seems to be a balanced course of action, which combines harsher regulation with positive incentives - region-specific to the cropping systems. Further studies are needed to analyze the effects of such incentive programs in the long term and to investigate new forms of business (e.g. bioenergy ventures) which will establish a consistent demand of crop residues. The literature, changing across the South Asia to North America, demonstrates that socioeconomic causes of burning are the only way to a sustainable change.

References

[1] Jack, B. K., Jayachandran, S., Kala, N., & Pande, R. (2025). Money (Not) to Burn: Payments for Ecosystem Services to Reduce Crop Residue Burning. AER Insights, 7(1), 39–55. DOI: 10.1257/aeri.20230431.

[2] Kambam, A. S. (2025). A comparative analysis of post-harvesting strategies: a case study on rice straw management in Arkansas, USA, and Punjab, India. Journal of Sustainable Development, 18(4), 165–179. DOI: 10.5539/jsd. v18n4p165.

[3] Lopes, A. A., Viriyavipart, A., Kim, A. S., Lahiri, N., & Bhanja, S. (2024). Crop residue burning increased during the COVID-19 lockdown: a case study of rural India. Heliyon, 10(6), e27910. DOI: 10.1016/j.heliyon. 2024.e27910.

[4] Bhatt, R., Giang, A., & Kandlikar, M. (2023). Incentivizing alternatives to agricultural waste burning in Northern India: trust, awareness, and access as barriers to adoption. Environment Systems and Decisions, 43, 358–370. DOI: 10.1007/s10669-022-09892-w.

[5] Cordeiro, U. A., Samaddar, A., Munshi, S., Ajay, A., Rossiter, D. G., Sohane, R. K., Malik, R., Craufurd, P., Pingali, P., & McDonald, A. J. (2024). Transitions to crop residue burning have multiple antecedents in Eastern India. Agronomy for Sustainable Development, 44, 59. DOI: 10.1007/s13593-024-00983-3.

[6] Erbaugh, J. T., Singh, G., Luo, Z., Koppa, G., Evans, J., & Shyamsundar, P. (2024). Farmer perspectives on crop residue burning and sociotechnical transition in Punjab, India. Journal of Rural Studies, 111, 103387. DOI: 10.1016/j.jrurstud.2024.103387.

[7] Yang, Z., Gupta, R., Walrand, M., & Majumdar, K. (2025). Perceptions of air pollution from stubble burning and its health risks in Punjab, India. Scientific Reports, 15, 2135. DOI: 10.1038/s41598-025-21235-8.

[8] Abdurrahman, M. I., Chaki, S., & Saini, G. S. (2020). Stubble burning: effects on health & environment, regulations and management practices. Environmental Advances, 2, 100011. DOI: 10.1016/j.envadv.2020.100011.

[9] Akahoshi, K., Zusman, E., Hanaoka, T., Kim Oanh, N. T., Nguyen Huy, L., Wangwongwatana, S., Homyok, P., Malley, C. S., Hirayama, T., & Goto, Y. (2023). The prospects of controlling open burning of crop residues in Thailand: a quantitative assessment of implementation barriers and costs. Atmosphere, 15(11), 1309. DOI: 10.3390/atmos15111309.

[10] Demirdogen, A. (2024). Stubble burning: what determines this fire? Environmental Development, 51, 101029. DOI: 10.1016/j.envdev.2024.101029.

[11] Gai, H., Yan, T., Zhang, A., Batchelor, W. D., & Tian, Y. (2021). Exploring factors influencing farmers' continuance intention to crop residue retention: evidence from rural China. International Journal of Environmental Research and Public Health, 18(16), 8359. DOI: 10.3390/ijerph18168359.

[12] Deshpande, M. V., Kumar, N., Pillai, D., Krishna, V. V., & Jain, M. (2023). Greenhouse gas emissions from agricultural residue burning have increased by 75% since 2011 across India. Science of The Total Environment, 904, 166944. DOI: 10.1016/j.scitotenv.2023.166944.[13] Ren, J., Yu, P., & Xu, X. (2019). Straw utilization in China: status and recommendations. Sustainability, 11(6), 1762. DOI: 10.3390/su11061762.

[14] Porichha, G. K., Hu, Y., Rao, K. T. V., & Xu, C. C. (2021). Crop residue management in India: stubble burning vs. other utilizations including bioenergy. Energies, 14(14), 4281. DOI: 10.3390/en14144281.

[15] Lin & Begho, T. (2022). Crop residue burning in South Asia: a review of the scale, effect, and solutions with a focus on reducing reactive nitrogen losses. Journal of Environmental Management, 314, 115104. DOI: 10.1016/j.jenvman.2022.115104.

[16] Raza, M. H., Abid, M., Faisal, M., Yan, T., Akhtar, S., & Adnan, K. M. M. (2022). Environmental and health impacts of crop residue burning: scope of sustainable crop residue management practices. International Journal of Environmental Research and Public Health, 19(8), 4753. DOI: 10.3390/ijerph19084753.

[17] Hyink, J., Bresnahan, R., McFadden, B. R., Shew, A. M., & Mitchell, J. (2024). Agricultural producer and non-producer perceptions of crop residue burning: a focus on Arkansas. Discover Sustainability, 5, 95. DOI: 10.1007/s43621-024-00278-3

[18] Ravindra, K., Singh, T., & Mor, S. (2019). Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. Journal of Cleaner Production, 208, 261–273. DOI: 10.1016/j.jclepro.2018.10.093.