



## ***Where There's Smoke, There Was Stubble***

**Applying Behavioural Insights to Design a Sustainable Solution to the Problem of  
Stubble Burning in Punjab, India**

**Phoebe Lever, Saniya Garyali, Timothy Hayden Huggins, Sven-Luca Winter**

**London School of Economics and Political Science**

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**Course convenors: Dr Fred Basso & Prof Saadi Lahlou  
Other teachers: Dr Maxi Heitmayer**

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*\*Following the allowance of a PEL course instructor, Adobe Firefly AI was used to generate parts of these images.*

## 1. Introduction

India boasts the second largest agricultural economy worldwide, responsible for the mass production of key international food staples including rice and wheat (Bhuvaneshwari et al., 2019). However, alongside agricultural bounty arises the mounting challenge of crop residue management, a major by-product of the sector and one which has proved particularly burdensome in areas of Northern India (Deshpande et al., 2023). In many cases, Indian farmers are compelled to burn the leftover stubble on their fields, a practice which is estimated to occur at a rate of 84 million tons per year, resulting in excessive gaseous emissions and air pollution (Abdurrahman et al., 2020). Stubble burning has become a major environmental and social problem across India creating a health crisis for its citizens and contributing significantly to global warming (Bhuvaneshwari et al., 2019; Kumar et al., 2015). Beyond the dire environmental and public health impacts off the field, the process has long-term consequences for agricultural productivity, threatening India's major industry. Despite continuous efforts to curb the use of stubble burning and foster more sustainable residue management practices, institutional complexities often underscore its continuation.

## 2. Background

### 2.1. The origins of stubble burning

Stubble burning originates from the necessity to address impracticalities associated with the rice-wheat rotational cropping system. However, the perpetuation of this practice has been deeply influenced by additional historical and policy-based factors.

The rice-wheat rotational cropping system (RWS) has been a prevalent practice in Northern India for over a century, with widespread uptake attributed to the climatic conditions observed in the region (Gupta et al., 2004). Such conditions dictate the volume of groundwater available; the primary source relied upon for crop irrigation (Dhanda et al., 2022). Northern India has a three-season climate, consisting of a hot summer between March and May, a monsoon season which extends from June to late October and a dry winter between November and February. Apprehension over groundwater depletion resulted in the RWS planting cycle which benefits from cyclical weather changes. Characterised as a water intensive crop, rice is well suited for cultivation during the monsoon season whereas wheat demands substantially less water, rendering it suitable for cultivation during the dry winter (Shyamsundar et al., 2019). As such, the rotational cropping system came to fruition.

The major constraint of RWS is the short time period between rice harvesting and the plantation of wheat (approximately 15 to 20 days), leaving a limited window to prepare the fields (Reddy et al., 2019; Dutta et al., 2022). The collection and disposal of rice crop residue is a significant practical problem. With delays incurred during this process adversely affecting the wheat crop, it has become custom for farmers to burn their crop residue, to prepare for the wheat planting season as rapidly as possible (Gupta et al., 2004). As such, the ease, cost-effectiveness, time-efficiency, and facilitation of early seed sowing has rendered stubble burning as the prevailing residue management practice for farmers in Northern India (Kumar et al., 2015).



## 2.2. The escalation of stubble burning in Punjab

The popularity of stubble burning was further exacerbated in the 1960s, with the emergence of the Green Revolution, a collection of government policies implemented to boost crop yields in Punjab, Haryana, and Western Uttar Pradesh (Singh, 2022). Widespread adoption of Green Revolution technologies, specifically mechanised harvesters, intended to increase the efficiency of the RWS, paradoxically exacerbated the challenges associated with crop residue management in these regions (Reddy et al., 2019). With 80% of rice crops being harvested using machines, the high levels of mechanisation and increased production rates specifically observed in Punjab amplified the imperative for farmers to burn their residue (Kumar et al., 2015). As such, whilst Punjab became India's chief granary, contributing almost a quarter of the share of rice and more than a third of wheat to the central pool, the Green Revolution led to the perpetuation of stubble burning (Khundrakpam & Sarmah, 2023). Ergo the practice is significantly more pronounced in Punjab than any other region across India, heightening the state's prolonged exposure to the dire impacts which accompany it.

## 2.3. Impacts of Stubble burning

### 2.3.1. *On field*

Stubble burning has a detrimental impact on soil productivity as it depletes the soil of essential nutrients (Gupta et al., 2004). There is an additional cost involved in restoring soil fertility through the application of fertilisers or compost (Singh et al., 2022). Furthermore, pollutants emitted throughout the process directly harm crops by causing damage to the leaves and grains, potentially resulting in plant mortality (Augustaitis et al., 2010). Effects of stubble burning also manifest in the creation of favourable conditions for aphid pests, responsible for distorting plant growth and transmitting plant viruses (Abdurrahman et al., 2020).

There is evidence for the viability of repurposed stubble to produce economically valuable and eco-friendly substances (Kumar & Joshi, 2013). Stubble can serve as a source of fuel for power plants, contribute to biomass for biofuel production, be blended into cement, and be utilised as a raw material to produce paper and pulp (Abdurrahman et al., 2020). The variety and availability of potential alternatives to stubble burning, amplify the opportunity cost associated with wasting crop residue.

### 2.3.2. *Off field*

While 'on field' issues associated with stubble burning primarily affect farmers themselves, the practice also has consequences for stakeholders 'off the field'. Evidence indicates that the practice of stubble burning emits significant quantities of toxic gases, including methane and carbon dioxide into the atmosphere (Reddy et al., 2019). Thus, stubble burning adds significantly to global emissions, exacerbating the climate crisis.

Furthermore, the combination of smoke and toxic gases released through stubble burning makes the practice one of the most prolific contributors to air quality degradation in Punjab (Chawala & Sandhu, 2020). Due to Punjab's geographical proximity to India's capital New-Delhi, the city is particularly exposed to the pollution caused by stubble burning and thus the diminished air quality poses a series health hazard to its residents (Khan et al., 2023). Exposure to the toxic

gases heightens the risk of developing eye and skin irritations, as well as more serious chronic health problems (Reddy et al., 2019).

## 2.4. Existing interventions

Despite federal and state regulations since 2013, interventions against stubble burning in Punjab have consistently failed to yield any substantial results. Nevertheless, efforts have been extensive, and can be broadly classified into three principal domains: Mandates and punitive measures, incentivisation strategies, and innovations (Table 1).

**Table 1:** Existing solutions to stubble burning (see A1 for extended table)

| Existing Solutions                    | Examples                                                                                                                                                                                            | Effectiveness                                                                                                                                |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Mandates and punitive measures</b> | 2013: Stubble burning banned<br>2015: Farmers held financially liable for environmental damages from burning<br>2018: Super SMS attachment made mandatory for combine harvesters                    | Difficult to enforce<br>Blame directed towards farmers<br>Accentuate the ‘us vs them’ narrative                                              |
| <b>Incentives</b>                     | 2018: 50%-80% subsidy for Super SMS equipment<br>2019: ₹2,500 per acre provided to farmers who do not burn in a season<br>2022: Incentives for crop diversification                                 | Subsidies for equipment and fuel are insufficient<br>Functional issues of equipment<br>Crop diversification can play a role                  |
| <b>Innovations</b>                    | 2018: Mobile apps for management, ecological monitoring, and incident tracking<br>Education/awareness campaigns<br>Start-ups targeting supply chain, stubble utilization, and collection technology | Apps mainly focus on monitoring<br>Farmers have reasons to continue despite increased awareness<br>Start-ups solve only pieces of the puzzle |

In response to the distribution of monetary fines, many farmers testify that it is more economical to accept the penalty, than to invest in the equipment required for sustainable residue management practices (Khundrakpam & Sarmah, 2023). Additionally, punishments imposed have accentuated the hostility between the farmers and the state and propagated the ‘us vs them’ attitude which is decidedly counterproductive for resolution development (Sharma, 2020). Incentivisation strategies have predominantly consisted of monetary favours in the form of subsidies, to cover the additional costs of alternative residue management practices. However, discord between the central government and the state regarding who should finance these subsidies, creates an intention-action gap (Reddy et al., 2019). It is reported that subsidies are seldomly received by the affected farmers, further aggravating the already distrustful relationship between Punjab farmers and the government (Shyamsundar et al., 2019; Salunkhe & Deshmush, 2014). Technological innovations offer a promising alternative and have been prioritised as more auspicious long-term solutions, however stubble burning persists, and farmers in Punjab continue to favour the practice.

### 3.1.1. 'Small and Medium' farmers

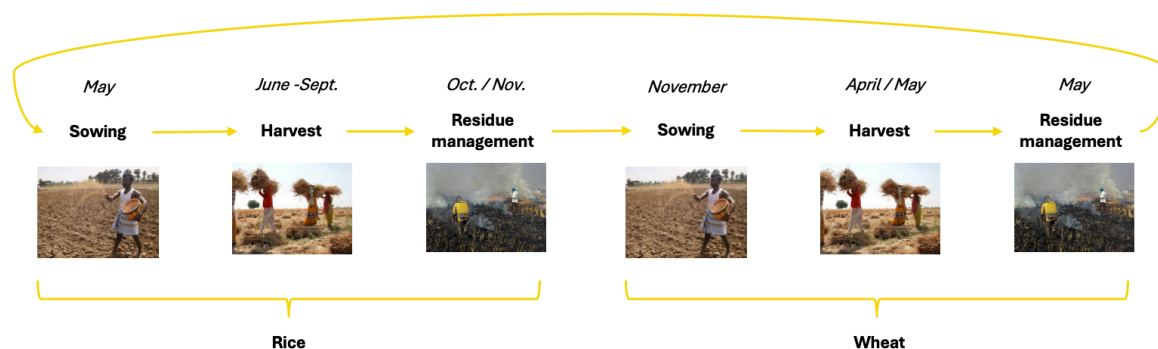
Given that the practice of stubble burning is upheld by farmers themselves, it is important to distinguish the relevant farmer subgroup. Literature indicates differences between those farmers operating ‘large farms’ (more than 10 acres), ‘medium farms’ (less than 10 acres) and ‘small farms’ (less than 5 acres) (Saini et al, 2022). Within Punjab, peasant land holders are responsible for owning and tilling half of the farmable land, and it is primarily at these smaller establishments, where alternative residue management practices are unfeasible (Ians, 2015; Kumar, 2023). As such, ‘small and medium’ farmers will form the basis of this analysis. Although sociological data on small scale farmers in Punjab is limited, it is recognised these individuals sometimes exhibit low levels of literacy (Kaur et al., 2020). Additionally, given that 70% of active ‘small-scale’ farmers are reported to be between the ages of 15 to 59, there is evidence to suggest intergenerational family working dynamics at play (Bera, 2015). Furthermore, according to the most recent 2011 Census of India, most Punjabis identify as Sikh, and religion plays an important role in their daily lives (Kramer, 2021).

Commonly regarded as the ‘breadbasket’ of India, farming is embedded into the culture of rural Punjab; however, economic constraints have forced many small farmers out of their familial industry, forcing them to find alternate employment (Singh & Bhogal, 2014). Given that most properties encompass less than ten acres, farmers are facing difficulties in producing sufficient crop yields on their land, leading to the accumulation of debt (Bera, 2015). This impact is exacerbated by the increased pressure from more equipped larger farms which dwarf their levels of productivity. Nevertheless, to protect their interests and livelihoods, farmers in Punjab are represented across 22 political unions, distributed across the state (Gill, 2022). These unions often join to form a collective, orchestrating nationwide efforts during periods of protest (ibid). An analysis of farm policy in Punjab reveals that despite constituting 33% of the farmer population, smallholders lack representation within these unions compared to the large farm domination (Singh, 2022). This marginalisation is further exacerbated by class and caste differences. These factors capitulate the challenging environment in which small and medium farmers are forced to operate.

### 3.1.2. Operational process

Further understanding ‘Small and Medium’ farmers’ operational processes and unveiling the motives which underpin their distinct decision to burn stubble, is crucial for identifying solutions to the problem. Outlining the RWS season will provide better context for this:

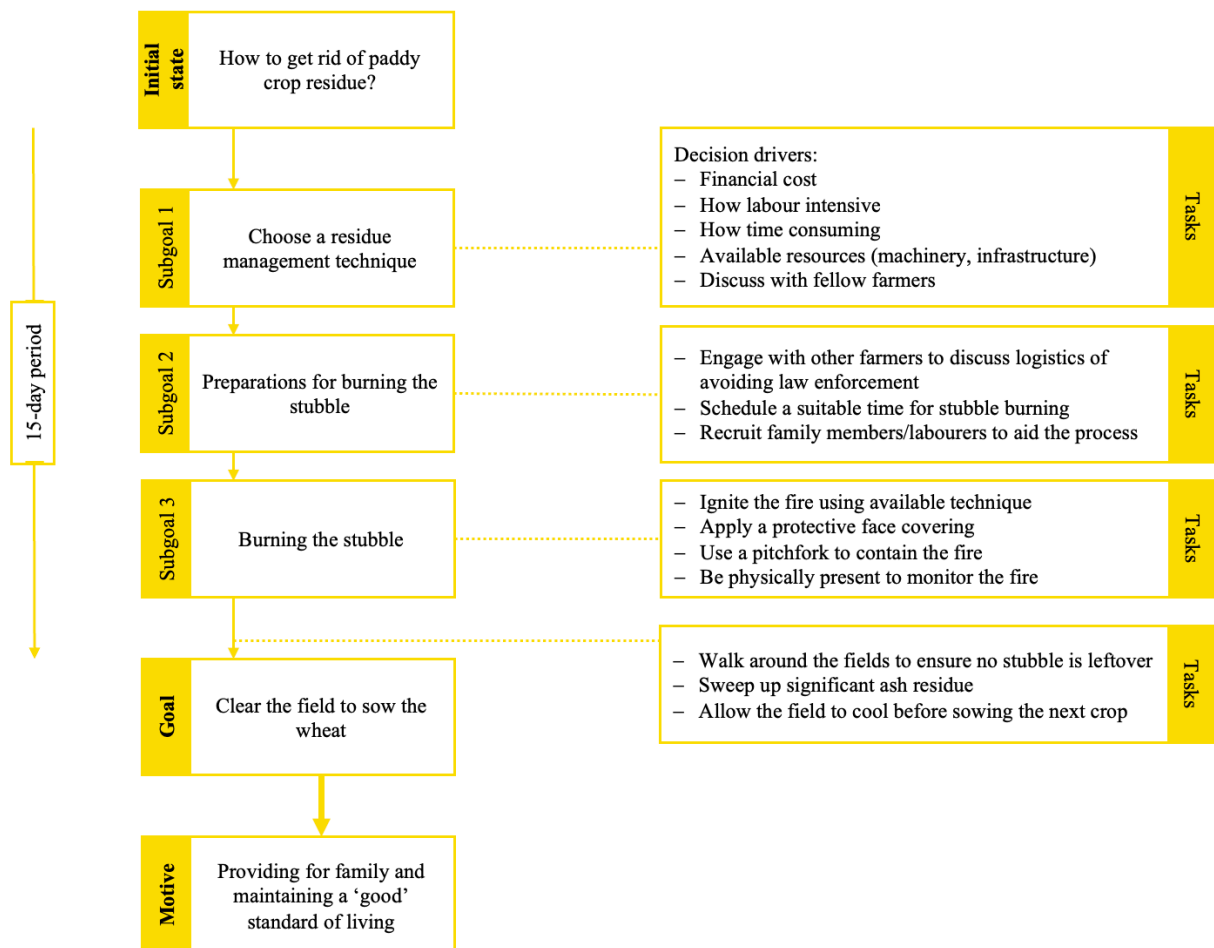
**Figure 2:** Crop cultivation cycle in the rice-wheat cropping system



The season outline (Figure 2; see extended version in B1) demonstrates the exceptionally limited interval in the cultivation cycle between harvesting rice and sowing wheat, allowing for only a brief window (15 to 20 days) to clear the fields and manage the residue. We identified

this as a key pain point to conduct a closer examination of the farmers activities, goals, and motives as it pertains to their chosen method of crop residue management in this time frame. Drawing upon activity theory (Lahlou, 2017; Leontiev, 1978) allows for the deconstruction of this process to expose potential intervention points.

**Figure 3:** *Small and medium farmers' activity grid for stubble burning*



Based on this activity sequence (Figure 3), it becomes clear that stubble burning emerges frequently as the quickest, easiest, most cost-effective, and least labour-intensive practice. Additionally, despite farmers' acknowledgment of the adverse impacts on their health, the environment, and the punishments which may result from burning, the adoption of more sustainable residue management techniques remains out of reach (Rathore, 2022).

### 3.2. Stubble market participants

#### 3.2.1. Intermediaries

Intermediaries are responsible for the handling and distribution of produce following the harvest season. It is typical for farmers to transport their goods to Agricultural Market Committees (AMPCs), commonly known as 'mandis', where middlemen or 'arhityas' purchase their produce at a 'minimum support price' (MSP) and oversee the preparation of the grain for auction (Chatterjee et al. 2020). Although a significantly less developed marketplace, the trade

of stubble typically follows a similar process. However, certain aspects of these markets operate unregulated, facilitating corruption and rendering farmers vulnerable to exploitation. Hence, alternative distribution channels for stubble are gaining momentum.

### **3.2.2. *Stubble consumers***

When stubble is collected and baled, the market for the material involves several consumers. Currently, the three main areas of stubble utilization off the field are predominantly for biomass energy projects, animal fodder, and product manufacturing (Govt. of Punjab, 2022). Alongside efforts to mitigate stubble burning, the Government of Punjab tasked the Department of New and Renewable Energy with ramping up biomass power generation, thereby necessitating an increased supply of stubble (ibid). Additionally, cattle farmers have an interest in cheap paddy straw for supplemental animal feed (Bhuvaneshwar et al., 2019), and start-up niches include novel product manufacturing from stubble (Dharaksha, Kriya Labs, and Straw Structure) and supply chain innovations (Farm2Energy and Biofuel Circle). We see the inclusion of these groups as relevant to a holistic solution as they account for the value creation needed to abate stubble burning.

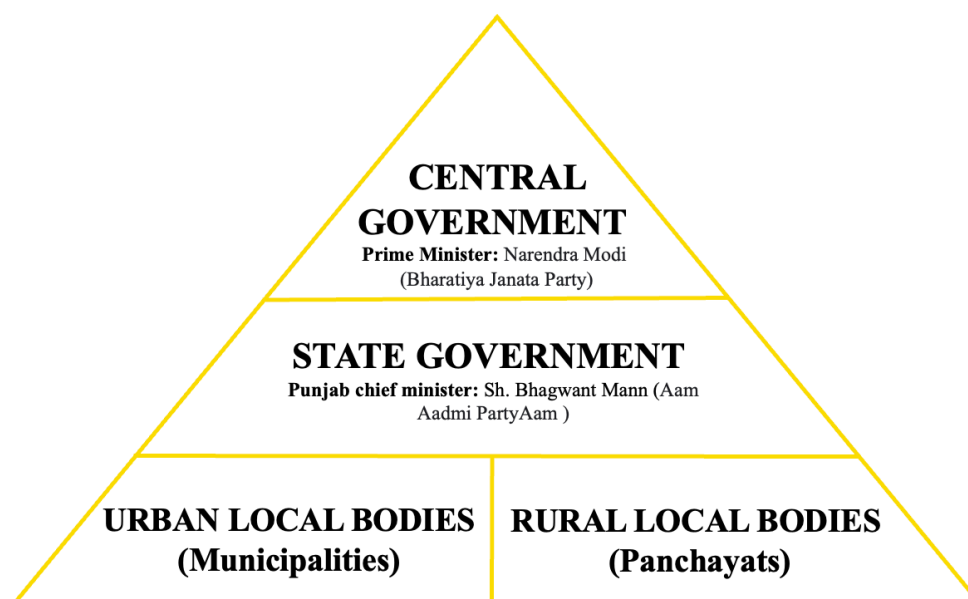
### **3.2.3. *Farmer-Producer Organisations (FPOs)***

Farmer-producer organisations (FPOs) have been on the rise in Punjab and play a vital role in consolidating and enhancing the economic well-being of primary producers (Govil & Neti, 2020). Ownership control is consistently maintained by the members, while management is overseen by representatives elected by the members themselves. There are around 12,500 villages in Punjab and 91 formal FPO's. They function on the principles of economies of scale and are engaged in activities such as input supply, seed production, marketing and several have established farm machinery rental shops (Talukdar & Vatta, 2016).

## **3.3. Governmental Bodies**

The final stakeholder in this analysis adopts a more regulatory position in Punjab's stubble burning process. Delineated in Central, State, and Local levels (Figure 4), navigating the specific government interests regarding crop residue management presents a challenge. This complexity is particularly pronounced in Punjab where the state congress, led by Chief Minister Bhagwant Mann of the AAP, is in opposition to the BJP-led central government under prime minister Narendra Modi. Although the decentralised system empowers local bodies to manage issues, state governments are still beholden to the central government for provisional resources (Arora, 2009). As such, there are ongoing disputes over the allocation of funds, the implementation of measures, and the pace of progress regarding the issue of stubble burning (Sharma, 2020).

**Figure 4:** Indian Governance structure



Where India's Central government is concerned with international environmental pressures, pursuing punitive measures signifies to the world a resolute stance to combating this issue (Khundrakpam & Sarmah, 2023). Comparatively, the state government of Punjab is more concerned with maintaining agricultural productivity, prioritising incentivisation policies that align with the interests of farmers and secure electoral support. In contrast, the local administration (Panchayats), headed by an elected representative (Sarpanch), prioritises the immediate social and health implications of their constituents, focusing their interests on practical enforcement strategies at the grassroots level (Kumar et al., 2015). This political misalignment exacerbates coordination challenges, hindering solution development.

Furthermore, culminating 50% of India's working population, farmers are a crucial voting bank (Cole, 2009). Their lobbying power reduces political will to prevent stubble burning and act in fear of dissuading their support (Kumar, 2023). As stubble burning continues with haste, the chasm between the country's farmers and policymakers, who historically incentivised the practice is escalating (Bhuvaneshwari et al., 2019). The imperative to reconcile the distrustful relationship between farmers and government entities is essential for addressing stubble burning effectively.

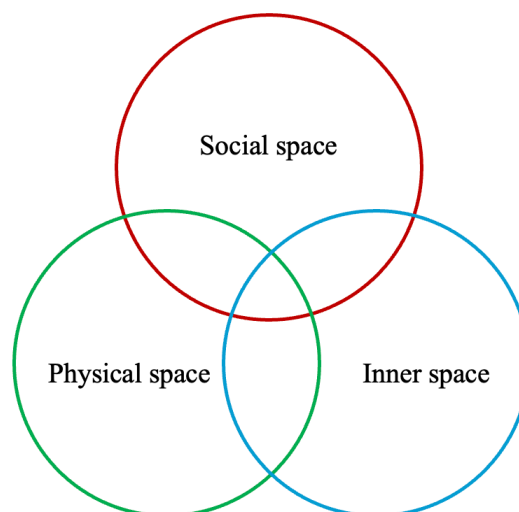
## **4. Application of Theoretical Concepts**

### **4.1. Installation Theory**

To develop a strong understanding of how behaviour is channelled, Installation Theory was applied (Lahlou, 2017). Installation Theory explains how three important layers, social regulation, physical affordances, and embodied competencies, influence people's behaviour and shape it into what can be observed (Lahlou, 2017). For this paper, Installation Theory was utilised in two ways: Firstly, to identify and analyse stubble burning as an installation (Figure 6). Secondly, to ensure that the proposed solution (See B2) facilitates sustainable behavioural change, by drawing upon the three layers (Figure 5).



**Figure 5:** Installation Theory's three layers (Lahlou, 2017, p. 34)



Utilising the findings derived from the analysis grounded in Activity Theory (3.1.2), the three subgoals were examined using Installation Theory. By considering the outline of a whole season, the most poignant point of intervention was realised, that being the distinct choice to burn the stubble and the factors underpinning that decision. Figure 5 provides an outline of the three different layers of Installation Theory.

**Figure 6:** Application of Installation Theory for stubble burning

|                              | Choice                                                                                                                                                                                                                                                                                                                                 | Preparation                                                                                                                                                                         | Burning                                                                                                                                                                                                                                                                     |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Social regulation</b>     | <ul style="list-style-type: none"> <li>• Laws informing about illegal practices</li> <li>• Acceptance of local community</li> <li>• Exchange among farmer community</li> <li>• Religious leaders' take on farming</li> <li>• High relevance of opinion of authority figures (e.g., oldest family member, religious leaders)</li> </ul> | <ul style="list-style-type: none"> <li>• Coordination with other farmers (finding 'good' time for setting fields on fire)</li> </ul>                                                | <ul style="list-style-type: none"> <li>• Stubble burning is forbidden</li> <li>• Law enforcement officers</li> <li>• Farmers' collective power against enforcement</li> </ul>                                                                                               |
| <b>Physical affordances</b>  | <ul style="list-style-type: none"> <li>• Available financial resources (money, subsidies etc.)</li> <li>• Available machinery</li> <li>• Available labour (for those techniques that are labour-intensive)</li> <li>• Very brief time for residue management as constraint</li> </ul>                                                  | <ul style="list-style-type: none"> <li>• Family members aid in process of stubble burning and function as labourers; they need to be informed</li> </ul>                            | <ul style="list-style-type: none"> <li>• Face coverage (e.g., proper face masks)</li> <li>• Pitchforks</li> <li>• Means of fire setting (e.g., lighter, matches)</li> <li>• Money to pay fines (if imposed)</li> <li>• Several people need to be present to help</li> </ul> |
| <b>Embodied competencies</b> | <ul style="list-style-type: none"> <li>• Intergenerational knowledge</li> <li>• Personal experience with different vs. one specific technique</li> <li>• Knowledge about different techniques from education and government campaigns</li> </ul>                                                                                       | <ul style="list-style-type: none"> <li>• Trust among those in the community who are involved in the practice of stubble burning that no one reports the others to police</li> </ul> | <ul style="list-style-type: none"> <li>• Knowledge about how to contain a fire</li> <li>• Closely monitor activities on the streets to ensure law enforcement isn't coming</li> </ul>                                                                                       |

In our immediate environment, we are surrounded by *physical affordances*. Such material surroundings are embedded into our everyday activities and facilitate behaviours (Lahlou, 2017). Figure 6 illustrates the multitude of material requisites involved in handling crop residue management. Financial resources, supply of labour, the availability of farming equipment and time constraints embody the key physical affordances in the activity attached to the process.

To make substantive sense of the material world, certain *embodied competencies* are required (Lahlou, 2017). Knowledge and skills resemble the broad interpretation of such competencies. In the context of farmers in Punjab, formal and factual knowledge holds lesser significance

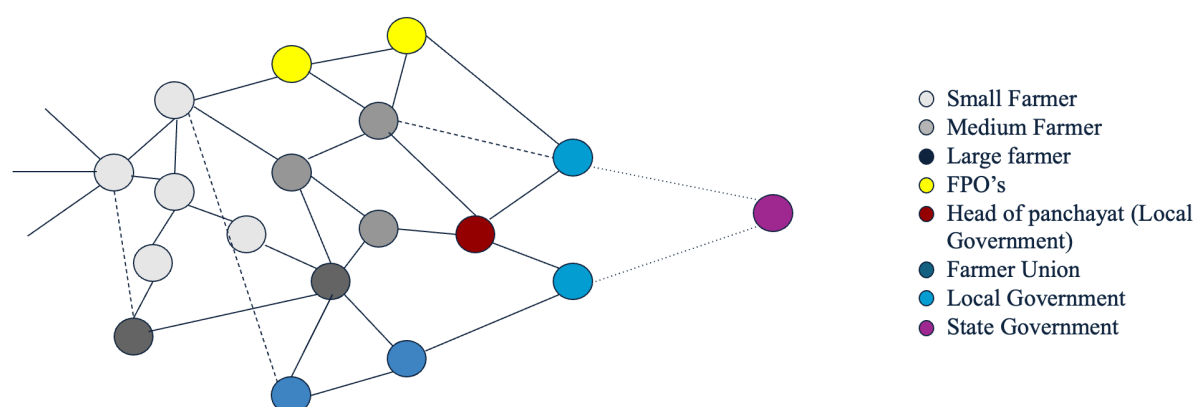


compared to experiential knowledge, specifically the dissemination of intergenerational expertise. Additionally, trust assumes a pivotal role within a system rife with corruption and empty promises (Figure 1).

The *social layer* illustrates how explicit and less explicit rules determine how people employ their knowledge and skills to make sense of their surroundings (Lahlou, 2017). Despite the presence of explicit rules in the form of preventative laws, farmers' behaviour is more profoundly influenced by their social community, religious influence and local authority figures who are distinct from state and central government representatives.

## 4.2. Social Network Analysis

**Figure 7: Social Network Analysis**



*\*Intermittent lines represent weaker social ties*

Social Network Analysis (SNA) is a methodological approach that examines the relationships and interactions among entities within a social system, to reveal patterns, structures, and dynamics in the network (Valente, 1995). Applying SNA, our objective is to identify the prominent actors to engage in our intervention, to maximise the solution adoption amongst the farmer community in Punjab. To understand the behaviour of the network in context of 'stubble burning' we identify 'nodes' or the key actors involved and 'edges' which symbolise the relationships between them. The Social Network Analysis is employed to examine the centrality of different nodes with the objective of identifying pivotal participants and information hubs.

**Degree Centrality** measures the number of connections a node possesses and is a key metric for identifying highly connected individuals within the network (Valente, 1995). 'Small and Medium Farmers' are identified as possessing the highest degree centrality in the network.

**Closeness Centrality:** Nodes with high closeness centrality can reach everyone else in the network in fewer steps and are capable of swiftly disseminating information, contributing to effective communication pathways (Valente, 1995). The elected head of the local government 'Sarpanch', the representatives of the 'farmer unions' and the representatives of the 'FPOs' are identified as having high closeness centrality. They are therefore best placed to influence the entire network quickly and are considered to be 'good broadcasters' (Valente, 1995).

***Betweenness centrality:*** Nodes with high betweenness centrality act as critical intermediaries, influencing the flow of information between different groups within the network (Valente, 1995). The most critical broker that emerges is the Sarpanch of the Panchayat, as they bridge the two most critical parties in our analysis together, small and medium farmers and the local government. The Sarpanch will act as a mediator facilitating cohesion among diverse parts of the network.

### **4.3. Window of Opportunity**

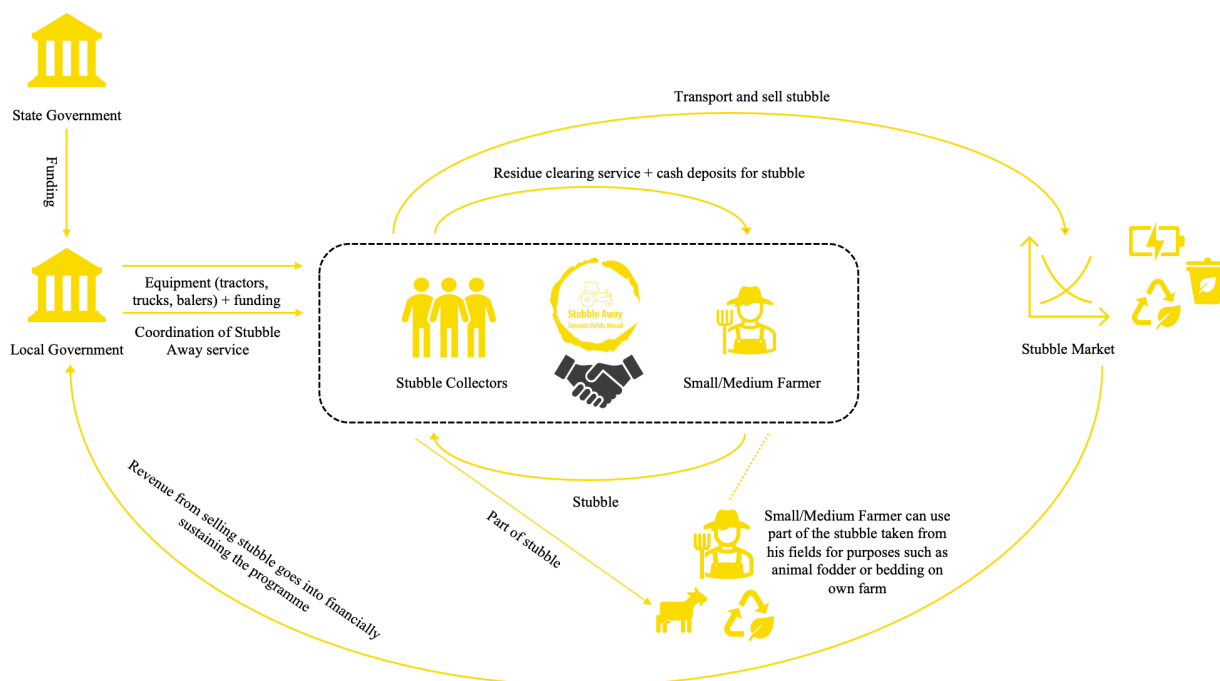
Given the challenging operational landscape confronting ‘small and medium’ farmers in Punjab, compounded by financial pressures, competition, corruption and conflicting governmental priorities, the inclination to adopt stubble burning as the preferred residue management technique is unsurprising. Such a choice reflects not only a form of rebellious dissent but a pragmatic consideration of cost-effectiveness and convenience. It is our take that alleviating the responsibility of stubble burning from the farmers and reframing the problem as a collective challenge, should ease some of these pressures. Leveraging the stakeholders identified through the Social Network Analysis who are most adept at implementing interventions within the farming community holds promise in mitigating the contentious relationship between farmers and the government, to foster a more trusting and collaborative dynamic.

## **5. Solution Proposal**

### **5.1. ‘Stubble Away’**

We have discerned the imperative for intervention at the pivotal juncture in which farmers are obliged to engage a crop residue management strategy. ‘Stubble Away’ is a solution which intends to alleviate this arduous task from farmers, by employing a body of stubble collectors to provide a comprehensive residue clearing and collection service. The full Stubble Away service will include the collection, transportation, storage, and distribution of stubble. Not only will this service be complementary for ‘small and medium’ farmers, but they will receive a proportion of the cash derived from the stubble collected or the choice to repurpose their segment of the stubble to their own discretion.

**Figure 8:** *Stubble Away fits into the existing stakeholder network and leverages positive relationships*



Should a farmer decide to select the ‘cash option’, Stubble Away employees will make an immediate direct cash transfer through the widely used Unified Payment Interfaces (for example: Google Pay) on the day of collection. As demonstrated in 3.1, there is a longstanding pattern of promised payments failing to reach farmers’ pockets, creating distrust in the system. Immediate and traceable cash payouts delivered on site will help build trust in the service.

## 5.2. Logistics

Stubble Away will be funded by the Punjab State Government and revenue collected from the sale of stubble. The operational and supervisory functions will be entrusted to the local government, empowering Panchayats to work in partnership with local communities and FPOs. Initially, the labour required for baling and transporting stubble will be procured through short-term contracts with underemployed labourers (3.1.1). These individuals are motivated by the prospect of additional income during the harvest season, possess suitable closeness centrality and hold the embodied competencies necessary to operate equipment and transport stubble to storage sites. As the programme expands, training outside labourers may be required. The State of Punjab will purchase equipment as an upfront cost to guarantee availability for stubble collection.

The quantity of stubble procured through Stubble Away will be communicated by the collectors, posting availability and central pick-up locations on existing trading platforms. With minor modifications, Stubble Away could become compatible with software-based markets, for example the application ‘BuyBy’ developed by Yale and Stanford university students that digitally connects farmers directly to stubble buyers in the Punjab region (Lac et al., 2021). This would enable stubble consumers to easily access the information needed to routinely purchase and pickup stubble. Initially, stubble will need to be priced at market rates to ensure consumer buy in. However, in cases where the market price falls below the threshold necessary to cover

costs, the state government will be required to provide a minimum support price. In our preliminary assessment, we see the concept as financially viable and promising (for a financial overview, see C1).

### **5.3. Implementation**

Stubble Away is a service that requires a Punjab-wide rollout to sustainably stop stubble burning in the whole region. However, many solutions have been attempted without widespread success and thus Stubble Away will be introduced as a small-scale pilot project, with certain benefits. Primarily, a pilot project requires fewer preliminary resources, thus garnering greater support from politicians who would have to devote relatively modest amounts of funding. Secondly, farmers harbor a degree of skepticism towards stubble burning alternatives. By highlighting small-scale success stories through a pilot project, it could help alleviate this skepticism.

One chosen community in Punjab will function as the pilot project site. It is suggested that the election of the Sarpanch in Kanoi village, Punjab, seemingly hinged upon a commitment to eradicate stubble burning, indicating a notable dedication to the issue from the local leader, along with the support from the community (Rathore, 2022). As such, Kanoi village represents a fitting location for the Stubble Away pilot project to be implemented. The pilot project will span across two agricultural seasons, a duration suitably warranted for cultivating trust within the local community (Rathore, 2022). This pilot project is compatible with a ‘segmentation’ strategy which identifies clusters of individuals, i.e. the specific community of small and medium farmers, who undergo simultaneous change. Within farming communities, decisions to change behaviour are often collective due to established norms. Consequently, there are fewer benefits attached to being an ‘early adopter’. Therefore, introducing uptake at a collective level is essential. Once the pilot phase observes success, Stubble Away will be rolled out in additional communities, leveraging the learnings from Kanoi village, to further refine the service.

Endorsement also plays a critical role in the implementation process of Stubble Away. Attributed to our village selection Kanoi, support from the Sarpanch who will run the service is expected, however endorsement by local religious leaders is also imperative, given their influence over local farmers. The Chief Minister of Punjab, Bhagwant Mann, has invoked Sikh principles on nature to persuade against stubble burning (ABP News Bureau, 2023). Therefore, gaining support of local Sikh leaders for Stubble Away will greatly benefit the adoption of the programme.

### **5.4. Communication**

We recognise the pivotal role that the communication and promotion of Stubble Away will play in determining the success of this intervention. Building on the SNA we use the ‘diffusion of innovation’ theory of ‘network interventions’ to inform our communication (Valente, 1995). The Stubble Away communication campaign will be launched prior to the initial implementation of the service and sustained throughout the subsequent roll-out (see Figure 9 and D2 in Appendix). Promotion will be enacted through a marketing campaign and direct message communication with farmers.

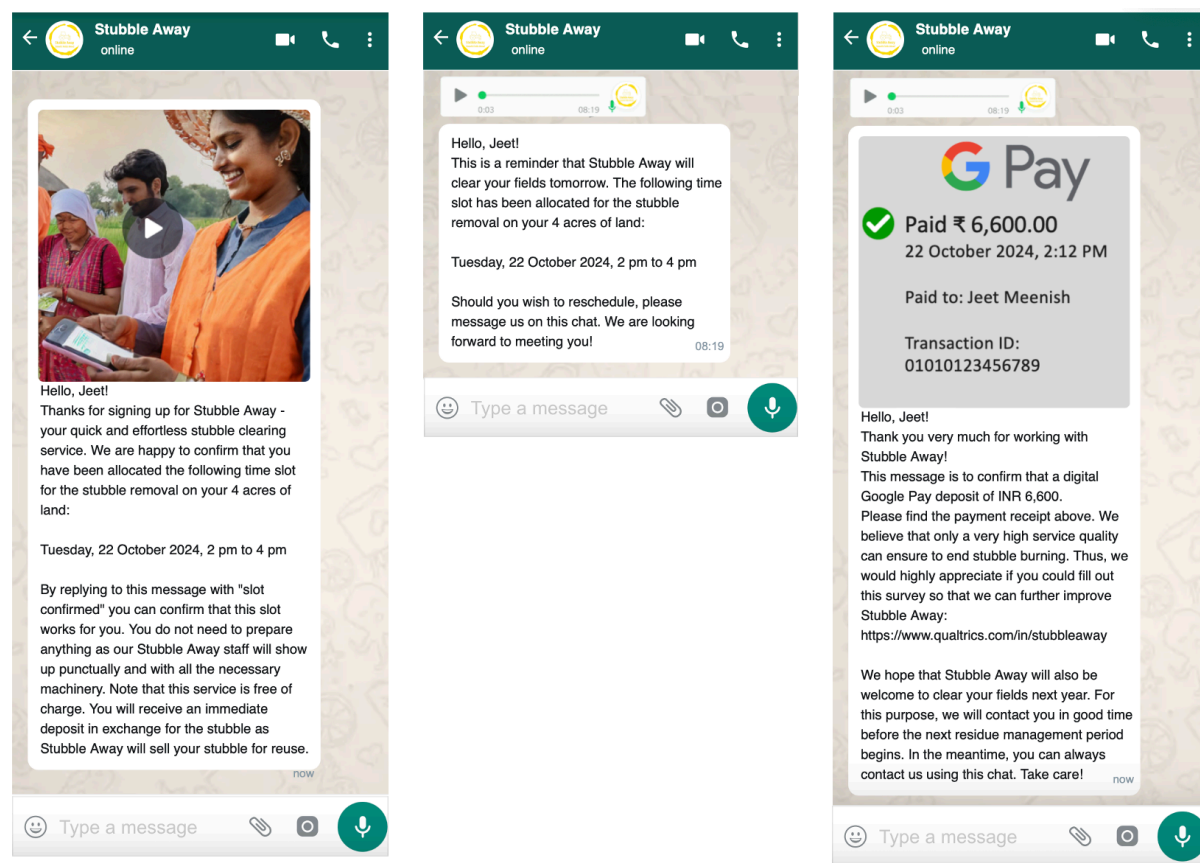
The social network analysis enabled us to identify ‘opinion leaders’ who will endorse our campaign and facilitate the communication, namely FPOs and farmer unions. As suggested by the Diffusion of Innovation Theory we use a combination of ‘advice networks’ and ‘discussion networks’ to facilitate communication since barriers to adoption are both cultural and technical. Cultural and religious events foster these informational interactions and play a critical role in facilitating access to farmers in Punjab. For example, the Lohri festival marks the end of the winter sowing season and is officially recognized as a holiday in the state of Punjab underscoring its cultural significance (MacFarlane, 2009). We intend to leverage these access points by making speeches and running marketing booths during these gatherings (Figure 11). Upon personal engagement with farmers, Stubble Away representatives can register their details (name, telephone number, farm location, farm acreage) and sign them up to the service. As delineated in 2.1, the narrow window for residue management remains uniform for all farmers in Punjab. As such, we contend that it is most feasible to assign a predetermined collection timeslot to each farmer following their engagement with Stubble Away.

**Figure 9:** *Stubble Away poster during pilot period*





**Figure 10:** Direct communication through WhatsApp business account



**Figure 11:** Information booth for farmer union gatherings and cultural festivals



Additionally, direct messaging will be part of Stubble Away's communication. Given the widespread adoption of WhatsApp in Punjab (Singh et al., 2022), setting up a WhatsApp business account is deemed the most cost-efficient, and effective means of coordination for the service. Additionally, this channel of communication allows for the usage of voice messages, which is vital considering the illiteracy rates observed in Punjab farmers (Kaur et al., 2020). The WhatsApp business channel will be structured into two domains, a direct channel for communication with farmers and a service helpline. Primarily, farmers will receive a welcome message containing a short video explaining the service, along with a confirmation of their allocated stubble clearing slot (Figure 10). Subsequent message reminders will be distributed one week and one day prior their stubble collection slot (Figure 10). Following the collection, a digital payment receipt will be delivered on the same chat, inclusive of a summary detailing the cleared acreage (Figure 10). Additionally, farmers will be able to reach Stubble Away staff by contacting the service helpline (568 000) which will be promoted during the marketing campaigns.

## 6. Discussion and Limitations

Stubble burning reveals itself as a poignant social and environmental crisis in Punjab. By unpacking the complex stakeholder network and using the layers of Installation Theory, we uncovered a feasible point of intervention to build upon the physical affordances and identified the specific leaders who could successfully engage with farmers to encourage the uptake of Stubble Away. However, it is imperative to acknowledge the potential barriers to uptake and limitations of this intervention.

To address possible barriers to uptake, we leverage the existing attitudes of farmers in Punjab, expanded upon in E1. Notably, farmers have been consistently blamed for the repercussions of stubble burning, particularly in regard to pollution levels in India's Capital New Delhi. However, the effects of burning are considerably more pronounced for farmers and their communities, than city dwellers. As such, we deliberately chose to frame the communication of our solution as a collective challenge, funded by the government, centered around convenience and empathy towards rural farmers. Furthermore, farmers in Punjab exhibit acute awareness of the adverse impacts of stubble burning but attribute their involvement in the practice to unfeasible alternatives. Therefore, we refrain from emphasizing the 'ill-effects' of stubble burning and instead, position our solution as a 'relief' from the persistent challenges associated with stubble management. The upfront payment made to farmers also acts as a tangible representation of this objective and testimony to the value of stubble.

With the initial implementation of Stubble Away materialising as a pilot project, we recognise the modest impact it will exert in relation to the widespread issue. Moreover, for this project to have the desired effect, it is contingent upon farmer participation and despite efforts to bolster cooperation through various measures, there remains the potential for resistance. Given our geographical remoteness from this issue and predominantly western-centric viewpoint, our intervention may have underestimated farmers' hostility towards change and reluctance to accept external involvement in farming practices. Additionally, while the current government leaders are in favour of reducing stubble burning, our solution requires buy-in against the history of many other failed solutions.

Constraints of Stubble Away also include logistical challenges of the service itself. Given that the Punjab State government is required to procure specific equipment for the service, which is only required for a limited period, it creates an additional storage problem during periods of

non-utilisation. Additionally, outlined bureaucracy amongst government levels (3.4) may accentuate logistical challenges and delay the procurement of funding to kickstart the pilot project. Furthermore, during the pilot missed collection slots within the short harvest period could erode farmers trust in the services reliability, leading them to revert back to burning.

Stubble burning presents a stock and flow problem where solutions could involve reducing the creation of stubble in the first place or utilizing it for a productive purpose. Alternative crop rotations to RWS would help eliminate the creation of stubble whereas our solution addresses only the utilization of stubble within the RWS process. RWS is challenging to make sustainable, yet it is also an important farming practice to efficiently feed India's growing population and to support farmers' livelihoods. Stubble utilization through Stubble Away allows for this and offered a more practical avenue of exploration within the scope of this essay. However, we recognize that some amount of crop diversification through different farming techniques addresses the issue on a fundamental level and must play a vital role alongside stubble utilization to completely abate stubble burning.



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## Image References (partly generated with tools using generative artificial intelligence)

### Title page image:

BBC News. (2020, November 30). Stubble burning: Why it continues to smother north India [Photograph]. *BBC News*. <https://www.bbc.co.uk/news/world-asia-india-54930380>

### Figures 9 and 10:

Adobe. (2024a). *Adobe Firefly, text to image generator* (February 27 free web version) [Large Language Model]. <https://www.adobe.com/products/firefly.html>

Prompt used: The scene is an average Indian village where farmers are using smartphones and are talking to representatives each other.

### Figure 11:

Adobe. (2024b). *Adobe Firefly, text to image generator* (February 25 free web version) [Large Language Model]. <https://www.adobe.com/products/firefly.html>

Prompt used: The scene is an average Indian village where farmers are at a promotional booth and one is a representative dressed in yellow clothes showing residue to an interested farmers.

### Figure D1:

Adobe. (2024c). *Adobe Firefly, text to image generator* (February 27 free web version) [Large Language Model]. <https://www.adobe.com/products/firefly.html>

Prompt used: The scene is an average Indian village where farmers have their stubble residue picked up by a truck.

## Appendices

### Appendix A: Existing Solutions

*Figure A1: Extensive Table of Existing Solutions*

| Solution                                                                                                                                | Description                                                                                                                            | Effectiveness                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Mandates and punitive measures set by various government entities</b>                                                                |                                                                                                                                        |                                                                                                                                                |
| <sup>a</sup> Stubble burning prohibited; Government of Punjab                                                                           | October 2013; subject to imprisonment and fines of <sup>b</sup> Air Act, 1981                                                          | Stubble burning continued, creating conflict.                                                                                                  |
| <sup>a</sup> Fines for environmental damage; National Green Tribunal (NGT)                                                              | December 2015; makes stubble burners liable to pay for environmental damage. Also subject to NGT Act, 2010                             | The fines are difficult to enforce and have not solved the problem.                                                                            |
| <sup>a</sup> Makes super SMS mandatory for combine harvesters; Punjab Pollution Control Board                                           | February 2015; subject to <sup>b</sup> Air Act, 1981. The super SMS attachment is designed to mulch stubble to decompose on the field. | Issues arise related to incomplete stubble decomposition, costs, and timing. Also, existing tractors may not be able to support the super SMS. |
| <sup>a</sup> Prohibition of Stubble burning at the District Magistrate level                                                            | 2018, ties more existing legislation to stubble burning penalties                                                                      | Reaction to previous legislative shortcomings, has not changed the practice.                                                                   |
| <sup>a</sup> Increased legislation for not using SMS or defaulting on fines, Punjab Pollution Control Board                             | September 2020; focuses on the enforcement of existing prohibited activities.                                                          | Reaction to previous legislative shortcomings.                                                                                                 |
| <sup>a</sup> Changes to punitive measures; The Commission for Air Quality Management in National Capital Region and Adjoining Areas Act | December 2020, excludes farmers from some fines and imprisonment, except for fines related to environmental damage through the NGT     | Many punitive measures remain and well-defined solutions have not been fully developed                                                         |
| <b>Incentives through government entities</b>                                                                                           |                                                                                                                                        |                                                                                                                                                |
| <sup>d</sup> 50%-80% subsidy for Super SMS; Ministry of Agriculture and Farmers Welfare                                                 | Began in the 2018-2019 season; Promotes mechanization of more sustainable farming.                                                     | The subsidy is based on prices that are above market value, so farmers still struggle to afford the equipment.                                 |
| <sup>d</sup> ₹2,500 per acre to farmers who do not burn stubble; Punjab and Haryana governments                                         | Began 2019; designed to account for fuel costs of running tractors to manage stubble.                                                  | There are too many other issues preventing equipment adoption beyond fuel costs to be effective.                                               |
| <sup>e</sup> Incentivise crop diversification / alternative rotations, Punjab Government                                                | The 2022-2023 and 2023-2024 budgets include funds for crop diversification to edible seed oils.                                        | Other crop rotations are less desirable to farmers. Diversification plays a role but cannot solve all burning.                                 |



|                                                                                                              |                                                                                                                                                                          |                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| <sup>e</sup> Funds for labour for stubble management, Punjab Government                                      | The 2022-2023 and 2023-2024 budgets include funds for labour for small and marginal farmers.                                                                             | It is not clear how this labour has been directed. Additional structure is needed to channel this resource to reduce burning.           |
| <b>Innovations</b> – platforms, technology, and social interventions by government and non-government actors |                                                                                                                                                                          |                                                                                                                                         |
| <sup>a</sup> Mobile Apps, Punjab Chief Minister                                                              | 2018, three apps were launched for crop residue management, ecological monitoring, and incident tracking                                                                 | The apps mainly focus on monitoring, not supporting alternatives                                                                        |
| <sup>a</sup> Education / campaigns; Punjab Government                                                        | Various local campaigns have been attempted to relate to local communities and farmers                                                                                   | Awareness is heightened, but practical reasons for burning limit change.                                                                |
| <sup>a</sup> Publicly recognize farmers who do not burn stubble, local governments                           | Farmers have been recognized at public events                                                                                                                            | Farmers have a variety of circumstances that may or may not make burning more likely.                                                   |
| <sup>a</sup> Private startup innovations                                                                     | Startups targeting supply chain (Farm2Energy, Biofuel Circle), stubble utilization (Dharaksha, Kriya Labs, Straw Structure), and collection technology (GFF Innovations) | Various startups have cropped up around different pieces of the stubble burning puzzle, but they do not account for the entire process. |

<sup>a</sup>Punjab State Government. (2022). *Action Plan for Control of Crop Residue in the State of Punjab*

<sup>b</sup>India Government. (2022). *The Air (Prevention and Control of Pollution) Act, 1981*

<sup>c</sup>Ministry of Agriculture and Farmers Welfare. (2022). *2022-2023 Annual Report*

<sup>d</sup>Punjab State Government. (2018). *Receipt Budget Book 18-19*

<sup>e</sup>Punjab State Government. (2018). *Demand for Grants FY 2023-2024*

## Appendix B: Applying Installation Theory

**Figure B1:** Installation grid for season outline

|                              | April<br>Variety selection                                                                                     | May<br>Sowing                                                                                                                   | May, June, September, October<br>Irrigation                                                                           | As needed<br>Fertilizer                                                                                                    | As needed<br>Pest management                                                         | November<br>Harvesting                                                                                               | November<br>Marketing                                                                                                                | November<br>Residue management                                                                                                                   |
|------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Social regulation</i>     | <ul style="list-style-type: none"> <li>Variety selection in a most productive way to feed community</li> </ul> | <ul style="list-style-type: none"> <li>Family help is expected and accepted</li> <li>Festival: Beginning of season</li> </ul>   | <ul style="list-style-type: none"> <li>Water as scarce resource of community – mindful usage is encouraged</li> </ul> | <ul style="list-style-type: none"> <li>Don't overfertilize – could poison ground water</li> <li>Gov regulations</li> </ul> | <ul style="list-style-type: none"> <li>Gov regulations</li> </ul>                    | <ul style="list-style-type: none"> <li>Family help is expected and accepted</li> <li>Festival: Harvesting</li> </ul> | <ul style="list-style-type: none"> <li>No bargaining</li> </ul>                                                                      | <ul style="list-style-type: none"> <li>Local communities would appreciate cleaner air</li> <li>Gov ban</li> </ul>                                |
| <i>Physical affordances</i>  | <ul style="list-style-type: none"> <li>Rice-wheat cropping system</li> <li>Purchase from market</li> </ul>     | <ul style="list-style-type: none"> <li>Basket</li> <li>Seeds</li> </ul>                                                         | <ul style="list-style-type: none"> <li>Building irrigation canals</li> <li>Pumping water from underground</li> </ul>  | <ul style="list-style-type: none"> <li>Purchase from market</li> <li>Piece of land selection</li> </ul>                    | <ul style="list-style-type: none"> <li>Fogging machine</li> <li>Pesticide</li> </ul> | <ul style="list-style-type: none"> <li>Sinn</li> <li>Rope</li> <li>Cart for transport</li> </ul>                     | <ul style="list-style-type: none"> <li>Local market/intermediaries</li> <li>Cart for transport</li> <li>Cash transactions</li> </ul> | <ul style="list-style-type: none"> <li>Lighter</li> <li>Fork</li> <li>Face coverage</li> </ul>                                                   |
| <i>Embodied competencies</i> | <ul style="list-style-type: none"> <li>Experience of crop-growing cycles</li> </ul>                            | <ul style="list-style-type: none"> <li>Knowledge of balanced sowing</li> <li>Checking balance by screening the field</li> </ul> | <ul style="list-style-type: none"> <li>Knowledge of local groundwater system</li> </ul>                               | <ul style="list-style-type: none"> <li>Knowledge of chemical composition of fertilizer</li> </ul>                          | <ul style="list-style-type: none"> <li>Knowledge of effective pesticides</li> </ul>  | <ul style="list-style-type: none"> <li>Knowledge of and experience with harvesting techniques</li> </ul>             | <ul style="list-style-type: none"> <li>Experience with the different levels of the distribution network</li> </ul>                   | <ul style="list-style-type: none"> <li>Experience with practice</li> <li>Knowing the numbers: Stubble burning is easiest and cheapest</li> </ul> |

**Figure B2:** How Installation Theory informs the solution proposal

|                              | Choice                                                                                                                                                                                                                                                                                                                                                                         | Stubble collection                                                                                                                                        | Post-implementation                                                                                                                                                                                                                                                                  |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Social regulation</i>     | <ul style="list-style-type: none"> <li>Laws informing about illegal practices</li> <li>Role model in local community needed</li> <li>Promotion on festive events in the local (farming) community</li> <li>Religious leaders' endorsement</li> <li>Endorsement of local head of government in pilot community who got elected on the promise to end stubble burning</li> </ul> | <ul style="list-style-type: none"> <li>None</li> </ul>                                                                                                    | <ul style="list-style-type: none"> <li>Exchanging experiences with other farmers</li> <li>Providing testimonials about Stubble Away to other farmers</li> </ul>                                                                                                                      |
| <i>Physical affordances</i>  | <ul style="list-style-type: none"> <li>Receive money (cash-like direct payment) for further use of stubble by Stubble Away</li> </ul>                                                                                                                                                                                                                                          | <ul style="list-style-type: none"> <li>Smartphone (to receive direct messages via WhatsApp)</li> </ul>                                                    | <ul style="list-style-type: none"> <li>In case that farmer keeps some stubble for own farm, pitchforks and wheelbarrows might be required to handle the logistics on own farm</li> </ul>                                                                                             |
| <i>Embodied competencies</i> | <ul style="list-style-type: none"> <li>Use knowledge about stubble usage to maybe let the collectors know if there is a potential use for own farm → this is supported by information campaign promoting "Stubble away"</li> </ul>                                                                                                                                             | <ul style="list-style-type: none"> <li>Trust in Stubble Away to do the job thoroughly (particularly relevant for first time using the service)</li> </ul> | <ul style="list-style-type: none"> <li>Assessing the differences between stubble collection by Stubble Away and stubble burning → Information campaign with excursions to farmers' fields that demonstrate that the soil is more nutrient-rich when stubble is not burnt)</li> </ul> |

While 4.1 demonstrates how the activity of stubble burning can be analysed using Installation Theory, the theory demonstrates additional value for analysing the service provided by Stubble Away from the perspectives of the farmers. If Figure 6 and Figure A3 in Appendix are compared, it is observable that the proposed solution to the problem of stubble burning primarily addresses the step in the chain of activities identified as most crucial, this being the distinct decision by the farmer regarding which residue management technique to utilise. Lack of resources, social

dynamics in Punjab farming communities, governmental distaste and ease of use pertaining to stubble burning, demonstrate that all three layers of Installation theory are adequately addressed.

## Appendix C: Business plan of ‘Stubble Away’

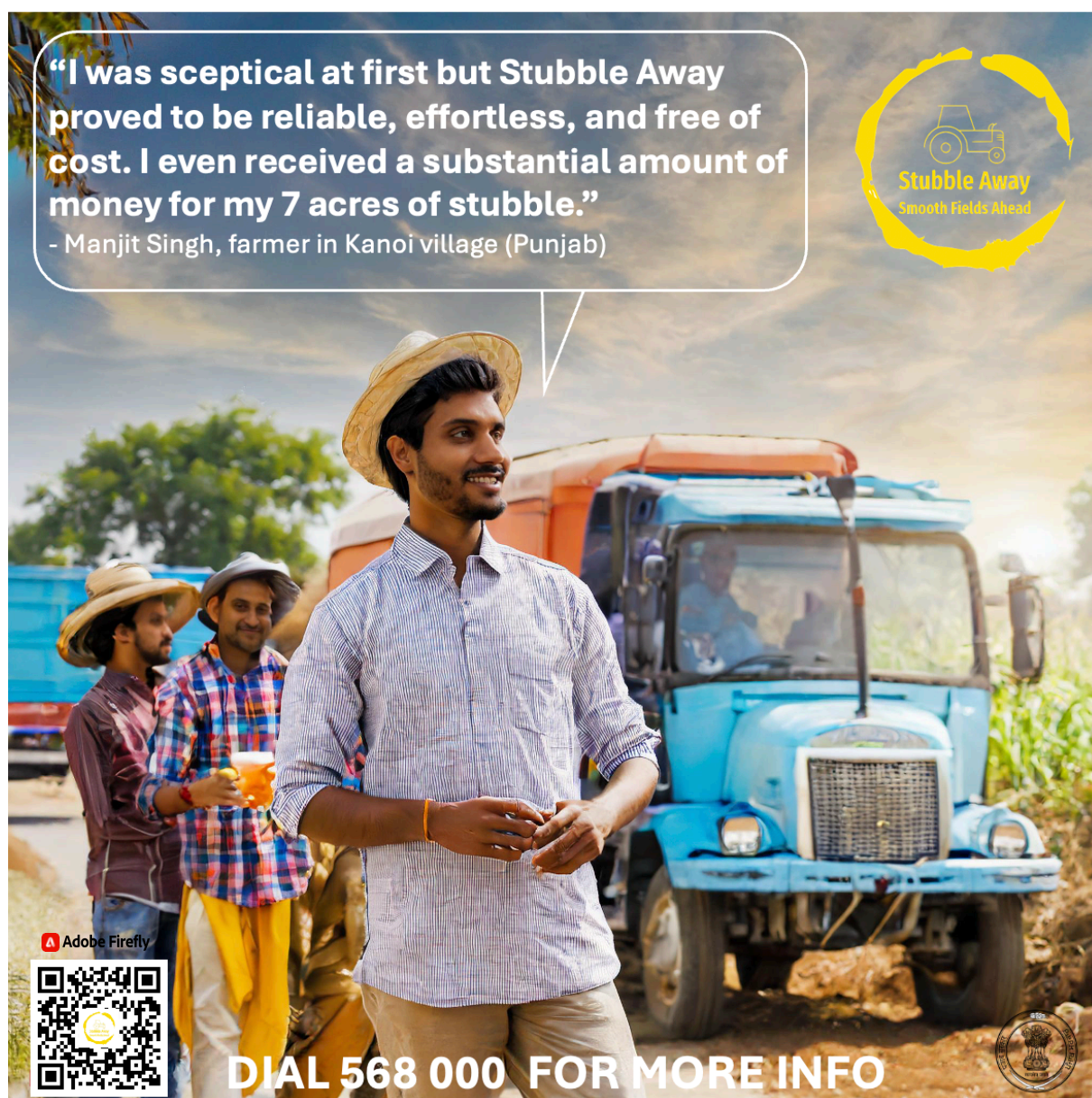
**Figure C1: Finances**

| Revenue & Costs                     |        |                                                       |          | Existing Funds & Cost Savings                                                                                                   |          |                                          |  |
|-------------------------------------|--------|-------------------------------------------------------|----------|---------------------------------------------------------------------------------------------------------------------------------|----------|------------------------------------------|--|
| Annual Projected Revenue: \$65K     |        | Annual Projected Costs: \$38K<br>Startup Costs: \$94K |          | Existing Public Funds: \$84K                                                                                                    |          | Conceptual Cost Savings                  |  |
| Revenue Variables                   |        | Cost Variables                                        |          | Funds in Punjab FY 2023/24 Budget                                                                                               |          | Cost Savings Opportunities               |  |
| Number of Acres                     | 500    | Baler Acres Covered Per Day                           | 20       | 50%-80% Mechanization Subsidies<br>(Towards Startup Costs)                                                                      | \$68,000 | Reduction in Stubble Burning Enforcement |  |
| Average Farm Acreage                | 7      | Available Working Days                                | 10       | Subsidies for Fuel (₹2,500 / Acre)<br>(Towards Annual Costs)                                                                    | \$15,000 | Reduction in Public Health Care          |  |
| Stubble Per Acre (Quintal)          | 22.5   | Startup - Baler Price (x3)                            | \$25,000 | Funds for Labour for Stubble<br>Management (Towards Annual<br>Costs)                                                            | \$1,000  | Reduction in Pollution Abatement         |  |
| Price – Harvest Season (\$/Quintal) | \$3.32 | Startup - Truck Price (x1)                            | \$14,000 | Budget amendment: Utilize existing funds<br>allocated to reduce stubble burning to support<br>the “Stubble Away” pilot program. |          | Increase in Tourism                      |  |
| Price – Offseason (\$/Quintal)      | \$6.63 | Contract Per Collector (x8)                           | \$1,200  |                                                                                                                                 |          |                                          |  |
| Share of Sales - Harvest Season     | 25%    | Average Payment Per Farm                              | \$150    |                                                                                                                                 |          |                                          |  |
| Share of Sales - Offseason          | 75%    | Fuel + Administrative Costs                           | \$18,000 |                                                                                                                                 |          |                                          |  |
|                                     |        | Startup - Storage Location Cost                       | \$5,000  |                                                                                                                                 |          |                                          |  |

The finances above give rough estimates for a preliminary judgment of the financial feasibility of Stubble Away for a 500-acre pilot involving around 70 small/medium farms. The projected annual revenue of \$65,000 exceeds the projected annual cost of \$38,000, which supports the feasibility. The \$94,000 startup cost could be greatly reduced in the case that the baler and transport truck are rented for the short 10-day time period instead of purchased upfront. However, the shortage of equipment during the most in-demand part of the year means that renting is not a reliable option. We identify existing public funds, already provided by the Government of Punjab in current budgets to reduce stubble burning, as further accounting for the startup costs. Additionally, the programme’s expansion means less government spending required towards enforcement, pollution, and health services, supporting the feasibility to convince policy adoption. Overall, the Government of Punjab’s role would be to provide financial stability to the system; it would require little to no additional public funds. As the startup, manufacturing, and energy production infrastructure grows, much of the existing public funds dedicated to stubble burning reduction could be phased out as it becomes more self-sustaining.

## Appendix D: Communication Campaign

**Figure D1:** Communication poster with farmer testimonials once pilot project has been successful



**"I was sceptical at first but Stubble Away proved to be reliable, effortless, and free of cost. I even received a substantial amount of money for my 7 acres of stubble."**

- Manjit Singh, farmer in Kanoi village (Punjab)

**Stubble Away**  
Smooth Fields Ahead

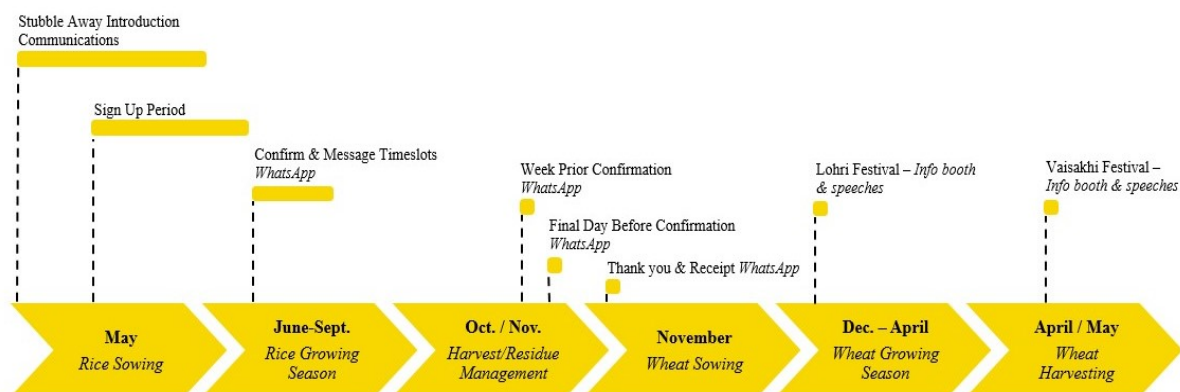
Adobe Firefly



**DIAL 568 000 FOR MORE INFO**





**Figure D2: Communication Timeline**

**Scaling up Communications:** Once our pilot project is implemented, we intend on scaling up our solution through ‘DD Kisan’, a widely watched government sponsored TV station among Punjab farmers with a viewership of 91 million nationwide. Research indicates that DD Kisan viewers exhibit high knowledge levels and moderate technology adoption (Upadhyay, 2018). We plan to broadcast an updated video, previously shared on farmers’ WhatsApp accounts, on this channel. Given the limited availability of TVs per household, TV viewing is often a communal activity, involving individuals watching collectively with family, neighbors, or at shared spaces. Launching this ad campaign could stimulate collective discussions, fostering a favorable environment for the adoption of our solution.

## Appendix E: Adoption barriers and attitudes

**Figure E1: Leveraging attitudes and barriers to uptake**



## Appendix F: Lewin's 3-stage Model of Change

**Figure F1:** Applying Lewin's Model of Change to our approach

