STUDY OF EVOLUTION OF TECHNOLOGIES AND ISSUES ARISING IN THE ADOPTION OF SUCH TECHNOLOGIES USED IN INDIAN CROP RESIDUE MANAGEMENT

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ABSTRACT

The issue of stubble burning in Northern India is no longer a localized concern or any particular state's responsibility rather lately it has caught global attention. Numerous unsuccessful attempts to solve the problem caused due to poor crop residue management by farmers have now led to life-threatening problems like air pollution. Although several technological solutions are provided still there's no shift in behaviour instead the numbers are on the rise every year. This article's objective is to create a bird's eye view of various technologies that are introduced, and the reasons for the extent of adoption of these technologies on the basis of five characteristics: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003) and reasons of failed adoption or weak adoption of these technologies due to mental model of 'partial view of innovation' (Tidd et al, 2005). The article suggests utilizing the present technology efficiently instead of finding more weakly adopted future technological solutions.

EMERGENCE OF THE CROP RESIDUE PROBLEM

Two main perspectives on agricultural reform emerged during the 1960s: one favoured a technological upgrade, while the other aimed for social change. The advocates of a technological revolution emphasized the need for the import of HYV seeds, and increased access to pesticides, fertilizers, and credit.

MS Swaminathan, a scientist at the Indian Agricultural Research Institute vouched for the same. Therefore, in 1964, the government adopted the idea of seed imports with price guarantees. However, this move encountered expected political resistance from advocates of a social revolution, who argued that it would primarily favour large-scale farmers and harm consumers. The debate concluded shortly after then-U.S. President Johnson expressed concerns about freely distributing food aid (PL480) to India. In 1966, he implemented the

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"ship-to-mouth" policy, delivering food aid only for immediate consumption, leaving no surplus for storage and keeping India reliant on constant shipments.

India viewed this as a humiliation, and Prime Minister Indira Gandhi used it to push for a technology-driven revolution with price guarantees, sparking the Green Revolution. The International Rice Research Institute in the Philippines developed the HYV variety of rice which had the ability to yield 7 tonnes of rice per hectare which was a significant improvement over the existing varieties that only produced 2 tonnes per hectare. In the 1970s, the adoption of high-yield rice (HYV) was a turning point in Punjab, Haryana, and western Uttar Pradesh. These regions although not historically known for rice cultivation were aggressively promoted by the State, with the government procuring around 80 percper centthe rice produced in Punjab in the 1980s. By the late ’90s, the region had fully adopted the rice-wh8eat-cropping system. But stubble burning became inevitable for the farmers of the region for multiple reasons.

Firstly, government-backed mandates in Punjab and Haryana aligned rice planting with the monsoon's onset in 2009, enforced by the Punjab Preservation of Subsoil Water Act. This resulted in a tight 15-day gap between the Kharif and Rabi crop cycles for rice and wheat. Farmers, under pressure to prepare fields quickly, resorted to burning crop residue as the fastest and cheapest method.

Secondly, the HYV rice ensured that the residue left was much taller than the basmati residue, while at the same time being less palatable as fodder for animals.

Thirdly, prior to the arrival of the Combine harvester, manual labour was employed to cut down the plant and then separate the edible part. After this technology, easy removal of the other edible parts and selling part part the plant became possible.

However, they had a drawback: they left behind a one-foot-tall plant residue. Farmers argue that this residue is even more challenging to remove manually due to its sharpness, causing injuries to farmers and hindering animal grazing. The residue had to be removed because it used to get stuck in the machines that plant the next crop, hence the most convenient way to rid of this residue is a pour on the fire.

When numerous farmers burn their crops in a region where agriculture is the primary livelihood, and when the winds are calm, it results in the entire area being shrouded in smoke and haze (see Table 1). This annual phenomenon, known as the "Great Smog", affects not only Delhi but also the entire northern Indian region.[13]

LEGAL PUSH THAT BACKFIRED

To mention a few, the Indian Government has introduced various laws to curb stubble burning, like Section 144 of the Civil Procedure Code (CPC) imposes imprisonment of up to 5 years or fines of up to 1 crore rupees or even both, the Air Prevention and Control of Pollution Act, 1981, the Environment Protection Act, 1986, the National Tribunal Act, 1995, etc. States like Rajasthan, Uttar Pradesh, Haryana, and Punjab have asked the National Green Tribunal (NGT) for intervention to restrict crop residue burning. [15] Even after the prevailing laws, stubble burning still persists.

The Punjab Preservation of Subsoil Water Act, 2009 was rolled out to preserve the groundwater. Eventually led to a delay in harvest and shrunk the harvest window leading to a shift in stubble burning timeline by 10 days of wheat and 12 days of paddy. The pollution associated with stubble-burning fires hence coincided with Diwali in northern India. Although the objective of the water conservation policy was supposed to preserve the groundwater by delaying the paddy transplantation and sowing bts mentation saw a drop in groundwater after 2013 at a rate of 29.2 mm/yr in these regions. [4]

TECHNOLOGICAL EVOLUTION TO SOLVE STUBBLE PROBLEM- Table 2

S.No.	Technology	Solution is provided
1.	Happy Seeder with straw spreader: ICAR, PAU	Seedling implanted without the need to remove stubble
2.	PUSA decomposer: IARI	A microbial capsule containing a consortium of 7 fungi to decompose residue in situ within 25 days

3.	Biochar	Converting biomass to biochar via pyrolysis
4.	Utilisation as Livestock fodder	Physical, chemical, and biological methods used to treat straw to enhance microbial activity in livestock gut
5.	Paper and pulp industry	Both rice and wheat straw as raw materials for paper production
6.	Compost preparation	A high C: N ratio in rice residue takes a longer time to decompose hence methods like using cow dung, earthworms, and mechanized composting wind rows are used.
7.	Bio methanation	Production of methane-rich biogas via anaerobic digestion used as renewable energy in power generation and vehicle fuel
8.	Power generation	Residue bricks Used in power plants either Co-fired with coal or alone.
9.	Production of bio-oils (ethanol)	Bioethanol produced via pyrolysis is better than diesel and is eco-friendly.
10.	Digital agriculture	• Apps on smartphones to connect rental machine providers • drones for spraying bio enzyme to decompose residue • Data management via sensors and tracking violation of laws prohibiting stubble burning

Pyrolysis: temp>500 degree Celsius

ICAR: Indian council of agriculture research

IARI: Indian Agriculture Research Institute

PAU: Punjab Agriculture University

C: N: carbon-nitrogen ratio

The Green Revolution introduced technology to help the agriculture sector, however, social and structural issues in this sector have hindered the widespread adoption of newer technologies (Table 2).

Incentives provided by the government (laws and policies) try to enhance the diffusion rate and adoption of innovation. But sometimes, the compatibility of a new technology also depends on the existing values and norms of the society and the actors (Rogers, 2003) the role of local politics in influencing farmers to continue to burn the stubble is yet another reason for the lack of adoptability. The contemporary party unit leaders and local pressure groups are found promoting and burning paddy straws to support the farmers as farmers constitute an influential and volatile vote bank in both Punjab and Haryana as no party wants to lose votes.

The problem of externally generated innovation ie government technological solutions that overlook the need for internal learning or development of technological competence of stakeholders involved (farmers in this case), becomes the hurdle in the adoption of technological innovation. (Tidd et al, 2005)

To have an overview (Table 3) of the extent of adoption of these technologies, the method of studying five characteristics of adoption and diffusion: relative advantage, compatibility, complexity, trialability, and observability are used [8] and the reasons for failure adoption or weak adoption are seen through the lens of the problem of the partial view of adoption. [7]

ANALYSIS

Table 3

Sr. No.	Technology	Characteristics of Adoption					Problems of Partial view of innovation
		Compatibility (Consistent with existing skill)	Complexity	Relative advantage in terms of affordability	Triability	Observability (result visible on ground)	
1	Happy Seeder	Yes	Less	Less	-	Yes	R&D focussed: User did not except
2	Pusa	No	Less	More	No	No	Only Agricultural scientist point of view considered
3	New variant seeds	Yes	Less	More	-	No	Improper use by end user
4	Utilisation as livestock Fodder	No	High	Less	-	-	Technology not user friendly, Lack of information
5	Paper	Yes	High	-	-	-	Lack of technical progression
6	Biochar	Yes	Less	More	Yes	Yes	Lack of incremental change
7	Bio Methanation	Yes	High	Less	-	-	
8	Bio Ethanol	Yes	High	More	-	-	
9	Digital Agriculture	No	High	More	Yes	Yes	Digital divide

When an innovation is easy to use and convenient to the potential adopter it has a relative advantage over the older technology. Pusa decomposer comes in capsule form and liquid formulations. The dosage should be four capsules with each cost around Rs 5 making this technology inexpensive. The efficiency in dissolving stubble is also high hence farmers can use it without caring about the extra cost and simultaneously stepping away from burning the residue. According to the Microbiology Division in PUSA, only four capsules can turn a hectare of stubble into usable compost (natural fertilizer). The fields preserve some moisture during the decomposition of agricultural waste, and the soil is enriched, minimizing the use of fertilizer. Another advantage of the capsule is that it does not have any side effects.

The Bastion conducted a case study 19 in Jhuljhuli, an 'urban' village located near the Haryana border. Because of the less complex nature of this technology and observable results, the adoption was widespread amongst the farmers and convinced almost all. But in some fields,

it worked and in some, it didn’t. The reasons anticipated for the failure of the PUSA decomposer are:

- Jhuljhuli fields are low-lying so, waterlogging can be seen commonly but this capsule works in certain moisture, temperature and soil conditions to successfully decompose stubble and the high moisture content of fields isn't conducive.

- The capsule is designed with respect to non-basmati varieties of rice. But in this village, only about 10 to 15% of the paddy grown is non-basmati.
- The ineffectiveness of the decomposition is that the colder conditions (of late October and early November) hamper the decomposer's fungal growth.

Hence, due to a lack of training sessions for farmers, the optimum usage of innovation is not possible, therefore, reducing adaptability. The case study is a classic example of the partial view of innovation when innovation is seen only from a 'specialist' point of view (agriculture scientists in this case), resulting in a lack of involvement and input of other stakeholders.

The introduction of short-duration varieties of paddy was meant to reduce water use and provide extra time for residue management. Seed varieties PR 121 and PR 126 take around 140 and 123 days respectively to mature. These varieties offer 3 to 6 weeks of added time as compared to the PUSA 44 (160 days) for residue management. However, according to a study, farmers of Amritsar started using this extra time to grow potatoes, peas, etc. leading to misuse of the extra time window developed by this technology and eventually still resorting to stubble burning [(21)]. The above lack of adaptability stems from the problem of partial views of innovation wherein strong R&D capability is only focussed upon and farmers opt to misuse this innovation other than the purpose it was actually developed to serve because of a lack of behaviour nudging incentives that should have been there to educate the proper use.

Despite 2022 being the fifth year that such machines are being distributed, most farmers in Punjab aren't trained adequately to use these machines and are still apprehensive about the impact on the wheat crop yields sowed by these Seeders. Various reasons for the weak adoption of Happy Seeders are high private ownership (37 %), secondly, the upfront cost of a Super Seeder is INR 2,70,000 whereas the maximum subsidy for it is INR 1,05,000 hence, farmers have to take loans with interest of up to 11% to buy these machines. [(21)]

Also, the rental model CHC (Community Hiring Center) has failed to win over the farmers due to delays in the availability of machines and inefficiencies in logistics. The awareness of the FARMS app was launched to popularise the CHC model but still adoption has been poor among the farmers. [20] [21]

In the rural areas, the most common source of livestock feed is rice straw. But has poor nutritional composition due to high silicon content acting as a physical barrier hampering the microbial degradation process. Hence, technological improvements need to be performed physically, chemically, and biologically. Physical pre-treatment like grinding, soaking in water, steam pressure, and pelleting is done. Chemical methods using alkaline agents like ammonia (urea), NaOH, and lime are used. These alkaline materials react with cellulose, softening the structural fibres and accelerating microbial activity in the livestock gut. Pre-treating biologically can be done by enzymatic or microbial activities with fungi or bacteria. However, its large-scale use is still not achieved due to a lack of technical skills, cost-effectiveness, handling, field conditions, and potential health risks to farmers. [5]

Both wheat and rice straws are sustainable and eco-friendly raw materials for the paper and pulp industry. Nearly 50% of paper industry in Punjab is using straw. The straws with high fibre content are easily pulped, which makes them appropriate candidates to produce high-quality paper. Fibrous agricultural residues are better as compared to woody biomass. In addition, the sludge generated from this industry can be later used for energy generation through the bio-mechanization process. [16]

The disadvantage of using agricultural residues is that straw usually presents high water content levels, reaching up to 70% on a weight basis, which needs to be dropped to levels around or below 25% to avoid microbial spoilage. Drying straw fibres itself is a challenge.

Hence, the problem with the partial view of such technological innovation is that it meets the customer's (farmer) need but lacks technical progression, leading to the inability to gain a competitive edge in this particular technology.

Biochar is a carbon-rich material produced through the pyrolysis of surplus biomass (stubble in this case) at high temperatures in a limited oxygen environment.

It provides significant ecosystem services that include nutrient retention and cycling of soil nutrients, improvement in soil quality and soil health, carbon sequestration and climate change mitigation. It can also reduce soil acidity and improve water retention, which is the need of hour in areas of water-scarce Indo-Gangetic plains. Another application of rice husk-based modified biochar has demonstrated effective fluoride ion adsorption from the polluted surface and groundwater. [17] However, biochar production is challenged due to the costly production process. Here, cost plays a major factor in creating the relative advantage of one innovation over the other and in the extent of diffusion. The export of crop residues from the farm to off-site for bioenergy generation is a challenge. It is also reported that excessive removal of crop residues may be harmful to the soil.

The production of methane-rich biogas through anaerobic digestion is called biomethanation. It can be used as a replacement for fossil fuels in both heat and power generation and as a vehicle fuel, thus, as a renewable source of energy. [3] As annually India produces nearly 686 MT of crop residue of which more than 1/3rd could be used for bio-energy production with a daily production potential of 46 Mm3, hence the technology has a lot of potential to tap. However, the hurdles in adoption are yet again the complexity of its usage. The obvious disadvantage of using agricultural crop residue is low conversion efficiency because of high silica content (as read above). Also, the studies on silica removal are very less. The pretreatment methods to remove silica are expensive, polluting, and laborious. On the other hand, biomethane, after purification also contains impurities and can damage engines, hence adding to extra maintenance costs. Storing biomethane in the form of LBM (liquid) and CBM (compressed) can be an alternative however, its tendency to evaporate, makes it necessary to be used within a week. Biogas digesters are suffering reactor failures due to a lack of regular maintenance and poor dissemination of information.

All the above issues arise due to neglect of the potential of incremental innovation and seeing innovation only about 'breakthrough changes'. For example, in rural India even though has the maximum number of biogas plants the awareness of how to utilize the substrate is limited to only cattle dung, and the usage remains limited as a cooking fuel substitute.

As a consistent rural power supply is a challenge to agriculture mechanisation hence one viable solution is to utilize surplus rice straw (as pellets) in power plants, either alone or in combination with coal. When burned in a boiler or gasifier under low-oxygen, high-temperature conditions, these residues are converted into producer gas (consisting of CO, H, and N). Reasons for the suitability of rice straw for the energy sector are: high calorific value, less ash content, renewable, additional income for farmers, fly ash as by-product usage in the cement industry, etc. [12]

Bio-oil is a high-density liquid derived from organic waste like bagasse, wheat residue, and rice hull through pyrolysis. It has diverse applications in boilers, heat generation, gas turbine operation, and eco-friendly transportation (better than diesel). India has the potential to annually produce 51.34 billion litres of bioethanol from various crops. [12]

However, this technological innovation is surrounded by open plugs and might lead to weak adoption in future like the rest of the above technologies discussed. Problems in bioenergy are- difficulty in storage due to the bulky nature of rice residue which requires huge spaces. (2) Secondly, the area needs to be waterproof, loose bales need to be protected from winds and the menace of rodents needs attention. Thirdly, due to the hygroscopic nature of straw, especially in the damp monsoon season, there is a possibility of fungal and mould attacks.

Another issue arises due to a lack of inter-ministerial coordination like MOEFCC's rule of mandatory using fly ash in brick kilns has reduced the demand for straw in these kilns. The research also suggests that the surplus use of biomass for cofiring in thermal power plants is presently limited because of high transportation costs, this shows the importance of setting up plants closer to crop residue sources.

CONCLUSION

After studying multiple technological interventions, one can observe that none of them gives a solution in a comprehensive manner and leaves one actor or the other in the process. Innovation that is partially adopted eventually discontinues. In the quest to find the solution to stubble burning, the approach of how one should manage innovation is faulty because solutions are pushed by the government on farmers neglecting other factors that do not let the farmers opt for these technologies.

Technological innovation when developed in silos like only from the lens of R&D or specialists' point of view or just customer needs or neglecting market needs or through the lens of only large firms, or when innovation is generated internally or just externally in a nutshell doesn't take all stakeholders in account. Hence, the stubble-burning problem still persists.

In order to overcome this "problem of the partial view of innovation", the inclusion of various forms of 'inter-organizational networking' needs to be opted for and not solely focus on the concerns of a single entity (Tidd et al., 2005). The focus must not be on developing more technologies but rather on making the present available one sustainable and scalable.

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