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Framework For Managing Largescale, Interorganizational Projects in the Sustainability Landscape

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Abstract

Global efforts to combat climate change, conserve natural resources, and promote sustainable development require large-scale, multi-organizational projects. We present a conceptual framework for designing, planning, and executing such long-term projects using lessons learned from a crop residue management project in India, which involves 29,000 farmers across 172 villages covering 160,000 acres of farmland. The concepts of social learning, adaptive management, and flexible governance structure are incorporated into our framework by drawing on the literature in ecological and social sciences. The findings from our case study demonstrate how the proposed framework and structure facilitate social learning at multiple levels, ultimately leading to successful adoption of eco-friendly practices. Our quantitative analysis makes use of data collected from more than 4000 farmers over a period of three years using both multivariate and regression analyses. It is gratifying to note from our findings that despite the increased cost, farmers exposed to ecofriendly methods through social learning mechanisms adopt them readily, and that in the long run eco-friendly practices also contribute to economic and social sustainability. Our study emphasizes the importance of stronger policy intervention and industry participation in order to ensure the success of large-scale sustainability and climate change projects.

Keywords: Emissions, Social Learning, Project Management, Sustainability, Environment

1. Introduction

Delhi, the capital city of India, had a death toll of approximately 57,000 in 2020 due to air pollution, which also caused a financial loss of $8.6 billion according to estimates by Greenpeace (World Health Organization, 2021). There is a 10-fold increase in acute respiratory infections across 9 different Indian cities due to high levels of Particulate Matter (PM2.5). Among the major contributing factors are crop residue burning in the nearby states of Punjab and Haryana (Hellin et al., 2021). In addition to the eco-system of the Indo-Gangetic plains, this open burning of biomass has negative impacts on health, climate, cryosphere, monsoon patterns, agricultural production, and the incomes of farmers (Bhattarai et al., 2019).

Nearly 4.2 million people die every year as a result of air pollution related chronic respiratory diseases, lung cancer, strokes, and heart disease (World Health Organization, 2021). In view of the scale, complexity, and number of stakeholders involved, organizations at all levels must work together to address this enormous challenge. The need for net zero emissions will drive the growth of large-scale interorganizational projects, not only to reduce air pollution, but also to conserve energy, water, soil, and biodiversity (Lee & Tang, 2018). The focus of such projects will be broad-based, on long-term conservation of natural resources, rather than on short-term objectives of scope, time, and cost (Kivilä et al., 2017). Extreme weather conditions – such as heatwaves, draughts, wildfires, floods, cyclones, and heavy rains - have increased in frequency and intensity and will continue to do so in the future (IPCC, 2021). The US, which has simultaneously become both drier and wetter during the last 30 years, with severe drought in the western states like California, and heavy downpour and flash floods in the eastern parts of the country, is a case in point (Bhatia & Popovich, 2021). It is therefore imperative that we limit the mindless extraction and consumption of natural resources and destruction of Earth's atmosphere, which can only be achieved with meaningful collaboration among various stakeholders, including governments, NGOs, private industry, and civil society (Tang & Zhou, 2012).

In addition, these projects are usually complex, very uncertain, and require cooperation between a range of stakeholders. This calls for innovation in their governance, management, and execution. Although prior studies (Davies et al., 2017; Kivilä et al., 2017) examined the complexities and uncertainties involved in large-scale projects with multiple stakeholders, they only addressed public-private partnerships (PPPs) without considering NGOs or social learning aspects nor flexible governance structures needed to manage projects of our interest. In response to Bendoly et al.'s (2021) call for new research on projects that are distinct both from theory and practice perspectives, we propose a conceptual framework for managing projects dealing with natural resource conservation (NRC), climate change (CC), and sustainable development (SD) related aspects.

India is a good geographic context for the study at hand, as it is surrounded on three sides by oceans that are warming more rapidly than global averages (IPCC, 2021). Furthermore, the intensifying degree and periodicity of changing monsoons and the melting of Himalayan glaciers threaten the survival of the Indian subcontinent (P. C. Pandey, 2020). Therefore, several largescale conservation projects are underway in India to conserve the climate, environmental diversity, and natural resources including water, energy, air quality, biodiversity, and topsoil (Diduck et al., 2007, B & P, 2018), which provide an opportunity to study the various aspects of project management discussed above.

The purpose of this study is to evaluate a large, inter-organizational project spanning multiple years to change the crop residue management (CRM) practices of farmers in two large Indian states, Punjab and Haryana, that contribute to peak air pollution episodes in northern India, including the Delhi National Capital Region (Shyamsundar et al., 2019; Pandey et al., 2020; Hellin et al., 2021). Due to the lack of an appropriate biomass management ecosystem, farmers in these two states end up burning massive quantities of rice straw during winter, which contributes to 50% of food grains distributed across India (Chauhan et al., 2012). Punjab alone sows rice on 7.5 million hectares of land each year, and in 2017, nearly 97% of farmers burned residual straw (CII-ITC CESD, 2020).

Researchers have shown that eliminating crop residue burning in northwest India would prevent disability-adjusted life years valued at $1.4 billion over five years (Chakrabarti et al., 2019).

After several failed attempts to change this farming practice (Chatterjee, 2019), the central government of India directed the state governments of Punjab, Haryana, and UP to draft private organizations (both for-profit and non-profit) to implement eco-friendly farming methods (Dhiman, 2018). As a response to the call for participation, private organizations, spearheaded by Confederation of Indian Industry (CII), began the CRM project in 19 villages in 2018; it expanded to 172 villages in 8 districts of Punjab and Haryana in 2020, covering nearly 160,000 acres of farmland and involving 29,000 farmers.

As in Shenhar (2001), we use a combination of qualitative and quantitative methods to offer an empirically tested conceptual model for the planning and execution of NRC, CC, and SD type projects with the learnings from the CRM project. By drawing on theories of social learning and adaptive management, we create a project management framework that enables stakeholders to learn at multiple levels and use this learning to adapt their practices in a dynamic manner to a complex and uncertain environment. Using the case study methodology, we first investigated how the CRM project was conceived and executed, and subsequently built a generic framework that can be used in other situations. Our next step involved performing regression analysis using the data collected over 3 years from more than 4000 farmers in the intervened villages in order to measure the effectiveness of the project.

The results of our study clearly indicate that the flexible governance system, coupled with relational contracts, and a social learning platform proved effective in preventing 90% of crop residue burning among farmers participating in this project after 3 years thanks to eco-friendly CRM practices. Interestingly, we find that, even when the cost of adopting these eco-friendly practices increased, farmers continued to adopt them in subsequent years as they began to reap other benefits including improved soil fertility, greater savings in water and farm inputs, and decreased air pollution. The 3 years of CRM intervention prevented the burning of 550 thousand tons of rice straw, leading to the reduction of 2,550 tonnes of PM10 and PM2.5 air pollution respectively, 552 thousand tonnes of secondary aerosols, 162 thousand tonnes of non-CO2 GHG emissions, 260 tonnes of black carbon, and 37.65 billion litres of water. In addition, 501 thousand tons of organic matter was returned to the soil. By facilitating multi-loop learning through intense handholding by the project team during the execution phase, we have been able to bring about this social change and recommend similar policy interventions in order to reduce CRB in the future.

2. Literature Survey and Theoretical Framework

The objective of this study is to devise an empirically tested governance structure and a management/execution framework for largescale projects involving multiple stakeholders from public, private, and non-governmental organizations. Such projects, especially those focusing on social change and adoption of new practices, require joint effort between various types of stakeholders in management of uncertainty and quick problem solving during the project execution phase (Gillingham & Bollinger, 2021). There are very few research studies that have examined these complex aspects and provide theoretical frameworks that can be adopted to such dynamic project execution contexts. We provide a detailed literature survey of these studies in **Annexure 1** of the Appendix and combine the review of relevant work with the theoretical framework in the section below to integrate both seamlessly.

2.1. Theoretical Framework

The projects focusing on NRC, CC and SD related aspects are complex in nature, and (i) require involvement of several stakeholders from both public and private speres, (ii) need significant resources in terms of both financial and manpower related, and (iii) must deal with environments that are context dependent and are fraught with uncertainties.

2.1.1. Multiple Stakeholders

According to the definition of Project Management Institute (PMI, 2013, p.30), "an individual, or group, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" is termed as a stakeholder. For the sake of brevity, we divide the various stakeholders that either affect or are affected by the projects under consideration into two categories: formal and informal. Following Pahl-Wostl (2009), we define formal institutions (in our case, formal stakeholders) as those who are linked to official channels of governmental bureaucracies, and hence need to follow legally binding regulatory frameworks. Informal institutions (or informal stakeholders) on the other hand follow socially shared rules such as social or cultural norms that are enforced outside the legally sanctioned channels.

Most largescale projects under the categories of NRC, CC and SD are spearheaded by either an established NGO – an informal institution – that is working in that specific field or by governmental organizations as part of nature conservation or sustainable development goals. For instance, the Nature Conservation Foundation (NCF) is working in Lakshadweep Archipelago since 1996 on conservation of coral reefs[i]. However, MOSE (Modulo Sperimentale Elettromeccanico, Experimental Electromechanical Module) is a project commissioned by the Ministry of Infrastructure and Transport, Venice Water authority – a formal institution – to protect the city of Venice from sinking and flooding, by isolating the Venetian Lagoon temporarily from the Adriatic Sea during high tides[ii]. Irrespective of which is the case, the organizations leading the project must work with several other stakeholders that either affect or are affected by the project. Including a broader set of stakeholders during the planning stage provides access to vital knowledge necessary for comprehensive assessment of the problems and innovative solutions to deal with them (Berkes & Folke, 2002). Please see **Annexure 2** in Appendix for more details on how this factor plays out in the two examples of MOSE and NCF mentioned above.

2.1.2. Project Resources

Again, due to their considerable scale and long-term nature, NRC/CC/SD projects require significant resources to plan and execute. Such resources include financial resources to fund the project, technical expertise to provide the right kind of solutions, and necessary manpower for execution and monitoring of the project. These resources are also likely to come from different organizations and stakeholders participating in the project, and hence require significant collaboration and cooperation between the stakeholders and the project teams (Lee & Tang, 2018).

2.1.3. Context Dependence and Uncertainty

The objectives and execution of projects under the categories of NRC/CC/SD, by nature depend on the geographical location and environmental context in which they are being undertaken. For instance, a water resource conservation project in a dry region like the sub-Saharan Africa would entail addressing different challenges and require adoption of a different set of practices by the local population, compared to a water conservation project in the Indian sub-continent which gets plenty of rain during the monsoon months. Given the large scale of such projects and their dependence on nature, often, teams within the same project may face different types of challenges in various site locations as the local practices and their interactions with external elements such as rainfall, water table, nature of soil and other such elements may result in different outcomes (Xiaojun et al., 2020).

In addition to context dependence, NRC/CC/SD projects also face considerable uncertainty during the execution phase, despite a much deliberated and well-planned design phase. By uncertainty, we mean, general lack of predictability in future conditions of various forms, their system dynamics and how they respond to managerial interventions. Uncertainty in project management can be technological, financial, regulatory, or environmental. The uncertainty in a given context can get further exacerbated when multiple forms of uncertainties arise simultaneously and interact with each other to magnify their impact due to system dynamics.

2.1.4. Conceptual Framework

Given the uncertainty and complexity of NRC/CC/SD projects, and multiplicity of stakeholders involved, and the scale at which such projects need to be executed, the structure of the project and its governance mechanisms need to consider the following aspects:

- Project governance structure must have sufficient flexibility and agility to address the issues arising out of various forms of uncertainty and enable empowerment and quick decision making by the multiple stakeholders participating in the project.
- The governing body must have both formal and informal institutions and multiple levels of governance structure, to represent the interests of various stakeholders and to enable active participation and social learning.
- There is a need for both formal and relational contracts to govern the interests of various stakeholders and to enable collaboration amongst them.
- Feedback mechanisms must be built into the project governance structure to enable single, double, and triple loop learning.

Figure 1 describes the linkages between various integral elements of the projects under consideration and what they entail in terms of project governance and structure.

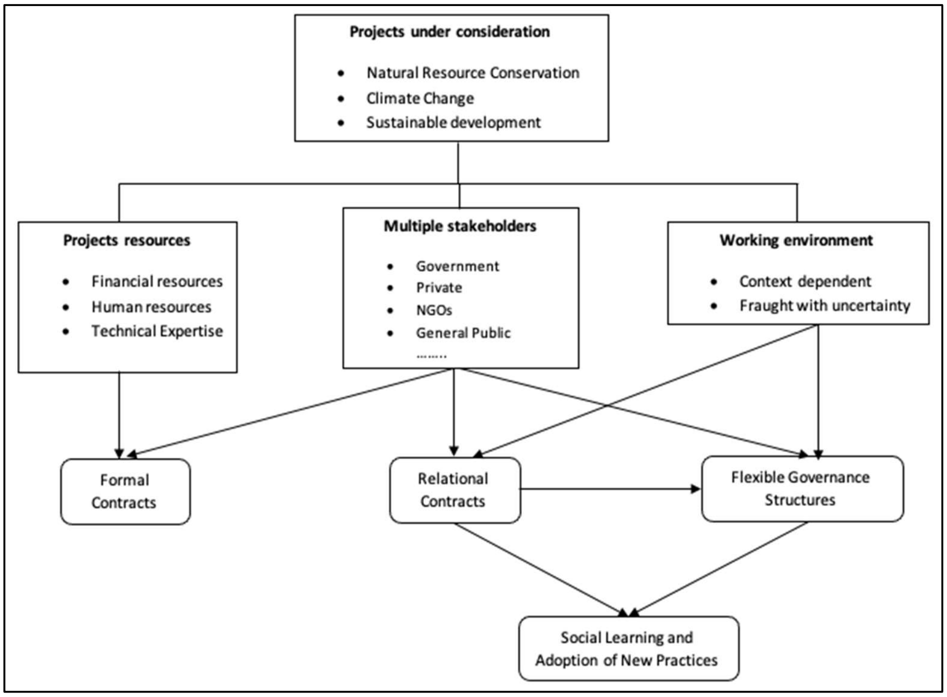


Figure 1. Conceptual framework for governing NRC/CC/SD projects

2.1.5. Flexible Governance Structure

One way to define project governance is based on the definition of OECD, which is "providing the structure through which the objectives of the project are set, and the means for attaining those objectives are determined, and the means of monitoring performance are determined" (Turner, 2006). In the project management literature, most often the planning phase gets emphasized and very little attention is given to the execution and control phases. In the context of our projects, however, it is the execution that makes or breaks the project, since it involves cooperation and collaboration between a variety of stakeholders over long periods leading hopefully to social learning and societal change. Therefore, while setting the right objectives is critical, it is also equally important to identify an appropriate governance structure and means for achieving these objectives during the execution and performance monitoring stages. The governance structure must also have the capability to ensure that the information coming through the feedback loops is assimilated by the relevant governing authorities, project leaders and team members, who in turn can ensure that social learning takes place at each level. **Figure 2** depicts a hierarchical governance system with three levels, representing the deliberation, planning and execution of a project under consideration, with feedback loops feeding the learning and knowledge back to the upper echelons, to facilitate multi-loop learning. Depending on the nature of the project and types of stakeholders involved, more levels of governance may become necessary. However, **Figure 2** provides a model that can be adapted based on the context and the need, as ‘one size does not fit all projects’ (Shenhar, 2001).

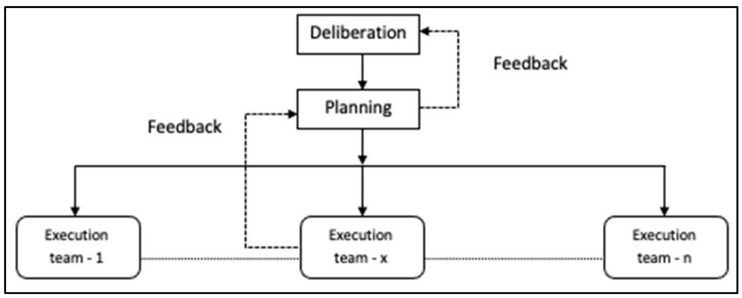


Figure 2. Hierarchical governance structure for management of NRC/CC/SD projects

Flexibility has been long recognized as the necessary capability to deal with high variability arising from uncertain demand and supply scenarios. Extending this concept to the context of project management, we propose that flexible governance structures, such as **polycentric governance system** (**PGS**) or **complex adaptive system** (**CAS**), are necessary to manage the considerable uncertainties that arise during the execution phase of NRC/CC/SD projects and to ensure effective collaboration and cooperation between the diverse stakeholders from formal and informal institutions. PGS is a complex, modular system, where differently sized governance units with different purpose, organization, spatial location interact to form together a largely self-organized governance regime (Pahl-Wostl, 2009). CAS on the other hand is a complex, non-linear interactive system, which has the ability to adapt to a changing environment (Levin, 1999).

For the types of projects under consideration in this study, there are multiple stakeholders and multiple levels of governance, and hence decision-making authority needs to be distributed in a nested hierarchy so as to ensure that no single level or individual has full authority to make abrupt changes in processes or objectives. However, at the same time, given the uncertainly and the complex nature of projects, we also need to build in the capability to adapt by changing the rules and the behavior, through swift coordination across various levels as more experience and learning gets accumulated. Following (Pahl-Wostl, 2009), we combine relevant elements of PGS and CAS to propose a flexible governance structure for the projects under our consideration, that enables:

(i) Participation of stakeholders at one level in decision processes at another level
(ii) Institutions (both formal and informal) at one level to influence decision processes and stakeholders at another level
(iii) Knowledge produced at one level to influence decision processes and stakeholders at another level

The above structure ensures that decision processes at various levels are connected and vertically coordinated, while simultaneously retaining flexibility and inclusion.

2.1.6. Formal and Relational contracts

Formal contracts are considered to be costly and difficult to enforce in complex and uncertain scenarios (whose outcomes are difficult to predict in advance) that involve large number of stakeholders (Hill, 1990). **Relational governance** is known to be a better substitute under such contexts, as it functions based on trust and mutual respect, which are self-enforcing mechanisms. Relational governance also allows for more flexibility, which is essential in the face of technological and environmental uncertainty. However, execution of largescale inter-organizational projects that span long time horizons with multiple stakeholders involves significant monetary and human resources, necessitating some form of formal contractual structure. While formal contracts narrow down the domain around which different stakeholders can behave opportunistically, the relational governance based on trust can build common intent, bilateralism, and provide informal means of conflict resolution in the face of uncertainty (Poppo & Zenger, 2002). Cao & Lumineau (2015) in their study found that formal and relational contracts reinforce each other in interorganizational relationships, and both have positive impacts on satisfaction and performance. We therefore argue that, in case of resource conservation and sustainable development, projects that typically involve a variety of stakeholders with differing objectives (Yuan, 2017) having formal as well as relational contracts, will be complementary in nature.

2.1.7. Social learning

The nature and objectives of the projects under consideration demand changes in behavior and practices of local communities/general public, which is not easy to bring about for any type of governing body. People largely prefer to function under status quo, and adoption of new practices requires a deliberate action to begin with and creation of social/societal learning in iterative loops of action and reflection over multiple cycles to sustain the change in the long run (Williams & Brown, 2014). Learning is an exploratory, stepwise search process that requires the stakeholders to experiment with various innovative solutions until they find an optimal fix to their problem. However, since each individual's knowledge is constructed based on his/her own experiences, it tends to be partial or limited. Social learning processes overcome this limitation by facilitating knowledge sharing and joint learning experiences between various stakeholders through shared processes of learning by doing (Harvey et al., 2012). Following Keen et al. (2012), social learning in our context can be defined as "the collective action and reflection that takes place amongst both individuals and groups when they work together to improve the management of the interrelationships between social and ecological systems".

Therefore, the projects of the type of NRC, CC, and SD, due to their complexity, uncertainty and by inherently requiring social learning to take place during the various cycles of their execution, need the so-called '**adaptive management**' at various levels of governance, for their successful implementation. Adaptive management in simple terms can be described as ‘learning by doing and adapting based on what is learned’ (Williams & Brown, 2018). Adaptive management needs to take place at various levels of project governance, to maximize the performance of a project. For instance, let us take the lowest level in **Figure 2**, the execution, at the level of a basic unit (say a team) that is solely responsible for implementing the project in a local unit (say a village). This team is to comprise several stakeholders representing both formal and informal institutions, as well as community members from the village. Since we are looking at the execution phase of a project, the necessary resources for execution in terms of cost and time, and requisite activities to be carried out or strategies to be adopted would have been decided during the planning phase itself (as depicted in **Figure 2**).

The execution of the project by the local team would then involve steps such as: (i) creation of awareness and training in various tools and solutions, (ii) implementation of identified strategies, (iii) performance assessment and learning, and finally (iv) adjustments and improvements. Due to the presence of various uncertainties, the team accumulates more knowledge about the compatibility of various strategies to the given context only during the execution phase, and also learns about the adjustments and improvements necessary for effective implementation based on local conditions. If this learning and knowledge is incorporated into the decision processes of next cycle, the future problems and incompatibilities can be reduced significantly. This type of ‘learning by doing’ or incremental improvement of action strategies at the execution level to reduce the technological uncertainties is called ‘technical learning’ or ‘single loop learning’ (Williams & Brown, 2018), as depicted in **Figure 3**.

Note however that, identification of appropriate strategies and the necessary resource allocations to implement these strategies occurs during the planning phase. Therefore, unless the knowledge gained at the execution phase and the improved strategies through technical learning are shared and considered through a feedback loop with the governing body at the planning phase, it is not possible for the executing team to obtain the necessary permissions and resources for implementation of improved strategies in future cycles. This practice of incorporating technical learning from current cycles into design, planning and resource allocation decisions of future cycles through participation of teams at lower levels in decision processes at the higher echelons, would result in 'managerial learning' or 'double-loop learning' (see **Figure 3**).

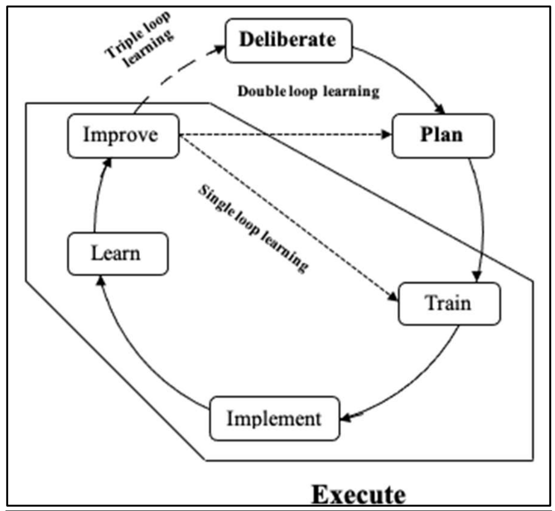


Figure 3. Triple loop and social learning framework for NRC/CC/SD projects

Note that, during 'double-loop learning', managers revisit their assumptions about cause-and-effect relationships within a value-normative framework and make the necessary changes in their assumptions and associated strategies based on the newly available knowledge from technical learning. However, to consider alternative strategies and resources for their execution, managers at the planning phase are likely to be constrained by the belief systems, structural and policy frameworks operating at the deliberate phase. If this is taken one step further, and if one were to incorporate this managerial learning into the upper most echelon, that is, the deliberate phase, inducing reconsideration of underlying values, beliefs and worldviews based on which governance structures and policies are formed (ultimately leading to changes in structures and policies as the underlying value-normative frameworks change), we would achieve the 'institutional learning', also known as 'triple-loop learning' (Hargrove, 2002). The triple loop learning is supposed to bring about complete transformation of belief paradigms, frames of reference, and result in changes in policy, governance norms and protocols, such that managers at the planning level can bring about the necessary changes and improvements based on the knowledge gained.

Such an approach of adaptive management enabled through a flexible, multi-level governance structure and participation of formal and informal stakeholders with formal/relational contracts as depicted in **Figure 2** would result in social and societal learning necessary for the long-term sustainability of changes these projects embark upon.

3. Application of Conceptual Framework to Empirical Context

In this section, we apply the conceptual framework developed above to a project that is being undertaken in the agriculture sector in the context of crop residue burning (CRB) that was polluting the air in the Indo Gangetic plains of India every winter and harming the health of a large population residing in NCR and other states in Northwestern India.

3.1. Empirical Context

CRB in Punjab and Haryana has been a major challenge to neighboring states and especially in the Delhi-NCR region, where air pollution had been worsening with Delhi NCR attaining the notoriety of one of the worst polluted cities in the world (TOI, 2018). Major sources of pollution, such as industrial and vehicle emissions, road dust, construction, and burning of municipal solid waste and fly ash, contributed to pollution in Delhi round the year (Chatterjee, 2019). However, during October and November every year, the major contributor (about 26-50%) was stubble burning by farmers in the neighboring states of Punjab, Haryana, and Uttar Pradesh (Burrows, 2018) after they had harvested paddy to prepare land for the next crop. For instance, in November 2016, air pollution parameters of $PM_{2.5}$ and PM_{10} in Delhi NCR spiked to extremely dangerous levels of 143 and 292 microgram/cubic meter, against safe limits of 60 and 100 microgram/cubic meter, respectively. In November 2017, the

Air Quality Index (AQI) crossed the hazardous value of 300 and touched 448, posing a severe health risk to all citizens. This situation hampered the daily life of Delhi citizens and necessitated shutting down of schools, construction work and other industrial activities for extended periods and disrupted traffic owing to smog.

There were multiple reasons behind prevalence of CRB in this region: (i) Larger than average landholding of farmers, (ii) Type of machinery/equipment used, (iii) the shorter time gap between paddy and the next crop (wheat/potato). The size of landholding in Punjab increased significantly during the last few decades, with an average Punjab farmer holding a farm size of 9.3 acres, versus the pan India average size of 3.7 acres[iii]. The large size of the farms requires machinery to prepare the land, due to labour shortage. As most of the farmers in this region typically use a machine called Combine Harvester (CH), designed to shave off the grainy part of the paddy, stubble of one foot or more is left standing on the field post harvesting. To manage this residue from paddy crop, the farmers have to use other machines like Super SMS or Mulcher, which costs both money and time.

However, the farmers in Punjab hardly have 3-4 weeks for clearing off the stubble and prepare the land for the next crop, which induces them to burn this residue. The reason is that, to reduce ground water usage for agriculture from a depleting water table and make optimum use of rainwater, the state government of Punjab pushed the transplantation of paddy by couple of weeks. While this shift has been estimated to save 2,000 billion litres of water (Vasdev, 2021), it is contributing to the air pollution across the north-western region and affecting the Hindu-Kush Mountain ecosystem (Bhattarai et al., 2019). Several efforts were made since the last couple of decades to reduce CRB in Punjab and Haryana, including levying of fines/penalties, ban on burning, cash incentives for adoption of alternative CRM methods, etc. However, none of them induced significant change in the farmers' behavior in any of the regions where CRB was prevalent.

3.2. Deliberation Phase – Recommendations by High-Level Task Force

As the number of CRB incidents skyrocketed, NITI Aayog, a policy think tank of the Government of India set up a task force headed by the Additional Secretary of Ministry of Environment, Forest & Climate Change (MoEFCC), to create an 'Action Plan for Biomass Management' in Punjab and Haryana in June 2017. This task force, anchored at CII under the 'Cleaner Air Better Life' initiative, carried out an extensive study of the existing alternatives for biomass management. They scanned through the existing literature, met farmers in various districts of Punjab and Haryana, held discussions with the scientists who were working on various technical solutions in state agricultural universities, and finally submitted a report in September 2017 that delineated various options, along with the costs and necessary incentives to be given to induce adoption by the farmers. Based on these findings as well as inputs from the chief secretaries of Punjab and Haryana, a subcommittee of High-level Task Force (SC-HTF) set up by MoEFCC came up with the final set of recommendations to reduce CRB (see **Table A1** in Appendix).

3.3. Planning Phase – Planning by Central and State Governments

Based on the recommendations of the SC-HTF, Government of India in its 2018-19 national budget announced subsidies on CRM machinery for farmer cooperatives (80% subsidy) and individual farmers (50%). The state governments of Punjab and Haryana quickly got into action and informed the machinery manufacturers their estimates, so that production capacity could be scaled up and the machinery would become available by the harvesting season of rice crop (October-November 2018). With speculations ripe about high demand for farm machinery notified by the government agencies, the prices in the market shot up immediately and nearly doubled. Capacity expansion was taking time and despite the subsidies for farmers cooperatives and farmers, doubling of prices in the market made the subsidies meaningless to the farmers, especially the small and marginal farmers. In the meantime, the two state governments asked their state agricultural departments and Krishi Vigyan Kendras (KVKs) to begin working with the farmers, on awareness creation, training, and transfer of knowledge from the labs to village farms.

3.4. Execution Phase - Actions by CIIF Team

The practice of CRB was widespread in Punjab and Haryana and farmers strongly believed that, burning the residue was not only the most efficient way of managing the crop residue in their farms, but also was necessary to kill any remaining pests from the previous season. Therefore, getting the farmers to adopt an alternative practice was not going to be easy. Therefore, after presenting their initial findings on possible eco-friendly solutions to the HTF, induced by Joint Secretary MoEFCC, to demonstrate the effectiveness of these solutions in the field, the CII decided to participate in the execution stage as well. It was felt that a successful CRM was not possible through government intervention alone and other stakeholders such as private companies, academic institutions and NGOs needed to come together and participate in this intervention to fill the gaps and bring about the necessary changes in the mindset of farmers.

Thus, CII brought in the CII Foundation (CIIF), which was a charitable trust set up by CII in 2011 to support social and developmental initiatives across India, to take part in the field intervention. The objective of CRM intervention by CIIF was twofold: (i) pollution reduction by eliminating the practice of CRB and (ii) better yields and lower costs to farmers through adoption of ecofriendly CRM practices. The CII Executive Committee (CII-EC), constituting the CIIF head, 2 core members, and one part time consultant decided to begin by first understanding the major roadblocks. At least one member of this committee was part of the CII-NITI Aayog task force (and one of the co-authors of this paper), and therefore had a fair idea of existing solutions to CRB, but they had no idea what challenges awaited them in the field. Thus, they created a field team or a project execution team (which we refer to simply as CIIF team) to gain better understanding of the problem. In April 2018, the CIIF team began by meeting the scientists in PAU, who had originally researched and created the eco-friendly alternatives to CRB and had been promoting them to farmers for nearly a decade, without much success. The CIIF team also met with Punjab Pollution Control Board (PPCB) and several NGOs who were already working in the villages on CRM-related activities[iv]. These meetings and field visits enabled the team to understand the main reasons behind CRB by farmers to be as follows:

- Farmers believed that CRB is good for their crops, and is more cost effective compared to other alternatives
- They also believed that CRB saved time, and since there was very short lead time between the two crops, farmers preferred to burn the residue.
- There was limited access to equipment necessary for adoption of CRM alternatives

3.4.1. Resources, Stakeholders and Contracts

Based on these findings, the CII-EC realized that they need to work on both cultural aspects such as changing the belief systems as well as technical aspects such as providing access to equipment and necessary training. While the former needed human resources and working closely with the villagers in capacity building and cultural change, the latter required access to funds and close collaboration with the equipment manufacturers. Therefore, the CII-EC decided to partner with other NGOs for awareness building and mobilization of farmers on the field. They also involved private companies with CSR funds as donors[v]. Other stakeholders included equipment manufacturers, the state agricultural departments and agricultural universities that were carrying out research on ecofriendly CRM practices in Punjab and Haryana. To bring together all stakeholders onto the CRM platform, CII-EC conducted a multi-stakeholder consultation and discussed strategies for farmers' engagement and technology adoption in Punjab. This consultation helped them to create awareness, raise funds, inspire industry collective to adopt villages and discuss regional strategies.

After this consultation, they entered into formal MoUs with all the doners, indicating the means and ways through which the funds would be utilized during the intervention. CII-EC also decided to engage the local NGOs and farmer groups (farmer producer organizations (FPOs) and farmer cooperative societies (FCSs)) in the villages, to facilitate informal collaborations and partnerships.

However, they did not enter into any formal MoUs with the governmental agencies, instead they built close technical collaborations[vi] by involving them in consultations, awareness creation and training programs during various stages of the intervention.

As some of these activities were sanctioned by the state governments and needed to be conducted by the government agencies such as KVKs and state agricultural departments anyway, these collaborative efforts turned out to be highly effective. The CII-EC found that it was important to build inter-personal relationships and strong partnerships towards a common goal with the government agencies. During the 3 years of the intervention period, they found that these institutional partnerships and informal collaborations were more important than formal MoUs, which were more of a hinderance due to the typical bureaucracy involved in any governmental processes. Similar to Gillingham & Bollinger, (2021), they also facilitated several farmer group discussions (FGDs) bringing together the FPOs/FCSs, partner NGOs and village volunteers, to ensure that knowledge sharing took place at regular intervals across the various stakeholders.

3.4.2. Managing Uncertainty and Context Dependence

CII began their CRM field intervention with 19 villages spanning two different districts, Ludhiana, and Patiala, in Punjab during 2018. These were divided into three clusters, Nabha, Samana belonging to Patiala district, and Raikot in Ludhiana. Most villages in these two districts followed a rice-wheat cropping system (RWS), wherein the rice crop was followed by a wheat crop every year. Since there was little time between the two seasons (about 3 to 4 weeks), farmers – after harvesting the rice crop around October/November– in a hurry to clear their fields to prepare the soil for wheat crop, typically burnt the residual grass in their fields. To wean away farmers from this environment-unfriendly practice, the CII-EC decided to use two distinct strategies. As Birla Soft, one of the partner NGOs was already working in the Samana cluster by providing financial assistance to the villagers who adopted ecofriendly alternatives to CRB, CII-EC decided to continue this practice in this cluster.

However, in the remaining two clusters, they decided to help the farmers by providing farm machinery and equipment necessary for managing the crop residue in a more ecofriendly manner. However, while they collaborated through local farmer groups (FCSs) in the Nabha cluster, they engaged an NGO called GBDSGNS Foundation, who had been actively working with local farmer communities on several developmental issues, in the Raikot cluster (**Table 1** depicts the various characteristics of these two clusters).

Based on the eco-friendly alternatives identified by the HTF during the deliberation phase, the CII-EC decided to encourage use of the in-situ methods called (i) Mulching and (ii) Straw Incorporation (SI) during their CRM intervention. The field trials by PAU had found these two to be the most environmentally sustainable alternatives to CRB. Mulching essentially involved chopping and shredding of crop residue into smaller pieces, which was then evenly spread on soil surface as a cover/mulch. Mulching helped in retention of soil nutrients and reduced water erosion as well as cost incurred for preparation of soil for the next crop. Mulching could be undertaken when rice paddy was being cut or once the field was completely harvested. Farmers typically used Super SMS, Mulcher or Cutter to finely chop straw and evenly spread it to facilitate mulching.

SI involved mixing of crop residue back into the soil during the sowing process. The crop residue was first chopped/shredded using relevant machinery, and then spread on the field. The shredded straw was next incorporated into the soil just before sowing with machines like Rotovator or Superseeder. Thus, similar to Mulching, SI was also found to be a more sustainable approach compared to CRB for long-term soil quality maintenance and believed to result in higher yields. Both the alternatives also had the potential to reduce input costs for the next crop, by requiring lesser quantity of water, fertilizers, and other nutrient substitutes.

During June/July 2018, the CIIF project execution team held intensive meetings in each village of the three clusters to collect detailed data on their farming practices, machinery/equipment shortages, and to identify local influencers and volunteers for the initiative. They next analyzed this data to identify what machinery/equipment needs to be purchased, worked with the local FPOs/FCSs/NGOs to collectively order this machinery/equipment so that they could avail the state subsidies. Wherever the FPOs/FCSs/NGOs could not raise sufficient funds from the farmers taking part in the intervention, CII-EC filled the gaps from their own fundraising activities.

Table 1. Various characteristics of Nabha and Raikot clusters

	Nabha (Patiala)			Raikot (Ludhiana)		
	2018	2019	2020	2018	2019	2020
Number of villages covered	9	56	73	7	27	39
Total operational area (acres)	5000	40145	52658	7100	32296	44314
Number of farmers	1500	5303	9326	1000	3218	5491
As per agricultural census 2011, number of						
Marginal farmers	180	636	1119	130	418	714
Small farmers	270	955	1679	160	515	879
Semi-medium and Medium farmers	945	3341	5875	610	1963	3350
Large farmers	105	371	653	100	322	549
Channel Partners	3 FCs & Doctors For You (NGO)	18 FCs & Doctors For You (NGO)	23 FCs & Doctors For You (NGO)	3 Farmer Producer Organisations & GBDGNS Foundation (NGO)		
Machinery support	43	207	238	27	109	123
Percentage of potato farmers	14.2	10	2.3	1.63	3.4	0
Soil type	Sandy (light and coarse textured) and Dakar (hard and clayey)			Dakar (hard and clayey)		

Note : GBDGNS: Gadri Baba Dulha Singh Giani Nihal Singh. According to Agricultural Census, 2011, marginal, small, semi-medium/medium, and large farmers in Nabha (Patiala) are 12%, 18%, 63%, and 7%, respectively, whereas in Raikot (Ludhiana) are 13%, 16%, 61%, and 10%, respectively. The figures in the above table represent the number of farmers from various categories participating in the CRM intervention from these two clusters across 2018 – 2020.

The next step was to place order for the machinery/equipment with the dealers/manufacturers. CIIF team held major events in each of the villages during the arrival of machinery/equipment, by inviting the local leaders/authorities, officials from KVKs, village heads and other influencers. This was a deliberate action adopted to create a festive like environment in the village and a major buzz around the new ecofriendly practices. This activity not only created a positive vibe, but also instilled trust in the farmers about the CIIF team’s commitment, as arrival of machinery/equipment was a clear indication that the team was seriously committed to the intervention and plans to deliver on their promises. Presence of local leaders, government authorities and village heads also formalized the CRM initiative and the new practices to be adopted in the eyes of the farmers.

3.4.3. Emergence of a Flexible Governance Structure

The next activity was to bring together various stakeholders, such as the machinery/equipment manufacturers, agricultural scientists from PAU and KVKs and some of the early adopters of ecofriendly methods, to provide necessary training on the new equipment to the local farmers in local languages, just before the rice harvesting season began in each village. The FPOs/FCSs/NGOs associated with each cluster purchased and maintained a number of different types of farm equipment in a warehouse and rented them out to farmers who did not have their own equipment, at nominal prices. By identifying locally active youth and early adopters who generally had higher social capital in the villages as volunteers to handhold the new adoptees, CIIF team could ensure that each village worked as a collective and the change was transformative in nature. Farmers were under peer pressure to change and at the same time felt comfortable in the knowledge that they were not alone. In the words of Gurnam Singh, a farmer from Shimbdo village, Punjab:

> *I am a farmer who wants to adopt new things/changes and do experiments in my land. When CII adopted our Village, many farmers hesitate in adopting the new techniques. I initiated and practiced zero burning on half of my land and practiced the old tradition on my remaining land. The land in which I practiced zero burning we saw many changes like less water consumption to less cost incurred while the yield was also higher as compared to stubble burning land. Now I practice straw incorporation on my whole land which results in increased fertility along with cost cutting as compared to other practice.*

The CIIF team had allocated a set of villages to each of their own project execution team members who in turn worked with the partnered organizations (FPOs/FCSs/NGOs) and the volunteers in their respective villages to facilitate adoption of these ecofriendly alternatives, whether in terms of knowledge/information, farm equipment or handholding to resolve the problems that were arising throughout the intervention period. **Figure 4** depicts how execution of CRM intervention was structured by CII. Thus, there was a continuous exchange of information and ideas between the CIIF project execution (or field) team members, the partner organizations, and the village volunteers, through which several issues specific to each individual village/cluster got resolved.

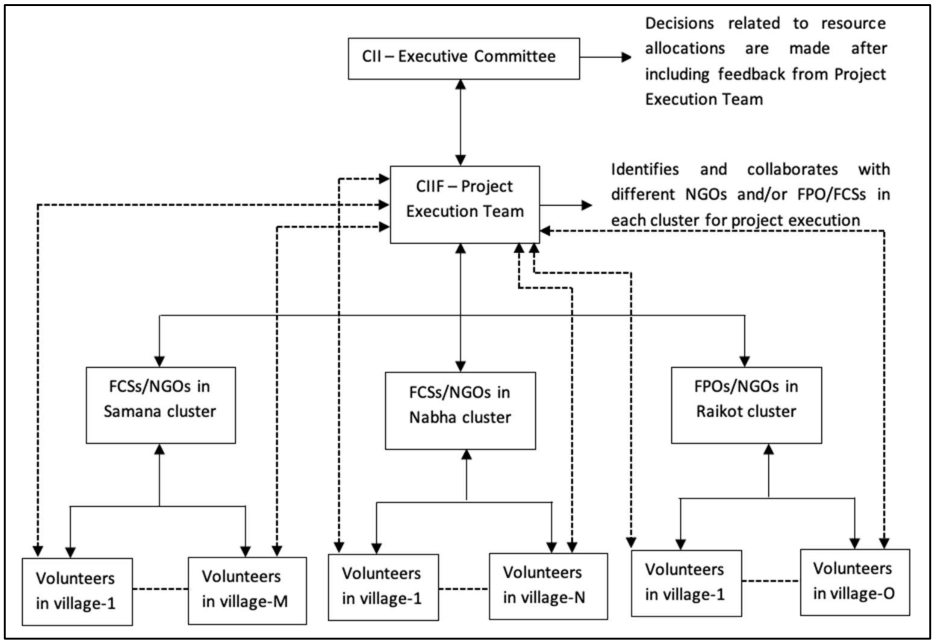


Figure 4. CIIF's Crop Residue Management Project Execution Committee structure

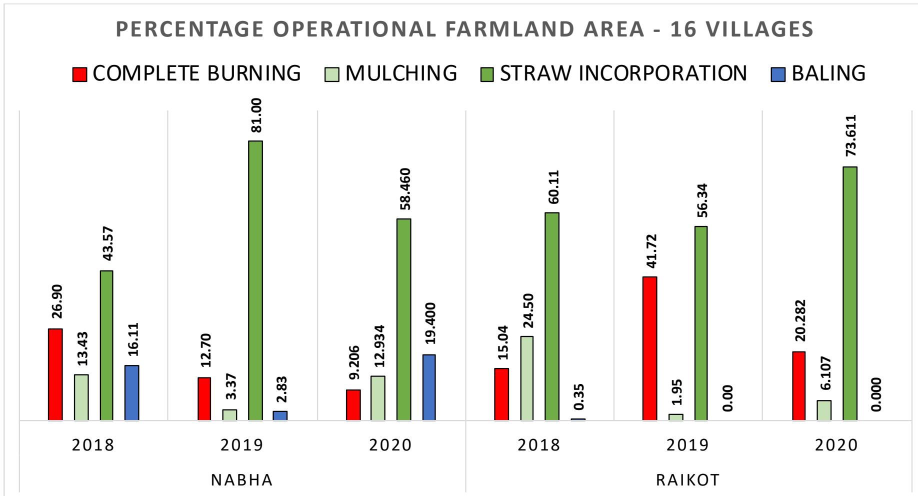
For instance, when CIIF team began working in the Nabha cluster, they had a tough time convincing the local villagers to adopt the two in-situ CRM solutions, Mulching and SI. The farmers in one particular village vehemently opposed both these alternatives, claiming that due to the nature of the soil in their village (which was sandy-loamy), and the type of crop they had to sow in the next season (potato), both these alternatives would not work for them. Since the CIIF team did not have sufficient technical knowledge on this aspect, and since other villages in the remaining two clusters did not raise any such issues, they felt that it was simply the reluctance of the local farmers towards change which was manifesting in this opposition. The CIIF team somehow convinced a few farmers through the local partner organization, to try out the two in-situ alternatives in this village. After a couple of weeks into the implementation, based on these pilot runs and the discussions with village volunteers, the CIIF team realized that the farmers were indeed right. Both Mulching and SI had resulted in excess moisture in the sandy-loamy soil which could hurt the yield of the next crop.

Thus, the technological uncertainty faced in this village could be resolved quickly through the pilot runs due to the relationship-based contract with the local partner organization and the trust enjoyed by this partner amongst the local farmers. Involvement of more experienced local farmers who had been experimenting with different ecofriendly practices over the years also helped them to quickly identify a more suitable alternative called 'Baling'[vii]. The flexibility allowed by the CII-EC to take decisions as per ground realities enabled the field team working in that village immediately switch to baling. They helped the local partner organization with necessary funds to procure the Baling machines for immediate deployment, even though these machines were not part of the state subsidy scheme. Thus, the self-organized governance regime within each village/cluster and the effective collaboration and cooperation between the diverse stakeholders and the local community members enabled the project execution team to identify customized solutions to local problems and ensure that the project objectives were ultimately met.

Proposition 1. *A flexible governance structure that empowers executing teams, enables customized solutions through adaptive management.*

3.4.4. Collaboration and social learning activities and their impact

Under mulching, shredded straw is left as a cover on top of the soil and the seeds are sown under the mulch using an equipment called Happy Seeder. There were two issues with this technique. First, the farmers could not see when the seeds germinated due to the mulch cover, and the second was waterlogging in the fields in case of heavy rains. Unfortunately, there were heavy rains during the sowing season of 2018 in the intervened villages, and a few farmers who experimented with mulching faced slower germination and lower yields (although those who took care to drain their farms did not face this issue). As the rumours quickly spread creating fears of lower yields, many farmers in 2019 switched from mulching to SI (in Nabha), and to CB (in Raikot), as can be seen from **Figure 5**.



Note : Mulching, Straw Incorporation and Baling are non-burning (eco-friendly) activities

Figure 5. Results of CRM intervention in Patiala and Ludhiana during 2018–2020

However, our field interviews revealed that, farmers who had good experience with mulching in 2018, did continue with mulching, though this percentage was relatively smaller. By the end of the 2019 harvesting season, it became quite evident that farmers who adopted mulching incurred lower costs (see **Table 2**) and experienced better yields than those who adopted the other alternatives, as is also evident from the following statement by Gurdeep Singh of Madpur village.

> *I have been sowing wheat with Happy Seeder after mulching the straw from the last three years. I found this method to be the cheapest and most beneficial. It has also significantly increased the fertility of my field.*

This news spread quickly, as the visually better-looking mulched farms, informal exchanges between farmers and formal discussions during community meetings began to highlight this benefit. Farmers also shared their experiences of how to address various challenges faced in Happy Seeder usage, waterlogging, etc. during the FGDs. These formal and informal discussions, and the performance assessment using the data collected at the end of 2018 and 2019 seasons (**Table 2**), helped CIIF to identify the new learnings and best practices, and share them amongst all the farmers participating in the CRM intervention. As a result, by 2020, more farmers adopted mulching in larger portions of their lands especially in Nabha cluster, some of them even switching completely to mulching. This type of *learning by doing* and *adapting based on what is learned* or the incremental improvement of adopted strategies is called 'single-loop' or 'technical learning' (Williams & Brown, 2018).

Table 2. Two sample t-test/z-test for cost and yield analysis

Parameters	**Data Collect**	**CB^{+}**	**M**	**SI**	**B**	**Mean Differences**		
		MEAN				M-CB	SI-CB	B-CB
Rent cost of machinery (Rs/acre)	2019	645.4	364.3	484.7	1934.5	-281.1^{**}	-160.7^{*}	1289.1^{***}
	2020	947	444.5	443	2135.3	-502.5^{***}	-504^{***}	1188.3^{***}
Average Yield^{++} (Quintal/acre)	2020	20.22	21.62	21.41	19.89	1.4^{***}	1.2^{***}	-0.33

Note 1: * p<0.1; ** p<0.05; *** p<0.01. CB = Complete Burning, M = Mulching, SI = Straw Incorporation and B = Baling.
$^{+}$ As CRM initiative scaled up, by 2020, some village FPOs/FCSs stopped lending the equipment to farmers unless they adopted 100% eco-friendly practices. As a result, the percentage of farmers who borrowed equipment from private service providers increased from 52% in 2019 to 85.7% in 2020, which resulted in the increase in rental cost of CB.
$^{++}$Yield data was not collected during the initial years of intervention, as it would take time for substantial changes in yield to show up (Sidhu et al., 2015;Ram et al., 2018)

Proposition 2: *The '**adaptive management**' facilitated through a flexible governance structure, specifically during the **execution phase**, enables social learning through technical or single-loop learning.*

The other alternative that went through similar changes as mulching across the 3 years of CRM intervention in the Nabha cluster was baling. The soil in several villages of Nabha was of sandy or sandy-loamy type, and 15% of the farmers were potato farmers (refer to **Table 1**), which made the in-situ techniques unsuitable. Therefore, farmers preferred baling. However, baling machines were very expensive (each costing approximately $28,500) and were not part of the state subsidy scheme. To make the farmers stop CRB, CIIF Project Execution Team procured a few balers for the FPOs/FCSs in these villages (as discussed above), which resulted in baling in 16% of the intervened area in 2018. However, as the scale of CRM intervention increased to 56 villages covering 38,285 acres of land in Nabha cluster in 2019 (**Table 1**), CIIF could not proportionately scale up the number of balers. As a result, more farmers adopted other CRM alternatives and some of them resorted to burning the straw

(**Figure 5**). Based on their technical learnings within the Nabha cluster, the CII–EC highlighted the need to include Balers also in the state subsidy scheme.

Since CRB had reduced significantly in the clusters where CII had intervened, the state governments of Punjab and Haryana considered their suggestions, and after sufficient deliberation, extended the state agricultural machinery subsidy to the Balers from 2020 onwards[viii]. This is a good example of 'Managerial or double-loop learning', since the technical/single-loop learning from previous cycles got incorporated into the planning and resource allocation of future cycles. Clearly, the CII-EC revisited their assumptions about using only in-situ methods for the CRM intervention; and based on the cause-and-effect relationships between the technology to be adopted, soil type, and the requirements from next crop; they made the necessary changes in their assumptions and associated strategies. Based on the newly available knowledge from this technical learning, the state government departments also made changes in their assumptions and decisions regarding which machinery and equipment should be part of the subsidy scheme. As the availability of balers increased, more farmers (19.4% of the intervened area as can be seen in **Figure 5**) in Nabha cluster adopted baling as the CRM alternative during the 2020 season.

Proposition 3: *Incorporation of technical learning into managerial decisions at* ***planning phase*** *of a project involving multiple cycles, enables managerial or double-loop learning.*

Based on the success of the CRM initiative in 2018, CII scaled up their intervention in 2019 covering more than 20,000 farmers and nearly 100,000 acres of land across 102 villages in 6 districts in Punjab and Haryana. Using their learnings from the 2018 pilot project, the CIIF field team drafted many more FPOs/FCSs into the CRM intervention and worked closely with volunteers in each village to create awareness. They also roped in local religious organizations (Gurudwaras) and worked with school children to spread the word around about the harmful consequences of CRB. They deployed a total of 391 farm machines in 2019 and trained the farmers with the help of equipment manufacturers.

By 2020, the scale of intervention increased to 172 villages in 8 districts, covering 1,59,024 acres of land involving 29,038 farmers, and the number of machines deployed increased to 496. **Tables A2** and **A3** (in Appendix) provides more details about the various activities carried out during 2019 and 2020 CRM interventions.

Two clusters, Sirsa (13 villages) and Fatehabad (5 villages) belonging to Haryana, stand out during the 2019-2020 interventions as can be seen from **Figure 6**. Before the CRM intervention in 2019, in-situ adoption was negligible in both these clusters, but the ex-situ baling was practiced by some farmers as there was demand for straw bales from dairy farmers in the neighbouring state of Rajasthan[ix]. However, due to lack of balers, only few farmers were selling hand harvested straw to vendors from Rajasthan, and other farmers were setting fire to their post-harvested fields to clear off the straw. When CIIF team visited these two clusters in 2019 in a bid to stop CRB, farmers demanded baling equipment. To get the farmers to stop burning the straw, CII supplied Balers, along with other in-situ machinery to all the villages in these clusters. In Sirsa, nearly 38% of the farmers adopted in-situ alternatives in 2019 with good success, whereas 55% farmers adopted baling and earned revenues from selling straw. However, in 2020, due to COVID-19 related lockdown and transportation challenges, the informal vendors from Rajasthan could not reach Sirsa for straw procurement. Since the in-situ methods were highly suitable to the soil in Sirsa villages and based on the successful implementation of these methods during the previous year, many more farmers (88%) adopted in-situ methods in 2020, as can be seen from **Figure 6**.

The story in Fatehabad cluster was slightly different. The agro-ecological conditions of Fatehabad were not amenable for in-situ methods, as the villages in this region had hard soil and irrigated lands, which faced water logging problem. Farmers in this region mostly (about 70% acreage) grew Pusa 1401 (a long duration, high yielding, tall plant variety), which resulted in high quantity (3 to 3.5 tonne) of straw per acre. Both the soil conditions and the high quantity of straw made SI and mulching impractical. Therefore, although 37% of the farmers tried in-situ methods in 2019 in

Fatehabad, their experience was not good. This, clubbed with the fact that balers were brought under the government subsidy scheme, and the continued demand for straw from Rajasthan, made baling the dominant practice (82%) in 2020. According to Amar Singh, a farmer from Dholu village in Fatehabad:

> *The soil in my land is hard soil, so it is very tough for me to do mulching or straw incorporation. So, when CIIF and CLP India offered us Balers, I managed to bale and sell my crop residue to the industry nearby my village. This way, I could earn some extra money through the crop residue also.*

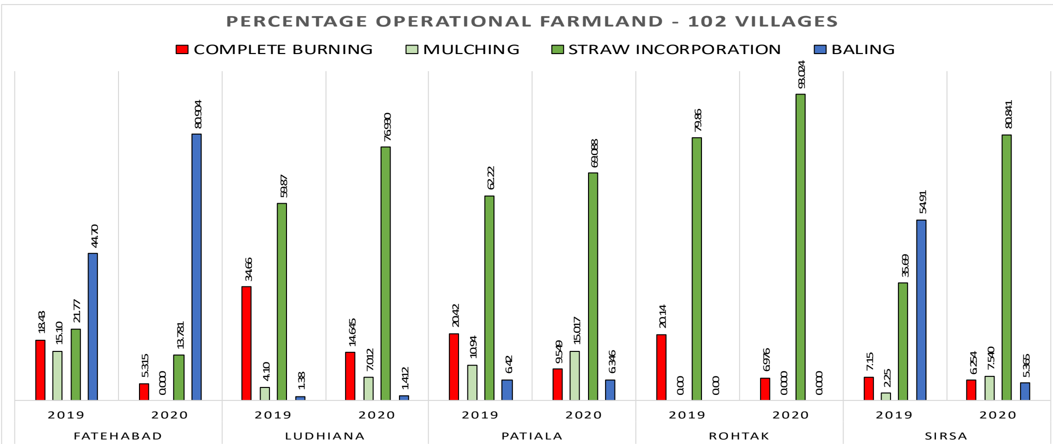


Figure 6. Results of CRM intervention in Punjab and Haryana during 2019 & 2020

Based on their experience of working with farmers in different agro-ecological conditions across different clusters during the 3 years of CRM intervention, the CIIF team learned that ex-situ methods like baling also need to be considered as one of the eco-friendly alternatives. While the double-loop or managerial learning by the state governments of Punjab and Haryana resulted in balers being brought under the subsidy scheme, baling was still an expensive proposition for farmers (see **Table 2**). Therefore, to make baling a viable and eco-friendly alternative there is a need to create market for baled straw outside the fields. With this objective, CII-CESD carried out several studies on usage of rice straw and identified viable business models (CCI-ITC CESD, 2021) in the form of (i) animal fodder, (ii)compost, (iii)bio-char, (iv)bio-CNG, (v)construction material, (vi)pulping and packaging solutions and (vi)solid fuel in industrial boilers and thermal power plants. **Table A4** (in Appendix) provides further details about these alternative uses of straw collected through ex-situ methods. Based on these studies, CII-EC made several recommendations to the Government of India and Delhi NCR Commission about the air quality management and the need to create market for rice straw, which will automatically turn farmers against CRB, as straw becomes a revenue earning opportunity rather than a waste.

If these recommendations are considered by the HTF, which deliberated and provided the policy framework for CRM as described in section 3.2 & **Table A1**, and appropriate policy level changes are undertaken to create market for straw bales, one would achieve 'institutional learning' or 'triple-loop learning' (Hargrove, 2002). The initial belief of HTF as per **Table A1**, was that ex-situ methods were inferior to in-situ methods, and hence must be discouraged. However, based on the double-loop and triple-loop learnings in the CRM project, it has been established that certain types of agro-ecological conditions make ex-situ more beneficial than in-situ methods. Such a learning, achieved through incorporation of managerial learning into the upper most echelons would bring about complete transformation of belief paradigms, frames of reference, and result in changes in policy, governance norms and protocols to be followed in future cycles of project.

Proposition 4: *Incorporation of managerial learning into policy decisions at **deliberate phase** of a project enables institutional or triple-loop learning.*

4. Performance Measurement and a Comprehensive Data Analysis

Attaining project goals through project execution has generally been built upon the definition of clear performance measures and substantiated through the use of various diagnostic project control mechanisms (Kivilä et al., 2017). Note that, the project itself was initiated with a prime objective of reducing CRB, which was causing significant pollution in the Hindu-Kush mountains and Delhi NCR region. This means, appropriate direct measures of performance assessment of CRM project would be (i) % reduction in CRB, (ii) CO_2 emissions, (iii) air pollution parameters $PM_{2.5}$ and PM_{10} (particulate matter), (iv) air quality index, etc. depending on which of these are directly measurable and other contributing factors are either absent or can be controlled during the time of intervention.

However, most of these metrics, except perhaps the first (% reduction in CRB) can be affected by multiple factors such as traffic pollution, pollution from factories, rainfall, and other environmental factors. Therefore, we only consider "**% reduction in CRB**" as the primary metric for assessing the success of CRM intervention. However, as mentioned earlier in section 2.3, unless the outcomes for stakeholders participating in the project are found to be beneficial to them, it is difficult to achieve expected outcomes for the project itself. Therefore, to induce farmers to change their practice of CRB, one must ensure that the aspects that have a direct bearing on farmers' occupation, health and social wellbeing are improved first. Since the intervention is focusing on adoption of a new CRM practice, one should measure the differential impact the adoption of new practice has on measures that affect the social and economic aspects of farmers vis-à-vis the old practice. Therefore, the most important metrics to track from the farmers' perspective are cost of CRM alternative, time taken for CRM, water usage, input cost for the next crop and air quality.

4.1. Data collection methodology

To understand the facts at the ground-level, we undertook a bottom-up approach to collect data and information from various stakeholders, including the farmers in the intervened areas. Primary information was gathered through surveys, semi-structured interviews, and FGDs were conducted with the farmers, FCSs, FPOs and other NGOs to authenticate the impact of the intervention. The CRM program increased its scale of operations from 19 villages in 2018 to 102 villages in six clusters of Punjab and Haryana during October 2019. The scale further increased in 2020 to 172 villages.

4.2. Data analysis

The impact of CRM program during 2019 and 2020 is quantified in this section with an overall objective to understand adoption of different CRM practices and seek farmers' feedback to improve the CRM program. Though a door-to-door survey of 277 farmers was conducted in 19 villages to assess the impact of 2018 pilot intervention, this data only captured the adoption of various CRM methods and the corresponding costs involved. The data pertaining to interventions in 2019 and 2020 was collected in a comprehensive fashion using an extensive door to door survey of 3,759 farmers, through custom digital data collection platform with geo-tagged information. Among these farmers, 2,795 (74.35%) had exclusively adopted only one of the CRM methods, namely, Complete Burning (CB), Mulching (M), Straw Incorporation (SI) and Baling (B). The overall adoption results across 3 years in the intervened areas based on these three surveys show that, the adoption of exclusive eco-friendly practices increased from 65% in 2018 pilot intervention to 90% in 2020, as can be seen from **Figure A1** in the Appendix.

To understand the impact of learning over time on savings in rental cost as well as other performance measures, we examined the data of farmers who adopted an exclusive CRM method for a minimum of 2 years, using the more nuanced micro level data from the 2019 and 2020 surveys, through application of ordinary least squares (OLS) regression and ordinal logit methodologies.

4.2.1 Rent cost

Cost of renting the machinery/equipment to manage the crop residue has been found to be one of the major deterrents to adoption of ecofriendly CRM practices in India (Sharma, 2020). However, we conjecture based on learning theories (Li & Rajagopalan, 1998; Solow, 2001), that this cost should reduce over a period of time, as farmers accrue more learning and become efficient at usage of such equipment. Therefore, we include a time element as well into our regression models to test this hypothesis. Note that, farmers can use their own/share machinery (Own) or rent them from FPO/FCSs or from a Private Service Provider (Pvt) to perform the various farm activities pertaining to the CRM method they have adopted. We only consider the sample of farmers who rent the machinery/equipment to test this hypothesis. The sample size for evaluation of *rent cost* is 782 after excluding the farmers who owned or shared the tools and after removing the outliers. The following relationship is estimated using ordinary least squares (OLS) regression at the farmer level.

MODEL 1: $Cost_i = \beta_0 + \beta_1 * TRL^1{}_i + \beta_2 * TRL^2{}_i + \beta_3 * Method_i + \beta_4 * (TRL^1{}_i * Method_i) + \beta_5 * Landholding\ type_i + \beta_6 * Age_i$ (1)

In equation (1), *i* indexes each individual farmer, $Cost_i$ are continuous variables representing the total rent cost (Rs./acre) of machinery used for the CRM practice they have adopted. $TRL_i{}^d$ represents the duration of learning (d) for individuals, where *d* takes values 0, 1 and 2. For example, year of data collection is 2020 and year of adoption is also 2020, then the value of *d* is 0 and denoted as $TRL_i{}^0$. Similarly, when year of data collection is 2020 and year of adoption is 2019 (2018), then *d* will take value 1(2) and it is denoted as $TRL_i{}^1$ ($TRL_i{}^2$). We consider $TRL_i{}^0$ to be the base dummy in our model. $Method_i$ is another primary independent variable which is categorical in nature and includes – Complete Burning (CB) which is the Base group, Mulching (Mu), Straw Incorporation (SI) and Baling (B). $(TRL^1{}_i * Method_i)$ captures the effect of 'one year of learning' on time across different CRM methods. $(TRL^2{}_i * Method_i)$ is not considered in the model since the farmers with 2 years of learning have not performed CB (which is the base category for $Method_i$ variable). Based on our observations in the field, size of the landholding and age of the farmers seem to have a bearing on the adoption of a specific CRM method, and hence we include them as control variables.

4.2.2. Other Benefits from the Eco-friendly Practices

In addition to reduction in emissions from crop burning which improves air quality, farmers can accrue several other benefits such as water conservation, reduction in fertilizer consumption, weed infestation and pest infestation by adopting eco-friendly CRM alternatives. We also evaluate how these benefits are accrued through individual CRM methods and duration of learning, using *Ordinal Logit regression* at the farmer level.

MODEL 2: $Y_i = \beta_0 + \beta_1 * TRL^1{}_i + \beta_2 * TRL^2{}_i + \beta_3 * Method_i + \beta_4 * Landholding\ type_i + \beta_5 * Age_i$ (2)

In equation (2), *i* indexes each individual farmer, Y_i takes the value of AQ_i, FC_i, WC_i, WI_i and PI_i, where AQ_i, a categorical variable, represents the improvement in air quality, and takes value of 1 if the responses are bad/very bad, 2 if the responses are remains same and value of 3 when responses are good/very good, compared to last year. Similarly, PI_i (pest infestation), WI_i (weed infestation), WC_i (water consumption), FC_i (fertilizer consumption) are categorical variables that take value of 1 if the responses are increases significantly/increases slightly, 2 if the responses are remains same and take value of 3 when responses are decreases significantly/decreases slightly, compared to last year.

4.3. Results and Discussion

Table 3a shows the summary statistics of all the dependent and independent variables for Model 1. Similarly, **Table 3b** tabulates the number of observation of farmers under each methods for different outcomes.

Table 3a: Summary Statistics of variables for Model 1

MODEL 1 (N=782)					
Variable	Min	Median	Mean	Max	SD
Total RC (Rs/acre)	100.00	369.00	719.88	3000.00	750.09
Age (years)	18.00	42.00	43.23	85.00	10.28
LH type	Mar	Sml	SM	Mdm	Lrg
Count	89	290	233	152	18
Methods	CB	M	SI	B	
Count	51	90	518	123	
DOL	TRL0	TRL1	TRL2		
Count	348	404	30		

Note : RC – Rent cost, LH – Landholding, DOL – Duration of Learning, Mar – Marginal, Sml – Small, SM – Semi-Medium, Mdm – Medium, Lrg – Large, CB – Complete Burning, M – Mulching, SI – Straw Incorporation, B – Baling, SD – Standard Deviation

Table 3b : Number of farmers responded (increase, decrease, remains same) under each methods for different outcomes

	PI			WI			WC			FC			AQ		
METHODS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Complete Burning	17	192	46	16	223	13	5	223	25	15	229	9	41	173	9
Mulching	21	55	32	21	56	32	21	63	24	18	56	30	75	29	0
Straw Incorporation	120	412	178	124	443	137	111	468	118	87	459	119	443	255	22
Baling	2	59	60	1	80	41	0	89	31	0	90	24	106	43	0

Note : 1, 2 and 3 for PI, WI, WC and FC represents increases significantly/ increases slightly, remains same and decreases significantly/ decreases slightly, respectively

During the 3 years of CRM intervention, a total of 550 thousand tons of rice straw was avoided from burning, which resulted in savings of air pollution – 2.5 & 2.3 thousand tons of PM10 and PM2.5 respectively, 5.52 thousand tons of secondary aerosols, 162 thousand tons of non-CO2 GHG emissions, 260 tons of black carbon, and 37.65 billion litres of water savings. Also, 501 thousand tons of organic matter was added back to the soil. **Table A5** in the Appendix list the details of these benefits across three years.

4.3.1. Results from Cost Analysis

Table 4 presents the results of OLS regression analysis given by equation (1). Results under column (1) represent the effect of including only the two main independent variables in the model, namely, the CRM method and duration of learning, on the cost incurred by the farmers. Results under column (2) include the control variables and column (3) include the interaction terms as well. There is no observed difference between the adjusted R^2 values across the models. We discuss below the results of the full model listed under column (3).

Table 4: Impact of different CRM methods and Learning on Rent cost

	Dependent variable:		
	Rent cost		
	(1)	(2)	(3)
TRL1	123.745***	132.846***	259.658
	(34.517)	(35.058)	(168.102)
TRL2	-201.813**	-185.031**	-185.077**
	(88.266)	(88.964)	(88.941)
Mulching	-287.412***	-296.515***	-272.045**
	(82.362)	(85.794)	(105.846)
Straw Incorporation	-269.105***	-276.011***	-226.929***
	(68.761)	(71.483)	(78.598)
Baling	1,335.336***	1,311.745***	1,168.318***
	(78.543)	(82.414)	(102.484)
TRL1 X Mulching			-136.865
			(195.292)

TRL1 X Straw Incorporation			-187.604
			(173.116)
TRL1 X Baling			126.600
			(189.382)
Farmer landholding types control		Yes	Yes
Age control		Yes	Yes
Constant	664.996***	518.355***	485.796***
	(64.768)	(103.402)	(107.369)
Observations	782	782	782
R2	0.626	0.629	0.635
Adjusted R2	0.623	0.624	0.628
Residual Std. Error	460.485 (df = 776)	459.729 (df = 771)	457.290 (df = 768)
F Statistic	259.259*** (df = 5; 776)	130.812*** (df = 10; 771)	102.566*** (df = 13; 768)

Note:*p<0.1; **p<0.05; ***p<0.01

Please note that the results under column (3) in **Table 4** use complete burning as the base method and year 0 as the base time period, and therefore should be considered relative to these two variables. As can be noted from the significant and negative coefficients, the total rent cost of Mulching and SI is clearly lower than CB, however the rent cost is higher for the ex-situ method Baling vis-à-vis CB. However, after taking into account the coefficient of duration of one-year learning (TRL1) and its interaction with Mulching, it is interesting to note that the cost incurred by a farmer practicing *Mulching* with one year of experience is significantly **higher** than those without any experience. The results for Straw Incorporation (SI) are similar to Mulching. Even though the coefficients of interaction terms are not significant (corresponding TRL1 × Mu and TRL1 × SI), the overall effect is positive as can be seen from Column (3) of **Table 4**. To understand this highly counterintuitive result, we did a post-hoc analysis of the absolute rent cost data incurred by farmers practicing different methods across the time period. This analysis revealed that the rent cost of the main equipment required for Mulching, SI and Baling, is higher for farmers with 1 year of learning compared to those who are adopting these eco-friendly methods for the first time. However, it has an inverted U shape, as the cost begins to decrease in the third year as compared to the second year (see **Figure 7**).

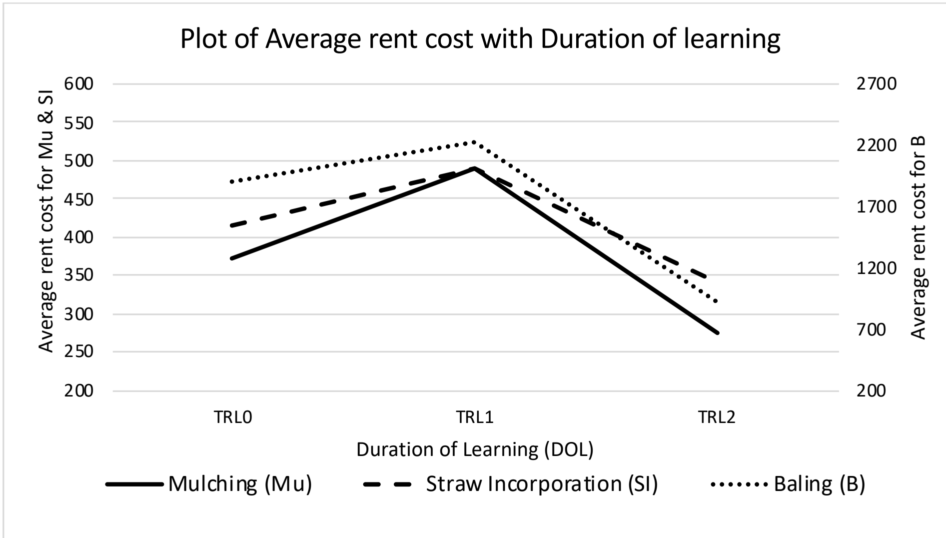


Figure 7. Plot of Average Rent cost with duration of learning for Mulching, Straw Incorporation and Baling

To understand the reasons behind this, we conducted field interviews with the farmers. These interviews revealed that, during the first year of intervention, CIIF team works very closely with the farmers and since the FPOs/FCSs in these villages get equipment through CIIF, the rental cost is low for the farmers. However, from second year onwards, the adoption rate within and surrounding the village increases as the word spreads about better outcomes of CRM alternatives. Due to this increase in scale of adoption, the CIIF supported 'equipment to farmers' ratio reduces. Therefore, farmers are forced to rent necessary equipment from private parties who charge much higher rent, which increases the cost during the second year. However, by third year (with 2 years of learning under their belt), farmers learn to use the equipment more efficiently, which reduces the rate of increase in cost of adoption.

In case of *Baling*, the baling cost is significantly much higher than complete burning, as can be seen from the results under column (3) in **Table 4**. The Baling cost also increases further for farmers with one year of experience, and then declines during the second year. Baling equipment was included in the state subsidy scheme in 2019-20, and became more widely available to the farmers, which reduced the cost of rent for all concerned from second year onwards. Further, as farmers gained more experience with baling, they also started engaging with the third-party aggregators, who clear the forms with their own baling equipment, convert the cut straw into bales and sell them for ex-situ purposes (mentioned in **Table A4** in Appendix), which reduced the overall cost of baling for these farmers. Though the rent cost of farmers with 2 years of learning is not evaluated through regression analysis due to lack of sufficient data, it has been calculated through survey dataset and graphically represented in **Figure 7**.

4.3.2. Analysis of Other Benefits

Results under columns (1-5) of **Table 5** represent the effect of the two main independent variables, namely, the CRM method and duration of learning, on the improvement in air quality (AQ), pest infestation (PI), weed infestation (WI), water consumption (WC) and fertilizer consumption (FC), controlling for farmer's landholding type and age, using *Ordinal Logit regression* as depicted in equation (2). In **Table 5** below, A value greater than 1 represents more likely odds of improvement, whereas a value less than 1 represents less likely odds of improvement.

TABLE 5: Effect of different CRM methods and Duration of Learning on improvement of AQ, FC, WC, WI and PI

	Dependent variable:				
	PI (1)	WI (2)	WC (3)	FC (4)	AQ (5)
DOL1	1.886	2.595	1.977	2.641	1.156
DOL2	1.577	3.337	1.415	2.190	1.450
Mulching	0.755	1.029	0.624	1.215	9.518
Straw Incorporation	0.714	0.783	0.594	0.942	5.564
Baling	2.758	2.542	1.627	1.936	8.956
Residual dev	2126.77	1917.79	1807.22	1642.57	1716.68
AIC	2150.77	1941.79	1831.22	1666.57	1740.68
Observations	1,194	1,187	1,178	1,136	1,196

Note: This table reports the ordinal logit regression results after controlling for landholding types of farmers and their age to show the proportional odds ratios (coefficients) of the predictor variables

As can be seen from **Table 5**, farmers with 1 and 2 years of experience in adoption of eco-friendly practices clearly have higher odds of improvement in AQ, PI, WI, WC and FC than that of farmers who are adopting these practices for the first time. When it comes to specific methods, the ex-situ Baling seems to perform much better than the in-situ methods, Mulching and Straw Incorporation. Based on these results, we can conclude that, it will take a consistent adoption for at least an year or two of the in-situ methods, to garner the indirect benefits of these eco-friendly practices.

5. Conclusions and Contribution to Theory and Practice

We began this research with two primary objectives, first to determine the framework for managing sustainability projects, and second, to identify the conditions necessary for social learning to facilitate the adoption of change. To achieve this, we drew upon the CRM project currently being implemented in the northern states of India, which involved a wide variety of stakeholders, including governmental, non-governmental, and for-profit organizations, as well as members of a rural population.

5.1. Conclusions

In conclusion, projects of this scale and nature require a governance structure which is flexible and agile enough to allow the diverse stakeholders to make quick decisions, in order to add value to the project, leveraging the learnings from the execution phase. Additionally, since sustainability projects need to work with local communities and bring about change in their day-to-day practices and behaviors, it is important to establish relationship-based contracts and peer pressure through informal mechanisms. Research shows that formal rules can be enforced by sanctions as well as by incorporating formal rules into actors' values and norms (Pahl-Wostl, 2009). As a result, granting non-governmental organizations, local communities, and religious organizations a meaningful role in governing these projects will facilitate mechanisms that are governed rather by values and norms derived from society and culture. Local communities are likely to comply with this approach, as demonstrated by the CRM project.

Furthermore, our findings suggest that involving the expertise of various stakeholders in decision processes will boost commitment to the project cause and ensure that relevant information and knowledge will be incorporated into the future cycles of decision making and execution. CII, for example, made strategic farmers and local organizations partners in its CRM project by bringing them into the decision-making process as volunteers. As a result of their social capital and involvement in the project, the rest of the farmers felt peer pressure to change their earlier practices, which were deemed harmful to society and the larger community. A community-driven approach also helped change belief systems, enabled social learning, and resulted in a lasting behavioral change by letting members experiment and identify best practices. According to our regression results, farmers who experienced the benefits of ecofriendly practices stayed with them despite a significant rise in the cost of renting farm equipment during the later years, thus reducing crop residue burning practices. Other indirect benefits of this consistent adoption across years include reductions in input costs, water consumption, pest and weed infestations, as well as improved air quality, which clearly illustrates the success of CRM.

In conclusion, we strongly recommend, based on our CRM intervention observations, that private, for-profit organizations be involved in projects of such scope and nature. Unlike governments and NGOs, which can mobilize certain types of resources (such as public funds, state machinery, local networks, etc.), private enterprises offer other capabilities (such as technical expertise, production and procurement capabilities, and CSR funds) that are vital for a successful and sustainable execution of projects, especially during times of crisis (Saranga & Raj, 2021). In light of the rapid pace of climate change, NRC/CC/SD projects have to be undertaken under crisis scenarios under tight time and budgetary constraints in the future. Consequently, we would need to work together, and the complementary nature of the resources and capabilities for-profit companies possess would prove invaluable in the execution of such projects and in the building of a sustainable future for humanity.

5.2. Contribution to Theory and Practice

We believe that this is the first study of its kind to address critical elements that exist at the intersection of operations management, project management, and sustainability, from a theoretical lens and test them with empirical data. While there have been several studies that examine OM related topics such as remanufacturing, refurbishment, and reverse supply chains (Tang & Zhou, 2012), there are very few that investigate the environmental and social sustainability related aspects, from a project management perspective. In their latest review paper, Lee & Tang (2018) urge the OM community to focus on more relevant topics that companies are tackling today, such as social responsibility, corporate social responsibility, environmental sustainability, and social innovation, rather than traditional topics like inventory, scheduling, queuing, and supply chain management. By providing a conceptual framework for the management of NRC/CC/SD projects, our paper contributes to the project management literature in the fields of environmental and social sustainability. The development of this framework draws upon the concepts of complex adaptive systems (Pahl-Wostl, 2009), social learning theory (Keen et al., 2012), and adaptive management theory (Williams & Brown, 2014; Williams & Brown, 2018) . By doing so, we open doors for researchers in the field of project management to gain insights from diverse streams of scholarship in the ecological and social sciences. Furthermore, we contribute to the empirical literature in sustainable and behavioral operations management domains by identifying factors that influence the adoption of ecofriendly practices and behavioral changes in communities in the context of a large-scale interorganizational initiative.

Our study findings have several implications for managers and policy makers. To begin with, our framework provides a useful tool for managers handling complex and dynamic multi-year projects with uncertain technical and environmental factors. Secondly, we provide a structure for project governance that allows multiple stakeholders to be involved and facilitates social learning and its inclusion in decision-making processes across various levels. In addition, our case study provides managers with insight into the development of relational contracts, adaptive management methods, and facilitating multi-loop learning so that knowledge generated during the execution phase can be incorporated into the planning and decision-making process. Our study provides policy makers with a roadmap for planning and executing sustainability initiatives, including largescale public adoption of ecofriendly practices. Moreover, we provide a flexible governance structure that allows diverse stakeholders to collaborate and contribute to a common goal. Our study findings indicate to the policy makers in the central and state governments of Punjab and Haryana that a market for crop residue must be created through environmentally sustainable means.

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i https://www.ncf-india.org/oceans-and-coasts

ii https://en.wikipedia.org/wiki/MOSE#:~:text=MOSE%20(MOdulo%20Sperimentale%20Elettromeccanico%2C%20Experimental,the%20Venetian%20Lagoon%20from%20flooding

iii https://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf

iv They found discussions with an NGO called ‘Birla Soft’ that had adopted couple of villages in the district of Nabha in Punjab, to be quite useful.

v Donors for the CRM initiative included Birlasoft, PTC Financial Services, PTC Foundation, CLP India, GAIL, ONGC Foundation, BPCL, Eicher Motors, Fidelity International, Cummins and industry associations such as Society of Indian Automobile Manufacturers (SIAM)

vi Through exchange of letters without any legally binding contracts

vii After harvesting the paddy using CH and chopping/shredding the straw using CCS, two additional machines – Raker and Baler – were required to create bales of straw, which were transported to the end users outside the crop fields in the form of bales. If these machines are not accessible, farmers typically chose to put fire to the straw, which resulted in CRB.

viii https://www.business-standard.com/article/current-affairs/punjab-haryana-to-bank-on-more-machines-biomass-to-reduce-stubble-burning-120081600487_1.html

ix Rajasthan being a dry region procured straw from neighbouring Sirsa and Fatehabad districts for animal fodder.