# The Evergreen Revolution

Six ways to empower India's no-burn agricultural future

WICKED ECON FEST

A partnership between The Nature Conservancy and the University of Minnesota's Institute on the Environment aims to break the mold of classic university-NGO collaborations. Opportunities to influence major decisions for conservation and human well-being involve increasingly complex issues related to economics, from subsidy design to corporate practice to financing options. In these fast-paced contexts, windows of opportunity arise—and close—quickly. Conservation faces a moment where the need to rapidly mobilize world class economics around "wicked" (complex, intractable) environmental problems is paramount.

The typical formula for university collaboration commonly falls short, so we have created Wicked Econ Fests. These one-time, problem-focused engagements convene leading economics, finance and policy experts with conservation and natural resource management practitioners for up to one week to tackle a specific decision-driven challenge. The workshops result in recommendations and the hand-off of advances in economic, finance, policy and conservation thinking to those who can drive recommendations to action.

This brief summarizes the findings of a workshop held in Jaipur, India on Nov 7-8, 2017.

**The Nature Conservancy India Program**

The Nature Conservancy is the largest conservation non-profit in the world that works to protect ecologically important lands and waters for nature and people. We are a science led organization that partners with governments, businesses and other NGOs to find solutions to the greatest challenges facing the planet.

The Nature Conservancy's India program was launched in 2015 and aims to work closely with the Indian Government, NGOs, research institutions and citizens to create science-based solutions that support India's efforts to develop while conserving the lands, rivers and oceans on which all life depends. The Nature Conservancy brings strong science, an ability to pilot and scale up on-the-ground programs, a focus on collaborating with stakeholders and a history of global conservation successes. We are supporting the Indian Government's priorities, particularly the National Mission for Clean Ganga and other river and wetland conservation initiatives, Renewable Energy goals and the Smart Cities Mission.

**Institute on the Environment, University of Minnesota**

The Institute on the Environment brings the power of a major research university to tackle important environmental issues. At the Institute on the Environment, we envision a world in which sustainable agriculture feeds the world; renewable energy powers healthy homes, efficient transportation and flourishing businesses; every person has access to food, water and shelter; oceans, lakes and rivers are clean and healthy; communities have vibrant economies, neighborhoods and cultures; and thriving ecosystems support thriving economies and societies. Overall, humanity restores and renews resources for the benefit of all living things. The Institute on the Environment is accelerating the transition to this future by supporting breakthrough research across disciplines, developing the next generation of global leaders and building transformative partnerships across the state, region and globe.

**Borlaug Institute for South Asia**

The Borlaug Institute for South Asia (BISA) is a non-profit international research institute dedicated to food, nutrition and livelihood security as well as environmental rehabilitation in South Asia, which is home to more than 300 million undernourished people. BISA is a collaborative effort involving the International Maize and Wheat Improvement Center (CIMMYT) and the Indian Council for Agricultural Research (ICAR). The objective of BISA is to harness the latest technology in agriculture to improve farm productivity and sustainably meet the demands of the future. BISA is more than an institute. It is a commitment to the people of South Asia, particularly to the farmers, and a concerted effort to catalyze a second Green Revolution. Established on October 5, 2011 with R&D centers in the districts of Ludhiana (Punjab), Jabalpur (Madhya Pradesh) and Samastipur (Bihar), BISA is an institute built on the legacy of Dr Norman E. Borlaug, the father of the Green Revolution, the winner of Nobel Peace Prize (1970) and the recipient of the Government of India's Padma Vibhushan (2006).

**International Maize and Wheat Improvement Center**

Headquartered in Mexico, the International Maize and Wheat Improvement Center (known by its Spanish acronym, CIMMYT) is one of the 15 CGIAR centers and a not-for-profit agricultural research and training organization. CIMMYT works with a mission of "Wheat and Maize Science for Improved Livelihoods." CIMMYT maintains the world's largest maize and wheat seed bank and is best known for initiating the Green Revolution, which saved millions of lives across Asia and for which CIMMYT's Dr. Norman Borlaug was awarded the Nobel Peace Prize. CIMMYT is a member of the CGIAR Consortium and receives support from national governments, foundations, development banks and other public and private agencies. For more information, please visit: www.cimmyt.org

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# Executive Summary

Air pollution is a major cause of premature mortality globally and the problem is particularly acute in rapidly developing countries like India. Crop residue burning contributes substantially to this problem. Currently, 80 percent of agriculture in Northwest India uses a rice-wheat production system dependent on burning rice residue. New crop residue management systems are needed to drive a profitable, no-burn agricultural system of the future. One exists, in the form of the "Happy Seeder" technology, a tractor mounted implement that allows no-till and no-burn planting of wheat into fields mulched with rice crop residue. Although a crop residue burning ban is in place, and the Happy Seeder technology is tested, profitable and subsidized, it is not yet widely adopted. Through two stakeholder dialogues and a Wicked Econ workshop, we identified six recommendations we believe can lead to a no-burn agricultural system for Northwest India in the next five years, setting a precedent for Asian agriculture and beyond.

**Strengthen innovation networks to accelerate Happy Seeder adoption.** Specifically, activate farmer-driven learning through innovation tools to increase Happy Seeder adoption and service provision.

**Clarify the business case for the Happy Seeder compared to other crop residue management options.** Specifically, develop the business case for farmers and service providers specifying private costs and benefits, and the public policy case that also includes social and environmental metrics.

**Create model business plans for entrepreneurs to provide Happy Seeder services.** Specifically, tailor plans to agro-economic zones, farm systems and service models.

**Implement an awareness and capacity-building initiative to rapidly scale Happy Seeder adoption.** Specifically, co-design the initiative with key public and private sector institutions.

**Increase production and purchase of Happy Seeders through finance mechanisms.** Specifically, increase manufacturing through purchase guarantees; and pilot additional purchase incentives such as low cost credit for service providers and farmers.

**Support the government's enforcement of the ban on residue burning by demonstrating farmer access to cost-effective, sustainable alternatives.** Specifically, increase policy maker confidence by implementing the preceding recommendations and communicating the viability of alternatives.

On net, these efforts may ease tension with farmers and give government officials the confidence they need to enforce the ban on residue burning. We believe a full transition away from crop residue burning in Northwest India in the next five years is possible. As pioneers of agricultural system change, India's farmers are poised to spark the world's next agricultural transformation. Such change cannot come soon enough. India and other countries worldwide face increasing challenges in meeting the multiple demands of food security, water security, clean air and water and a stable climate. We look to India, a center of the initial agricultural Green Revolution, to spark an Evergreen Revolution and redefine the future of agriculture.

# Problem/Opportunity Statement

In the 1960's and 70's, India's "Green Revolution" succeeded in part thanks to agricultural technology advances and the adoption of new, high-yield rice-wheat systems. Indian farmers have played a significant role in providing food security and ensuring the country remains famine-free. Yet the same capital, technical and institutional advances that helped farmers achieve nearly complete adoption of these systems has had unintended consequences. Resource intensive farming, driven by subsidies on machinery, fertilizers, energy and water, have diminished water supply in the 10.5 million ha of cropped land in the Indo-Gangetic plains. As an adaptive measure, the governments of Punjab and Haryana mandated that the timing of rice planting coincide with the monsoon rains. This shift has left farmers with a short window of about 15 days to harvest rice, dispose of rice residues, and plant the subsequent wheat crop (NAAS 2017). As a result, common practice for the estimated 2.5 million (25 Lakh) farmers in Northwest India, where the rice-wheat system dominates, is to burn an estimated 23 million (2.3 Crore) tonnes of rice residues in the field (NAAS 2017). This practice quickly clears fields for planting, but diminishes soil fertility, requires more groundwater for irrigation, produces substantial seasonal air pollution and releases greenhouse gases (GHG).

Particulate air pollution from crop residue burning affects the local population as well as downwind communities, including the 19 million (1.9 Crore) people living in Delhi. Delhi struggles with pollution from multiple sources in the winter months, with massive school closings becoming an increasingly regular response. On a global scale, air pollution is now the single largest environmental determinant of disease, contributing to 4.2 million deaths a year (Landrigan et al. 2017). Regionally, seasonal rice residue burning is estimated to contribute as much as 26 percent of Delhi's air pollution in the winter months (Sharma and Dikshit 2016). Even in rural districts such as Ludhiana in Punjab, particulate air pollution levels exceeded 337 μg/m$^3$ during the 2017 season, more than five times the safe daily threshold of 60 μg/m$^3$ (daily average from Central Pollution Control Board 2017). Acute illness and lost work days during the burning season are common, and long-term effects include increased lung and heart diseases for both local farming communities and downwind cities. During the two most intense weeks of burning, haze in Delhi brings the city to a standstill through travel delays, school closings, and hospitalizations from road accidents and overexposure to particulate pollution. Deaths due to crop waste burning across India were estimated at ~42,000 in 2010 (Lelieveld et al. 2015).

Beyond health effects, the release of GHG from burning contributes to climate change. In particular, the burning of rice residues releases black carbon, a potent climate modifier that blackens glaciers in the Himalayas, thereby exacerbating melting and their eventual disappearance (EPA 2012). These snowfields feed the Ganga, Indus and Brahmaputra Rivers, which in turn provide water to millions of people. Black carbon has also been implicated in the seasonal changes to monsoon patterns that have been accelerating in recent years (EPA 2012), and in agricultural yield reductions in India (Auffhammer et al. 2006, Burney and Ramanathan 2014). Beyond black carbon emissions, global rice production contributes

755 Tg of carbon dioxide equivalent ($CO_2e$) annually, mostly in the form of methane emissions. A portion of GHG emissions are from residue burning. Better management of rice production systems including residue management could eliminate 159 Tg $CO_2e$ for costs less than \$100 per ton $CO_2e$ globally (Griscom et al. 2017).

It will be difficult to sustain agricultural production and feed India's growing population without severe health and environmental impacts as long as crop burning is maintained as the dominant crop residue management approach in Northwest India's rice-wheat system. These challenges have put intense pressure on farmers and the government at all levels to identify and implement profitable alternatives to burning rice residues.

## Opportunity Statement

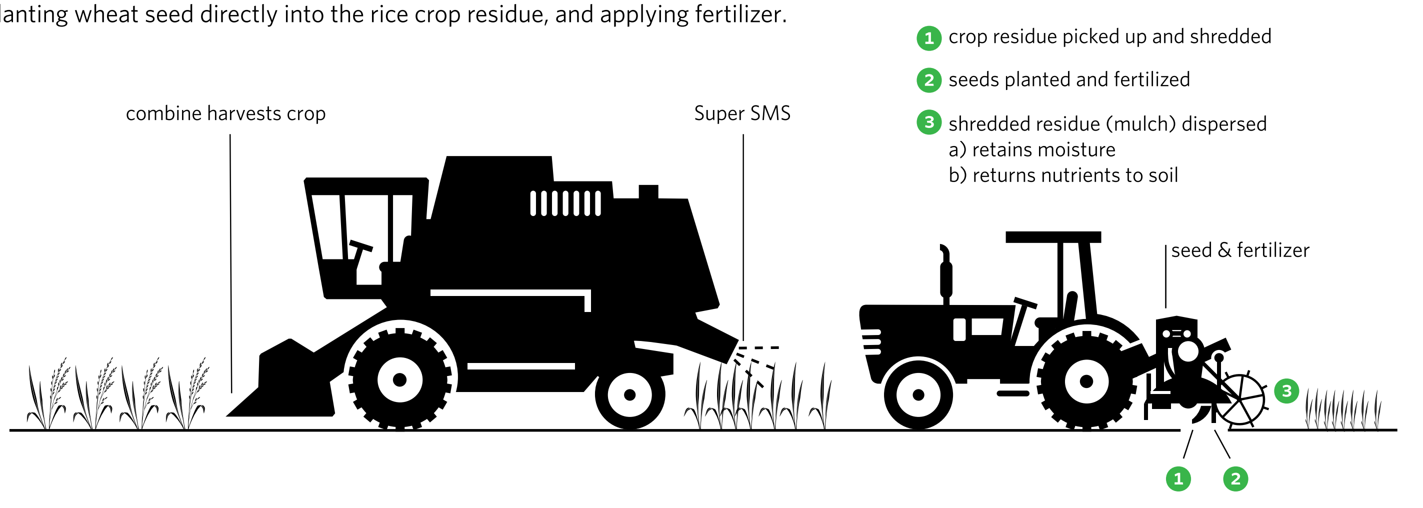
A goal of zero burning in five years is achievable for Northwest India. National and state governments are actively working toward solving the crop residue burning problem. There have been policies to discourage crop residue burning since 1981. Recently, a ban on residue burning was instituted in 2015 by the National Green Tribunal and the Supreme Court. Subsequently, the High Court of Punjab and Haryana, key agricultural states in the Northwest region, requested the state governments to identify steps to reduce burning. The Punjab Government has agreed to fully ban burning by 2019-20, and the Haryana Government is piloting an incentive program to farmers who do not burn.

Several programs have been introduced to increase in-situ use of crop residue as alternatives to burning. A recent report by the National Academy of Agricultural Sciences prepared at the request of Prime Minister Narendra Modi examined these alternatives. Their conclusion was that while all avenues should continue to be explored, in-situ solutions that turn crop residues into a mulch layer over the seeds of the next crop are the lowest cost, contribute the most to farm sustainability and are quickest to implement (NAAS 2017). One promising option for mulching is the "Happy Seeder," a tractor mounted implement that acts as a no-till seeder. By using the Happy Seeder with a spreader (often called a straw management system (SMS) and attached to a Combine Harvester), residue is deposited around the seed as mulch in one simple operation (Figure 1). In addition to removing the need for burning crop residue, the use of the Happy Seeder lowers energy and water use and improves soil health and carbon sequestration.

This technology has been refined and tested in local conditions for the last 10 years by the Punjab Agricultural University, the Indian Council of Agricultural Research and CIMMYT-BISA (Sidhu et al. 2015, Lohan et al. 2018). The evidence from these tests suggests that the adoption of Happy Seeder technology will increase profits of farmers by lowering equipment and labor costs and reducing fuel, fertilizer and herbicide requirements while modestly increasing yields. There are currently about 1000 Happy Seeders with SMS spreaders in operation, with demand for an additional 2000 machines (NAAS 2017). More than 15 manufacturers have entered the Happy Seeder market and district governments offer a 30 percent incentive for Happy Seeder purchases.

FIGURE 1.

**Happy Seeder rice residue management system.**
A combine is fitted with a Super Straw Management System (SMS) so that rice residue is spread evenly across the field during harvest. A Happy Seeder follows, planting wheat seed directly into the rice crop residue, and applying fertilizer.



Northwest India led the first Green Revolution, and in recent years, other conservation technologies such as laser-land levelers have been quickly embraced by farmers and service providers here. However, even with a profitable business case and incentive programs in place, adoption of the new Happy Seeder technology is low. Less than 1 percent of rice-wheat farmland in Northwest India is under Happy Seeder management (NAAS 2017). The opportunity to transform Indian agriculture through adoption of the Happy Seeder is massive, but behavioral, technical, economic or financial barriers remain.

## Sparking an Evergreen Revolution

We used a rapid series of three workshops to understand remaining barriers to Happy Seeder adoption and identify solutions that could speed adoption and make significant progress towards a zero burning goal in the next five years.

Two stakeholder dialogues were jointly organized by The Nature Conservancy (TNC), the International Maize and Wheat Improvement Centre (CIMMYT), the Borlaug Institute for South Asia (BISA), the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS), and the Council for Energy, Environment and Water (CEEW). These were followed by a two-day expert review workshop in Jaipur where the stakeholder discussions were synthesized into concrete recommendations for further action.

## Field Dialogue

*Ludhiana, 1 November 2017*

The Field Dialogue provided an opportunity to understand the practical challenges faced by various players in the Indian farming systems. More than 75 participants engaged in the dialogue, representing varied stakeholders, including farmers, agricultural research institutions, agricultural machinery manufacturers, service providers and relevant government departments. Participants witnessed a live demonstration of the Happy Seeder technology and visited several farms to experience the differences between fields which used this technology versus those that burned crop residues. This was followed by visits to Happy Seeder manufacturing facilities, a Climate Smart Village and a Krishi Vigyan Kendra (KVK) to understand gaps in outreach and support. The key takeaways from the workshop were:

- Farmers who use the Happy Seeder technology report satisfaction with its use. Several farmers noted increased yields and decreased input costs, with indications of soil health and ground water supply improvements. However, a majority of the farmers who continue crop residue burning are unaware of the benefits of Happy Seeder use. Addressing this knowledge gap will be critical to reducing crop burning.

- Eighteen manufacturers currently produce Happy Seeder and twenty-eight companies have signed agreements to produce Super Straw Management System (SMS) spreaders that can be attached to Combine Harvesters (a necessary complementary technology for Happy Seeder use). Manufacturers noted that Happy Seeder design has improved significantly and is now an effective technology for seeding wheat. There is certainly manufacturing capacity to increase production and supply high quality Happy Seeders to the market, however, this needs to be coupled with demand.

- Government representatives discussed the need to take a holistic approach to agriculture. There is great concern over the decline in water tables, for instance, in Punjab and farmers were encouraged to think about the sustainability of agricultural practices along with current profits. The Happy Seeder was acknowledged to be useful since it offered farmers with a no-burn alternative and made it possible to enforce the burning ban. KVKs were identified as important innovation centers that could demonstrate the benefits of Happy Seeder use. Funding support may help increase their outreach and address farmer knowledge gaps.

Participants included farmers from Ludhiana (Punjab) and Karnal (Haryana), Agricultural Machinery Manufacturers' Association, Governments of Punjab and Haryana, Indian Council of Agral Research (ICAR), Krishi Vigyan Kendra (KVK), Punjab Agricultural University, State Agriculture Department, Government of Haryana, and researchers of the organizing institutions.

## Policy Dialogue

*New Delhi, 3 November 2017*

The Policy Dialogue aimed to hear perspectives from government actors responsible for agriculture, health and air quality. This workshop was attended by more than 70 individuals, representing a range of stakeholders including key Indian and international NGOs, research institutions, and government departments. The National Academy of Agricultural Sciences recently published a Policy Brief titled, "Innovative Viable Solutions to Rice Residue Burning in a Rice-Wheat Cropping System through Concurrent Use of Super Straw Management System-Fitted Combines and Turbo Happy Seeder." This report formed the basis of discussions. Presentations and deliberations focused on agricultural research and policy, as well as health and air quality. The key takeaways for the workshop organizers were:

- Ministries have to collaborate towards tackling air pollution, including ministries of Agriculture, Transport, Environment, Urban Development and Health. Currently, efforts across ministries are not coordinated and non-government organizations may play a role in fostering better collaboration.

- It is important to ensure efforts towards reducing air pollution across all sources are coordinated so reduction from one source does not lead to increased pollution from another.

- In order for burning alternatives to be effective, they must provide value for farmers and not just a solution to Delhi's air quality challenge.

- Political will to create an enabling environment for the uptake of solutions through bans on burning is important, and would be possible to generate when solutions are available for farmers.

- Several solutions exist for managing rice crop residue without burning. However, the Happy Seeder technology has the highest scalability potential and provides farmers with the greatest economic benefits. It is a holistic solution that contributes to several Sustainable Development Goals and can improve soil quality, reduce water consumption, improve yield and reduce labor and other inputs in fields. Other solutions have incremental carbon reduction benefits whereas Happy Seeder is a carbon-negative solution.

- To advance the uptake of Happy Seeder technology, it will be important to catalyze both demand and supply, by raising awareness and capacity-building of farmers and entrepreneurs as well as providing financial tools to manufacturers.

- Punjab and Haryana are facing severe water shortages indicating that the current rice-wheat system cannot sustainably

> support agriculture. Given the climatic and water conditions in these states, there needs to be a debate about whether an incremental approach to improving cropping practices is the right solution, or whether a shift away from these crops is required.

Participants included Punjab farmers, Asar Social Impact Advisors, Association for Scientific and Academic Research (ASAR), Australian Centre for International Agricultural Research (ACIAR, Australian Government), Bloomberg Philanthropies, Central Pollution Control Board (CPCB), Centre for Agriculture and Biosciences International (CABI), Centre for Energy and Environment Development (CEED), Centre for Research in Rural and Industrial Development (CRRID), Centre for Science and Environment (CSE), Global Environment Facility (GEF), Indian Agricultural Research Institute (IARI), Indian Council for Agricultural Research (ICAR), Indian Statistical Institute (ISI), International Agriculture for Development, International Center for Agricultural Research in the Dry Areas (ICARDA), International Plant Nutrition Institute (IPNI), International Rice Research Institute (IRRI), Legal Initiative for Forest and Environment (LIFE), Ministry of Agriculture and Farmers Welfare (MoAFW), Ministry of Health and Family Welfare (MoHFW), National Environmental Engineering Research Institute (CSIR-NEERI, MoST), Okapi Research and Advisory, Public Health Foundation of India (PHFI), Purpose Campaigns, Shakti Sustainable Energy Foundation, The Energy and Resources Institute (TERI), and members of the organizing institutions BISA, CCAFS, CEEW, CIMMYT, and TNC.


## Expert Review Workshop

*Jaipur, 6-7 November 2017*

The expert review workshop aimed to distill key recommendations for transforming the Northwest Indian rice-wheat system to a no-burn system within five years. Conversations drew from the learnings of the Field and Policy Dialogues as well as inputs from expert economists, agronomists, finance specialists, service providers, natural scientists and practitioners. Key findings of the dialogues were discussed and placed in the context of broader agricultural experience in Northwest India and other relevant global settings. Lessons were taken from previous successes and failures in technology adoption in the region.

Participants in the expert workshop included the authors of this report.

# Recommendations

**Strengthen innovation networks to accelerate Happy Seeder adoption. Specifically, activate farmer-driven learning through innovation tools to increase Happy Seeder adoption and service provision.**

Every fall, India's "airpocalypse" intensifies, becoming a common feature in national headlines and damaging lungs and lives across the country. The need for solutions is urgent, and the scale of change required in farming practice is immense. While the Happy Seeder is a known, profitable solution to rice residue burning, its adoption is not taking off. Perceived or real behavioral, technical, economic or financial barriers still exist. Innovation platforms and networks have helped spark rapid change at large scales in many sectors, including agriculture, but are underused today in Northwest India. Farmers themselves are in the best position to find solutions rapidly, but lack support and opportunities to problem solve together.

Amplifying existing innovation networks and creating new ones would unleash ideas and may stimulate new solutions to residue burning. In other contexts, innovation platforms encourage entrepreneurs to explore new ideas, test them quickly, learn from failures and try again (Blank 2013). In an agricultural context, some innovation platforms embrace the full supply chain and create spaces for farmers, service providers, manufacturers, buyers and others to identify challenges and problem solve together (Thiele et al. 2011). Such platforms can be used for farmer-to-farmer learning and to encourage social nudges that can remove barriers to change. Behavioral sciences show that social recognition or pressure can be a strong influencer in changing social norms and individual behavior (Blackstock et al. 2010).

We recommend the rapid development of new innovation networks where required, and the strengthening of existing platforms. Krishi Vigyan Kendra (KVK), located in all districts in Punjab and Haryana, is one such platform. Supported by the Indian Council of Agricultural Research (ICAR), these centers provide farmer training, demonstrate new technologies and support information and technology diffusion. KVKs are an important potential institutional entry point driving farmer innovation. Resources from agricultural banks such as National Bank for Agriculture and Rural Development (NABARD) and social impact funds could be used to further strengthen KVKs or other innovative networks. KVKs could expand their offerings by partnering with other existing innovation platforms such as the Global Social Benefit Incubator at Santa Clara University.

Innovation networks can support a range of opportunities, from informal farmer-to-farmer meetings that allow alternative technology demonstrations, to competitions that award prize money to support innovative new ideas. These activities will be improved by hosts or facilitators experienced in helping diverse groups through problem definition and processes to surface new ideas. Such hosts can also prompt groups to explore ideas they may not think of as solutions, such as pro-social nudges, or ways to empower their neighbors as well as themselves. For example, social incentives that elevate and reward positive changes (e.g. farmer champions, ambassadors, neighbour comparisons) have been effective in other fields such as energy conservation (Ayres et al. 2013),

but have not been tried much in natural resource management. Network incentives that encourage people to utilize their networks for change have worked in consumer marketing and other contexts, and may be valuable for adoption of burning alternatives.

Innovation platforms work best when they are supported by people familiar with rapid learning loop processes, and able to help groups with very different views move through problem identification and problem solving productively. They also work best when ideas produced by farmers and their networks are met with opportunities for new business, skills, incentives, or partnerships. In short, creating effective innovation networks will take time and money from both the entrepreneurs and others. In Northwest India, several KVKs function very well, and could be ready platforms for more farmer innovation. KVKs could be enhanced in three ways; a) bring KVKs together to co-design residue management solutions by deploying innovation network strategies; b) use a data-driven 'test through trial' approach to pilot specific KVK interventions to reduce residue management; and, c) grow the network of strong KVKs by creating a closed loop learning where successful KVKs share learning with other KVKs.

## Clarify the business case for the Happy Seeder compared to other crop residue management options. Specifically, develop the business case for farmers and service providers specifying private costs and benefits and the public policy case that also includes social and environmental metrics.

Some farmers and policy makers remain unconvinced that the Happy Seeder is a good business choice. Confidence could be improved by clear and compelling evidence that switching from field burning to Happy Seeder use is both privately profitable and socially desirable. Evidence suggests that switching from field burning to the Happy Seeder is beneficial for farmers and service providers, the environment, and human health (Singh et al. 2008, Sidhu et al. 2015). We recommend clear documentation of these benefits in a transparent business case that compares the Happy Seeder with multiple alternative crop residue management options including burning. We anticipate such a case demonstrating four headline results:

1. Farmer profits improve by switching to the Happy Seeder,
2. Service providers have profitable opportunities for supplying Happy Seeder equipment and associated services to farmers,
3. There are large human health benefits when farmers no longer burn their fields, and
4. Happy Seeder use provides productivity, environmental and resource benefits in terms of greater water use efficiency, reduced climate impacts, and improved soil health.

We have developed a framework for creating business case comparisons between Happy Seeder and crop residue management alternatives (Table 1). We include both in-situ management options (Happy Seeder, incorporation of crop residual into the soil, and burning) as well as ex-situ management options where crop residues are removed from fields and sold for various off-farm uses (paper production, biofuels, biothermal power, bedding material, mushroom cultivation, and fodder). Some ex situ uses have capacity and time constraints on how much crop residue can be used, or how far it is profitable to transport crop residue, that limit the scale of use.

The business case framework identifies benefits and costs under alternative management options for three groups; farmers, service providers, and society as a whole. For farmers, revenues and cost under each alternative can be tracked on a per hectare basis, which then allows comparison of which alternative is most profitable for the farmer. We recommend populating this framework with data specific to each agro-economic zone because yield and inputs vary by zone. For service providers, we show revenues and costs for renting various types of equipment to farmers, again reported on a per hectare basis. Fixed costs would be shown as annualized costs of machinery that includes both purchase price and maintenance.

For policy makers, we recommend tracking the implications of residue management alternatives for society as a whole. The framework prompts a comparison of the societal benefits and costs under each farming alternative, where societal benefits and costs consist of the private net returns to farmers, the private net returns to service operators for renting machinery necessary for that farming alternative, and the net value of social, environmental, and health impacts under that alternative. Social, environmental and health impacts in this assessment include impacts on jobs, air pollution, greenhouse gases, soil health, and water resources. For easy comparison, many, but not all, of these impacts can be converted to a monetary value using methods from environmental economics.

Some management alternatives have implications for resilience and stability of returns. For example, reductions in crop losses following a severe rainfall have been documented with use of the Happy Seeder (Aryal et al. 2016). The recommended framework includes revenue and yield stability for farmers and society.

The information on benefits and costs can be assembled in different ways to make a variety of business cases. The most direct use of this information is to clarify that Happy Seeder adoption is privately profitable and socially desirable, by showing that net benefits are higher than for other management alternatives. Information can be disaggregated to show benefits to specific regions or specific groups in society beyond farmers and service providers (e.g., urban residents, farm laborers). The information can also be used to compute return-on-investment (ROI), for example, for investment by a service provider on purchase of a Happy Seeder.

To take this recommendation forward, The region's agricultural universities in partnership with the global networks of experts at CIMMYT, BISA and the Institute on the Environment at the University of Minnesota should refine the business case framework. The complete business case needs to be in place by spring 2018 to impact the next crop burning cycle.

TABLE 1.

**Business case framework for Happy Seeder and alternative rice residue management systems**

Farmers, service providers and policy makers lack easy access to the evidence on Happy Seeder costs and benefits relative to other rice residue management options. Clear business cases designed around the following framework could make this evidence clear. The service provider section identifies different machinery options to choose from, and the listed, associated costs and benefits from each can be quantified. The farmer section lists different management options (combinations of machinery and products) available to farmers. The listed costs and benefits can be quantified to show each option's private business case (private costs and benefits) and public policy case (public costs and benefits). DALYs = disability adjusted life years.

**SERVICE PROVIDER**

**Options**

(A) Happy Seeder
(B) Combine
(C) Combine with Super SMS
(D) Rotovator
(E) Chopper
(F) Shredder
(G) Disk harrow
(H) Smoother
(I) Seeder
(J) Deep plow
(K) Rake
(L) Bailer
(M) Transport vehicles

**Private Costs**

Equipment purchase
Equipment maintenance
Labor
Diesel (and other energy)
Training
Storage
Insurance
Penalties
Taxes

**Private Benefits**

Days of operation
Revenue per ha
Area coverage per day
Revenue from machine rentals
Revenue from product sales
Subsidies
Revenue stability
Net profit

**FARMER OPTIONS**

**In-Situ Rice Residue Management Options**

(C), (A)
(B), (F), (A)
(B), Hand spread, (A)
(B), (F), (G), (H), (I)
(B), (F), (J), (G), (H), (I)
(B), Burn, (G), (H), (I)
(B), Burn, (D), (I)

**Ex-Situ Rice Residue Management Options**

(B), (K), (L), (M), (G), (H), (I)
(B), (K), (L), (M), (D), (H), (I)
(B), (K), (L), (M), (A)

Transport includes for sale of:

- Paper production
- Biofuel (oil)
- Biothermal power

(B), (K), (E), (M), (G), (H), (I)
(B), (K), (E), (M), (D), (H), (I)

Transport includes for sale of:

- Bedding material
- Mushroom cultivation
- Fodder

**Potential Volume**

**Private Costs**

Service fees
Irrigation
Chemical inputs
Labor
Seed
Diesel (and other energy)
Penalties
Insurance
Taxes

**Private Benefits**

Revenue from crop sales
Subsidies
Revenue from byproduct sales
Revenue stability
Net profit

**Public Costs**

Campaigns
Energy subsidies
Irrigation subsidies
Fertilizer subsidies
Machinery subsidies

**Public Benefits**

Soil fertility
GHG emissions
Particulate air pollution
DALYs from air pollution
Water consumption
Job creation
Yield stability

## Create model business plans for entrepreneurs desiring to provide Happy Seeder services. Specifically, tailor plans to agro-economic zones, farm systems and service models.

The use of Happy Seeders will only lead to widespread reductions in rice residue burning if thousands of entrepreneurs begin providing Happy Seeder services. Potential entrepreneurs need practical information, training and financial resources to start these new businesses. Model business plans coupled with training and financing packages would decrease the information gap and moderate the risk of starting a new Happy Seeder business.

We recommend the creation of a set of concrete, model business plans for potential entrepreneurs to use in different segments of the northwest Indian agricultural system. These plans could be based upon the business case comparisons suggested in the previous recommendation and structured using existing model business plans for farming implement service providers. The set of business models should be tailored to local contexts and describe uber-type (HelloTractor), rental, and manufacturer service models. These model plans would specify annual costs and potential profits, necessary upfront costs, return on investment, options for funding and training, marketing outlets, and a step-by-step description of how to apply for funding, receive necessary training, and provide services using the specific model.

Given the timing of crop residue burning, model business plans will have greatest impact on the 2018 fall burn season if they are created and distributed widely by May 2018. This would allow time for entrepreneurs to act and prepare for business during the next burn season.

Targeting useable and accessible plans for distinct local contexts will be challenging. Information must be gathered and packaged into a compact, culturally-relevant form, and such information may be difficult to find. Some entrepreneurs may find it difficult to transfer the model into new business without additional assistance. Entrepreneurial support would be useful, but this would require identifying institutional and financial support and launching a support platform.

Model plans also need to be marketed to entrepreneurs through various communication channels. Since these models will be documents, they can be distributed as PDFs, flyers, or mailed documents relatively easily. Extension services (KVK, Sub-Mission on Agricultural Mechanization (SMAM), etc.) may be useful to communicate with existing farmers, but young entrepreneurs and potential service providers in other sectors may not be connected with these networks. Model plans could be provided to universities and integrated within coursework, particularly at Punjab Agricultural University, ICAR-IARI and ICAR-Central Institute of Agricultural Engineering (ICAR). In addition, plans could be made available to institutions that could provide the actual financing for entrepreneurs, including local banking institutions and other potential agricultural development funders such as SMAM, Ministry of Environment, Forests and Climate Change, National Bank For Agriculture And Rural Development (NABARD), and GIZ green climate fund on climate change.

## Implement an awareness and capacity-building initiative to rapidly scale Happy Seeder adoption. Specifically, co-design the initiative with key public and private sector institutions.

One hypothesis about low Happy Seeder adoption rates is that farmers, service providers and policy makers simply don't know enough about the technology. If they do know, they may have partial information, or lack knowledge on how to access and apply Happy Seeders as a burning alternative. Another hypothesis is that farmers are risk averse and will only slowly try new technologies that require significant changes in farming practices. To address some of these barriers to adoption, we recommend raising awareness among farmers, service providers and policy makers about the merits of the technology through multiple means, including widespread demonstrations. In addition, we recommend strengthening the technical ability of farmers to adopt Happy Seeder practices through training and by expanding opportunities for farmers to test the Happy Seeder. Rapid increases in awareness and capacity could be achieved through targeted information campaigns and capacity-building programs that are co-designed by a coalition of partners who serve the agricultural community. Short-term incentives to farmers that reduce the risk of adopting the Happy Seeder are discussed in the next recommendation.

We recommend the implementation of an information initiative that communicates the benefits of the Happy Seeder approach relative to alternate residue management systems, including burning. The business case recommended above would be highly valuable as fodder for such an initiative. Campaigns tailored to different audiences will be most effective, and we recommend targeting at least two key audiences through diverse media platforms (radio, TV, social, newspaper, etc). Young farmers could be targeted as potential new adopters of the Happy Seeder approach as they are generally more interested in trying new technologies and entrepreneurship. Awareness of new technologies may also attract new young people to farming who otherwise would not have sought this profession. A second promising audience is urban residents in Northwest India, especially the middle class in Delhi, who may be especially responsive given recent high air pollution levels in that National Capital Area. We propose that any such awareness initiatives be developed by a coalition of partners.

In addition, we recommend the implementation of a Happy Seeder capacity-building initiative alongside awareness building efforts. In Northwest India, many capacity-building mechanisms exist, but farmers and service providers still lack the skills and support to use the Happy Seeder system. For example, large private contractors, small service providers and cooperatives all provide farmer services and machinery rental, but few currently support the Happy

Seeder system. As Table 2 shows, large private contractors have the skills and capacity to use new technologies such as the Happy Seeder. Smaller service providers, on the other hand, are flexible, trusted by farmers and have the ability to reach large numbers of farmers. However, to expand Happy Seeder use by thousands of small operators, training and demonstration is essential and farmers engaged in these platforms could be ready recipients of such training. In addition, any mechanisms that enable small operators to better maintain their capital equipment will ensure steady advances.

We recommend that this capacity-building initiative be led through a coalition chaired by Punjab Agricultural University and ICAR's Agriculture Technology Applications Research Institute (ATARI) partnership with BISA/CIMMYT. Many state, private and central government institutions facilitate farm innovation and support improvements in farming systems across Northwest India, but they remain somewhat uncoordinated, and do not yet provide sufficient support for Happy Seeder adoption. By combining efforts and co-designing a capacity-building strategy, these organizations can each flex their own strengths and complement each other's impacts. This coalition will need to take up the task of training farmers and service providers to use the Happy Seeder, set up demonstration sites in multiple agro-ecological zones, and provide advisories on how farm practices will change when crops are sown with the Happy Seeder.

TABLE 2

**Relative strengths of existing farm service provider entities in Northwest India.**

| ADVANTAGE | LARGE SERVICE PROVIDER/CONTRACTOR | SMALL SERVICE PROVIDER | FARMER COOPERATIVES |
|---|---|---|---|
| Multiple services | High | Low | Medium |
| Local knowledge | Medium | High | High |
| Established client network | Medium | High | High |
| Service coordination | High | Low | Medium |
| Machinery maintenance | High | Low | Low |
| Monitoring | Medium | High | High |
| Flexibility (timing, costs, cash or barter) | Low | High | Low |
| Tailor made services | Low | High | Low |
| Risk/Cost of Capital | High | Medium | Low |
| Trained operators/ Technical Knowledge | High | Medium | Medium |
| Politicized | Low | Low | High |
| Efficiency | Medium | High | Low |

LOW MEDIUM HIGH

### Increase production and purchase of Happy Seeders through finance mechanisms. Specifically, increase manufacturing through purchase guarantees, and pilot additional purchase incentives such as low cost credit for service providers and farmers.

Around 60,000 Happy Seeders will be required to meet a no-burn goal for the rice-wheat crop system in India. Manufacturing of Happy Seeders is rapidly increasing, but overall production remains very low, and on-farm usage of the Happy Seeder stands at less than one percent of agricultural acreage in Northwest India.

One theory for increasing adoption is that short-term financial incentives can help increase both Happy Seeder supply and demand by aiding farmers, service providers and manufacturers to overcome financial risks associated with adopting new technologies. In other new technology contexts, such as hybrid vehicles in the U.S., short-term incentives have played this role of speeding and spreading adoption more effectively (Sierzchula 2014).

We recommend enhancing Happy Seeder supply and demand through short-term, targeted financial incentives for manufacturers, service providers and farmers. The Indian government is experimenting with pilot equipment purchase payments, but this program is small without readily available funds for expansion. To stimulate Happy Seeder supply, we recommend programs for: 1) Limited term purchase guarantees to increase equipment manufacturing capacity and 2) One-time incentives to new and current service providers for Happy Seeder and associated Super Straw Management System (SMS) spreader purchase.

Manufacturers have begun to show interest in producing Happy Seeders and SMS spreaders. More than 15 local companies have filed applications to license the equipment but current manufacturing levels must be dramatically increased to meet the total need. Reaching no-burn status through this technology in five years will require production of at least 12,000 Happy Seeders each year.

To rapidly increase manufacturer supply of Happy Seeders and Super SMS spreaders, we recommend offering purchase guarantees. Such guarantees would allow manufacturers to produce new machines at lower risk, and in time for the next burning season. Guarantees could be backed by a consortium of government and international organizations. Any unsold machines could be sold to the guarantor at a specified guarantee price and then resold, rented or leased for the following season by the guarantor to recoup investment cost. This eliminates any risk that manufacturers will be stuck with unsold machines because this risk is transferred to the guarantor. The placement of large orders with manufacturers should also significantly lower the Happy Seeder purchase price due to efficiencies of manufacturing at scale. Several international groups have expressed interest in providing manufacturing guarantees to accelerate the availability of equipment in anticipation of next year's harvest season. After several years of expanded production, it is likely that guarantees will no longer be required. This approach requires no additional government investments, removing the need for allocation of government funds and allowing rapid implementation.

Stimulating thousands of farmers, and new and current service providers to expand is another critical entry point for increasing Happy Seeder supply. Happy Seeders typically need to be utilized over at least 25 ha (100 acres) per year to be cost effective. As this is larger than the typical farm in Northwest India, entrepreneurial farmers, small to large service providers and even cooperatives rent the use of Happy Seeders to other farmers. Concurrent with manufacturing supply efforts, service supply through these mechanisms also needs to expand.

We recommend the creation of one-time incentives for new and existing service providers to purchase Happy Seeders. In addition to direct purchase subsidies from the government, there is an opportunity to create low or no interest loans for Happy Seeder purchase. In particular, the Indian banking system mandates that banks service farmers, providing an opening for both the cooperative bank system and private sector banks to create lending incentives for farmers. Financial subsidies or loan guarantees to banks could reduce the risk of lending on low or no interest (e.g. "Zero Burn, Zero Interest") loan products (current interest rates are 10-15 percent). Loan guarantees could come from multilateral lenders or sources of impact capital. The total capital required is not large; 60,000 Happy Seeders would cost about $120 million (780 crores), but it is urgent to deploy capital quickly over the next 12-36 months to stimulate new entrepreneurs.

Further, we recommend the exploration of other short-term incentive models to help drive farmer and service provider adoption of the Happy Seeder system. These options could include such incentives as avoided fines for residents of villages that are using at least one Happy Seeder, or one-time bonuses for the first farmer in a village that purchases a Happy Seeder. Softer incentives, such as free cell phone data or airtime and free Happy Seeder service texts and videos could also be deployed. As evidence suggests that the Happy Seeder is profitable and returns its purchase price within two years in most cases, permanent subsidies are not necessary or efficient. At the same time, short-term incentives may motivate risk averse farmers who are uncertain about the benefits of conservation agriculture to try the Happy Seeder system.

### Support the government's enforcement of the ban on residue burning by demonstrating farmer access to cost-effective, sustainable alternatives. Specifically, increase policy maker confidence by implementing previous recommendations and communicating the viability of alternatives.

The national crop residue burning ban has been variably enforced at the state government level. The suite of fines, possible criminal charges, and subsidies in place to discourage burning have started to decrease burning and increase Happy Seeder manufacturing and demand. However, the burning ban is still taken by some farmers as a harsh shock to the farming system. Farmers in Northwest India face a short period during which they need to transition their fields from rice harvest to wheat planting, and rice residue burning is still perceived as the most cost-effective means to clear fields. Converting to the Happy Seeder system requires access to and understanding of how to use new equipment, and acceptance of standing rice stubble on fields. The difficulties of this transition add to the burden of the many worries farmers already face.

The actions we recommend above aim to increase farm profits and make it easier for farmers to comply with the ban on burning. Evidence shows that the use of the Happy Seeder is profitable to farmers during normal years with even greater returns during extreme weather years. Clarifying this business case will help farmers understand their options and the related costs and benefits, and demonstrate to the government how valuable a transition away from burning will be for India's citizens. Model business plans will provide an on-ramp to new Happy Seeder service providers and innovation networks will open new doors for entrepreneurs to find efficient, bottom-up solutions for Happy Seeder adoption. Targeted awareness and capacity-building initiatives will ready more farmers for Happy Seeder adoption, and build public support for crop-burning alternatives. Together, these efforts may address cultural barriers to the Happy Seeder system and reduce perceived uncertainty over the net returns to adopting this new technology. Financial packages for service provides and guarantees for manufacturers will also enable an increase in access to Happy Seeder.

While our recommendations may propel farmers, service providers and manufacturers into a post-burn future, these impacts will not speak for themselves. State and national governments need to be informed of changes as they occur. We recommend intentional efforts by the proposed Happy Seeder coalition to keep state and national government officials abreast of progress with burning alternatives. In net, these efforts may ease tension with farmers and give government officials the confidence they need to enforce the ban on residue burning.

## System Solutions

In the short term, the Happy Seeder is a practical and tangible solution to the immediate challenge of rice residue burning in Northwest India. Over the longer term, there are a set of larger issues which may require more dramatic changes to sustain an agricultural system in this and other agro-ecosystems. India has policy goals of doubling farmer income, improving food and water security, improving air and water quality, and reducing greenhouse gas emissions to help achieve climate stabilization. Harmonizing policies across ministries to simultaneously achieve multiple goals can offer substantial efficiency gains. Agricultural subsidies offer a poignant example, where current subsidies within the sector are having many unintended consequences including groundwater depletion, negative impacts on soil health, increased air pollution and increased greenhouse gas emissions. Removing conflicting and untargeted irrigation, fertilizer, technology and energy subsidies, will dramatically reduce negative impacts. In addition, replacing subsidies with financial and institutional supports will strengthen the agricultural system. Sustainability of the Northwest Indian agricultural system will be further bolstered by reestablishment of more diversified cropping systems. While Green Revolution technologies and policies doubled cropping of rice and wheat production (Sidhu, Vatta, and Dhaliwal 2010), the amplification of water-thirsty crops has stressed water supplies, and the associated fall in crop diversity has left this system prone to climate shocks, pests, market fluctuations and other risks. Near-term solutions such as the Happy Seeder technology should not detract from efforts to overcome the underlying, systemic challenges facing Northwest Indian agriculture.

## Join the Evergreen Revolution

Northwest India was the beneficiary of tremendous improvements in crop yields and farmer income during the initial Green Revolution. Today, however, the agricultural production system is the source of air pollution that threatens public health, and unsustainable practices are causing the decline in crucial natural capital including groundwater resources and soil health. What is needed now is an Evergreen Revolution, one that improves yields and incomes alongside improved human health and environmental assets (Swaminathan 2010).

The first step towards an Evergreen Revolution is a complete transition away from crop residue burning. Reaching this goal in five years will require concerted and coordinated efforts by numerous governmental, NGO, and private sector organizations. Initial commitments toward reducing burning have been made by organizations contributing to this report. The Nature Conservancy has committed to trial a zero-interest loan program for Happy Seeder purchases, and to undertake field experimental trials with other mechanisms for encouraging Happy Seeder adoption. The University of Minnesota, CIMMYT and BISA will produce a clear business case for farmers, service providers and policy makers on the basis of the framework provided here (Table 1). However, getting to the ambitious goal of zero burning will require further commitments from an even wider group of organizations. We invite you to join the Evergreen Revolution!

## Citations


Aryal, J.P., Sapkota, T.B., Stirling, C.M., Jat, M.L., Jat, H.S., Rai, M., Mittal, S., and Sutaliya, J.M. 2016. Conservation agriculture-based wheat production better copes with extreme climate events than conventional tillage-based systems: A case of untimely excess rainfall in Haryana, India. *Agriculture, Ecosystems and Environment* 233: 325–35. https://doi.org/10.1016/j.agee.2016.09.013

Auffhammer, Maximilian, V. Ramanathan, and Jeffrey R. Vincent. 2006. "Integrated Model Shows That Atmospheric Brown Clouds and Greenhouse Gases Have Reduced Rice Harvests in India." *Proceedings of the National Academy of Sciences* 103 (52):19668–72. https://doi.org/10.1073/pnas.0609584104.

Ayres, Ian, Sophie Raseman, and Alice Shih. 2013. "Evidence from Two Large Field Experiments That Peer Comparison Feedback Can Reduce Residential Energy Usage." *The Journal of Law, Economics, and Organization* 29 (5):992–1022. https://doi.org/10.1093/jleo/ews020.

Blank, Steve. 2013. "Why the Lean Start-up Changes Everything." *Harvard Business Review* 91 (5):63–72. https://hbr.org/2013/05/why-the-lean-start-up-changes-everything

Blackstock, Kirsty L., Julie Ingram, Rob Burton, Katrina M. Brown, and Bill Slee. 2010. "Understanding and Influencing Behaviour Change by Farmers to Improve Water Quality." *Science of the Total Environment* 408 (23):5631–38.

Burney, Jennifer, and V. Ramanathan. 2014. "Recent Climate and Air Pollution Impacts on Indian Agriculture." *Proceedings of the National Academy of Sciences* 111 (46):16319–24. https://doi.org/10.1073/pnas.1317275111.

Central Pollution Control Board of India. 2017. "Continuous Ambient Air Quality Dataset." Ministry of Environment, Forests, and Climate Change. November 10, 2017. http://www.cpcb.gov.in/CAAQM/frmUserAvgReportCriteria.aspx.

EPA. 2012. "Report to Congress on Black Carbon." EPA-450/R-12-001. Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010. https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf.

Griscom, Bronson W., Justin Adams, Peter W. Ellis, Richard A. Houghton, Guy Lomax, Daniela A. Miteva, William H. Schlesinger, David Shoch, Juha V. Siikamäki, et al.2017. "Natural Climate Solutions." *Proceedings of the National Academy of Sciences* 114:11645–50. https://doi.org/10.1073/pnas.1710465114.

Landrigan, Philip J., Richard Fuller, Nereus J. R. Acosta, Olusoji Adeyi, Robert Arnold, Niladri Basu, Abdoulaye Bibi Baldé, et al. 2017. "The Lancet Commission on Pollution and Health." *The Lancet*. In press. https://doi.org/10.1016/S0140-6736(17)32345-0.

Lelieveld, J., J. S. Evans, M. Fnais, D. Giannadaki, and A. Pozzer. 2015. "The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale." Nature 525 (7569):367–71. https://doi.org/10.1038/nature15371.

Lohan, SK., Jat, HS., Yadav, AK., Sidhu, HS., Jat, ML., Choudhary, M., Peter, JK and Sharma, PC. 2018. Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews* 81: 693–706. https://doi.org/10.1016/j.rser.2017.08.057.

NAAS 2017. Innovative Viable Solution to Rice Residue Burning in Rice-Wheat Cropping System through Concurrent Use of Super Straw Management System-fitted Combines and Turbo Happy Seeder. Policy Brief No. 2, National Academy of Agricultural Sciences, New Delhi: 16 p. http://naasindia.org/page.php?pageid=81.

Sharma, M., and O. Dikshit. 2016. "Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi." Report #208016. P. 334. Kanpur: Indian Institute of Technology. http://delhi.gov.in/DoIT/Environment/PDFs/Final_Report.pdf.

Sidhu, R. S., Kamal Vatta, and H. S. Dhaliwal. 2010. "Conservation Agriculture in Punjab—Economic Implications of Technologies and Practices." *Indian Journal of Agricultural Economics* 65 (3):413.

Sidhu, H.S., Manpreet Singh, Yadvinder Singh, J. Blackwell, Shiv Kumar Lohan, E. Humphreys, M.L. Jat, Vicky Singh, and Sarbjeet Singh. 2015. "Development and Evaluation of the Turbo Happy Seeder for Sowing Wheat into Heavy Rice Residues in NW India." *Field Crops Research* 184 (December):201–12. https://doi.org/10.1016/j.fcr.2015.07.025.

Sierzchula, William, Sjoerd Bakker, Kees Maat, and Bert van Wee. 2014. "The Influence of Financial Incentives and Other Socio-Economic Factors on Electric Vehicle Adoption." *Energy Policy* 68 (Supplement C):183–94. https://doi.org/10.1016/j.enpol.2014.01.043.

Singh, R.P., H.S. Dhaliwal, Singh-Tejpal, H.S. Sidhu, Manpreet-Singh, Yadvinder-Singh, and E. Humpherys. 2008. "A Financial Assessment of the Happy Seeder for Rice–wheat Systems in Punjab, India." In *Permanent Beds and Rice-Residue Management for Rice-Wheat Systems in the Indo-Gangetic Plain: Proceedings of a Workshop Held in Ludhiana, India, 7-9 September 2006*, edited by E. Humphreys and C.H. Roth, p. 182–92. ACIAR Proceedings 127. Canberra: Australian Centre for International Agricultural Research.

Swaminathan, M. S. 2010. From Green to Evergreen Revolution: Indian Agriculture: *Performance and Emerging Challenges*. Delhi, India: Academic Foundation.

Thiele, Graham, André Devaux, Iván Reinoso, Hernán Pico, Fabián Montesdeoca, Manuel Pumisacho, Jorge Andrade-Piedra, et al. 2011. "Multi-Stakeholder Platforms for Linking Small Farmers to Value Chains: Evidence from the Andes." *International Journal of Agricultural Sustainability* 9 (3):423–33. https://doi.org/10.1080/14735903.2011.589206.