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POLICY BRIEF

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Reducing Post-Harvest Losses in Indian Agriculture- A Case Study of Selected Crops

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Glossary

CIPHET	Central Institute of Post-Harvest Engineering & Technology
CWC	Central Warehousing Corporation
DES	Directorate of Economics and Statistics
DGFT	Directorate General of Foreign Trade
ECA	Essential Commodity Act
FAO	Food and Agriculture Organisations
GOI	Government of India
ICAR	Indian Council for Agricultural Research
JPMA	Jute Packaging Material Act
MOFPI	Ministry of Food Processing Industries
NABCONS	NABARD Consultancy Services
NFSA	National Food Security Act
PDS	Public Distribution System
SWC	State Warehousing Corporation

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India suffers a food loss of about Rs. 1.53 trillion (USD 18.5 billion) every year as per the latest large-scale study conducted by NABCONs during 2020 to 2022. Reducing post-harvest losses (PHL) is much more cost effective and benign to nature's basic resource endowment, namely soil, water, air, and bio-diversity than producing more and losing more. India needs to ramp up its efforts in this direction with modern technologies in harvesting, drying, storing, and transporting its agri-produce from farmers' fields to retail outlets.

Introduction

Tackling food loss and waste is a triple win opportunity benefiting farmers, enhancing food security, and ensuring sustainability in agri-food systems. Globally 13.2 percent is food loss[1] from harvest up to retail and 17 percent is food waste[2] at the retail and consumer levels. Together, around 30 percent of the food produced never reaches the human stomach (FAO, 2021). In this regard, there is a stark contrast between developing and developed nations in terms of food loss and waste. While developing countries grapple with substantial food loss from post-harvest to storage and transporting to retail outlets, developed nations incur significant food waste at the consumer end. Given the gravity of the situation United Nations integrated reduction of food loss and waste (FLW) in Sustainable Development Goal target 12.3, which aims to halve per capita global FLW by 2030.

There are no national-level surveys on food waste in India. However, efforts have been made in understanding the nature and quantum of post-harvest food loss through three extensive pan-India surveys conducted by ICAR-CIPHET in 2012 and 2015, and NABCONS in 2022. India indeed achieved tremendous growth in food grain production from 74.23 million metric tonnes (MMT) in 1966-67 to 330.5 MMT in 2022-23 (DES, 2023) and is also a key exporter comprising 40 percent share of global rice trade (DGFT, 2023). Horticulture production in India also expanded from 96.6 MMT in 1991-92 to 355.25 MMT in 2022-23 (DES, 2023). Increasing production of grains, fruits and vegetables (F&V) poses a challenge of minimising post-harvest losses (PHL) in the face of limited mechanisation and weak logistics from storage to transportation to retail outlets. Even though the three all India surveys mentioned above show that PHL have somewhat reduced as percentage of production over this period (2012 to 2022), the country still suffers a staggering loss of Rs. 1.53 trillion (USD 18.5 billion) annually during 2020 to 2022 due to PHL of crops and agri-allied produce, as estimated by NABCONS study, 2022. If one can reduce this PHL, one can commensurately save that much exploitation and degradation of soil, declining water table, and green-house gas (GHG) emissions that are associated with their production. It is important to note that in comparison to global levels, India faces higher PHL in cereals, pulses, and oilseeds, indicating lower levels of farm mechanisation and poor infrastructure for storage and transportation. In China, the loss percentage for cereals is at 2.22 percent, compared to India's figure of 4.44

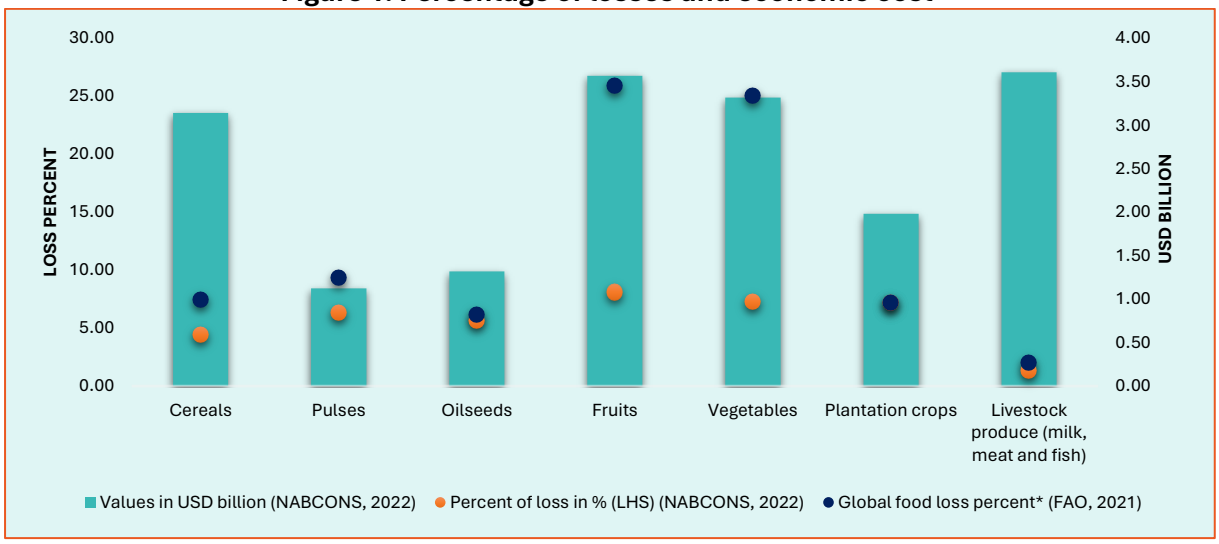
[1] Food loss refers to the reduction in both quantity and quality that occurs in the supply chain, commencing from harvest and extending up to the retail stage.

[2] 'Food waste' pertains to the consumption phase, encompassing the removal of edible and inedible portions of food during the phases of manufacturing, retail, food services, and at the household level.

percent. Thus, there is urgent need to address PHL in case of cereals, pulses, and oilseeds.

But interestingly, in case of F&V, although the losses are higher (in terms of percentage of production) compared to grains and oilseeds, yet relative to global average PHL figures, India's losses in F&V are much lower (**Figure *1***). One of the weak features of Indian surveys on PHL is that they capture only the quantity losses, and not the quality losses that occur in the post-harvest stage (in threshing, winnowing, transporting from farm to home or nearest mandi, and then further in storage, and transporting to retail outlets later). It is this absence of quality loss measurement that inspired us to capture this, along with quantity loss, in our study. Given the resource constraints, we could not undertake an all-India survey, but focused on selected crops in selected states. In this context, we undertook surveys to capture both quantity and quality losses[3] in three cereals (paddy, wheat, maize) and one oilseed (soybean). The primary survey collected data of 1200 farmers and 116 market-level stakeholders, distributed across districts of Punjab, Madhya Pradesh, and Bihar using a stratified random sampling method[4]. Addressing quality loss is critical as damage and spillage of grain lead to price reduction of the produce and loss in its nutritional value.

Figure 1: Percentage of losses and economic cost



Source: NABCONS 2022, FAO, 2021

Our study is centred on two main objectives. Firstly, we aim to estimate both the quantity and quality losses associated with key cereal crops including paddy, wheat, maize, and one oilseed (soybean), while also identifying the underlying factors contributing to post-harvest losses at the farmers' level. Secondly, we undertake a thorough evaluation of the grain management practices implemented by the Food Corporation of India (FCI) for public distribution across the country. Additionally, we examine the challenges faced by private sector stakeholders in expanding storage infrastructure, with the overarching goal of

[3] Quantity losses occur when there is reduction in the physical amount of food from harvest to retail, whereas quality loss is the deterioration, breakage or contamination of food leading to losses. In this study, such quality deterioration has been transformed as equivalent quantity loss.

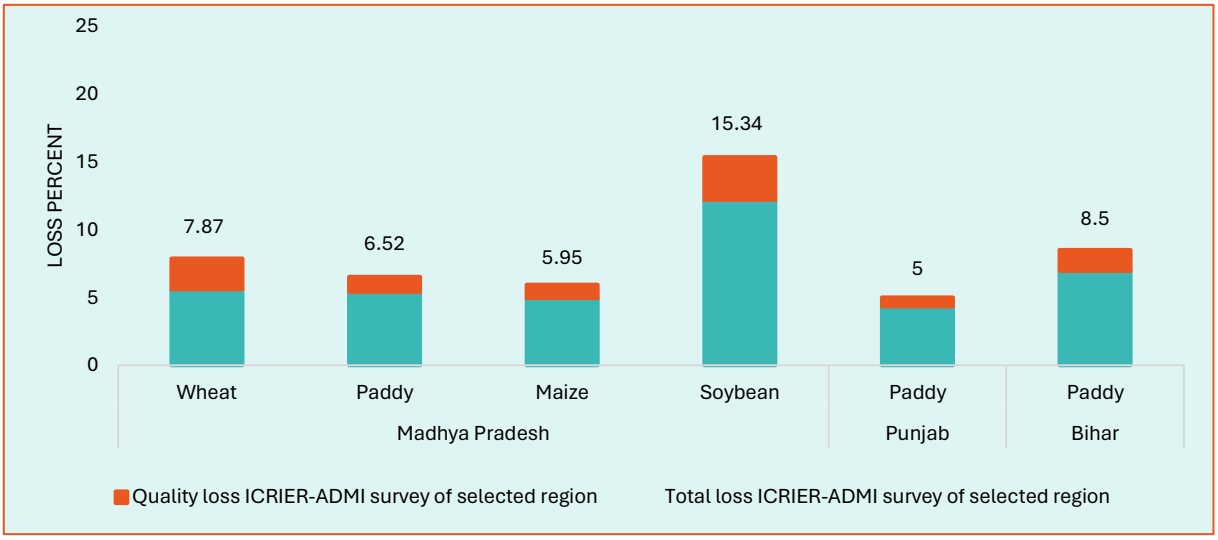
[4] The sample includes 600 paddy farmers, 200 each of wheat, maize, and soybean farmers, as well as 60 paddy, 20 each of maize and soybean, and 16 wheat market-level stakeholders, conducted in 2021-22. The ICRIER-ADMI survey encompasses 12 crop districts selected to capture diverse agricultural landscapes. In Punjab, Amritsar and Bhatinda are selected, each representing different agro-climatic zone. Similarly, in Bihar, Rohtas and Muzaffarpur are selected from different agro-ecological regions for paddy crop. In Madhya Pradesh, Raisen and Gwalior are surveyed for paddy and wheat, respectively, from varied agro-climatic conditions. Similarly, Ujjain, Bhopal, and Rajgarh are included for soybean, while Chhindwara and Rajgarh are surveyed for maize, representing different agro-ecological regions (Gulati et al., 2024).

reducing losses throughout the grain supply chain. Through these focused objectives, our study aims to offer actionable insights for policymakers, agricultural practitioners, and stakeholders for reducing PHL at farmer level as well as in the supply chain for efficient grain management.

Estimation of quantity and quality loss at farmer level

Our analysis reveals significant variations of losses across different crops, with soybean exhibiting the highest loss percentage at 15.34 percent, followed by wheat at 7.87 percent, paddy at 6.37 percent, and maize at 5.95 percent (**Figure 2**). Of particular interest is the observation that wheat, among the studied cereal crops, incurs a higher quality loss of 2.27 percent. This can be attributed to the crop's hygroscopic[5] nature, leading to degradation of quality during storage. While quantity loss estimations may not directly reflect quantity deductions, quality loss assessments account for factors such as spillage, weevilled grains, and other impairments.

Figure 2: Percentage of post-harvest losses across commodities in India



Source: ICRIER-ADMI food loss survey

Furthermore, our study highlights regional disparities in paddy losses within India, indicating the impact of level of agricultural development of the state on post-harvest losses (**Figure 2**). A critical finding of our research is the higher incidence of losses during harvesting and threshing, compared to storage losses. Addressing the specific challenges faced by farmers during initial stages of supply-chain is essential through mechanization for improving overall agricultural productivity and reducing PHL.

What are the determinants of PHL at farmer level in India?

To empirically determine the factors behind PHL at farmer level, we took the case for paddy and ran a linear regression on the 600 paddy farmers across three states. Regression results are tabulated in Annexure (**Table 1**). The dependent variable is PHL per hectare for paddy, whereas significant explanatory variables are area under crop in ha., usage of combine harvesters (yes=1, no=0), education

[5] Hygroscopic property of the grain indicates water absorption capacity and increasing moisture content during storage.

level of the head of the household (illiterate=0, primary=1, secondary=2, secondary and above=3), and distance from *mandi* in km.

The foremost finding is marginalisation of land (small and marginal holdings) leading to higher PHL. A one unit increase in area under crop is associated with 7 percent lower paddy losses per hectare at a statistically significant level. India with 86 percent farmers below 2 hectares of land face more post-harvest losses due to labour intensive cropping practices. The extent of marginalisation of land is the highest in Bihar compared to Punjab and Madhya Pradesh, contributing to higher loss per hectare in the state. The mean loss per hectare for marginal farmers in Bihar is 3.5 kg per hectare, whereas it is 1.16 kg per hectare and 0.69 kg per hectare for semi-medium and medium farmers of the state, respectively. The other major determinant of PHL is the lack of mechanisation at farmer level measured by the usage of combine harvesters.

The regression results show that the coefficient of usage of combine harvester is negatively associated with losses per hectare for paddy and statistically significant. Agricultural households using combine harvesters on an average face 0.50 kg per hectare lesser loss compared to manual harvesting for paddy, and the results are statistically significant. Additionally, the adoption of combine harvesters not only reduces losses but also minimizes harvesting time, which in turn further helps in reducing grain losses.

There is a strong association between education level of the farmer and the PHL per hectare. Education profile reflects the awareness and knowledge of farmers. The regression result shows that secondary and secondary above educated farmers experienced lesser loss compared to primary educated farmers. Higher education helps farmers for better knowledge capability for technological change and access to extension services. Across all states, farmers with secondary education or above exhibit a substantial (13 percent) reduction in paddy grain losses compared to those with only primary education. This underscores the critical role of education in equipping farmers with the requisite capabilities to adopt optimal agricultural practices and minimize losses.

Distance covered during transport of grains for the market is a key variable explaining total loss. The variable is not significant for Punjab and MP due to higher market density, whereas the variable is significant for Bihar. As per the spatial spread of agriculture markets in India, market density varies from 0.32 - 0.84 per 1000 sq. km in Bihar, 0.85 – 1.43 per 1000 sq. km. in MP, and 3.31 – 6.93 per 1000 sq. km. in Punjab (Agmarknet). A one unit increase in distance from mandi increases paddy loss per ha. by 1.4 percent in Bihar. Our survey results also show that in Bihar, 61.50 percent used tractor as mode of transport whereas the share is almost 100 percent in other two states. Small farmers find it difficult to afford for transport facilities and often get engaged in distress sales to local traders, hence expansion of storage infrastructure is necessary for reducing PHL.

What strategies can India implement to effectively reduce PHL at the farmers' level?

By adopting a comprehensive approach that includes mechanization, promoting education among farmers, and enhancing storage infrastructure, policymakers and stakeholders can effectively tackle the challenge of PHL at farmers' level. Some of the specific policy prescriptions are listed below:

1. **Technical guidance for farmers to minimize losses**

Our analysis shows that farmers with secondary and above education have association with lower harvest and post-harvest losses. More awareness programmes for the farmers and labourers can reduce losses during crop harvesting. Additionally, increase in extension services holds promise in enhancing the technical efficiency of farmers, through promoting effective crop management practices to reduce post-harvest losses.

2. **Foster usage of combine harvesters and mechanical dryers through Custom Hiring Centres**

As our study shows usage of combine harvesters significantly contribute to lower harvest and threshing losses. Usage of combine harvesters is particularly low among small farmers in Bihar. In most cases, combine harvesters are mainly owned by merchants and private parties and rented out to farmers, due to financial constraints faced by small farmers. Expanding mechanical drying is imperative as well. Mechanical drying reduces the risk of mycotoxin contamination during storage and minimizes the presence of foreign matters compared to traditional sun drying. In this context, Farmer Producer Organisations (FPOs) can play a crucial role in promoting group leasing arrangements for agricultural machinery including combine harvesters, mechanical and solar dryers through Custom Hiring Centres (CHCs) to reduce post-harvest losses.

3. **Role of warehouse receipt to reduce post-harvest losses**

At the farmer level, investing in modern storage infrastructure poses significant challenges, particularly as farmers often require immediate cash settlements at the time of harvest. The successful implementation of the National Warehousing Receipt (NWR) system necessitates the availability of private warehouses by reducing government interventions in the market, especially sudden imposition of stocking limits.

4. **The Road to increase storage capacity at grass-root level through PACs**

Government of India (GoI) has announced in 2020 the Agriculture Investment Fund to promote post-harvest technological development through Primary Agricultural Credit Societies (PACS), FPOs for interest subvention of 3 percent to invest in infrastructure. The Union Cabinet on May 31 2023 approved the construction of warehouses for agricultural produce through PACs which can also serve as custom hiring centres, processing units and Fair Price Shops (FPS), etc. FCI is implementing a pilot project in 24 PACS of 24 states/union territories. The Prime Minister of India has launched it as the 'World's largest grain storage plan in the cooperative sector,' in February 2024. This initiative is part of a broader strategy aimed at modernizing the agricultural system of India, a crucial step towards the *Viksit Bharat*. The plan entails an ambitious expansion of storage capacity by 70 MMT, requiring an estimated investment of Rs. 1.25 trillion (equivalent to USD 15.09 billion) over the next five years. This visionary initiative holds immense potential to tackle post-harvest losses at the grassroots level.

By providing farmers with the option to store their produce in private registered warehouses and receive warehousing receipts, the NWR system offers a viable solution to minimize post-harvest losses, particularly in regions where procurement is less. This also helps smallholder farmers to store their produce in warehouses with maintained quality standards, rather than storing it at home, which can significantly reduce losses associated with inadequate storage facilities.

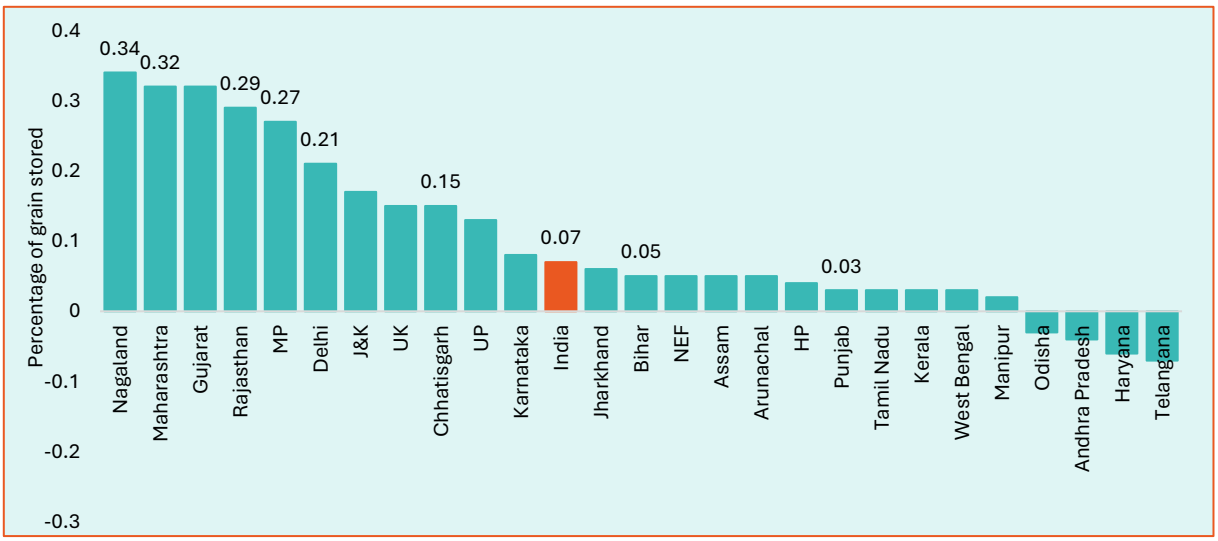
Grain Management: Post-harvest losses in India

While it is essential to focus on reducing losses at the farmer level from harvest to markets, equal if not more significant attention must be directed towards the grain management system in India. It may be noted that GoI runs world's largest and highly subsidized public distribution system (PDS) under its National Food Security Act (NFSA, 2013), under which more than 800 million people are given free 5 kg of grain (rice or wheat) per person per month. Over the years, FCI, the nodal public agency for grain management (procurement, storage, distribution) has done quite a lot on expanding storage capacity in India. However, storage and transit losses from procuring states remain a challenge due to lack of modern infrastructure and regulated market structure. FCI employs diverse grain storage methods, encompassing various facilities, labour utilization, techniques, and management practices. The grain management by FCI incurs high economic cost for the government with mounting food subsidy bill of Rs. 2.87 trillion (USD 34.69 billion) as per the revised budget estimate (RE) for financial year 2022-23 (FY23). The storage infrastructure has improved over the years in the country, however expanding storage facilities remain a challenge due to lack of private investment.

Storage and transit loss in grain management by FCI

At the national level, there has been a noticeable decline in storage losses for grains over the years. However, concerning wheat, the data on storage loss indicates a negative trend primarily attributed to moisture gain attribute of the grain. Conversely, storage loss trends for rice exhibit a positive trajectory at the national level, with variations observed across states (**Figure 3**).

Figure 3: Storage Loss in rice at FCI warehouses for Apr-Sep 2023



Source: FCI

It is important to note that FCI only account quantity loss by measuring weight differences of grains at the time of loading and offloading. However, quality loss of grains occurs during storage due to factors such as high moisture content and storage duration, which are not currently estimated at the FCI level.

In terms of storage capacity distribution across states, there is a distinct regional bias, with Punjab, Haryana, and Madhya Pradesh

collectively holding 63 percent of the total storage capacity of FCI. This concentration leads to distress sales among farmers who lack access to adequate storage facilities in other states. The recent report from the Standing Committee on Food, Consumer Affairs and Public Distribution (2021-22) has underscored the magnitude of losses incurred in grain management, with 0.41 MMT of grains (wheat and rice) lost, resulting in an economic loss of Rs. 11.09 billion over the last four years. Transit losses during distribution processes remain a significant concern, currently standing at 0.22 percent as of 2021-22. The primary contributors to transit losses include transport of grain from procurement states to other states, inadequate infrastructure at the *mandal* level buffer storage facilities, spillage during handling, pilferage, litigation issues leading to seized rice stocks, and distant transportation before reaching fair price shops. Addressing these challenges requires comprehensive interventions aimed at improving storage infrastructure, optimizing distribution processes through decentralised procurement, shifting towards direct cash transfers to ensure efficient grain management and minimize losses across the supply chain.

Role of private players in expanding storage infrastructure

To cater the storage facilities required for grain, private players play a crucial role in the management of post-harvest grain losses, particularly in expanding modern storage infrastructure. The Shanta Kumar Committee Report of 2015 emphasizes the necessity to phase out Covered and Plinth (CAP) storage and replace it with more efficient alternatives such as silo bag technology and covered warehouses. Recognizing the increasing demand for storage capacity due to rising food grain production, private sector participation has been instrumental in meeting this demand without relying excessively on CAP storages. However, at the current stage this is mostly done through the Private Entrepreneurs Guarantee Scheme (PEG)[6], initiated in 2008, facilitates the construction of warehouses through Public-Private Partnership (PPP) mode. As of October 31, 2023, approximately 18.9 MMT of storage capacity have been approved, with 14.6 MMTs completed.

Also, expansion of modern silos attributes to lower post-harvest losses. Private investors, CWC, SWC, and other state agencies have played a pivotal role in funding these capacities. Despite these efforts, the completion of steel silos capacity remains limited, with only 1.97 MMT out of the planned 14.03 MMT completed as of September 30, 2023. A notable example is the investment made by Adani Agri Logistics Limited (AALL) in Moga, Punjab, which boasts the largest storage unit in India with a total capacity of 0.2 MMT. This facility comprises 16 silos, each capable of storing 0.012 MMT, along with an additional 4 silos of 0.005 MMT each for pre-silo storage requirements. Equipped with semi-automated functionality and railway sides, these silos facilitate efficient transit, handling, and storage of grains, thereby minimizing losses throughout the supply chain.

6 Under this PEG scheme, private investors, Central Warehousing Corporation (CWC), and State Warehousing Corporations (SWCs) are incentivized to construct warehouses, with the government providing rent guarantees for up to 10 years. This scheme encourages private investment in storage infrastructure while holding parties accountable for storage losses beyond prescribed limits.

Policy suggestions for improving grain management

1. Agriculture Market Reform

The primary hurdle hindering private players from investing in grain storage infrastructure lies in the persistence of the Essential Commodities Act (ECA), a policy relic from the 1950s designed to regulate stock limits. Despite the overflow of grain in FCI storage facilities, the archaic nature of our legal framework, rooted in decades-old policies, serves as a significant deterrent for private sector investment in storage infrastructure. The ECA of 1955 gives the government the power to impose stock limits on any trader, processor, or exporter at a moment's notice. This creates uncertainty and risk for potential investors in storage. This legal landscape not only discourages private investment but also stifles transparency in reporting stock holdings, storage capacities, trading activities, and carry forward positions. Although the GoI had tried to amend the ECA, but it was taken back with the repeal of Farm Laws of 2020. Amending the outdated provisions of the ECA holds the promise of unlocking the potential for private sector investment in storage infrastructure and warehouses. By doing so, farmers would gain access to modern storage facilities at individual level or through cooperatives and the option to store their produce in exchange for warehouse receipts.

2. Usage of hermetic bag for reducing storage loss

At FCI level, jute bags are most widely used packaging material. The use of hermetic bag is limited for the post-harvest storages. Hermetic bags are safe chemical free 'green' technology for storage for rice to avoid insect infestation, prevention of mould growth, to maintain storage quality, and for longer durability. There are many global studies indicating lower storage losses in hermetic technology. For instance, the case study on paddy storage in Bangladesh exhibits that hermetic GrainPro bag and Cocoon bag technologies have reduced paddy losses and economically more feasible compared to traditional storage technologies (Alam et al., 2022).

In case of possibility of using hermetic bag in India, there is Jute Packaging Material (JPM Act, 1987) for mandatory use of jute bags by GOI for packaging rice, wheat grains. Even though jute is bio-degradable, it is a water guzzler, hydrophilic, and labour-intensive crop and the usage leads to frequent rodent attack, pilferage, infestation due to tropical climate. Hence, there is a need to re-visit the JPM Act for faster expansion of usage of hermetic bags that has potential to lower storage and transit losses. And if the hermetic bags are adopted, the "hook system" of labourers carrying gunny bags on their backs will have to be changed to conveyer belts, as the hooks in gunny bags lead to continuous spilling of grain from the bags.

3. Expanding bulk storage (steel silos) to consuming centres

Silos use one-third of the space used by conventional covered warehouses for the same storage capacity. Labour cost is significantly reduced as compared to conventional storages due to semi-automation technology. For better preservation of grains, bulk capacity through steel silos needs to be expanded in the country. FCI has plans to expand silo facilities in consuming regions to reduce transit losses. However, as of September 2023, 14 percent of the 10 MMT target capacity has been met. Rice silos are yet under experiment, which need to be expanded in eastern and southern states (major consuming centres) to reduce transit losses. Repealing ECA of 1955 can increase the private investment in expanding modern silos construction to reduce storage and transit losses.

These outlined policy suggestions along with modern technologies ranging from hermetic bags to steel silos, can significantly improve grain management practices and reduce losses throughout the supply chain. By implementing targeted strategies aimed at enhancing infrastructure facilities, promoting technological innovation, and agriculture market reform, India can substantially reduce post-harvest losses.

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Annexure

Table 1: Regression results on determinants of PHL per hectare for paddy farmer

Dependent variable= Quantity loss (kg per hectare)	All states (Model1)		Punjab (Model 2)		Bihar (Model 3)		MP (Model 4)	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Independent variables								
Area under the crop in ha.	-0.075*	0.006*	-0.062*	0.006	-0.983*	0.053	-0.069*	0.009
Secondary or above education (Yes=1, No=0)	-0.130**	0.063	-0.060	0.051	-0.096**	0.075	-0.127**	0.139
Use of combine harvester (Yes=1, No=0)	-0.509*	0.104	-1.316*	0.165	-0.241**	0.126	-0.402**	0.171
Distance from mandi in km.					0.014***	0.004		
Constant	1.885*	0.085*	2.267	0.163	3.734*	0.102	1.732*	0.192
R squared	0.401		0.508		0.648		0.209	
N	600		200		200		200	

*Notes: Only significant variables are used in the regression models. ***p< 0.01, **p <0.05, *p <0.10*

Source: ICRIER-ADMI field survey.

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