International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 08-08-2021, Accepted: 20-08-2021, Published: 28-09-2021
Volume 6, Issue 5, 2021, Page No. 116-123

Implementation of smart gadgets in agriculture commodities storage–A techno economic survey based profitability analysis from the farmers', traders' and processors' perspective

Aruna Nair U K[1, 2], Amudhasurabi A[3], Yadav B K[4], Venkatachalapathy N[3], Loganathan M[3], Sinija V R[3*]

[1] Research Scholar, Indian Institute of Food Processing Technology (Ministry of Food Processing Industries, Govt. of India), Thanjavur, Tamil Nadu, India

[2] Affiliated with Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

[3] Professor, Indian Institute of Food Processing Technology (Ministry of Food Processing Industries, Govt. of India), Thanjavur, Tamil Nadu, India

[4] Professor, Liaison Office, Indian Institute of Food Processing Technology (Ministry of Food Processing Industries, Govt. of India), Guwahati, Assam, India

Abstract

The profile of selected farmers, traders and processors of rice and their perception on preference and application of smart gadgets and remote monitoring of grain quality were analysed in the economic perspective. Considering the quantum of rice production and major trading centres, one representative state was selected from each region – Tamil Nadu (TN) from south, Assam (AS) from north east and Punjab (PB) from north west. While most of TN and AS had medium scale farmers (5-10 acres), PB had large scale (>10 acres) farmers. Most farmers stored their produce for less than 100 days, the traders stored up to 180 days and the processors stored for up to 10 days only, their stock being dynamic. TN traders had some of their stock stored in CAP storage alongside godown storage, while AS and PB rely more on godown storage. TN traders stored their stock at an average moisture content of 12 % while AS and PB stored at 14 %. In case of processors, TN had higher average capacity of mills than AS and PB. Economic analysis pointed out that the usage of sensors are not economically feasible for the processors, but it doesn't affect the profitability of farmers and traders.

Keywords: survey, sensors, storage, farmers, traders, processors

Introduction

Losses in grain handling and storage

Good storage practices are a main factor that contribute to food supplies and buffer stock of a nation (Basavaraja, Mahajanashetti, & Udagatti, 2007) [3]. About 10 % of total food grains are lost during postharvest storage. This loss can be attributed to microbial and pest infestation due to improper and unscientific storage. Grains that retain less than 8 % moisture content are rarely contaminated by microbes. Under conditions such as 65-70 % air humidity and more than 15 % grain moisture content, mites and fungi can develop faster (Gahukar, 1994) [11]. Insect infestation contributes to INR 1300 crores out of the annual monetary loss of INR 7000 crores due to loss of 14 million tonnes of grains. The insects account for 2 – 4.2 % for the grain loss, whereas rodents contribute to 2.5 % followed by 0.85 % because of birds and 0.68 % because of grain moisture.

According to World Bank, 7-10 % of grains are lost during post-harvest operations, 4-5 % grains are lost during distribution. Out of the postharvest losses, 75 % happens at the farm level and the remaining happens at the market level. 17 % of the losses happens due to harvesting and threshing at the farm level and 20 % of losses occur during the transit of the produces (Kumar & Kalita, 2017; Manandhar, Milindi, & Shah, 2018) [16, 21].

Online monitoring system- use of sensors to reduce post-harvest losses

The losses that occur during harvesting and threshing can be reduced by mechanization of these two processes. But the losses during storage demands restructuring of the existing storage systems with adaptation of sensor technology for an online monitoring system. Timely prediction of the possible occurrence of storage losses can help in reducing them. Researches have been conducted on development grain monitoring systems ranging from basic temperature sensors, all the way to embedded E-nose (De Lacy Costello, Ewen, Gunson, Ratcliffe, & Spencer-Phillips, 2000; Deshpande, Shaligram, Botre, Bindal, & Sadistap, 2010) [6, 8] and Micro Electro Mechanical System for handheld devices(Pérez-Marín, Paz, Guerrero, Garrido-Varo, & Sánchez, 2010) [26], by deploying them on storage location and comparing the collected dataset to check if the threshold for safe storage is being exceeded (Luthra, Shafiekhani, Stephens, Sadaka, & Atungulu, 2019; Muthukumar, Sherine Mary, Kamali, Kavva, & Ramyadevi, 2018; Shilpa & Sheeba, 2018) [19, 24, 29]. Wireless sensors have proven to be very helpful in places where cabling cannot be done(Løkke, Seefeldt, Edwards, & Green, 2011) [17]. Deployment of sensors range from silos (Mabrouk, Abdelmonsef, & Toman, 2017) [20] to grain bag (Ward & Davis, 2013) [31] but most are deployed in the room of storage for sensing temperature and humidity gradient. While the data monitoring and control could be performed using PLC (Kalaivani, Anjalipriya, & Surendar, 2012) [15], which is mostly applied for smart godown systems and automated silos, the remote control of data monitoring could be achieved by technologies such as GSM (Anil Kumar et al., 2018) [2] and Internet of Things (IoT) (Xu, Zhang, & Yang, 2012) [32]. The main advantage of IoT is that smartphones could be used for controlling IoT devices (Gargelwar Sunil V Kuntawar, 2019) [13]. This enables ease of access to users without implementing any additional infrastructure. Such online monitoring systems can reduce human interference and saves time and resource. Sensors that can enable the same are highly valued. The value of an information lies in the kind of decision making it leads to (Niyato, Lu, Wang, Kim, & Han, 2016) [25] – in this case, timely monitoring and warning of the deterioration in the stored products can help reduce post harvest losses. Most of the researches undertaken in examining post harvest losses study the storage practices and the technology used for betterment in storage (Abdoulaye et al., 2016; Bendinelli, Su, Péra, & Caixeta Filho, 2020; Gangwar, Tyagi, Kumar, Singh, & Singh, 2014a; Long & McCallum, 2015; Sharma & Singh, 2011) [1, 4, 12]. This is why use of sensors at the storage level is of high importance.

Paddy production and food grain management system in India

The global rice production stands at 497.9 million tonnes (projected value) (Childs & Skorbiansky, 2017) [5]. India is the second largest consumer of rice in the world succeeding China. Rice is a major staple food of the subcontinent of India, especially in its eastern and southern states. As of March 2019, the production of rice in India stands at 115.60 Million Tonnes (MT), out of which 10.57 MT is being exported and 26.39 MT ends up in the stock in the central pool. This leaves with 101.43 MT available for domestic consumption (Department of Agriculture Co-operation & Farmers' Welfare, 2019) [7]. India is a highly biodiverse in terms of climatic and soil conditions. Hence the variety and yield of rice varies from region to region. Major states of rice production are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab and Tamil Nadu. Figure 1 shows the production of rice in major states of India during 2017-2018.The entire nation was divided into 3 major zones based on geography and climatic conditions – South, North-East and North West. The south zone is characterised by heavy summer and scanty monsoons (in the plains). The north east is characterised by mild summer and heavy monsoon while the North West experiences mild summer and heavy winter. The temperature and humidity of these region differ accordingly. In 2018-2019, India ranked second on global level in rice consumption with 100 Million Metric Tonnes (Shahbandeh, 2020) [27] which highlights the importance of rice in India. It is estimated that around 12 to 16 million metric tonnes of food grains are lost each year in India due to post harvest losses. As per the stipulation by the World Bank, the lost amount of grains could feed one-third of India's poor and amount to Rs. 50,000 crores each year (Singh, 2010) [30]. Approximately, INR 4000 crore worth grains are damaged annually as a result of improper storage and poor grain management. This is a loss that a developing nation such as India cannot afford. An increase by 60 % would be needed to meet the food demands of the rising population by 2050 (Gangwar, Tyagi, Kumar, Singh, & Singh, 2014) [12]. Rice is harvested in the form of paddy at the farm level which is then sent for traders who store it until the millers mill the paddy into rice which is then sent back to the traders for storage until distribution.

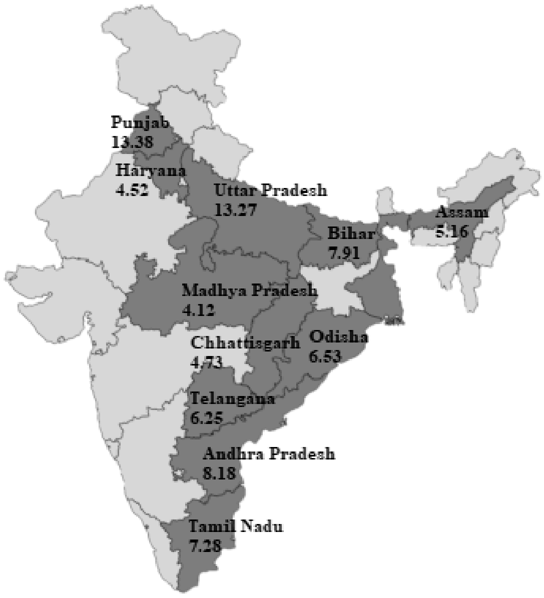

Fig 1: Production of rice in major producing states during 2017-2018–Data Source: (Directorate of Economics and Statistics, 2019) [9]

Note: The values are represented in units of Million Tonnes

Paddy production is not uniform in all Indian states and so is the consumption. Hence, India has a decentralised system of food grain distribution maintained by the government of India. There are states which produce surplus of what they consume and states which are deficit in production but high in consumption of rice. Based on these production and consumption trends of the states, the Food Corporation of India (FCI) has divided the states into two categories – Procuring states and consuming states. Procuring states are the ones which produce paddy in surplus and the consuming states are the ones with the deficit of paddy. The grains are procured from the procuring states by the FCI into the central pool and transported to the consuming states from where it reaches the public through Targeted Public Distribution System (TPDS) and Other Welfare Schemes (OWS). The TPDS benefits 160 million households by enabling them to purchase their grains on a subsidized price through a network amounting to 50,000 ration shops, also termed as the fair price shops (Ministry of Consumer Affairs Food and Public Distribution, 2011). The paddy once harvested undergoes threshing and winnowing after which it is stored at the farm level. It varies with different regions and the holding level of the farmer as to how much of the harvested paddy is stored at the farm level. The paddy intended for immediate marketing is taken to the Direct Purchase Centres (DPC). These DPCs hold the paddy for a very short time of 2 to 3 days before it is transported to the State Civil Supplies Corporation godowns. The statewise storage capacity of godowns are depicted in figure 2. The paddy spends up to 6 months in the godown and further transported to the rice mill where the drying, dehusking and polishing takes place. The milled rice is transported back to the godown where the rice is stored until further distribution through the distribution centres according to the order of the government.

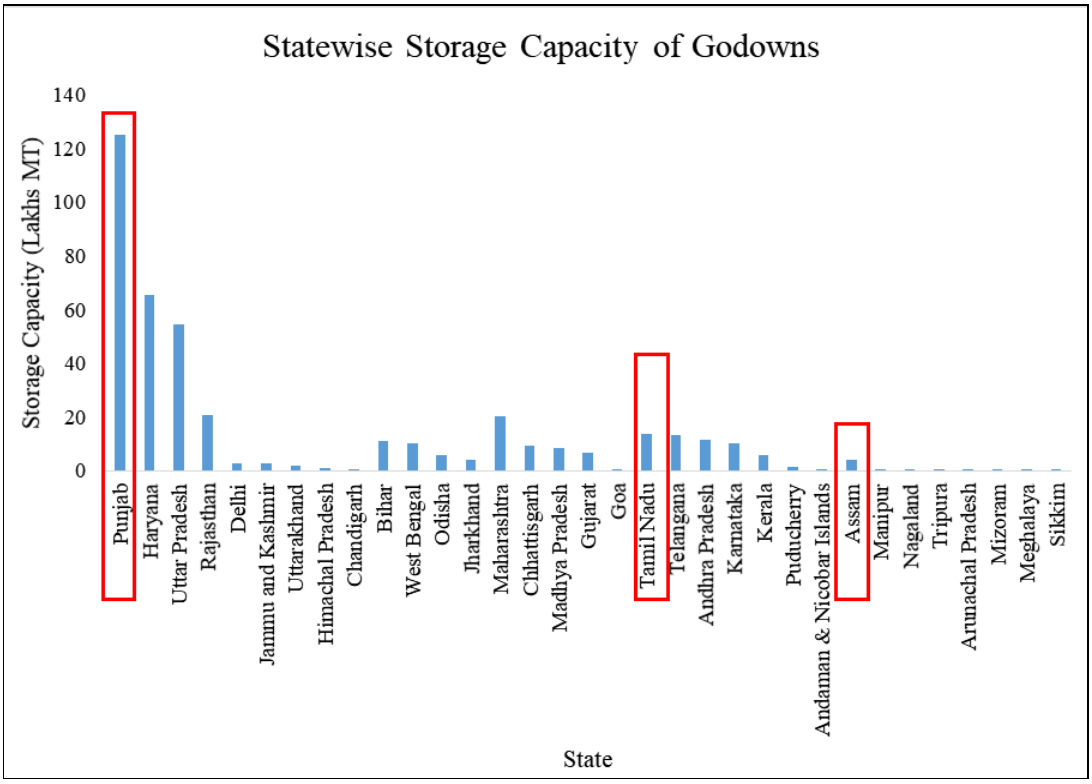

Fig 2: State wise storage capacity of godowns (FCI, 2020) [10]

The trader section includes both public and private sector key players. Apart from distributing to the public each season, the government maintains a buffer stock for reserve purposes. This is achieved by the government by buying more than the market demands. A portion of the surplus goes to the stock. Typically, one third of the total production of grains are usually bought by the government each year. The aim of the buffer stock is to be used to regulate the pricing of grain during the times of deficit supply. Besides, it helps towards achieving a level of independence in grain trade so that the nation cannot be held ransom by stoppage of trade during the deficit times. This stock increases the fiscal burden due to low purchasing prices by the government, hence losses in grain within this stock is highly undesirable given that it is used for emergency purposes.

Feasibility of using sensors

Sensors have been used in India for temperature indication and control. While the use of sensors have been limited to that of private stakeholders in agriculture and food processing, India is a country where the public sector's grain management system reaches the majority of population. Paddy mainly passes through three sub groups in the grain management system – Farmers, Traders and Processors. A feasibility study has to be conducted before deployment of sensors at these different levels. Every aspect including the area of cultivation, levels of storage, conditions of storage, cost involved at each level and conditions of power and internet supply in various locations within the country has to be studied through an ecosystem survey which forms the aim of the current study.

Materials and Methods

Selection of representative states

Considering the ease of accessibility, rice production and major trading centres, one representative state was selected from each region – Tamil Nadu to represent the south, Assam to represent the north east and Punjab to represent the north west. These states were found to be abundant (compared to their respective regions) in production and storage of rice (refer figure 1 and 2).

Sample size and data collection

Participants were divided into three categories – farmer, trader and processor. Farmer category consisted of personnel who exclusively dealt with the crop production and preliminary marketing for their produce. The traders buy from the farmers or any middle men who buy from the farmers and store the produce pre milling (in the form of paddy) and post milling (in the form of rice). Processors are millers who mill the paddy to obtain rice. The participants were selected by simple random sampling on an unbiased basis with a sample size of 30 participants under each category. Data was collected on the basis of a structured interview with the participants, which consisted mostly of close ended objective questions to ease the process for the participants. The interview schedule also was prepared in a customised way according to the category it dealt with – hence three different schedules were prepared.

Data analysis and representation

Data was stratified and categorised based on discretion and presented in the form of percentages and the data that are in ranges are presented as box and whiskers plot to depict distribution pattern of data where necessary. Boxplots are used for displaying data distribution in a standardised way as a five number summary.

Economic feasibility study

The economic feasibility was studied by analysing the weighing the cost that occurs on installation of sensors and how it could affect the profitability in each category. This was achieved using an F test which involved considering factors that are illustrated in figure 3. The outermost ring in figure 3 shows the three sectors considered for study – farmers, traders and processors. The next inner circle shows the factors considered to calculate the profit with and without sensors.

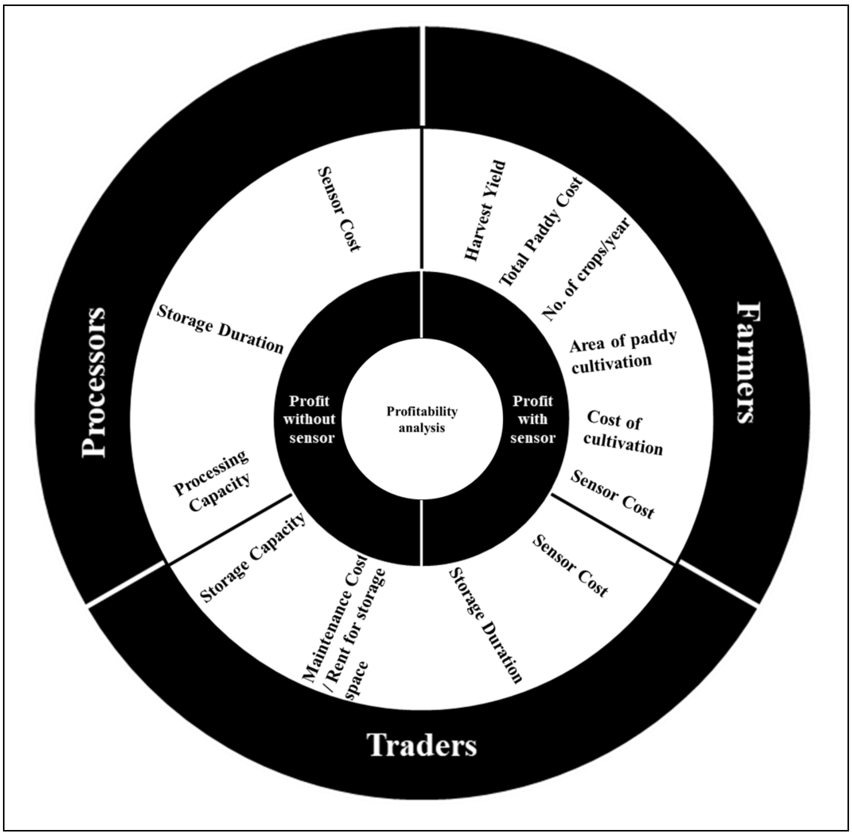

Fig 3: Factors considered for profitability analysis

Results and Discussion

Farmers

Area of paddy cultivation of the farmers of each region were assessed and categorised into small, medium and large. Small area of cultivation corresponds to less than 5 acres of paddy cultivation, whereas medium corresponds to 5 to 10 acres and large corresponds to more than 10 acres of paddy cultivation. Figure 4 depicts the box plot of Location Vs Area of Paddy cultivation.

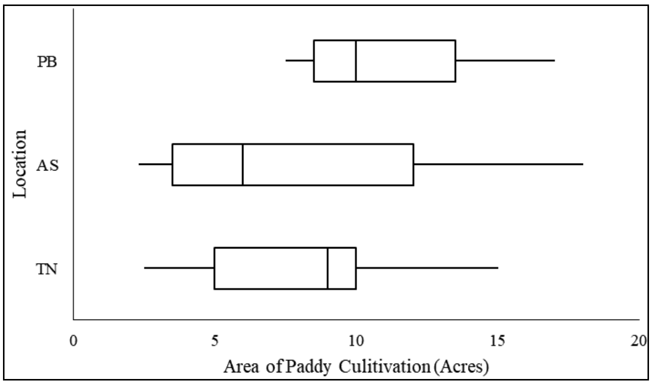

Fig 4: Box plot of Area of paddy cultivation at different locations

The survey findings, as depicted in the boxplot, pointed out that most of the farmers fall under the medium category with 60 % in case of Tamil Nadu (TN), 55 % in Punjab (PB) whereas in Assam (AS), the categories were equally distributed with 33.33 % in each category. Large category farmers were more in case of Punjab with 45 %. But when it comes to average farm holdings, all three locations have moreover similar results with 3.34 ha in TN, 3.07 ha in AS and 4.5 ha in PB. Paddy is harvested mostly in Kharif season in TN and mostly in the Rabi season in PB, whereas it is harvested in both Kharif and Rabi seasons in AS. Harvesting is done mostly using the machineries rather than manual in all 3 locations. While the AS farmers delivered their harvest mostly to DPC, it was mostly delivered to non DPC centres and to both in case of PB. Figure 5 depicts the boxplot for quantity of grains stored for seed purpose at different locations.

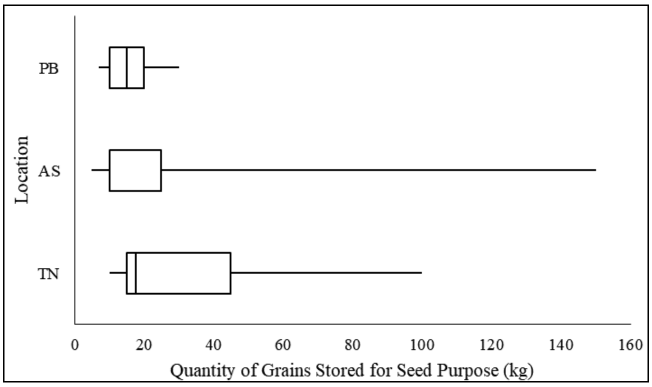

Fig 5: Boxplot for quantity of grains stored for seed purpose at different locations

Grains are stored at farm level by only 30 % of farmers in TN, but 80 % of AS farmers store grains at farm level but not much in the case of PB and the storage is mostly for personal consumption and seed purpose. As depicted in the boxplot, most of the storage is done below 50 kg (for seed purpose). The study by (Hosakoti, Dolli, Hiremath, & Angadi, 2013; Mobolade, Bunindro, Sahoo, & Rajashekar, 2019) [14, 23] inferred that the farmers store their produce for reasons such as personal consumption, for seed purpose and future sales. An average of 34 kg/tonne is stored for seed purpose in TN, 37 kg/tonne in AS and 16 kg/tonne in PB. Storage structures are made of paddy/straw in TN (nelpattarai) and in bharols made of bamboo and wood in AS with capacity ranging from 5 to 100 quintals. The storage duration ranges from 30 to 180 days as depicted in figure 6. It depicts that most of the farmers stored the grains for less than 100 days.

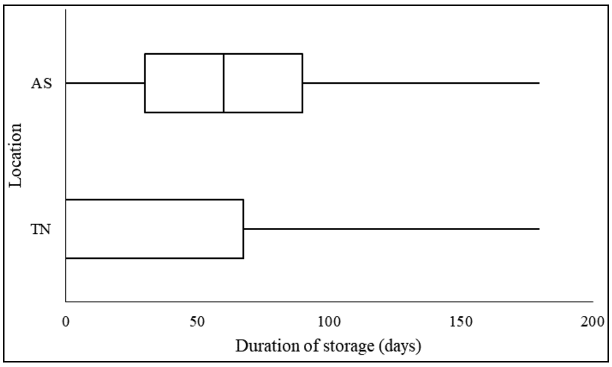

Fig 6: Boxplot for duration of storage of grains on a farm level at different locations

The farmers of AS dry the paddy at farm level to bring down the moisture content to less than 15 %. All farmers responded that major loss in grains was due to moisture imbibition upon climatic changes besides pest infestation. Power supply was available 24 X 7 for 70 % of farmers in TN, 22 % in AS and 27 % in PB. Internet facility (through mobile phones) were available for all respondents in AS and PB but only for 60 % in TN.

Traders

All traders participated in the survey stored raw rice in their storage facility. The duration of storage at different locations is depicted as box plot in figure 4. Most of the traders in AS and PB stored from 90 to 180 days whereas majority portion of TN traders stored to a month although a few stored from 90 to 180 days. This is shown clearly in figure 7.

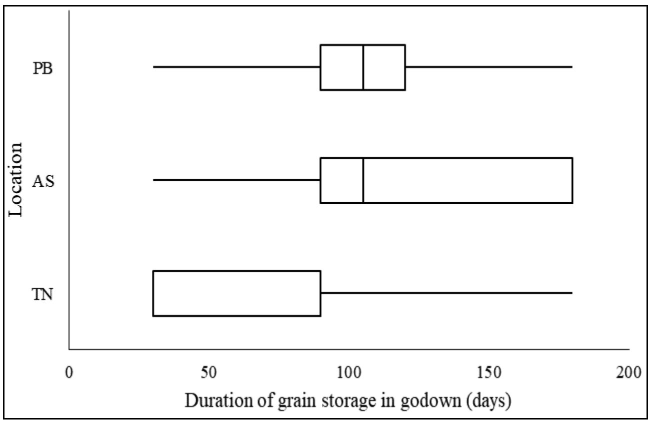

Fig 7: Boxplot for duration of storage of grains in godowns at different locations

CAP storage was not encouraged in AS and PB owing to their rainfall and winter condition but in TN nearly half of the stock was stored in CAP storage with the remaining stored in godown structures.

Large godowns with an average capacity of 50671 MT were found in PB which were much larger than the ones in AS and TN. The high storage temperature of TN (29.9 °C average) enabled the grains to be stored at 12 % moisture content (average w.b.) whereas the average moisture content at AS and PB were at 14 % approximately. Power supply was available on a continuous mode for all traders as was the internet connection. About 20 % of them even had Wi Fi setup at their facility. While most of TN and PB traders deliver their stored grains to market or millers, AS traders deliver an equivalent share of grains with PDS too along with market and millers. To be clear on the aforementioned statement, milled grains are transported to market or PDS while grains to be milled are transported to millers, also termed as processors in our study, for milling and further sent back to traders for storage.

Processors

The paddy processing facilities were studied at all 3 locations and found that the average capacity of rice mill (tonnes/hour) was higher in TN when compared to that of AS and PB as depicted in figure 8.

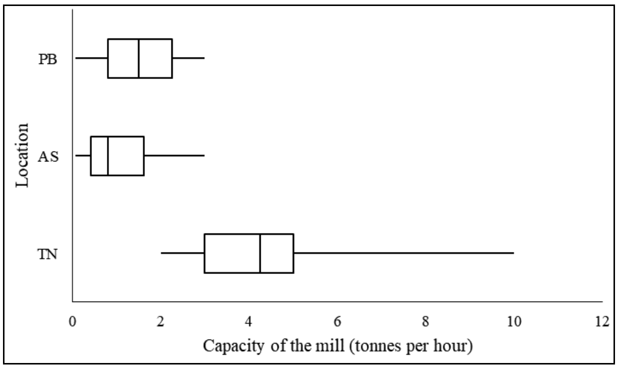

Fig 8: Boxplot for processing capacity of mills at different locations

Same pattern was observed in case of dryers. Processors stored grains for as less as a week to 10 days only because their stocks were always dynamic and were moved as soon as being processed. While the inlet moisture content of grains at TN were maintained at 14 ºC, it was at the range of 18 ºC in case of AS and PB. The outlet moisture content was maintained at 14 ºC for both AS and PB and at 12 ºC for TN. The drying duration at the processing facility ranged from 10 to 12 hours. Average milling yield from the processors stood at 67 % (67 kg rice from 100 kg paddy). Yield from smaller mills were low due to reasons such as small scale production, poor calibration and lack of maintenance. The same was pointed out by Kumar and Kalita, 2017. The types of equipments used at the facility were also studied. Vibratory air cleaners were used in most of the processing facilities, while only 39 % used hand operated screen cleaners for pre cleaning purpose. Grading was done mostly using intended cylinder separator and a few facilities used disk separator. Destoning was performed using pneumatic and aspirator separators. Dehusking was carried out mostly using rubber roll sheller in TN and AS, whereas PB processors used pneumatic rubber roll shellers.

Grains were separated using compartment type paddy separators and very few used tray separator for the same purpose. Most of the processors used emery scourers for polishing rice, while few used cone polishing or rubber polisher for the same. While whiteners were not used by most of the processors, few used jet pearler or vertical whitening cone for the purpose. The grading of milled grains were done using oscillating grading sieves in TN and rotating intended cylinders in PB. While colour sorter were not used by most of the processors in AS, optical sensor type sorter were used in both TN and PB.

Cost analysis involving sensor usage

In case of farmers, the harvest yield in tonnes per acre and area of cultivation in acres was obtained from survey findings. The net profit was calculated from the paddy selling price and cost of cultivation per acre. The sensor preference cost was suggested by the survey participants of all 3 sectors (farmers, traders and processors). Considering the cost of sensors within profit gives the net profit when sensors are used. The variances among the net profit with and without sensors were analysed using F test which are tabulated in Table 1.

Table 1: F-Test Two-Sample for Variances

Farmers		
	Net profit with sensor cost	*Net profit*
Mean	78472.45667	162820.8933
Variance	6506388366	6251433689
Observations	30	30
Df	29	29
F	1.040783393	
P(F<=f) one-tail	0.457511411	
F Critical one-tail	1.860811435	
Traders		
	Net cost	*Net cost with sensor*
Mean	699931000	641515626.7
Variance	4.66378E+18	4.05932E+18
Observations	30	30
Df	29	29
F	1.148904404	
P(F<=f) one-tail	0.355542496	
F Critical one-tail	1.860811435	
Processors		
	Net cost	*Net cost with sensor*
Mean	542800000	11805629.33
Variance	1.48066E+17	7.55242E+13
Observations	30	30
Df	29	29
F	1960.513948	
P(F<=f) one-tail	7.08705E-41	
F Critical one-tail	1.860811435	

The F value being less than the F_{crit} value points out that there is no significant difference in variance which shows that usage of sensors will not affect the profit of farmers. In case of traders, the storage capacity of the godowns and the cost involved for storing per MT of produce was considered for calculating the total cost involved in storage. The cost of sensors when reduced from this cost gives the net cost on usage of sensors. F test was applied similar to that case of farmers and similar results indicate that usage of sensors would not affect the variance in cost involved for storage of grains. In case of processors, cost of processing on a monthly basis and the cost of sensors were considered to calculate the cost of processing with usage of sensors. In this case, the F value being much bigger than the F_{crit} value shows that the usage of sensor affects the cost involved. Moreover, the milled grains are stored for very short duration only. Hence, the usage of sensors are not economically feasible for the processors, but it doesn’t affect the total cost for farmers and traders. Considering that traders store the produce the longest, sensors suit the trader storage condition the most although it could be applied to farmer storage structures too.

Conclusion

Rice is one of the prime and staple crops of the Indian subcontinent. While the nation stands second in the global production of rice, the production is not evenly distributed within the country. Owing to the diversity in agro-climatic conditions throughout the country, some states produce in plenty whereas the others produce scantily. The study throws light on the feasibility of usage of sensors to prevent postharvest losses in farming, trading and processing levels and their economic impact. Punjab not only had the highest production among the selected representative states, but also had most them being large category farmers while Tamil Nadu and Assam had medium category farmers. But Punjab farmers had lesser on farm storage when compared to Tamil Nadu and Assam.

The farmers stored for less than 100 days, while traders stored up to 180 days and processors stored up to 10 days. The traders mostly relied on the godown storage and had a stable power supply and internet access when compared to the other categories. The processors had a very dynamic stock and cleared them on processing and this is why the average duration of stock was very low in case of processors. The cost analysis applied to the three sectors pointed out that the usage of sensors brings only a non-significant difference to the total cost for farmers and traders, but affects the processors. The traders and farmers store produce for a much longer time than the processors, hence the usage of sensors is economically feasible for them.

Acknowledgement
The authors acknowledge the Food Corporation of India and Central Warehousing Corporation of India for providing their infrastructure for carrying out the research work. The authors also acknowledge the Director, IIFPT, for the technical support and providing infrastructure to carry out this research work.

Funding
This work was supported by the Department of Biotechnology under the Ministry of Science & Technology, Government of India under Indo-UK collaborative research - Newton Bhabha Fund.

Conflict of Interest
The authors have no conflict of interest to declare.

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