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MANAGEMENT OF RICE RESIDUES AFTER HARVESTING: A REVIEW OF MECHANIZATION STATUS, OPPORTUNITIES, AND STRATEGIES

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Abstract
Rice crop residues systems are a very dominating system of India. Crop residues are the byproduct of crop production, management of crop residue as a well-known practice related to key component of conservation agriculture. The paddy straw harvesting problem is solved with a baler carried by a 30-HP tractor, which also has a collection capacity equal to five persons. Consequently, the volumetric weight of mechanically compacted straw bales is 50–100% higher than that of loose straw, reducing handling and transportation costs significantly. To enhance performance and minimize transportation costs, mechanized straw harvesting has become required. Paddy straw may be collected and compacted in a variety of sizes and densities with baling machinery. Paddy straw management must have improved significantly since the implementation of rice straw baler's. Mechanized rice straw collection and densification have enhanced the value chain and resulted in crop residue handling that is sustainable. This chapter discusses the various rice straw collecting systems, including their advantages and drawbacks, as well as opportunities for further densification to minimize transportation and handling costs. The benefits and costs of various mechanized straw collection and densification techniques are evaluated and built upon.

Keywords- Paddy Residues, Mechanized Machinery, Straw Baler's Etc.

Introduction

India's economy is based on agriculture. In its various agro-ecological regions, much of the land is used for farming, and a wide variety of crops are cultivated. According to the 2014-15 land use statistics, the total area is 328.7 Mha, the planted net and the plowed area are 140.1 Mha and 198.4 Mha respectively, with an investment rate of 142%. The net investment area accounts for 43 percent of the total area. A total of 68.4 Mha of land is irrigated. Total rice production for 2018-19, (MoA, 2019-20) is expected to be a record 116.42 Mt. This data is also an impressive 8.62 Mt than five years ago of 107.80 Mt. Wheat productions is expected to raise the record 102.19 Mt, up 2.32 Mt from last year's value 99.87 Mt. over a five-year average of 94.61 Mt. but both the bulk of the crop residues on and off the farm are bought naturally.

Indian agriculture currently produces 500-550 Mt of crop residues per year, with cereals and fiber crops accounting for 58% and 23% of crop residue, respectively. The remaining 19 percent of crop residue is made up of sugarcane, pulses, oilseeds, and other crops. However, a large portion of these crop residues, to about 90-140 Mt per year, are burned on-farm mainly to clear the fields in order to enable the planting of crop production (NASS, 2012). Mostly the farmers and their users use the crop residues as manure, soil mulching, animal feeding, fuel for domestic and industrial purposes etc.

Rice straw production is estimated to be 21 Mt per year, to up to approximately 5% used as cattle feed, 2% used to develop farm structures, 5% used as a raw material for making paper and cardboard, and 7% used as packaging material for horticultural crops and goods like chinaware (Sehgal et al 1999). Due to the low temperatures and limited time between rice harvesting and wheat sowing, incorporating rice straw before wheat planting is challenging. Because it is a quick and easy method of disposing of paddy straw, approximately 70-75 percent of straw is burned in the fields to ensure that the wheat crop is sown on time. By burning one tonne of paddy straw, approximately 400 kg organic carbon, 5.5 kg nitrogen, 2.3 kg phosphorus, and 25 kg of potash and 1.2 kg of sulfur were lost (Anon 2014).

Plate 1 Burning of paddy crop residue.

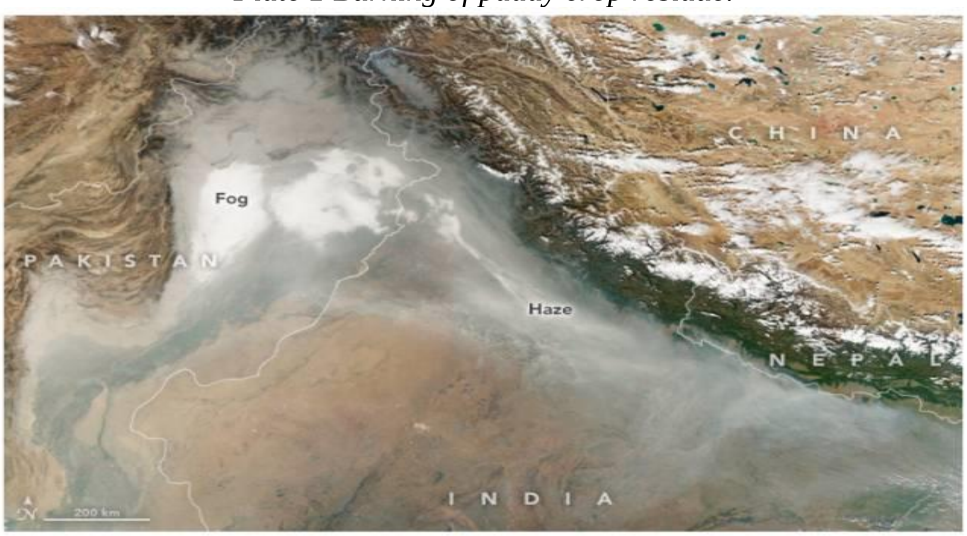


Plate 2 *NASA Earth Observatory image of fog and haze distribution over the Northern States of India on 8 November 2017*

Managing crop residues with conservation agriculture

In the last five decades, Indian agriculture has made significant progress. However, it has been facing a number of challenges in recent years, including a stagnating net sown area, a decrease in per capita land availability, the effects of climate change, and a reduction in land quality. The root cause of agricultural land degradation is low soil carbon content, which disrupts many important soil-mediated ecosystems. Conservation agriculture, which adheres to the three core interconnected principles listed below, is a viable option for sustainable agriculture and an effective solution to land degradation (Kassam, 2011).

- To improve soil organic matter content and soil health, minimize mechanical soil disturbance, and seed directly into tilled soil.
- Cover crops and/or crop residues can be used to increase soil organic matter cover. This protects the soil surface, conserves water and nutrients, encourages soil biological activity, and helps with integrated pest management.
- Crop diversification in associations, sequences, and rotations to improve system resilience.

Status of Farm Mechanization

The Indian agricultural equipment market is booming, with plenty of room for future expansion. Agricultural machinery demand in the Asia-Pacific region was more than double that of any other region. In Asia-Pacific region, India has remained one of the primary nations which fuelled the growth of the market for tractors, power tillers and agricultural equipment. Tractor and power tiller the sale of tractors in India has grown at a CAGR of 10.64 % from 217,456 in 2001-02 to 661,431 in 2012-13 during the last 11 years. The 23-30 kW tractor segment has traditionally dominated the Indian tractor market. Based on density and productivity in major states of India is shown in Fig. 4. The lines of average tractor density (33 tractors/1000 ha) and average food grain productivity (2.06 t/ha) are superimposed on Fig. 4 to divide these states into four categories i.e., high tractor density and high yield, high tractor density and low yield, low tractor density and low yield and low tractor density and high yield. The first category was of high tractor density and high yield states of Haryana, Punjab, Tamil Nadu (TN), Uttar Pradesh (UP) and Andhra Pradesh (AP). These states made the most of their tractor power in order to boost productivity. The second category is low tractor density and high yield states such as West Bengal (WB) and Kerala. This indicated that these states utilized more human and animal power sources than tractor power source. The third category is high tractor density and low yield states of Bihar and Gujarat. This may be because of lack of awareness on agricultural machinery and tractor usage. The fourth category is of low tractor density and low yield in eight states of Assam, Himachal Pradesh (HP), Odisha, Maharashtra (MH), Jammu & Kashmir (J & K), Madhya Pradesh (MP), Rajasthan (RJ) and Karnataka. This may be due to resource poor farmers and low farm power availability in these states.

Table 1 Market Overview of the major farm machinery used in India

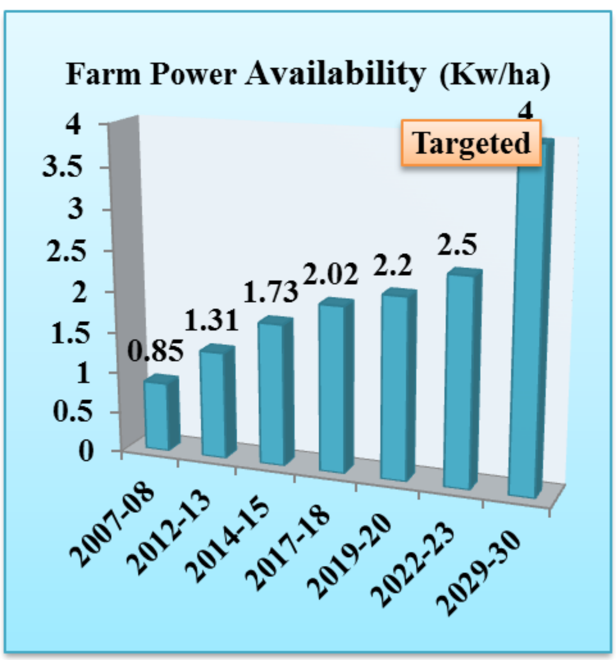
Name of machinery	Market size annually	Cost, US $
Tractor	600000	7,000-12,000
Power tiller	56,000	2100
Combine harvester	4000-5000	22000-5000

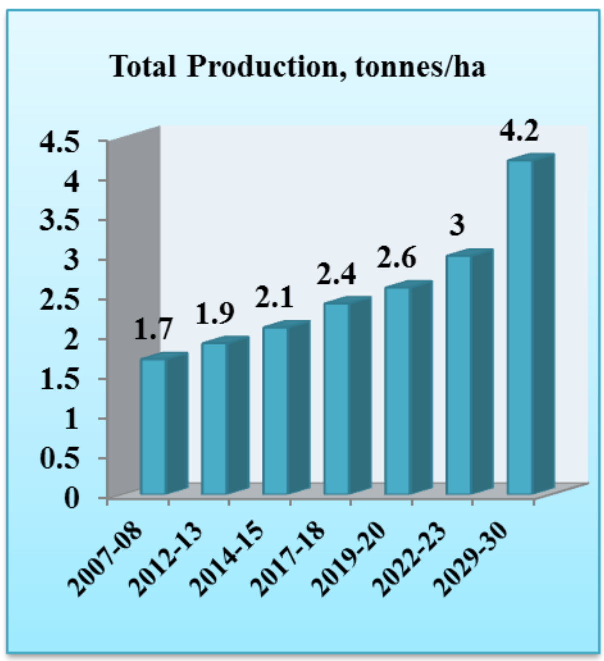
Thresher	100000	1600-2500
Rotavator	60000-80000	1300-2000
Self-propelled vertical conveyor reaper	4000-5000	1300-2000
Zero till seed drill	25000-30000	750-850
Multi-crop planter	1000-2000	850-1000
Laser land leveller	3000-4000	5800-6500
Power weeder	25000	8500

Source: *Status, Challenges and Strategies for Farm Mechanization in India by (CR Mehta 2014)*

Farm power availability

Agricultural productivity has a favorable relationship with farm power availability in terms of automation to increase output. India has been effectively automated in order to get the crucial inputs for agricultural modernization. High levels of mechanical power and improved equipment have enabled places like Punjab, Haryana, and the west part of Uttar Pradesh to accomplish it. The average agricultural power availability in India has grown over the previous 62 years, from around 0.30 kW/ha in 1961–62 to roughly 2.50 kW/ha in 2022–23, with a target of 4.0 kw/h in 2030. It is also planned to enhance production by 4.2 t/ha. While biological sources of power provided 24.80 percent of agricultural power in 1961-62, their contribution is expected to increase to around 92.30 percent in 2021, with mechanical and electrical power sources increasing from 7.00 percent in 1961-61 to nearly 91 percent in 2021.





Opportunities for Mechanization technologies practices for paddy straw collection

Traditionally, tools such as rakes or makeshift sticks are carried on a canvass for handling or rice straw is collected by hand after harvesting (fig.3).This method is very laborious and takes a lot of time to handle the straw from the harvested area. Because balers (fig. 4) are mechanized, the more efficient time-wasting, the fewer people are required to handle the loose straw from the paddy field. Collection of paddy straw is a major challenge once it is gathered from the field in the paddy straw supply chain. Round and square bundles of rice straw need to be compressed into small compact bales to easily reduce the cost of transportation. In combine harvested paddy fields, the introduction tends to leave the rice straw in the field and collecting it becomes very harder and expensive.

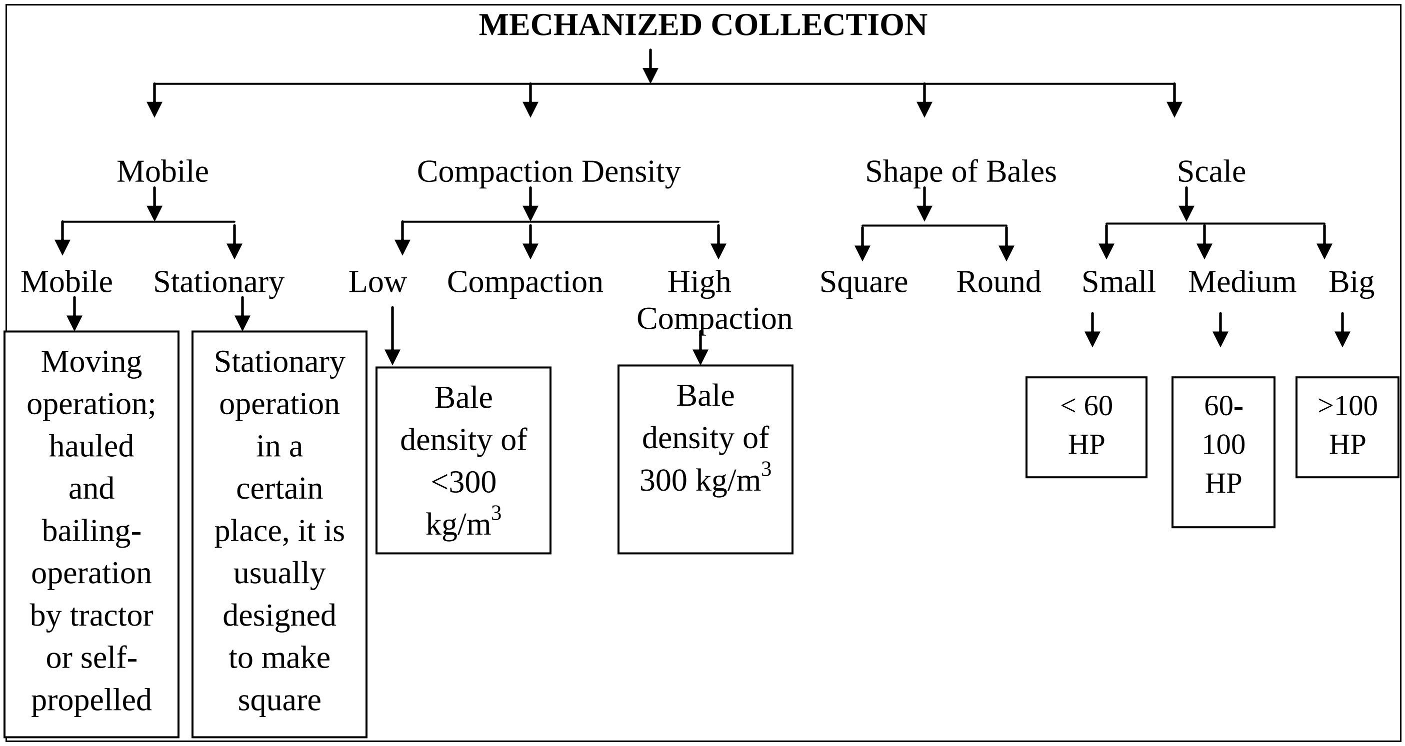


Fig 3 Manually collecting the paddy straw after harvest paddy field

Fig 4 Mechanized paddy straw collection with a tractor drawn round and square baler From harvest paddy field

In 2016, we studied the collecting of straw in the Mekong river delta of Vietnam to perform performance evaluation and demonstration of the straw machines. This study included three types of machinery, such as a tractor-operated pull-type roller baler (fig. 5).A self-propelled baler (fig. 6) and another self-propelled loose straw-gathering straw bales (fig. 7) collect and transport the bales of bund to separate operations. These front two machineries are different from this baler. The self-propelled machines bale and also bring the baled straw to the bund. The gathering machine only collects the loose straw but does not bale the straw.

Fig. 5 Tractor-Operated Pull-Type Roller Baler	Fig. 6 Self-Propelled Baler	Fig. 7 Self-Propelled Loose Straw-Gathering

Off- field paddy straw management

Utilization, collection and storing of paddy straw is increasing due to the development of technologies for removing it from the fields to be used for resource-full purposes such as mushroom cultivation, cattle feed and energy production under improved management practices. The cropping system of rice to identified with the use of high-yielding and less time varieties with less time required for multi-cropping systems. In combined harvested paddy field larger amount of straw spread out in the field. The straw collected by manual from the field is unprofitable due to high labor cost. Every year the incorporation if paddy straw in soil poses challenges as two to three cropping system per year. Because insufficient time required for decomposition, and leaving the straw with poor properties of fertilizer for soil and handling to the crop establishment.

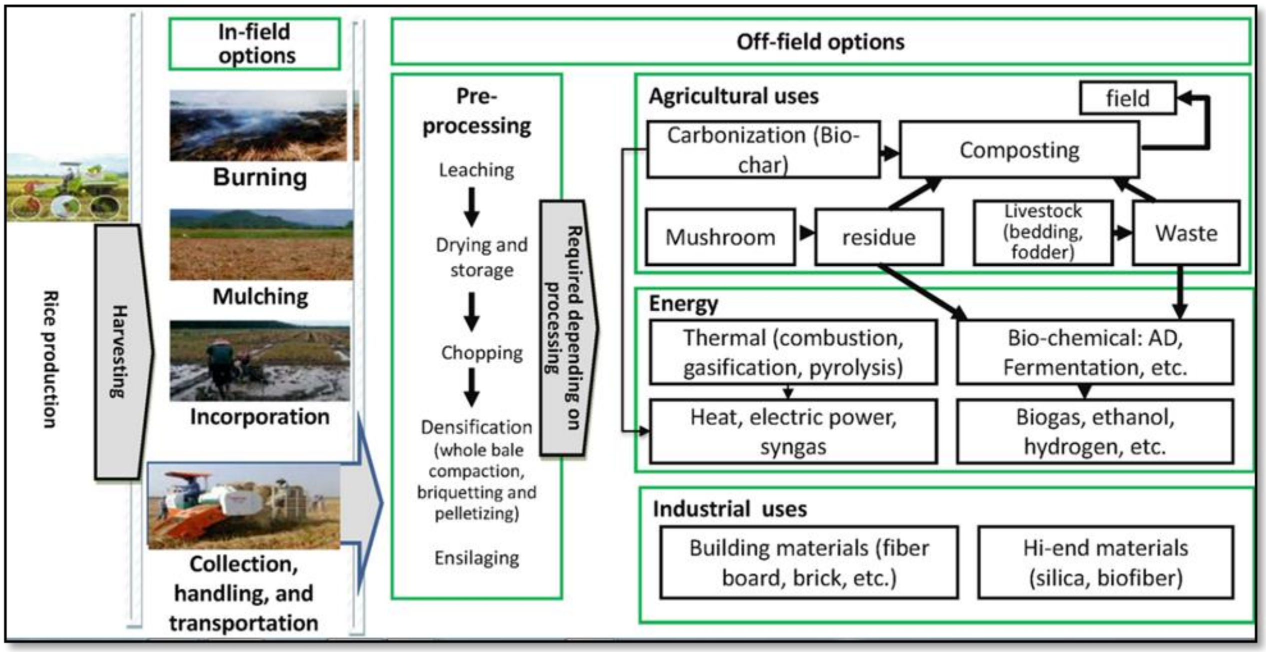


Fig 8 Rice –straw management option (sustainable rice straw management pp 1-13 by hung NV 2019)

Strategy for Mechanization of Indian Agriculture

Agricultural mechanization should contribute to sustainable increase in productivity and cropping intensity so the planned growth rates in agricultural production are achieved. Mechanization requires lots of cash, and our country has put lots of cash into it. Investing in mechanization might not yield the expected results if proper planning and direction aren't in situ. India adopts a policy of selective mechanization under diverse conditions, which makes the agricultural mechanization a challenging task. It’s necessary to adopt appropriate mechanization technology that's tailored to the wants of farmers. This may be accomplished by following the rules outlined below.

1. The widely fragmented and scattered land holdings in many parts of the country have to be consolidated (virtual or real) to allow access for his or her owners to the advantages of agricultural mechanization.
2. There’s a desire to own more interaction among the farmers, research and development workers, departments of agriculture and industry to create farm machinery research and development base stronger.
3. To attain higher production levels, the standard of operations like seedbed preparation, sowing, application of fertilizer, chemicals and irrigation water, weeding, harvesting and threshing will should be improved by using precision and efficient equipment.
4. The rice transplanting operation will be mechanized by introduction of self- propelled walking type rice trans planters on small and medium land holdings. The riding type rice transplanted could also be introduced on large size land holdings on custom hiring basis (Mehta and Pajnoo, 2013).

5. The advantages of agricultural mechanization should be extended to any or all categories of farmers with due consideration to small and marginal farmers, to any or all cropping systems including horticultural crops and to all or any regions of the country especially the rain fed areas.
6. There's a requirement to innovate custom service or a rental model by institutionalization for top cost farm machinery like combine harvester, sugarcane harvester, potato combine, paddy transplanter, laser guided land leveler, rotavator etc. and may be adopted by private players or State or Central Organizations in major production hubs.
7. The high capacity rice combines is also introduced to paddy growing areas on custom hiring basis. It will help in timely harvesting and better yield of paddy crop.
8. Medium and enormous scale farmers is also given Govt. subsidies to encourage them to shop for and to use advanced medium and high size machinery like cotton picker, rice transplanter, sugarcane harvester and mix harvester on their fields (Mehta and Pajnoo, 2013).
9. The farm machinery bank could also be established for machines being manufactured elsewhere within the country and provide to users/farmers on custom hiring mode.
10. Provision could also be made for special credit support at lower interest rates to rural individuals, venturing into entrepreneurial use of farm machinery through custom hiring (Mehta and Pajnoo, 2013).
11. Manufacturing units that are set-up in areas with lower mechanization must be supported by extending tax and duty sops. This might lead to easier reach of the equipment to farmers in those areas (Mehta and Pajnoo, 2013).
12. There's a requirement for quality manufacturing and after sales support for reliability of farm machinery. This could be achieved by streamlining of testing procedure, training of engineers and conducting testing of farm equipment for standardization and internal control in farm equipment manufacturing.
13. There's a necessity for strengthening training programmers at various levels and for various categories of individuals on operation, repair and maintenance of agricultural machinery, tractors, power tillers, rice transplanters, combines etc. and for transfer of technology.
14. The standard of life and work environment of farmers/farm women have to be improved. Their work involves considerable drudgery and discomfort. Agricultural equipment should be designed with proper ergonomics in mind, including the most recent safety features and "comfort features."

Conclusion

Global warming, groundwater depletion, declining soil health, air pollution, changing weed flora, insect infestations, and stubble burning are a few issues that rice-wheat farming methods have brought about in India. Due to its low economic value and the short time between rice harvest and wheat sowing, farmers sometimes resort to burning the residue of mechanically harvested rice. In India, during the months of October and November each year, there is a rise in particulate matter and emissions of greenhouse gases, which is a clear indication that stubble burning worsens soil health, increases air pollution, and poses major health risks, including respiratory infections and heart disorders. To improve nutrient availability, preserve moisture, and reduce weed density, technological measures have been promoted to mulch or integrate residue into the soil. These eco-friendly solutions benefit farmers by improving crop yields and profitability while reducing the adverse environmental impacts of burning leftovers. Farmers are also encouraged to use ex-situ management of rice wastes, such as charcoal, energy, biofuel, and bales. While certain ex-situ management systems still require improvement, they

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have favorable economic and environmental effects. Future residue burning can be reduced in three ways: by avoidance, awareness, and adoption. Farmers have the choice of not growing rice and using a more varied agricultural method. Due to the unstable economy and absence of controlled markets for other crops, this is improbable. There is a need for rice varieties with a high harvest index, and farmers should be encouraged to adopt them through extension. To increase awareness, show their operational viability, and alter farmers' conventional perspectives, technological interventions with economic advantages must be developed and made available to them. Another alternative is residue bio-decomposition, although there is not enough information to make any judgments.

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