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Extent of Farm Mechanization in North Bank Plains Zone of Assam, India

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Abstract

The study was conducted from April, 2022 to March, 2023 in the North Bank Plains Zone (NBPZ) of Assam, India to assess the extent of mechanization and its impact on crop production. Among the six (6) districts of North Bank Plains Zone of Assam, three districts viz., Lakhimpur, Sonitpur and Darrang were selected randomly. Mechanization Index (MI) values were calculated for three key crops: sali rice, toria, and potato. Among these, potato had the highest MI (84.87%), followed by sali rice (74.65%) and toria (51.29%). Most farmers (72%) were classified under the medium mechanization category, indicating a moderate adoption of agricultural machinery. Mechanization significantly improved cropping intensity, which rose from 131.42% to 140.93%, an 8.45% increase, highlighting more effective land utilization and higher productivity. Additionally, mechanization reduced labor intensity, increased operational efficiency, and enhanced yields across crops. However, the adoption of mechanized technologies was not without challenges. Farmers faced high fuel costs, inadequate access to machinery during peak agricultural seasons, and a shortage of skilled personnel for machine operation and maintenance. Furthermore, frequent machinery breakdowns, often attributed to poor quality, disrupted farming activities and escalated costs. To address these challenges, the establishment of additional custom hiring centers (CHCs) was recommended. These centers would enable farmers to access high-quality machinery at affordable rates, minimizing delays and operational costs. Furthermore, training programs for operators and regular maintenance support at CHCs could alleviate technical difficulties. By addressing these constraints, mechanization can be effectively scaled, ensuring increased productivity and fostering sustainable agricultural development in the NBPZ.

Keywords: Farm power availability, mechanization index, cropping intensity

1. Introduction

Farm mechanization has seen significant growth among small farmers in South Asia, despite a positive correlation between farm size and mechanization levels (Ghosh, 2010; Van den Berg et al., 2007). India leads the region in mechanization (Aryal et al., 2021), driven by the development of locally manufactured machinery for small, fragmented landholdings (Sidhu et al., 2015) and the expansion of custom hiring services. These services enable farmers to access expensive machinery without owning it (Biggs and Justice, 2015; Zhang et al., 2017). Equipment such as laser land levelers, zero-till seed drills, threshers, and mini-tillers are widely rented, often by smallholder owners who also generate additional income through rental services (Baudron et al., 2015; Mandal, 2016).

Mechanization is increasingly recognized as a cornerstone for modernizing agriculture in India. It enhances productivity, efficiency, and income while addressing labor scarcity, a persistent rural challenge. Using machinery can save 20–30% time, 15–20% seeds, 20–25% fertilizers, and 10–20% labor, and increase cropping intensity by 10% (Singh, 2006). Studies highlight its benefits in reducing input costs, boosting yields, and saving labor compared to traditional methods (Kassie et al., 2011; Abid et al., 2016; Adu-Baffour et al., 2019; Yan et al., 2021).

Farm power availability in India has risen significantly, shifting from human and animal power to mechanical power due to labor shortages and the high cost of animal maintenance. Farm power increased from 0.28 kW ha^{-1} in 1960–61 to 2.10 kW ha^{-1} in 2013–14 and is projected to reach 5.17 kW ha^{-1} by 2032–33 (Tiwari et al., 2019; Mehta et al., 2023). While animal power contributed 69% of farm power in 1971–72, mechanical power now accounts for 95% of total availability (Bhandari et al., 2023). The Green Revolution accelerated mechanization, particularly in Punjab and Haryana (Singh, 2011). Mechanization's growth is shaped by institutional, environmental, and social factors (Daum and Birner, 2020). Custom hiring services and cooperative systems have advanced small-scale mechanization in South Asia (Aryal et al., 2019; Justice and Biggs, 2020). In Punjab and Haryana, commercialization has further spurred demand for labor-saving technologies (Soni and Ou, 2010).

Despite these advancements, mechanization in India has grown less than 5% in two decades. As of August, 2022, only 47% of agricultural activities are mechanized, lagging behind China (60%) and Brazil (75%) (Anonymous, 2022–23). The average farm power availability is 2.5 kW ha^{-1}, with a target of 4 kW ha^{-1} by 2030. However, significant disparities exist: Punjab has 6 kW ha^{-1}, while northeastern states like Assam and Mizoram have just 1.2 kW ha^{-1} and 0.7 kW ha^{-1}, respectively. Challenges in Assam include fragmented landholdings, financial constraints, and high transportation costs.

The Assam Agribusiness and Rural Transformation Project (APART), launched in 2016–17, addresses these challenges under its Component C. Initially targeting rice and potato, the program has expanded to crops like toria, maize, pulses, and vegetables. Demonstrations of mechanized practices have reduced labor costs, improved efficiency, and enhanced input use (Mehta et al., 2014; Barman and Deka, 2019). Custom hiring centers have provided smallholders access to advanced machinery, boosting productivity and income. Expanding mechanization to diversified crops under APART aims to enhance resilience and sustainability in Assam's agriculture. This study evaluates the impacts of farm mechanization in North Bank Plains Zone of Assam to guide further adoption and productivity improvements.

2. Materials and Methods

The present study was conducted during April, 2022 to March, 2023 in North Bank Plains Zone (NBPZ) of Assam, where World Bank aided-Assam Agribusiness and Rural Transformation (APART) project has been implemented by Assam Agricultural University. Among the six (6) districts of North Bank Plains Zone of Assam, three districts viz., Lakhimpur, Sonitpur and Darrang were selected randomly. KVK Lakhimpur, KVK Sonitpur and KVK Darrangwere selected and secondary data was collected from each KVK. A complete list of beneficiary farmers was prepared with the help of APART personnel. The farmer who received training and demonstrations from the respective KVKs under APART project with special reference to farm mechanization during 2020–21 were considered as respondents for the study. From Lakhimpur, a total beneficiary farmer list of 30; from Sonitpur, a total beneficiary farmer list of 40 and from Darrang, a total beneficiary farmer list of 30 was obtained. From the prepared list of 100 beneficiary farmers, finally all 100 beneficiary farmers were selected to constitute the total group of respondents for the present study. Data were collected and pooled for final analysis.

The extent of farm mechanisation was measured with the help of Mechanisation Index(MI) as suggested by Nowacki, 1974. Mechanisation Index represent the percentage of work(energy) performed by machinery to the total work performed by hand labor and machinery.

$$MI\ \% = \{M_{ET}/(M_{ET}+L_{ET})\} \times 100$$

Where:

MI=Mechanisation index

=Average sum of all mechanical operation work performed by the machines (kW ha^{-1})

=Average sum of all manual work done by labor (kW ha^{-1}).

Machinery input energy (kW ha^{-1}): Average energy input by motorized machinery was calculated as reported by OlaoyeandAdekanye (2014) by using formula

$$M_E = 0.2 \times T_P \times T_M$$

M_E=Average energy input per hectare by motorized machines (kW ha^{-1})

T_P =Average power of used machines (kW)

T_M=Rated working time (h ha^{-1})

2.1. Energy input of labor (kWh ha^{-1})

Number of working labours in each operation was considered. The average energy input of work provided exclusively by a labor per hectare was calculated as reported by (Bawatharaniand karunarachchi, 2017) as follows:

$$L_E = 0.1 \times N_H \times T_H / A$$

Where,

L_E=Average energy input or work provided per hectare by a labor (kW ha^{-1}).

0.1 = Theoretical average power of an average man working optimally (kW).

N_H=Average number of labor employed.

T_H=Average working time of manual operation (h).

A=Area of cultivated land (ha).

Impact of mechanization was measured in terms of change in area, change in production, change in productivity and change in cropping intensity, if any, on before and after mechanization.

In order to measure the change in area, change in production and change in productivity, each respondents were asked to tell regarding the area, production, productivity under sali rice, toria and potato crop in hectare on before and after mechanization separately i.e. before 2020–21 and during 2022–23 crop season. On the basis of the responses of the respondents, the mean area before and after mechanization was calculated out to find out the difference in area. Likewise on the basis of the responses of the respondents, the mean yield for before and after mechanization was calculated out to find out the difference in production. The mean yield per hectare for before and after mechanization was calculated out to find out the difference in productivity.

Cropping intensity refers to growing of a number of crops from the same field during one crop year. The cropping intensity was calculated using the following formula:

Cropping intensity=(Gross cropped area/Net sown area)×100

o Gross cropped area: This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year.

o Net sown area: This represents the total area sown with crops. Area sown more than once in the same year is counted only once.

In order to measure the change in cropping intensity, each respondents were asked to tell regarding the crops grown in the respective farms on before and after mechanization separately i.e. before 2020–21 and during 2022–23 crop season. On the basis of the responses of the respondents, cropping intensity for before and after mechanization was calculated out to find out the difference in cropping intensity.

3. Results and Discussion

3.1. *Crop wise mechanization index (MI)*

The crop wise Mechanization Index (MI) for three crops viz., sali rice, toria and potato were calculated separately. The three crops were selected as the mechanization interventions under APART project was given commonly to the three crops in all the three districts under study during 2016–17 to 2020–21. Again, only engine powered machineries were considered for inclusion in the calculation of MI (%) in the present study.

Table 1 shows the extent of mechanization for three crops viz., Sali rice, toria and potato in percentage. The Mechanization Index (MI) for each crop was calculated considering each operation separately. Then all the MI for each operation was summed up and averaged to get MI (%) for each crop. Data presented in the Table 1 reveals that highest MI was for potato (84.87%) followed by sali rice (74.65%). Toria showed lowest MI i.e. 51.29% among the three selected crops in the study areas.

Data presented in Table 1 reveals highest MI in potato (84.87%) among the three crops selected for the study. Machineries were found to be used in land preparation (MI=98.53%), sowing (MI=99.43%) and harvesting (MI=56.66%) of potato crop in the study areas. Potato was found to be grown in rice fallows as recommended by the APART project in few cases and in separate land suitable for potato crop in most of the cases. Machineries specifically designed for potato crop like potato planter and potato harvester were made available in Custom Hiring Centers established by APART project along with machineries like tractor, power tiller and sprayer etc. Hence, respondents were found to use those machineries in potato cultivation on hiring basis indicating a high percentage of MI in all the cultivation operations (Table 1) in case of potato in the study areas.

Table 1: Crop wise mechanization index, N=100

Operations	MI % crop wise		
	Salirice	Toria	Potato
Land preparation	99.24	99.73	98.53
Seedbed preparation	93.85	0.00	0.00
Transplanting	55.90	0.00	0.00
Sowing	34.86	21.79	99.43
Weeding	69.55	0.00	0.00
Harvesting	94.48	32.35	56.66
Av. MI %	74.65	51.29	84.87

In case of sali rice, operation wise, highest MI (%) was seen in land preparation (99.24%) followed by seed bed preparation (93.85%) and lowest MI (%) in sowing (34.86%). Respondents reported that traditionally seed beds are raised individually in small areas and seeds are sown manually in seed bed. Whereas main field preparation demands use of tractors and power tillers to address the scarcity of labor in most of the cases. Again in case of paddy transplanting, the MI is only 55.90%. This is may be due to fact that to use paddy transplanters, recommended method of seed bed preparation and seedling raising must be followed. Again, in fields with maintained spacing from row to row and plant to plant, the mechanical weeder may be used. Hence the results showed 69.55% MI in case of weeding in sali rice. The results (Table 1) further reveals 94.48% MI in harvesting of sali rice in the study areas.

For Paddy cultivation in India, irrigation followed by field preparation is the operations which show the highest Mechanization Index. Plant protection shows a relatively low mechanization Index in most of the states, except for Punjab and Karnataka (Yadav et al., 2023). Chaudhari and Moses (2023) also found similar result in paddy stating that the lowest mechanization index was observed in transplanting operations (0%) whereas highest mechanization index was observed in harrowing harrowing and puddling operations (99%). Gogoi et al. (2022) while studying the extent of farm mechanization in selected agroclimatic zones of Assam revealed that highest percentage of mechanization was observed in NBPZ (89.17%) followed by CBVZ, UBVZ, BVZ and LBVZ accounting for 86.67%, 85.83%, 85.00% and 83.33%, respectively. Primary tillage/ploughing, threshing and transportation were the major operations mechanised by 86.00%, 79.83% and 53.39% farmers respectively, while interculture operation, irrigation, harvesting and winnowing and bagging were mechanised by 10.83%, 27.00%, 7.12% and 31.83% farmers respectively.

In case of toria (Table 1), highest MI (%) was found in land preparation (99.73%) followed by harvesting (32.35%). Less use of machineries was seen in case of sowing of toria (MI= 21.79%). Toria was found to be grown in rice fallows as recommended by the APART project. And tractors and power tillers were used for land preparation. Traditionally, toria seeds are broadcasted manually in the main field in Assam.

3.2. *Distribution of respondents according to Mechanization Index(MI)*

Distribution of respondents according to Mechanization Index

(MI) (Table 2) reveals that majority of respondents (72.00%) belonged to medium mechanization category followed by 15.00% in the low mechanization category. While, remaining 13.00% of respondents were found to be in the category of high mechanization.

Table 2: Distribution of respondents according to mechanization index (MI)

Category	Range	Frequency (Percentage)
Low mechanization	0.83- 0 .92	15 (15.00)
Medium mechanization	0.92 -0.97	72(72.00)
High mechanization	0 .97-0.99	13 (13.00)

3.3. *Impacts of mechanization on the beneficiary farmers under APART project*

Impacts of mechanization on the beneficiary farmers under APART project was assessed in terms of change in area, production, productivity of Sali rice, toria and potato on before-after mechanization basis. Impact was also assessed in terms of change in cropping intensity on before-after mechanization basis.

3.4. *Impact of mechanization on sali rice in terms of change in area, production, productivity*

Data collected from the respondents reveals that they got direct benefit from the project for growing sali rice High Yielding Variety (HYV) Ranjit sub-1 and machineries like tractor, power tiller, knapsack sprayer, drum seeder, paddy transplanter, power weeder, reaper, combined harvester and thresher during the project period. After the hand holding period, the respondents were found to hire machineries from Custom Hiring Centers (CHCs) established by respective KVKs under the project APART. This situation was considered as after mechanization for the present study. Whereas, prior to the mechanization interventions given by the APART, respondents reported that they used to hire tractor, power tiller, sprayer only from local private sources as and when needed and used to grow varieties like Manohar, Biroi, Bahadur and in few cases variety Ranjit. This situation was considered as before mechanization for the present study. Table 3 showed changed in area (ha), production(q) and productivity (q ha^{-1}) on before and after mechanization for sali rice in the study areas.

Table 3 reveals that for sali rice, average area before mechanization was 1.04 ha and which increased to 1.44 ha after mechanization. Likewise, the average production of sali rice before mechanization was 41.70 q which increased to 79.20 q after mechanization. The average productivity was found to be 40.10 q ha^{-1} before mechanization and 55.00 q ha^{-1} after mechanization in sali rice.

3.5. *Impact of mechanization on toria in terms of change in area, production, productivity*

Data collected from the respondents reveals that they got direct benefit from the APART project for growing Toria HYVs TS-36, TS-38, TS-67 and machineries like tractor, power tiller, knapsack sprayer, seed cum fertilizer during the project period. After the hand holding period, the respondents were found to hire machineries from Custom Hiring Centers established by respective KVKs under the project APART. This situation was considered as after mechanization for the present study. Whereas, prior to the mechanization interventions given by the APART, respondents reported to hire tractor, power tiller, sprayer only from local private sources and used to grow varieties like M-27, Bongalixorioh. This situation was considered as before mechanization for the present study. Table 4 shows changed in area (ha), production (q) and productivity (q ha^{-1}) on before and after mechanization for toria in the study area

Table 3: Average change in area, production and productivity of Sali rice, N=100

Crop-sali rice	Before mechanization	After mechanization	t value
Area (ha)	1.04	1.44	19.622**
Production (q)	41.70	79.20	21.079**
Productivity (q ha^{-1})	40.10	55.00	19.063**

For Toria average area before mechanization was 0.34 ha and area was increased with the application of mechanization that is 0.52 ha (Table 4). The average production of toria before mechanization was 2.68 q which was increased to 5.77 q after mechanization. The productivity was found 2.68 qha^{-1} before mechanization and 5.77 q ha^{-1} after mechanization.

Table 4: Average change in area, production and productivity of toria, N=100

Crop-Toria	Before mechanization	After mechanization	t value
Area (ha)	0.34	0.52	26.798**
Production (q)	2.68	5.77	28.436**
Productivity (q ha^{-1})	7.90	11.10	16.201**

3.6. *Impact of mechanization on potato in terms of change in area, production and productivity*

Data collected from the respondents reveals that they got direct benefit from the APART project for growing potato HYV Kufrijyoti and machineries like tractor, power tiller,sprayer, potato planter and potato harvester. After the hand holding period, the respondents were found to hire machineries from Custom Hiring Centers established by respective KVK under the project APART. This situation was considered as after mechanization for the present study. Whereas, prior to the mechanization interventions given by the APART, respondents reported to use tractor, power tiller, sprayer only on hiring basis and used to grow locally available varieties.This situation was considered as before mechanization for the present study.Table 5 shows changed in area (ha), production (q) and productivity (q ha^{-1}) on before and after mechanization for potato in the study area.

For potato average area before mechanization was 0.92 ha and area was increased with the application of mechanization that is 1.24 ha (Table 5). The average production of potato before mechanization was 65.50 q which was increased to 245.64 q after mechanization.The productivity was found 71.20 q ha^{-1} before mechanization and 198.10 q ha^{-1} after mechanization.

Agricultural mechanisation has boosted agricultural production by reducing the power bottlenecks in agricultural operations, and enhancing land-use intensification (Pingali, 2007; Sarkar, 2020). In fact, mechanisation can be a boon for small and inefficient farmers in developing countries and helps them cope with the shortage of labour and improve farm efficiency (Van Loon et al., 2020; Pingali et al., 2019). Kandpal et al. (2019) said that mechanization is a crucial input in increasing farmers income by facilitating timely farm operations, input use efficiency, cropping intensity and farm productivity. Amare et al. (2016) found that Farm mechanization has greatly helped the farming community in the overall economic up-liftment. The studies conducted on impact of mechanization on farm income clearly support this view point. Sahara et al. (2022) concluded that mechanization and fertilizer improvement positively impacted potato farming.

Table 5: Average change in area, production and productivity of Potato, N=100

Crop-Potato	Before mechanization	After mechanization	t value
Area (ha)	0.92	1.24	24.226**
Production (q)	65.50	245.64	16.670**
Productivity (q ha^{-1})	71.20	198.10	23.931**

3.7. Impact of mechanization in terms of change in cropping intensity

Finding presented in table 6. reveals that the mean cropping intensity before mechanization was 131.42% and after mechanization it increased to 140.93%.

3.8. *Problems faced by the beneficiary farmers in adoption of the mechanization intervention*

Major constraints faced by beneficiary farmers in adoption of the mechanization intervention were (Table 7) - High fuel cost to run machineries (Rank I); Small and scattered land holding causing difficulties in management during peak crop season(Rank II); Non availability of required farm machinery at peak season as less number of farm machineries are available compared to demand (RankIII); Long distance between crop fields and fuel pumps leading high procurement cost (Rank IV); Non availability of trained person to maintain machines locally (Rank V) and Machineries of low quality leading frequent repairing (Rank VI)

Table 6: Impact of mechanization in terms of change in cropping intensity, N =100

Before mechanization (%)	After mechanization (%)	t test
131.42	140.93	8.451**

Small Land Holdings, high initial costs, lack of awareness and training, limited access to credit, crop and climate diversity, inadequate Custom Hiring facilities, poor rural infrastructure, weather dependency, scale issues, resistance to change and after-sales service are problems of farm mechanization in India (Sharif et al., 2024**).** Similarly, Barman and Deka (2019) found that small and scattered land holding and inadequate sufficient funds to meet the initial cost of purchasing were the most serious problem faced by the farmers in the Central Brahmaputra Valley and Upper Brahmaputra Valley Zone of Assam.

Table 7: Problem faced by beneficiary farmers in adoption of mechanization, N=100

Problems	Extent of problem confrontation						
	High	Medium	Low	Not at all	Total	PCI	Rank
1.High fuel cost to run machineries	85	15	0	0	100	285	I
2. Small and scattered land holding causing difficulties in management during peak crop season	60	35	5	0	100	255	II
3. Non availability of required farm machineries at peak season as less number of farm machineries are available compared to demand	65	20	15	0	100	250	III
4. Long distance between crop fields and fuel pumps leading high fuel procurement cost	15	50	25	10	100	170	IV
5. Non availability of trained person to maintain machines locally	8	62	15	15	100	163	V
6. Machineries of low quality leading frequent repairing	6	5	2	87	100	30	VI

4. Conclusion

The mechanization index (MI) for sali rice, toria, and potato was calculated, with potato showing the highest MI at 84.87%, followed by sali rice at 74.65%, and toria at 51.29%. Mechanization significantly increased area, production, and productivity, with sali rice's area rising from 1.04 to 1.44 ha. Major constraints in adoption were high fuel costs, small land holdings, limited machinery availability, distant fuel pumps, lack of trained personnel, and low-quality machines. Suggestions include improving equipment access, offering subsidies, training, and promoting shared machinery use through farmer groups.

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