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Mechanization in Indian Agriculture: A Field Level Investigation

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Abstract **– Mechanization in agriculture holds a significant role with its potential to increase crop productivity, reduce cost of cultivation and improve efficiency of the farming operations. However, the adoption of mechanization in different states in India has been uneven and faces several challenges. The research paper aims to explore the status of mechanization in Indian agriculture. Mechanization Index has been developed to measure the crop-wise and operation-wise level of mechanization and patterns across regions. The research findings show that the northern states Punjab and Haryana and the southern states Telangana and Andhra Pradesh more mechanized, while Bihar, Jharkhand, Assam, and Odisha exhibiting low levels of mechanization. Wheat and gram crops display the highest mechanization index, indicating a higher degree of automation in their cultivation processes. Taking a bird's eye view of the operation-wise mechanization pattern, the mechanization index shows that irrigation and field preparation operations are generally highly mechanized. However, harvesting operations requires both machine and human labour. Meanwhile, plant protection and sowing/planting operations are predominantly carried out manually. Moreover, investment more on machine cost doesn't relate with more value generation, rather investing more on machine hour shows positive correlation with value generation. Results reveal that large farmers have a high Mechanization Index as compared to the small and medium farmers. Assets like owned and hired agriculture machinery also had a significant effect. The paper concludes by offering suggestions for addressing these challenges and promoting sustainable and inclusive mechanization in the Indian agriculture sector.**

Keywords **– Mechanization Index, Cost of Cultivation, Farm Operations, Machine Hours, Data Analysis.**

I. INTRODUCTION

Agriculture is the backbone of India's economy, employing a significant proportion of its population and contributing substantially to its GDP. For an extended period, Indian agriculture has been marked by low productivity, limited profitability, and modest income levels (Balakrishnan et. al., 2008; Mishra & Reddy, 2011). The country's green revolution to a significant increase in agricultural production and productivity with the evolution of high-yielding crop varieties, increased use of chemical fertilizers, development of irrigation facilities, and plant protection measures, accompanied by effective price support programs for farm products. However, with the increased use of purchased inputs in agriculture, there is a need to improve their use efficiency through mechanization.

Basu & Nandi (2014) observed that there is no rational use of human labour in Indian agriculture, this means that the productivity of the laborers is not equal to the wages they receive on average which shows improvement in the agriculture sector. There might be a lack of proper training or skill development opportunities for laborers, which prevents them from maximizing their productivity and rational use. Additionally, there could be factors such as out dated farming techniques, inadequate infrastructure, or limited access to resources and technology that hinder the efficient use of labour in agriculture. Rajkhowa & Kubik (2021) study revealed that with the unit increase in level of farm mechanization, the demand for hired labour increases by 12%. Singh (2006) estimated

a mechanization index based on the cost of machinery use relative to the total cost of animate and machinery. The analysis shows that human labour cost remains the largest component in the cost of cultivation, despite the fact that 78.5% of farm power is contributed by mechanical sources.

Binswanger (1986) found power-intensive farm operations were the first to be mechanized based on trends across different regions. In India, tractor use for land preparation is predominant compared to other operations, there is an extreme uneven trend of mechanization in India across states, agroclimatic zones and crops (Sarkar, 2020; Bhattarai et al., 2020, pp. 104). Farm mechanization is a process which replaces human and animal labour with machines like tractors, harvesters, and pumps. This boosts labour productivity, enabling workers to engage in non-farm sectors if available (Timmer, 2009). Mechanization of farming activities depends much upon the crops and crop-specific requirements of machines in various farming activities. In a country like India, where the majority of farms are marginal farms and crops are grown in fragmented and scattered plots, the extent of use of machines is highly restricted. Further the use of machinery for a specific farm activity is influenced by various factors such as crop specific requirement, economic status, soil quality, topography etc. It is under this context that this study attempts to examine the pattern of mechanization of the farms covered under the Comprehensive scheme for studying the cost of cultivation of principal crops in India. The first section of the study examines the regional and crop-wise variation in Mechanization Index (MI) across the country. The authors try to identify which farming operations are more mechanized and their regional variation. Lastly, the study examines the influence of mechanization on various factors such as value of output, farm size and ownership of machines.

II. DATA AND METHODOLOGY

The study utilises the data from the Comprehensive scheme for studying the cost of cultivation of principal crops in India, implemented by the Department of Agriculture and Farmers Welfare. Under this scheme a comprehensive data on household, land inventory, machinery, animal inventory, crop operations, input, output etc. are collected on the sample farms in a scientific manner for the purpose of estimating cost of cultivation and cost of production for principal crops in India.

For this study, we have used the unit level data of 8100 farmers across 19 states for the year 2021-22. Further, major producing states for all crops from crop groups like cereals, pulses and oilseeds has been selected based on a minimum farmer sample size of 20. An Index from the different farm hours has been computed using the formula. Data is extracted from various data sources and a farmer database is prepared with farmers ID as the primary key from different features or attribute and an exploratory data analysis is performed using python libraries. Statistically analysis on the data variables is performed using R, to check the correlation among them. Data visualization is done in Tableau software by preparing a dashboard to generate tailored insights.

Derivation of Mechanization Index (MI)

The mechanization index is a measure of the mechanization in the farming practices, and it has important implications for farm productivity. If farmers can optimize their use of machines, they may be able to improve their crop yields and increase their income. For this purpose, the Mechanization Index is suggested as a proxy for estimating the spread of farm mechanization in India.

$$\text{Mechanization Index} = \frac{(\text{Total Machine hours})}{(\text{Total Hours})}$$

Where,

Total Hours = Total Machine Hours + Total.

Human Hours + Total Animal Hours.

Total Machine hours includes time spent in Hired machine and Owned machine. Total human hours compromise the time spent by casual workers, family members and servants for all men, women and children. While for Total Animal hours both hired and owned animal time is considered.

III. Result/Discussion on Pattern of Machinery use in India

The pattern of mechanization in Indian agriculture is diverse and varies from region to region depending on the scale of farming, access to capital, and availability of machinery. While there has been significant progress in the adoption of machinery, there is still a long way to go, especially in terms of reaching out to small and marginal farmers who form the backbone of Indian agriculture for which the empirical evidence has been studied in later sections of this paper. In this section we attempt to study the status and trends of mechanization in Indian agriculture.

3.1. *Crop Wise Variation in Mechanization Index:*

Among the crops, wheat has the highest MI value on average across all states at 0.22, followed by Gram at 0.21. Tur has the lowest MI value on average across all states at 0.13, followed by rapeseed and mustard (0.15). As compared to cereal crops like wheat and rice, pulses such as Tur, Urad and Moong have lower mechanization index. This could be due to the fact that pulses are often grown in smaller areas, and manual labour is more suitable for these crops.

The mechanization index values differ for each crop, reflecting the specific requirements and suitability of mechanization techniques for different crops. For instance, crops like rice and wheat tend to have higher mechanization index values, indicating a relatively higher level of mechanization in their cultivation compared to crops like groundnut or gram. This might be due to factors such as crop characteristics, market demand, or technological advancements specific to each crop.

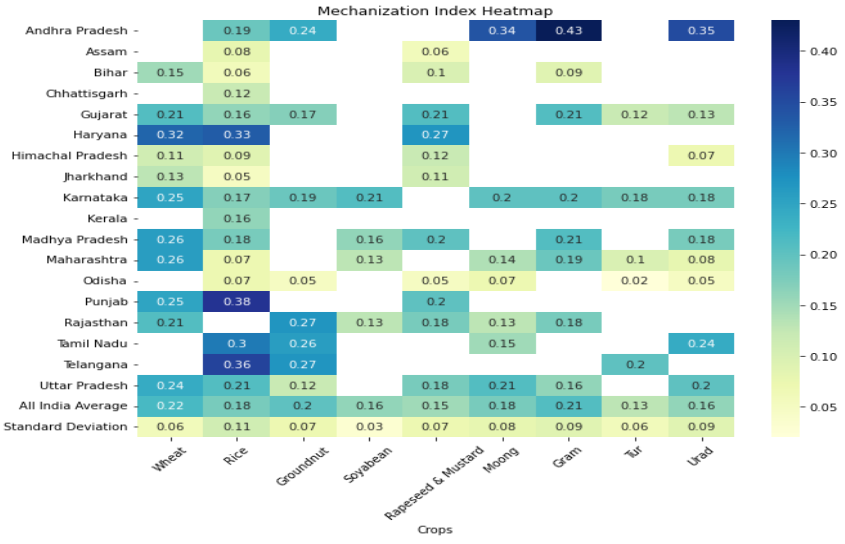

Fig. 1. MI values of different crops in different states; Source: Author.

The "Standard Deviation" row indicates the variability or spread of the mechanization index values for each crop across different states. Higher standard deviation values imply more significant variations in mechanization levels across states. This might reflect differences in agricultural practices, policy interventions, or regional factors influencing the adoption of mechanization.

For instance, the MI values for Wheat exhibit a low standard deviation of 0.06, indicating that the states show a similar level of mechanization for this crop. However, in the case of Paddy, the MI values have a significantly higher standard deviation of 0.11, revealing a considerable variation in the level of mechanization across the states. This implies that while some states like Punjab have high mechanization levels for Paddy, others state like Bihar and Assam have low levels, resulting in a wide range of MI values. This finding provides valuable insights into the regional differences in crop mechanization and highlights the need for crop-specific policy interventions based on the local context.

3.2. *Region Wise Variation in Mechanization Index:*

The mechanization index varies across different states, indicating regional differences in the extent of mechanization in agriculture. For example, the northern states of Haryana and Punjab and southern states of Telangana and Andhra Pradesh have the highest MI for most crops, while the states of Bihar, Jharkhand, Assam and Odisha have the lowest MI for most crops.

Further, it's interesting to note that some states have MI values for certain crops that are significantly higher than the national average, while for other crops they have significantly lower values. For example, Karnataka has low MI for rice compared to the national average, but a much higher MI for Pulses i.e. Moong, Tur, Urad and Gram. Similarly, Uttar Pradesh shows high MI for Rice and Wheat whereas for gram and groundnut the MI is lower than national average. It's worth noting that some values are missing in the table (e.g., Tamil Nadu and Telangana for Wheat, Rice in Rajasthan etc.) due to unavailability of data and less production of the particular crop.

3.3. *Mechanization in Various Farm Operations*

Mechanization of farming involves a wide range of activities performed in various stages of production. In this section we attempt to examine the mechanization in various farm operations. To study the operation wise mechanization extent, this study will focus on Wheat and Paddy crops. For this purpose, all the farm operations specified in Cost of Cultivation data are classified into 6 categories as tabulated below.

Table 1. Classification of all farm operations used for this study; Source: Author.

Combined/Labelled Operation Used for the Study	**All Farm Operations**
Field preparation	Preparatory tillage
Sowing/Planting	Sowing/Planting, Transplanting, Re-sowing
Plant Protection	Plant Protection, Manuring, Intercultural/Weeding, Guarding/Supervision, Transport on Farm
Irrigation	Irrigation, Fertigation
Harvesting and Threshing	Harvesting/Picking, Heaping, Threshing/Winnowing,

Combined/Labelled Operation Used for the Study	All Farm Operations
	Retting/dipping, Stripping, Extraction of fibre, Drying
Others operation	Contractual farming, other operations

A detailed analysis of operation wise use of machines suggests that the pattern of mechanization is significantly different between states and between crops.

3.3.1. *Paddy*

For Paddy cultivation in India, Irrigation followed by Field Preparation are the operations which show the highest Mechanization Index. Further, few states such as Haryana, Kerala, Punjab and Telangana show relatively high mechanization in Harvesting and Threshing. Plant protection shows a relatively low mechanization Index in most of the states, except for Punjab and Karnataka.

Overall the data suggests that the farming practices and conditions vary greatly between states, and that the use of machines is adapted to these specific circumstances. For example, the states of Haryana, Punjab and Telangana show a relatively high Mechanization Index in all the farming operations as compared to the rest of the states.

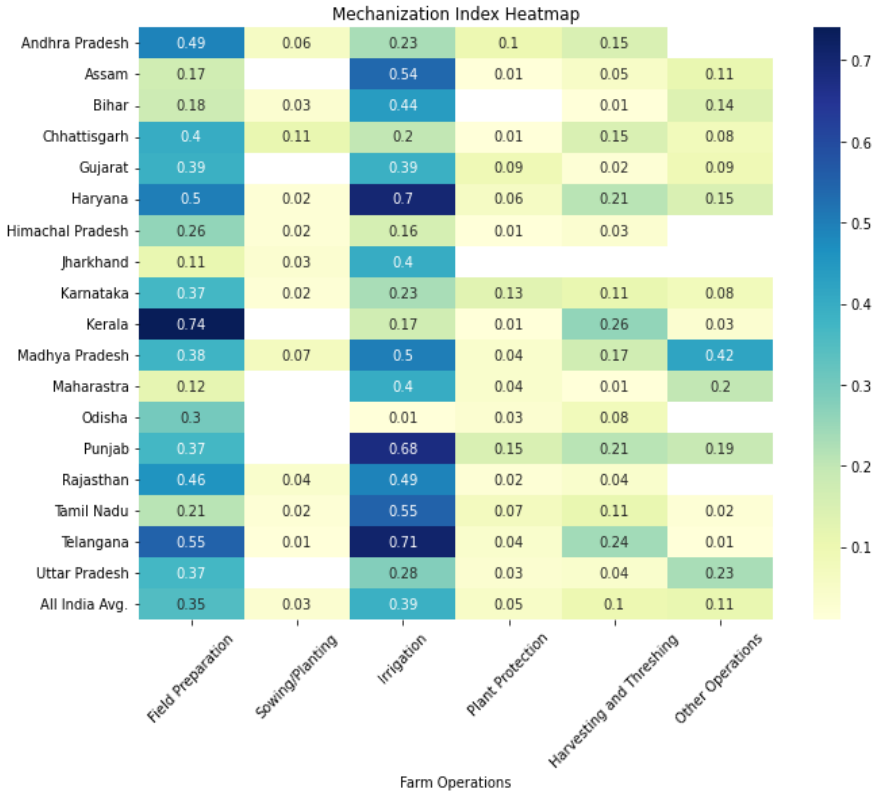

Fig. 2. MI of Paddy in different states across different farm operations; Source: Author.

3.3.2. *Wheat*

For Wheat cultivation in India, high mechanization Index is seen in Irrigation, field Preparation and Sowing/ Planting operations. Comparing the state wise mechanization index for various farm operations for Wheat cultivation, it is observed that Bihar and Rajasthan show a very low mechanization in harvesting operation as

compared to rest of the states. Bihar also has the lowest MI value for Sowing/planting operation. Plant protection operations in Punjab are far more mechanised than other states.

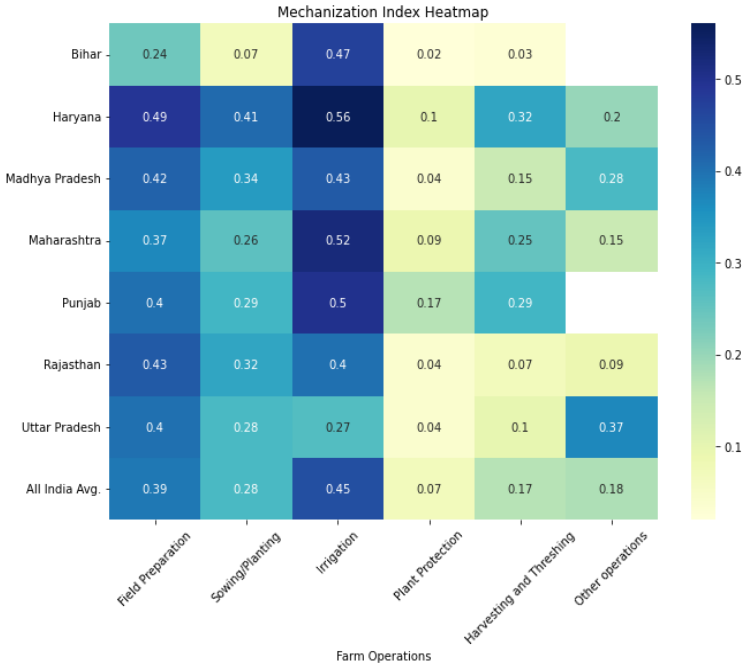

Fig. 3. MI of Wheat in different states across different farm operations; Source: Author.

3.4. *Relation of Mechanization Index on Socio-Economic Factors*

Mechanization Index clearly tells about the use of more machine hours out of total hours and high MI value means saving farmer from the monotony of his farm work, sparing him time for other activities; improvement of farmer's status in the community and consequent attraction for more youth with involvement of less drudgery activity. These are all advantages of the application of and access to automation in the farm. Since mechanization opens up new career prospects in fields like manufacturing, maintenance, and mechanization services, it has a favourable impact on rural employment. Only when a smallholder farmer generates more value or output from the crop, then it can result in eradicating their socio-economic crises. This section deals with the relation and trends of mechanization index with the farmers income, land holding and assets holding.

3.4.1. *Trends of Farm Mechanization on Farmers' Value from the Produce*

Agriculture offering limited income can significantly dampen the enthusiasm of agricultural labourers, so it becomes evident to notice how investment of time and money in the farm, whether it is from machine, human or animal gives more value to the farmer. Correlation analysis of Investment in machine time and Investment in machine cost on value generated per hectare from the produce reveals interesting trends and regional insights. All crops in crops groups like cereals, pulses and oilseeds have been considered to analyse the relation.

Let's first examine the relation of Mechanization index versus Value generated (Rs./ha) from the crops. It is estimated there is a positive correlation between these two variables with correlation coefficient of 0.46 (n = 6K). For all cereal crops, states like Punjab, Haryana, Assam, Bihar, Jharkhand and Telangana show the highest R^2 value of 0.56 (n = 2K) for both variables. Implying, more variation in output value per ha for a crop can be explained by the variation in Mechanization Index; that means more is the MI value, more is the value obtained

from a crop. *(n = sample size)*

On the other hand, when we search for evidence of the relation of the proportion of machine cost to the total cost of cultivation (C.O.C.) and the value generated from the produce (Rs./ha) for all the crops, it was apparent from the results that both variables showed almost zero correlation. Here, total cost of cultivation includes all cost or payment on machine, animal labour, human labour, seed, manure, fertilizer, insecticide, irrigation, insurance, contractor, miscellaneous and all other fixed costs. Therefore, we can't claim that investing more on machine cost can guarantee more value from the produce. Exception for wheat case as top producing states like UP, MP, Punjab, Haryana and Gujrat generated more value from investing more on the machine cost. Concluding, we can see that investing more on machine cost doesn't relate with more value generation from crop, rather investing more on machine hour show positive correlation with value generation for all crops.

3.4.2. *Effect of Farm Size on Farm Mechanization*

Farm Mechanization refers to activities occurring inside the boundaries or at the farm unit level whether village or community. Indian farmers have fragmented lands, so for small and marginalized farmers to own high power machines tends to be costly as well as turns out to be redundant unless it becomes operational for lending or hiring purposes. For this study the sampled farmers were divided based on their total land holding (in hectares) into categories of different farm size groups.

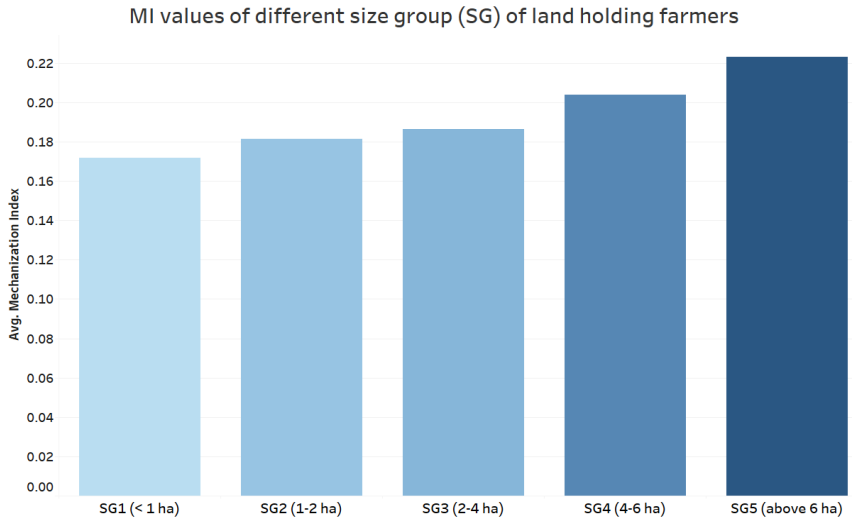

Fig. 4. MI values of different land holding farmers; Source: Author.

The above figure shows different farm size farmers with their Mechanization index for overall crops in India and becomes apparent that as the farm size increases the MI also increases. Whereas highest yield is observed in SG1 category and there is a subtle decrease in yield as we increase the landholding size.

3.4.3. *Trends in Different Type of Machine Hold by the Farmer on Farm Mechanization*

Farmers automating their field for different crops with different machinery doesn't own all the types of machines for different farm operations purposes, as most of the farmers are small and marginalized with slight income, ultimately, they had to hire other equipment. When this is seen through the lens of the mechanization index, that for which type of machinery whether owned or hired, what is the proportion of machine hours invested by the farmer.

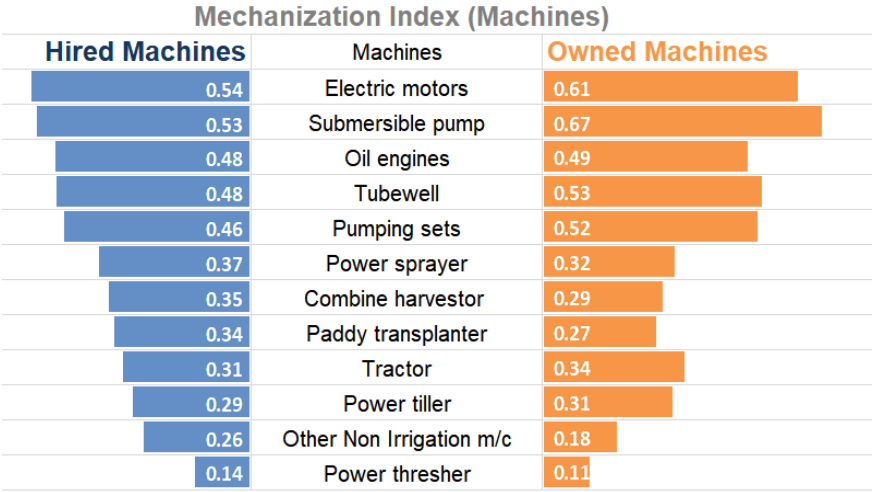

Fig. 5. MI values of Owned vs Hired Machineries; Source: Author.

From this butterfly comparison graph, it is indicating that irrigation machinery like submersible pumps, tube wells, pumping sets are more mechanized along with other machines like electric motors and oil engines. MI values of irrigation equipment are more for owned purposes than for hired purposes.

IV. Discussions and Conclusion

In conclusion, this research paper delves into the multifaceted landscape of mechanization in Indian agriculture, presenting a comprehensive exploration of its patterns, variations, and implications. The study utilizes a comprehensive dataset from the Cost of Cultivation Scheme, offering valuable insights into the patterns and variations of mechanization across different states, crops, and farm operations signalling the presence of distinct challenges and opportunities within India's diverse agricultural tapestry.

The development and utilization of the Mechanization Index (MI) as a measurement tool proves to be a valuable contribution to understanding the level of mechanization across crops and regions. Through this index, the paper elucidates that while northern states such as Punjab and Haryana and southern states like Telangana and Andhra Pradesh demonstrate advanced mechanization, other states, particularly Bihar, Jharkhand, Assam, and Odisha, exhibit a lower degree of mechanization. This regional disparity underscores the need for tailored strategies to encourage sustainable mechanization in underdeveloped regions, thus ensuring equitable agricultural progress. Further, mechanization plays a crucial role in enhancing labour efficiency in agriculture. By reducing the dependence on manual labour, machines enable farmers to achieve higher productivity with fewer laborers. Agricultural machinery can perform tasks at a faster rate compared to manual labour, thereby reducing the time required for various agricultural operations. This increased efficiency and time save allows agricultural laborers to focus more on other income-generating activities, leading to improved socio-economic conditions.

The crop-specific analysis within the paper unveils nuanced insights into mechanization trends. Crops like wheat and gram exhibit higher MI values, reflective of increased automation in cultivation practices, while pulses like Tur and Urad display lower mechanization due to their compatibility with manual labour-intensive methods. This divergence emphasizes the necessity of adapting mechanization strategies in accordance with crop requirements, fostering a balanced approach that optimizes both productivity and efficiency.

The research extends its analysis to explore the interplay between mechanization and socio-economic factors. Notably, the study reveals that the value generated per hectare does not necessarily correlate with the investment in machine costs. Instead, the positive correlation between mechanization index and value generated underscores the significance of optimizing machine hours to improve output, suggesting a pathway towards better income generation for smallholder farmers.

In essence, this research paper provides a comprehensive overview of mechanization in Indian agriculture, analysing its patterns, drivers, and implications. As India's agricultural landscape continues to evolve, these insights offer a foundation for targeted strategies that promote sustainable and inclusive mechanization, fostering productivity, economic growth, and improved livelihoods across the sector. The research paper is constrained by its narrow emphasis solely on machine usage duration for deriving MI values across states. It overlooks crucial factors such as machinery quality and farmers' proficiency.

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