

An Ex-post impact assessment of seed-to-seed mechanization in maize in Telangana State, India

Abstract

In Telangana, India, maize is cultivated in large areas next to rice and cotton. Considering the importance of the crop, Professor Jayashankar Telangana state Agricultural University (PJTSAU) is focusing on the development of new maize hybrids and agro-technologies that increase yield and income for farmers and reduce input and management costs. In order to evaluate the impacts of seed-to-seed mechanization technology, the Economic Surplus (ES) approach was applied in the present study that quantifies aggregate social benefits which includes producer and consumer surplus. Results revealed a total surplus of Rs. 76.97 lakhs, mainly benefiting producers (72.09 per cent) and consumers (27.91 per cent). The investment in seed-to-seed mechanization demonstrated a promising 59 per cent internal rate of return (IRR), a net present value (NPV) of Rs. 37.85 lakhs, and a favorable BC ratio of 3.76:1. The results of study found that the adoption of novel technology increased farm income and reduced the labour cost.

Key words: Mechanization, impact assessment, economic surplus, ex-post evaluation

Introduction

Maize, often referred to as the “queen of cereals,” holds significant importance as the third most crucial cereal crop in India, following rice and wheat. Traditionally, maize in India was cultivated during the kharif, or rainy season, in northern regions. However, over time, rabi, or winter maize, has also gained popularity in non-traditional areas such as coastal Andhra Pradesh, Bihar, Telangana, West Bengal, and others. Maize crop versatility allows it to thrive in diverse agro-ecological zones. The introduction of sweet corn, baby corn, and popcorn has significantly boosted the demand for maize in the Indian market (Sagar *et al.*, 2019).

Globally, maize covers around 150 million hectares across over 160 nations, adapting to a wide spectrum of soils, environments, ecologies and management practices. Impressively, maize contributes to 36% (782 million metric tons) of the total global grain production (Kumar *et al.*, 2022). In India, maize is cultivated in approximately 10.04 million hectares, with a production of 33.62 million metric tons and a productivity of 3349 kg/ha. Telangana contributes 6.35 per cent of the total maize production in the country, with a production of 2.13 million tons and a yield of 5178 kg/hectare (DA&FW, E&S Division, Fourth advance estimates, 2021-22). The demand from feed industries and various industrial sectors like starch and bakeries notably influences maize production in the state (Kumar *et al.*, 2014).

The conventional methods of maize cultivation in the country are labour-intensive, resulting to challenges in timely operations, reduced crop yield and increased cultivation costs. The adoption of mechanization not only enhances production efficiency but also encourages

large-scale production, subsequently fostering urbanization and commercialization within the agricultural sector (Barman *et al.*, 2019). Farm mechanization in India is about 40–45 per cent, which is relatively low as compared to other countries like the US, Brazil, and China, according to the International Exhibition and Conference on Agri-Machine and Equipment, 2015. The scarcity of agricultural labour during peak periods leads to delays in crucial operations such as land preparation, sowing, weeding, nutrient application, irrigation, and harvesting. This demand-driven labour scarcity also pushes up labour wages, consequently adding to cultivation expenses (Dixit *et al.*, 2017).

All these factors collectively contribute to production losses, rendering agricultural practices financially unviable under certain circumstances. Hence, it is the need of the hour and a challenge to change the strategy of maize cultivation from conventional methods of cultivation practices to appropriate mechanization with improved implements suited to local conditions (Mada and Mahai, 2013, Rahman *et al.*, 2011, and Mehta *et al.*, 2014). Further mechanization adds organic matter and enriches soil fertility upon decomposition (Jagadeeshwar *et al.*, 2021). Adamade and Jackson (2014) stated that the benefit-cost ratio of mechanized farms was 26.6% higher than that of traditional farms.

A pioneering example of seed-to-seed mechanization developed by PJTSAU and demonstrated across districts like Medak, Jangaon, Sangareddy, Warangal Rural and Karimnagar during 2018–19 revealed the cost-effectiveness that the cost of seed-to-seed operations was highest in the conventional method at Rs. 53,700 per ha over the mechanized method at Rs. 42,710 per ha.

Study area and data sources

The present study was conducted in Jangaon district, Telangana state, India, which was chosen based on the extensive cultivation of maize. Two mandals were selected from the district using a simple random sampling technique to gather data from 120 sample farmers. The sample consisted of 60 farmers who adopted the seed-to-seed mechanization technology and 60 farmers who did not adopt the technology.

Data were collected through farmer interviews during the period of 2021–22. Information related to the adoption of seed-to-seed technology and its impact variables was considered from the year of release of the technology by PJTSAU in 2019 and projected until 2025, assuming the technology's impact would last for 6 years before receding due to the introduction of new agro-technologies. Secondary data on area, production and productivity were collected from DES website for the years 2017–2022, and projected until 2025, using the Compound Annual Growth Rate (CAGR) based on the past 20 years data.

To assess the impact of technology adoption, social gains were quantified using the economic surplus approach. This method involves calculating the average yield difference and adoption costs between adopters and non-adopters based on the field survey of the sample respondents. The economic surplus method is used to measure the total economic benefits of a technology or research project. It helps in estimating the return on investment by calculating variations in consumer and producer surplus resulting from technological changes arising from

research. The economic surplus calculated along with research costs is then used to calculate the Net Present Value (NPV) and the Internal Rate of Return (IRR) (Maredia *et al.*, 2000).

The rate of adoption was defined as the ratio of the area under improved maize technology selected to the total area of maize cultivation in the region. Since data on the area under the technology in the study region was unavailable, an adoption rate of 1 per cent was assumed. Information on research and extension costs incurred by PJTSAU, Hyderabad, for seed-to-seed mechanization in maize was collected from the relevant agronomist. Additionally, economic parameters like the price elasticity of demand and the price elasticity of supply for maize were obtained from Kostandini *et al.*, (2009).

Methodology

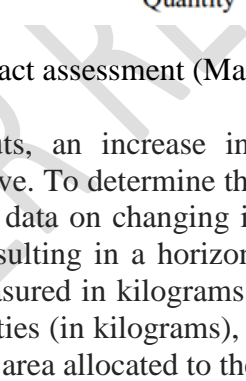
Mechanization in high-demand crops like maize can significantly reduce costs and increase farmer's income. Since maize is cultivated throughout the year due to its high demand, adopting mechanization from sowing to harvesting becomes crucial, especially during periods when labour availability is limited due to competing crops like rice and cotton demanding more labour. By utilizing the improved implements at different stages of the crop cycle, such as the vacuum planter for precise single-seed sowing, the seed-cum-ferti drill for maintaining sowing depth, and the combined harvester for direct harvesting and threshing, farmers can reduce labour requirements and overall cultivation costs while simultaneously boosting productivity. The primary data for this study were collected in Jangaon district, Telangana State, from a sample of 60 farmers who adopted these mechanized techniques and 60 farmers who did not, during the Kharif season of 2021–22.

The study employed an economic surplus approach to assess the socio-economic impacts of sustained maize technology utilization, specifically focusing on seed-to-seed mechanization. This assessment can be categorized as ex-post, as the technology has already been adopted by farmers since its release in 2019 (Ogunsumi *et al.*, 2005). The methodology used in this study centered on estimating cost reductions in relation to the observed maize output levels and then accounting for the quantity changes associated with shifts in prices.

Figure 1 illustrates the concept of ex-post impact assessment, as outlined by Masters (1996). In this context, the measurement of total social gain corresponds to area R, which includes area T. Area R represents the societal benefits arising from reduced production costs at the observed production level, denoted as Q1, while area T accounts for the adjustment needed due to changes in quantity resulting from technology adoption.

The economic surplus approach operates by first determining the extent of cost reduction at the observed output level (area R) and subsequently making adjustments for quantity changes resulting from price fluctuations (area T). As Masters (1996) suggests, the height of area R, which includes area T in this case, plays a pivotal role in shaping the outcomes of the impact assessment.

Figure 1 also depicts the impacts of research outcomes when assessed in relation to the efficiency of output per unit of inputs, commonly referred to as output gain. This can be observed, for instance, in the context of enhanced crop yields per hectare. The integration of a



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In the case of a parallel shift with linear supply and demand curves, the social gain (SG) can be expressed as the combined area of "R" (a parallelogram) and "T" (a triangle) in Figure 1. The precise formulas for estimating the area of the SG, as well as each of the individual parameters used in this estimation, are provided as follows (Ahmed et al., 1994).

$$\text{Let } SG = KPQ - 0.5KPAQ \dots\dots\dots (1)$$

Where SG = Social Gain; K = supply shift (vertical) which is not directly measured but estimated; Q = observed produced quantity measured at field level); ΔQ = change in quantity produced as a result of research (Q-Q' in ex-post analysis) must be estimated. To estimate K and ΔQ , our initial focus must be on estimating J and I. The J parameter represents the total production increase resulting from the adoption of new technology, assuming no changes in costs or prices. It can be expressed as:

$$J = \Delta Y \times t \times A \dots\dots\dots (2)$$

Where ΔY = increase in yield from adoption of new technology (kg/ha); t = adoption rate, expressed as proportion of the total area under new technology; and A = total cropped area (ha) (Ahmed *et al.*, 1994). In proportional terms, J parameter can be calculated as increase in quantity produced as a share of total quantity, given by:

$$J = J/Q \dots\dots\dots (3)$$

This transformation allows the estimation of supply shift parameter (J) in terms of yield increase, adoption rates and overall average yield (Y), *i.e.*,

$$J = (\Delta Y \times t)/Y \dots\dots\dots (4)$$

$$Y = Q/A \dots\dots\dots (5)$$

The I parameter is defined as increase in per unit costs required for obtaining given increase in production (J) and represented as:

$$I = \Delta C \times t/Y \dots\dots\dots (6)$$

In proportional terms, I parameter can be calculated as the share of observed product price (P) and the parameter proportional cost increase (c) is:

$$c = I/P = (\Delta C \times t)/(Y \times P) \dots\dots\dots (7)$$

Where c is adoption cost per unit of area under new technology; t is adoption rate in terms of area; Y = overall average yield and P is observed product price.

K parameter, or shift in the supply curve which means net reduction in production costs induced by the technology and can be obtained by combining the effects of productivity increase (J) and adoption costs (I).

$$K = J / (\epsilon * Q/P) - I ; K = [JP/ \epsilon Q] - I$$

K is used in proportional terms, *i.e.*, net reduction in production cost as a proportion of production price, *i.e.*,

$$k = K/P = [JP/\epsilon QP] - I/P = (j/\epsilon) - c \quad \dots\dots\dots(8)$$

Where,

ϵ = price elasticity of supply

To estimate the social gains, price elasticity of supply and demand of maize were obtained from Kostandini *et al.*, (2009).

The change in quantity is given by

$$\Delta Q = Q_e \epsilon_k / (e + \epsilon) \quad \dots\dots\dots(9)$$

Estimation of social gains is computed using the formula

$$SG = (kPQ) \pm \frac{1}{2} (kP\Delta Q) \quad \dots\dots\dots(10)$$

Research and extension costs of seed-to-seed mechanization were used to obtain net social benefits by subtracting the research & extension costs from total social gains obtained.

Net social gain = Social gain – Research and extension costs

The producer and consumer surplus were computed by decomposing the social gains and total surplus is computed as follows:

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 k (1 + 0.5Ze) \quad \dots\dots\dots(11)$$

$$\Delta CS = P_0 Q_0 Z (1 + 0.5Ze) \quad \dots\dots\dots(12)$$

$$\Delta PS = P_0 Q_0 (k - Z) (1 + 0.5Ze) \quad \dots\dots\dots(13)$$

Where,

Net social gains obtained from deducting total research & extension costs are used to estimate the net present value (NPV).

$$NPV = \sum_{i=1}^n Y_n (1 + r)^{-n} - I \quad \dots\dots\dots(14)$$

Where,

Y_n = Net social gains

r = Discount rate at 8 %

i = years, 1 to n .

n = number of years

Results and discussion

Based on Table 1, the comparative farm business analysis between adopters and non-adopters of mechanization revealed some notable findings. The total cost of cultivation of technology adopters was 9.02 per cent lower compared to the non-adopters enjoying a yield advantage of 1.83 q/ha. Furthermore, the net returns of adopter farmers were Rs. 31,620.11, which was 52 per cent higher than the non-adopter, who earned Rs. 21,022.76. Moreover, adopter farmers exhibited higher farm business income, farm labour income and farm investment income by 15.61 per cent, 21.50 per cent, and 31.34 per cent respectively, compared to the non-adopters of technology. Notably, the returns per rupee spent were higher for technology adopters (1.34) compared to non-adopters (1.21), indicating its superior performance in the study region. The results were in accordance with Manjulatha *et al.* (2021). Hence, adopters of seed-to-seed mechanization were found better economically in comparison to the other non-adopters in the area.

Table 1. Farm business analysis of adopters and non adopters of seed-to-seed mechanization in the study area

S. No.	Particulars	Adopters	Non-adopters
1	Total cost of cultivation (Rs./ha)	92671.77	101031.80
2	Yield (q/ha)	65.21	63.38
3	Market price (Rs./q)	1788.17	1795.83
4	Gross return (Rs./ha)	124291.90	122054.60
5	Farm business income (Rs./ha)	67411.57	58311.79
6	Family labour income (Rs./ha)	51142.06	42090.88
7	Net return (Rs./ha)	31620.11	21022.76
8	Difference in net return of both varieties (%)	50.41	
9	Farm investment income (Rs./ha)	60944.70	46400.75
10	Return per rupee spent	1.34	1.21

The economic benefits attributable to the adoption of seed to seed mechanization technology in Telangana during the period 2017–2025 was analyzed through economic surplus model presented in Table 2. By taking into account a demand elasticity of 0.31 and a supply elasticity of 0.12 (Kostandini *et al.* 2009), the economic surplus resulting from the adoption of the technology amounted to Rs. 76.97 lakhs. Out of this total surplus, the producer surplus constituted 72.09 per cent, while the consumer surplus constituted 27.91 per cent. Therefore, producers reaped relatively greater benefits compared to consumers in the context of the technology adoption.

Table 2. Results of economic analysis of seed-to-seed mechanization in maize using economic surplus method

S. No.	Particulars	Total benefits due to the technology adoption (Rs.)
1	Change in Consumer surplus (ΔCS)	21,48,051.19 (27.91)

2	Change in Producer surplus (ΔPS)	55,49,132.23 (72.09)
3	Change in Total surplus (ΔTS)	76,97,183.42
4	NPV at 8% discount rate	37,85,967.57
5	IRR	59%
6	B:C ratio	3.76:1

Note: Figures in parenthesis represents percentage to total

The overall impact of technology adoption was assessed in terms of net present value, internal rate of return and benefit-cost ratio. To account for the time value of money, the stream of net social gains generated by the technology over the years was discounted at a discount rate of 8 per cent. The net present value was calculated to be Rs. 37.85 lakhs, indicating the overall benefit to society (Rovere *et al.*, 2009). Additionally, the research investment on the technology showed an impressive internal rate of return (IRR) of 59 per cent, BCR at 3.76:1, further emphasizing the substantial value and desirability of the investment made in researching the seed to seed mechanization technology. The results were in accordance with Hurley *et al.*, 2016, Dikitanan *et al.*, 2022 and Brennam and Malayabayabs (2011).

Conclusion

In conclusion, the present study described the significant benefits of adopting seed-to-seed mechanization technology in maize cultivation. The findings demonstrated that mechanization has a profound positive impact on maize productivity, cost-effectiveness, and labour efficiency. The adoption of this technology enables timely and precise operations, including sowing and harvesting, facilitated by combined harvesters, which ultimately lead to increased yields and reduced production costs. One of the key advantages highlighted in the study was the substantial labour-saving effect of mechanization. By decreasing the labour requirements for farmers, the technology allows them to reallocate their time and resources to other productive activities, contributing to overall cost savings and potentially improving their livelihoods. This aspect is crucial, particularly in regions where labour availability and costs are significant concerns. Moreover, the economic surplus method utilized in this study provided a comprehensive and inclusive assessment, taking into account both producers and consumers.

REFERENCES

- Adamade and Jackson. 2014. Agricultural mechanization: a strategy for food sufficiency. *Journal of Agricultural Sciences*. 4: 152.
- Agricultural Statistics at a glance 2022. GOI, Ministry of Agriculture & Farmers Welfare, Department of Agriculture & Farmers Welfare, Economics & Statistics division.
- Ahmed, M. M., Masters, W., Sanders, J. 1994. Returns from Research with Policy. Distortions Hybrid, Sorghum. *Sudan Agricultural Economics*. 12: 15-27.
- Bamboriya, S. D., Jat, S. L., Shreelatha, D., Mahala, D. M and Rakshit, S. 2020. Mechanized maize production for enhanced productivity and profitability. IIMR Technical Bulletin 2020/1. Indian Institute of Maize Research, PAU Campus, Ludhiana.

Barman, S., Deka, N and Deka, P. 2019. Factors affecting farm mechanization - A case study in Assam, India. *Asian Journal of Agricultural Extension, Economics & Sociology*. 32(1): 1-7.

Brennam, J. P and Malabayabas, A. 2011. Brennan J.P. and Malabayabas A. 2011. International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia. ACIAR Impact Assessment Series Report No. 74. Australian Centre for International Agricultural Research: Canberra. 111pp.

Dikitanan, R. C., Pede, V. O., Rejesus, R. M., Bhandari, H., Alam, G. M. M and Andrade, R. S. 2022. Assessing returns to research investments in rice varietal development: Evidence from the Philippines and Bangladesh. *Global Food Security*. 33: 100646.

Dixit, J., Khan, J. N and Rohitashw, K. 2017. Maize mechanization for hill agriculture to enhance productivity and profitability. *SKUAST Journal of Research*. 19(1): 83-91.

Hurley, T. M., Pardey, P. G., Rao, X and Andrade, R. S. 2016. Returns to Food and Agricultural R&D Investments Worldwide, 1958-2015. InStePP brief. International Science & Technology Practice & Policy.

ICAR – Indian Institute of Maize Research. <https://iimr.icar.gov.in/>

Jagadeeshwar, R., Ramanjaneyulu, A. V., Rajaiah, P., Kumar, M. V., Sudhaker, C., Manjulatha, G and chouhan, S. 2021. Role of Mechanization in Crop Residue Management in Telangana. *Chronicle of Bioresource Management*. 5(2): 069-076.

Kostandini, G., Mills, B. F., Omamo, S. W and Wood, S. 2009. Ex ante analysis of the benefits of transgenic drought tolerance research on cereal crops in low-income countries. *Agricultural Economics*. 40: 477–492.

Kumar, R., Bhardwaj, A., Singh, L. P and Singh, G. 2022. Environmental Impact Assessment of Maize Production in Northern India. IOP Conf. Series: *Earth and Environmental Science*. 1084: 012042.

Kumar, R., Srinivas, K., Boiroju, N. K and Gedam, P. C. 2014. Production performance of maize in India: Approaching an inflection point. *International Journal of Agricultural and Statistical Science*. 10(1): 241-248.

Mada, D. A and Mahai, S. 2013. The role of agricultural mechanization in the economic development for small scale farms in Andaman State. *Journal of Engineering and Science*. 2: 91.

Manjulatha, G., Sowjanya, B and Rajanikanth, E. 2021. Comparative economics of maize cultivation under conventional and mechanization. *International Journal of Environment and Climate Change*. 11(12): 113-118.

Maredia, M., Byerlee, D., Anderson, J. 2000. Ex post evaluation of economic impacts of agricultural research programs: A tour of good practice. Paper Presented In: Workshop on the Future of Impact Assessment in CGIAR: Needs, Constraints, and Options. Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee, Rome.

Masters, W. 1996. The Economic Impact of Agricultural Research: A Practical Guide. Department of Agricultural economics, Perdue University, West Lafayette, IN.

Mehta, C. R., Chandel, N. S., Senthilkumar, T and Singh, K. K. 2014. Trends of Agricultural Mechanization in India. CSAM Policy Brief. 2: 1-13.

Ogunsumi, L. O., Ewuola, S. O., Daramola, A. G. 2005. Socio-economic impact of maize production technology on farmers' welfare in Southwest, Nigeria. *Journal of Central European Agriculture*. 6(1): 15-26.

Rahman, M. S., Miah, M., Moniruzzaman and Hussain, S. 2011. Impact of farm mechanization on labour use for wheat cultivation in northern Bangladesh. *Journal of Animal and Plant Sciences*. 21(3) : 589-594.

Rovere, R. L., Mathema, S., Dixon, J., Mercado, P. A and Gurung, K. 2009. Assessing impacts of maize research through a livelihoods lens: findings and lessons from the hill regions of Mexico and Nepal. *Impact Assessment and Project Appraisal*. 27(3): 233–245.

Sagar, M. S., Shankar, T., Manasa, P., Sairam, M. 2019. Present status and future prospects of maize cultivation in South Odisha. *International Journal of Bio Resource Science*. 6(1): 27-33.

Santosh, K., Rakshya, P., Min, T. S and Tulsi, P. 2021. Status of farm mechanization and its impact on maize production in Jhapa District, Nepal. *Archives of Agriculture and Environmental Science*. 6(3): 290- 294.

Sreelatha, D., Manjulatha, G., Rajanikanth, E and Rajaiah, P. 2022. Technical bulletin Mechanization in Maize – A move towards farm profitability, PJTSAU, Maize Research Centre, ARI, Rajendranagar.