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

Abstract

Maize is the third-important cereal crop in India after rice and wheat. 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. This study investigated the impact of research investment on seed-to-seed mechanization technology in the maize crop in Telangana from a sample of 120 respondents. In order to evaluate the impacts of technology, the Economic Surplus (ES) approach was applied in the present study. 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, a net present value of Rs. 37.85 lakhs, and a favorable BC ratio of 3.76:1. The results of the study found that the adoption of new technology increased farm income and reduced the labour cost.

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

Introduction

Maize, 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 grown during the kharif, or rainy season, in northern regions. 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. The introduction of sweet corn, baby corn, and popcorn has significantly boosted the demand for maize in the Indian market. Maize's versatility allows it to thrive in diverse agro-ecological zones (Sagar et al., 2019).

It is cultivated on approximately 150 million hectares in over 160 nations, in a broad range of soil, environment, ecology, and management activities, and accounts for 36% (782 million metric tons) of 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 an yield of 5178 kg/hectare (DA&FW, E&S Division, Fourth advance estimates, 2021-22). Maize production in the state has been largely influenced by increasing demand from the feed industries and various industrial uses like starch and bakery industries (Kumar et al., 2014).

The traditional methods of maize cultivation in the country are labor-intensive, leading to challenges in timely operations, reduced crop yield, and increased cultivation costs. Mechanization encourages the improvement of efficiency in production, encourages large-scale production, and ultimately leads to urbanization and commercialization in the agricultural sector (Barman et al., 2019). Farm mechanization in India is about 40–45 per cent, which is comparatively low as compared to countries like the US, Brazil, and China, according to the International Exhibition and Conference on Agri-Machine and Equipment, 2015. The scarcity of agricultural laborers at peak periods causes delays in key operations like land preparation and sowing and intercultural operations like weeding, nutrient application, irrigation, and harvesting. Further, higher demand for laborers in peak cropping periods enhances labor wages, leading to an additional cost of cultivation (Dixit et al., 2017).

All these factors lead to production losses, making agriculture production non-viable 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.

The seed-to-seed mechanization developed by PJTSAU and demonstrated in districts viz., Medak, Jangaon, Sangareddy, Warangal Rural, and Karimnagar during 2018-19 revealed 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 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 regarding area, production, and productivity were collected from the 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, 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 farmers' 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 labor availability is limited due to competing crops like rice and cotton demanding more labor. 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 labor 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.

Conceptual model

Economic surplus approach was employed in this study to determine the socio-economic impact assessment for the sustained use of maize technology (seed to seed mechanization). The model can be regarded as an ex-post assessment, since the technology was already in adoption among the farmers, since the release of technology in the year 2019 (Ogunsumi et al., 2005). In this study the assessment method was based on estimating the magnitude of cost reductions given the observed level of maize output and then making an adjustment for the change in quantity associated with the change in price.

Figure 1 illustrates the case of an ex-post impact assessment (Masters, 1996). In this situation the total social gain measurement is area R (which includes area T in this case) less area T. Area R represents the social gain resulting from the reduction in production costs at the observed level of production Q1 and area T represents a correction for the change in quantity caused by technology adoption.

This economic surplus approach works on the basis of estimating the magnitude of cost reduction given the observed level of output (area R) and then making an adjustment for the change in quantity associated with change in price (area T). According to Masters (1996), the height of area R (which in this case includes area T, the social gain to be measured) is generally the most important determinant of the impact assessment results.

Figure 1 also illustrates the effects of research result measured in terms of the quantity of output per unit inputs (output gain) such as the increased crop yield per hectare. The adoption of a new technology may require some form of investment in new inputs. In this study, for a given level of output, this increased cost represented by a vertical (I) that is, shift of the supply curve from S’ to S’’ (Figure 1).

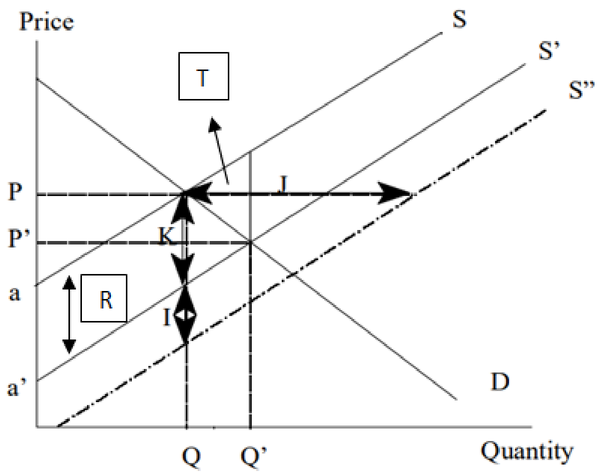

Figure 1. An illustration of Ex-post impact assessment (Masters et al., 1996)

Furthermore, for a given cost of inputs, the increased quantities represent a horizontal (J) shift of the supply curve. In order to obtain the net shift in terms of costs per unit output, it is necessary to combine data on changing input costs (vertical shift) and changing quantities (horizontal shift). Generally the relevant data are observed in terms of yields per hectare (kg/ha). To obtain a J parameter, whose units are total quantities (kg), yield gain per hectare (kg/ha) must be multiplied by area allocated to the new technology.

Provided the new technology can be adopted at zero cost, then S’’ curve would be the supply curve with technology adoption. However, adoption usually requires some investment in new inputs such as, certified seed, or additional machine labour input. The vertical distance I represent those “adoption costs” on a per-unit basis. Typically, the relevant data are observed in terms of some additional costs per hectare. To obtain the relevant parameter I, adoption costs per hectare must then be divided by the average yield over total area.

Taking both J and I into account leads to a net shift in the supply curve from S (without technology) to S’ (with technology). The vertical distance K represents the net gains in terms of a decrease in production costs. It is the height of the area R in Figure 1 or vertical shift in the supply curve and is often referred to as the “shift” of “K” parameter. It is evident that the supply curve could take different forms. But for simplicity it is assumed to be a straight line. Similarly, for practical reasons it is appropriate to assume that the technical change produces a parallel shift, that is, an equal cost reduction at each possible level of production (the shift in the supply curve). For the case of parallel shift with linear supply and demand curves, the social gain (SG) can be expressed as area R (a Parallelogram) and T (a triangle) in Figure 1. The precise formulae for estimating the area of the SG, and each of the individual parameters used in that estimation, are given as follow (Ahmed et al., 1994).

Let SG=KPQ - 0.5KPΔQ ……………… (1)

Where SG = Social Gain; K = vertical shift in supply which is not directly measured but estimated; Q = the observed quantity produced measured at field level (for example, from agricultural census); ΔQ = change in quantity produced as a result of research (Q-Q' in ex-post analysis) must be estimated. In estimating K and ΔQ, we must first estimate J and I. The J parameter is defined as the total increase in production that would be caused by adopting the new technology, in the absence of any change in costs or price and is given as:

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

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

$J = J/Q$ ………………………(3)

This transformation permits the estimation of the supply shift parameter (J) in terms of the yield gains, adoption rates and the overall average yield level (Y), that is,

$J = (\Delta Y \times t)/Y$ ………………(4)

It is important to note that this is valid only if Y is defined as the overall average yield

$Y = Q/A$ ……………………..(5)

The I parameter is defined as the increase in per unit costs required to obtain the given production increase (J) and given as:

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

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

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

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

K parameter, or shift in the supply curve, to be estimated. The K-parameter is the net reduction in production costs induced by the variety and can be obtained by combining the effects of increased productivity (J) and adoption costs (I). Given J and I, it can be computed using the slope of the supply curve (b_s) as

$K = (J * b_s) – I$ …………………………(8)

The slope of the supply curve (b_s) is associated with units of measurement. Therefore, supply elasticity (€), which is independent of units of measurement, is computed as follows:

€ = % ΔQ / %ΔP

$= (\Delta Q/Q) / (\Delta P/P)$

$= (\Delta Q/\Delta P) * (P/Q)$

$= (1/b_s) * (P/Q)$

$b_s = € * Q / P$

$K = J / (€ * Q/P) – I$; $K = [JP/ €Q] – I$

Again, K is used in proportional terms, i.e., the net reduction in production cost as a proportion of the production price. The formula used is

$k = K/P = [JP/€QP] - I/P = (j/€) - c$ ………………………(9)

Where,

€ = price elasticity of supply

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

Estimate equilibrium output quantity change: ΔQ

The equilibrium situation without technology would be price and quantity, which satisfy both demand and supply.

$Q_d = Q_s$

$P = (a_s - a_d) / (b_d - b_s)$

Similarly

$P1 = (a_s - a_d + b_s K) / (b_d - b_s)$

$\Delta P = b_s K / (b_d+b_s)$

The change in quantity is given by

$\Delta Q = b_d \Delta P$ …………………………(10)

$= b_d b_s K / (b_d +b_s)$

To substitute elasticities for slopes, assume the elasticity of demand is e,

$e = \%\Delta Q / \%\Delta P$

$= (\Delta Q/Q) / (\Delta P/P)$

$= (\Delta Q/\Delta P) (P/Q)$

$= b_d (P/Q)$

$b_d = e\,(Q/P)$

Thus ΔQ = (e* Q/P) x (€*Q/P) K / [(e* Q/P) + [€* Q/P]

Here, we use ΔQ in proportional terms, and it is given by the formula

ΔQ = Qe €k / (e+€) …………………………(11)

Step 8: Estimation of social gains. It is computed using the formula

SG = (kPQ) ± ½ (kPΔQ) …………………...(12)

Step 9: Incorporate the research and extension costs of seed-to-seed mechanization to obtain social benefits for each year. The net social benefits were computed by subtracting extension costs from the total social gains obtained.

Step 10: Net social gain = Social gain – Research and extension costs

The producer surplus and consumer surplus were computed by decomposing the social gains (SG) and total surplus given by the equation as follows:

$\Delta TS = \Delta CS + \Delta PS = P_0Q_0k\,(1+0.5Ze)$ …………………..(13)

$\Delta CS = P_0Q_0Z\,(1+0.5Ze)$ ………………………………(14)

$\Delta PS = P_0Q_0\,(k-Z)\,(1+0.5Ze)$ …………………………….(15)

Where,

Z = k* € / e+€ ………………………………(16)

The net social gains obtained from deducting total extension costs are used to estimate the NPV (Net Present Value).

$$\mathbf{NPV} = \sum_{i=1}^{n} Y_n (1+r)^{-n} - I$$ ……………………(17)

Where,

Y_n = Net social gains

r = Discount rate, taken as 8 %

i = year 1 to n.

n = total 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 (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR). To account for the time value of money, the stream of net social gains generated by the technology over the years was discounted at an 8 per cent discount rate. 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 of 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 labor 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 labor-saving effect of mechanization. By decreasing the labor 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 labor 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.

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