Journal of Agricultural Development and Policy, 2023
Volume 33, No. 2, 174-182

Potential of Maize Crop for Sustainable Agriculture in Punjab

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Abstract

The present study was conducted to see the potential of maize crop for sustainable agriculture in Punjab. The secondary data was collected from the year 1950-51 to 2022-23 to analyze the trends in maize area, production and yield of Punjab. In order to depict the better growth trends, the overall study was divided into pre-green revolution, green revolution, post-green revolution, liberalization period and neo-liberalization period. The area under maize stands at 0.93 lakh ha in 2022-23, a decline of more than 83 percent compared to 1970-71. The area and production of the maize crop has declined significantly over the years. The yield of crop, on the other hand has shown a significant positive growth owing to the introduction of hybrid varieties. The district wise scenario revealed that a good number of districts registered high growth rate (>4.0%) in area under maize crop during pre-green revolution period but with the passage of time except Roopnagar and Sahibzada Ajit Singh Nagar (SAS) districts, all the districts shifted to negative growth rate. For the ex-ante evaluation of maize, PMH 14 variety of maize has been selected in comparison to PMH 1 variety to estimate the economic surplus over 8 years (2023–2030). The findings of the economic surplus estimation of newly released variety PMH 14 suggests that assuming maximum adoption rates of five percent and ten percent, the total surplus generated will be Rs 42 crores and Rs 84 crores, respectively. Considering the potential of maize as an alternative for paddy in Punjab, the study suggests assured market for maize crop is the only key for diversification, Regular extension services should be provided to maize growers, Establishment of maize based agro industries in Punjab is the need of hour for better marketing and high prices for farmers and in addition it also generate employment in the state.

Keywords: Maize, Potential, Liberalization, Variety, Economic surplus

JEL: O13, R11, O16, L25, H62

Introduction

The success of the green revolution in Punjab, driven by improved access to irrigation, the adoption of high-yielding crop varieties, and increased use of fertilizers and agrochemicals, coupled with guaranteed procurement at remunerative minimum support prices, resulted in a significantly higher profitability of the paddy-wheat system. This success triggered a virtuous cycle, leading to greater investments in irrigation, higher cropping intensity, increased input utilization, improved productivity, and rising profitability. As a consequence, Punjab transformed into a highly cultivated, double-cropped state, achieving some of the highest levels of input utilization, high-yielding crop varieties, food production, and agricultural productivity indicators in the country (Bembi., 2006; Vatta and Sidhu., 2007; Gulati *et al*., 2017). In the early 1970s, persistent droughts led to significant fluctuations in rice production, amounting to 4-5 million tons. The production of rice became increasingly unstable. To address this issue, the central government resolved to bring electricity to all villages in Punjab (approximately 12,000 at that time). The scheme was officially inaugurated by the Prime Minister, Mrs. Indira Gandhi, on May 31, 1976, in Malerkotla, Punjab. Following this strategic decision, the area dedicated to water-intensive crops, particularly rice, witnessed a steady increase, while the cultivation of maize experienced a decline. Due to its stable and high yield, Punjab farmers embraced paddy cultivation on a large scale.

Nevertheless, post the 1990s, this virtuous cycle transitioned into a vicious one characterized by escalating costs, stagnant productivity, and declining profitability. The persistence of the rice-wheat cropping system in Punjab gave rise to various challenges, including the depletion of natural soil fertility, a declining water table, soil structural degradation, increased soil and water pollution, heightened greenhouse gas emissions, and the burning of rice residue. These issues pose a serious threat to human, animal, and overall environmental health (Kumar *et al*., 2015; Gulati

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et al., 2021).

As a result, there is an urgent need to diversify the existing rice-wheat cropping system with other suitable crops to ensure the sustainability of agriculture in the state. Among various cropping systems, the maize-wheat-mungbean (M-W-M) cropping system stands out as a viable option for diversification in Punjab and Haryana (Rakshit et al., 2021). Maize requires significantly less water compared to rice and has a shorter cropping duration, making it a more sustainable choice. Moreover, maize has versatile uses as food, feed and fodder, and is a source of numerous industrial products, offering the potential for industrial development and entrepreneurship in the state. Among cereals, maize holds the highest yield potential and is a globally growing crop (Nirupma *et al.,* 2012; Kumar *et al*.,2013; Tuli *et al*., 2022)

Historically, Punjab was a traditional maize-growing state until rice gained popularity. However, the area under maize cultivation has declined by 82 percent in 2022-23 compared to 1970-71 (GoP, 2023). Despite various technological advancements, the decline in maize acreage was primarily driven by the introduction of high-yielding varieties of rice (Singh et al., 2003).In terms of production; the decline is to the tune of 52 percent during this period. However, the yield of the crop has increased by more than 200 percent owing to the development of hybrid varieties. The major maize-producing districts in Punjab include Hoshiarpur, Roopnagar, NawanShahar, Kapurthala, Ropar, and Amritsar (GoP, 2013).

Recognizing the potential of maize as a sustainable alternative to paddy, the agricultural policy of Punjab has been actively promoting its cultivation. Efforts include the Crop Diversification Scheme initiated in 2014, offering financial incentives to farmers who switch from rice to alternate crops. Additionally, NABARD implemented a scheme on crop residue burning from 2018-20, providing financial support to farmers diversifying from rice. These measures are expected to boost maize production significantly. To further encourage maize cultivation, the Punjab Government has decided to provide a 50 percent subsidy on maize seeds and required pesticides. The Punjab Agricultural University has also played a vital role by developing new and improved maize varieties over the years. In this backdrop, this study aims to analyze the trends in maize cultivation, production, and productivity in Punjab. Additionally, it seeks to estimate the potential economic surplus that may be generated by a newly released PAU maize variety, PMH 14 in the year 2023.

Data sources and Methodology

Secondary data on area, yield and production of maize in Punjab from 1950-51 to 2022-23 was analyzed to find out the trends in maize production. The study period (1950-51 to 2022-23) was divided into different periods. The compound annual growth rates of area, production and yield of maize were estimated for the periods.

I. Pre-green revolution period (1950-51 to 1965-66)
II. Green revolution period (1966-67 to 1985-86)
III. Post-green revolution period (1986-87 to 1994-95)
IV. Liberalization period (1995-96 to 2022-23)

After the economic reforms of 1990's, the period from 1995-96 is called Liberalization Period. In the year 2006, SAS Nagar (Sahibzada Ajit Singh Nagar) was made which took most of the maize growing area of Roopnagar district, so in order to depict the better growth trends of maize growing districts of Punjab state, the liberalization Period was further divided into sub-periods:

- Liberalization period-I (1995-96 to 2005-06)
- Liberalization period-II (2006-07 to 2013-14)
- Neo-liberalization period (2014-15 to 2022-23)

As a result, the overall study has been divided into six sub-periods, namely, Pre-green revolution, Green revolution, Post-green revolution, Liberalization period-I and Liberalization period-II and Neo-liberalization period.

Estimation of Growth

The annual growth rates for area, production and yield of maize for all the districts of the state were computed using the growth model for the different periods.

The growth model adopted in the exponential form of regression was as under:

$$Y_t = a\, b^t u$$

Where

Y_t = Absolute value, (e.g. area/production/yield of maize crop) for the year 't'

t = Time variable,

Log transformation of the above function is

$$\ln Y_t = \ln a + t (\ln b) + e$$

a = Constant

ln b = Regression coefficient of time

u = Error term

Where $r = [\text{Antilog } (\ln b) - 1]$

$CGR (\%) = r \times 100$

The compound growth rates were also tested to determine their statistical significance.

Estimation of Economic Surplus

Maize is considered as an important cereal crop after rice and wheat which is known as the queen of cereals. Being a less water consuming crop, maize crop is chosen as an alternative crop for crop diversification. The PMH series of maize varieties is developed and released in Punjab Agricultural University, Ludhiana. PMH 14 variety was

released in the year 2023 and according to the experts opinion; this newly released PAU variety has potential for covering wider area and increased yield than previously released varieties in Punjab. PMH 14 variety of maize is selected in comparison to PMH 1 variety to estimate the economic surplus. For this purpose, the economic benefits of the variety (PMH 14) was estimated vis-à-vis PMH 1 which was released in the year 2005 i.e. yield enhancement of PMH 14 over PMH 1 was used for economic surplus analysis. The benefits that will accrue due to increased area under PMH 14 i.e. adoption of this variety was predicted for a period of 8 years (2023-2030). The study employs the Economic Surplus Model (ESM) using a closed economy framework. Due to its less stringent assumptions and minimal data requirements, this methodology is a frequently utilized impact assessment methodology (Alston *et al*., 1998). The farm-level economic advantages could be scaled up to a higher-level spatial unit, such as Punjab in this case by using this method and benefits accruing between producers and consumers can be estimated. The values of parameters used for estimating economic surplus are given in Table 5. Producer surplus and consumer surplus together make up the entire economic benefits of technology adoption (TS=PS+CS), called as total surplus.

The change in the consumer, producer, and overall surplus can be expressed mathematically as:

$$\Delta CS = P_0 Q_0 Z_t (1+0.5\ Z_t \eta)$$

$$\Delta PS = P_0 Q_0 (K_t - Z_t) (1+0.5\ Z_t \eta)$$

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K_t (1+0.5\ Z_t \eta)$$

Where,

P_0= initial price, Q_0= initial level of production, η= =absolute value of price elasticity of demand

Z_t is the price reduction in year t due to increased supply with the adoption of the improved technology and is estimated as

$$Z_t = K_t \varepsilon / (\varepsilon + \eta)$$

Where, ε= elasticity of supply.

K_t indicates the proportionate reduction in cost per ton of production in time t or research-induced shift in supply and is calculated as

$$K_t = ((E(Y)/\varepsilon) - (E(C)/ (1+E(Y)) p A_t (1-d)^t$$

Where,

E(Y) = change in yield per hectare

E(C) = change in variable cost per hectare

A_t = adoption rate of the technology in year t

p = probability of success of the technology

d= depreciation rate of the technology

Results and Discussion

The results and discussion section comprises of trends in area, yield and production of maize crop for a period of 72 years. District wise analysis has been worked out for these years depicting high, medium, low and negative growth rates. The cumulative benefits from increase in area under PMH 14 hybrid newly released maize variety were predicted by ex-ante assessment using economic surplus model.

The results of the Table 1 showed that the area under maize in the year 1950-51 was 2.64 lakh ha and decreased to 0.93 lakh ha in the year 2022-23. The maximum area under maize was observed in 1975-76 i.e. 5.8 lakh ha. The results further revealed that trend in production of maize were also fluctuating. Similarly, production also reached maxima of 8.50 lakh tonnes in the same year.

Table 1. Trends in maize area, yield and production in Punjab, 1950-51 to 2022-23

Year	Area (000 ha)	Yield (kg/ha)	Production (000 metric tonnes)
1950-51	264	667	147
1965-66	355	1565	601
1975-76	580	1236	850
1985-86	260	1581	412
1995-96	171	1796	307
2005-06	151	2734	413
2015-16	127	3735	474
2022-23	93.3	4393	410

On overall basis, production increased from 1.47 lakh tonnes in 1950-51 to 4.10 lakh tonnes in 2022-23. The overall increase in yield was observed due to the increase in production per hectare. In 1950-51, the yield recorded per ha was 667 kg which increased 1236 kg in 1975-76 reaching 4393 kg in 2022-23. It was due to the advent of single cross hybrid varieties of maize crop. During early years i.e. 1950's and 1960's double cross hybrid seeds were there, but the yield was not uniform in these hybrids. Varieties like Ganga 101 and Ganga Hybrid Makka 3, Ganga 1, Deccan 101, Sangam resulted in increasing yield on farm. The year 1989-90 had been a landmark year, since this year saw two major changes in policy i.e. launch of single cross hybrid project and creation of new seed policy in India. Due to this, yield increased drastically. Since the release of hybrid varieties namely PMH1 in the year 2005, Punjab Agricultural University has released 14 hybrid varieties such as PMH 1, PMH 2, PMH 11, PMH 13 and Punjab baby corn 1 etc. which has shown a positive impact on yield.

Compound Annual Growth Rate of Area, Yield and Production of Maize

A glance on table 2 revealed that the compound annual growth rate of area under maize crop was estimated to be 3.01 per cent per annum during pre-green revolution period but it decreased to -3.31 per cent during green revolution. The

figures were statistically significant at one per cent level of significance in all the periods. It further decreased to -4.69 per cent during post-green revolution period. The growth of area under maize had turned out to be negative (-2.46 per cent) per annum in neo-liberalization period which was positive accounting to 3 percent per annum in pre-green revolution period. The area under maize has shown decreasing growth rate, whereas yield has shown positive trend due to the adoption of improved varieties or hybrid varieties in the state. During liberalization period-I, the growth rate of maize area was -1.00 per cent, the area under maize declined at a low rate in this period as compared to other periods as the area remained more or less stable in this period with a fall of just 20 thousand hectares in this period.

During liberalization period-II and neo-liberalization period, it again decreased to -2.40 per cent and -2.46 percent respectively. Overall, area under maize increased from 2.64 lakh hectares to 3.55 lakh hectares in pre-green revolution period, giving a positive growth rate, there after it continuously declined from 4.28 lakh ha to 1.38 lakh ha depicting negative growth. The growth rate of yield was positive over the periods except post-green revolution period, where it was negative (-0.20) but non-significant. The study further revealed that maximum increase in the yield was witnessed during last two periods i.e. after 1995-96 (called as Liberalization period-I and II) only due to the 90 per cent adoption of hybrid varieties by the maize growers. The trends in production were fluctuating, the growth rate of production was positive in pre-green revolution period and in liberalization period-I and negative in the remaining periods. The growth rate of production was maximum and significant in pre-green period i.e. 5.66 per cent and negative during neo-liberalization period where it was -2.26 per cent and significant at five percent level.

District wise Growth Performance of Area and Yield under Maize Crop in Punjab

District wise compound annual growth rates were computed for various periods and districts were further divided on the basis of growth rates. The districts which have growth of more than or equal to four per cent are hence forth named as high growth districts, while those having growth rate between two per cent to 3.9 per cent have been termed medium growth districts. The districts having growth up to 1.9 per cent are termed as low growth districts and those depicting negative growth are clubbed under negative growth districts. The CAGR's were calculated, based on the data available for each of the maize growing districts.

Status of Maize Area in Punjab

The analysis showed that, in pre-green revolution period, districts like Kapurthala, Jalandhar, Ludhiana, Ferozepur and Bathinda were under high growth giving a significant growth ranging from 4.27 per cent to 12.55 per cent per annum respectively (Table 3). During the same period, Sangrur district with growth rate of 3.22 per cent lies in medium growth whereas none of the district showed negative growth in area under maize crop till the year 1966. In the succeeding periods, the majority of the maize growing districts showed negative area growth; as a result, nearly 90 percent of maize growing districts were grouped together as negative growth districts, plainly indicating a decrease in area in all the maize –growing districts. Only Hoshiarpur (0.57%) and Roopnagar (0.47%) from green revolution period, Kapurthala (0.09%) from the post-green revolution period, Hoshiarpur (0.50%) and Sangrur (1.76%) from the liberalization period-I, Roopnagar (1.09%) and SAS Nagar (0.47%) from the neo-liberalization period came under low growth districts.

Status of Maize Yield in Punjab

According to the district-level growth results for maize yield in Punjab (Table 4), Hoshiarpur had a significant growth rate of 6.39 percent during the pre-green revolution period, while Kapurthala (-3.48 percent) and Ferozepur (-1.23 percent) had negative growth rates. Most districts during the green revolution fell into the category of low growth districts, although Ludhiana, Bathinda, and Patiala saw negative growth during that time, with growth rates of 1.93 percent, 1.82 percent, and 0.47 percent, respectively,

Table 2. Compound annual growth rate of maize area, yield and production in Punjab, 1950-51 to 2022-23

Periods	Years	CAGR (%)		
		Area	Yield	Production
Pre-green revolution period	1950-1965	3.01***	1.05^{NS}	5.66***
Green revolution period	1966-1985	-3.31***	1.31**	-2.59***
Post-green revolution period	1986-1994	-4.69***	-0.20^{NS}	-2.25^{NS}
Liberalization period-I	1995-2005	-1.00***	3.71**	2.69*
Liberalization period-II	2006-2013	-2.40***	3.95***	-0.03^{NS}
Neo-liberalization period	2014-2023	-2.46***	0.23^{NS}	-2.26**

*Note: ***, ** denotes significance level at 1%, 5% level respectively. NS denotes non-significant*

Table 3: District wise growth performance of area under maize crop in Punjab during 1950-51 to 2022-23

Particulars	Pre-green revolution period (1950-1965)	Green revolution period (1966-1985)	Post-green revolution period (1986-1994)	Liberalization period-I (1995-2005)	Liberalization period-II (2006-2013)	Neo-liberalization period (2014-2023)
High growth districts (>4.0 percent)	Kapurthala (4.7***) Jalandhar (4.27***) Ludhiana (5.17***) Ferozepur (7.49***) Bathinda (12.55***)					
Medium growth districts (Between 2.0-3.9 percent)	Sangrur (3.22***)				SAS Nagar (2.07^{NS})	
Low growth districts (Up to 1.9 percent)	Gurdaspur (0.88^{NS}) Amritsar (0.33***) Hoshiarpur (0.98*) Patiala (0.38^{NS})	Hoshiarpur (0.57*) Roopnagar (0.47^{NS})	Kapurthala (0.09^{NS})	Hoshiarpur (0.50*)	Ludhiana (0.00) Tarn tarn (0.00)	Roopnagar (1.09^{NS}) SAS Nagar (0.47^{NS})
Negative growth districts		Gurdaspur (-3.6***) Amritsar (-6.48***) Kapurthala (-4.82***) Jalandhar (-1.26**) Ludhiana (-4.17***) Ferozepur (15.77) Bathinda (-10.8***) Sangrur (-5.72) Patiala (-6.18***) Faridkot (-15.38***)	Amritsar (-4.95***) Gurdaspur (-3.82***) Hoshiarpur (-0.82^{NS}) Jalandhar (-6.70***) Ludhiana (-20.05***) Patiala (-4.07**) Roopnagar (-2.22***) Sangrur (-27.10***) Faridkot (-22.92**) Ferozepur (-9.24^{NS}) Bathinda (-12.94^{NS})	Amritsar (-7.37***) F.G. Sahib (-0.81^{NS}) Gurdaspur (-1.26*) Jalandhar (-2.46**) Kapurthala (-4.11**) Ludhiana (-4.58*) Patiala (-11.78***) Roopnagar (-0.04^{NS}) S.B.S. Nagar (-0.11^{NS})	Amritsar (-9.43**) F.G. Sahib (-3.93^{NS}) Gurdaspur (-4.58***) Hoshiarpur (-2.58***) Jalandhar (-8.26***) Kapurthala (-3.79^{NS}) SBS Nagar (-5.98***) Patiala (-6.39^{NS}) Roopnagar (-0.57^{NS})	Gurdaspur (-12.26**) Pathankot (-0.76^{NS}) Amritsar (-3.14^{NS}) Tarn Tarn (-24.07^{NS}) Kapurthala (-19.56*) Jalandhar (-7.91***) SBS Nagar (-5.09***) Hoshiarpur (-1.93**) Ludhiana (-17.48*) Fazilka (-16.70^{NS}) Bathinda (-29.39*) Patiala (-8.63^{NS}) F.G. Sahib (-21.31**)

Table 4: District wise growth performance of yield under maize crop in Punjab during 1950-51 to 2022-23

Particulars	Pre-green revolution period (1950-1965)	Green revolution period (1966-1985)	Post-green revolution period (1986-1994)	Liberalization period-I (1995-2005)	Liberalization period-II (2006-2013)	Neo-liberalization period (2014-2023)
High growth districts (>4.0 percent)	Hoshiarpur (6.39***)	Faridkot (4.52***)	Jalandhar (4.25^{NS}) Kapurthala (6.54^{NS}) Faridkot (6.75^{NS}) Ferozepur (8.29^{NS})	Amritsar (4.08**) F.S. Sahib (9.13***) Jalandhar (4.04**) Roopnagar (4.39***)	Kapurthala (7.08**) Patiala (10.13**) SAS Nagar (4.9^{NS}) Tarn Tarn (7.66**)	Pathankot (8.16**) Kapurthala (11.60*) SBS Nagar (4.44**)
Medium growth districts (Between 2.0-3.9 percent)	Gurdaspur (2.27^{NS}) Jalandhar (2.03^{NS}) Ludhiana (3.42***) Bathinda (2.00*)	Kapurthala (2.03***)	Amritsar (3.26^{NS}) Hoshiarpur (3.84^{NS}) Roopnagar (2.71^{NS})	Gurdaspur (3.7**) Hoshairpur (3.74**) Kapurthala (2.89**) Ludhiana (3.58*) Patiala (2.23^{NS}) Sangrur (2.26^{NS}) S.B.S. Nagar (3.62**)	Gurdaspur (3.7**) Hoshairpur (3.74**) Ludhiana (3.58*) Roopnagar (2.56^{NS})	
Low growth districts (Up to 1.9 percent)	Amritsar (0.53^{NS}) Sangrur (0.57^{NS}) Patiala (1.17^{NS})	Gurdaspur (1.91^{NS}) Amritsar (1.78^{NS}) Jalandhar (1.41**) Hoshiarpur (1.35**) Roopnagar (1.72**) Ferozepur (0.28^{NS} Sangrur (0.41^{NS})	Ludhiana (0.89^{NS}) Sangrur (0.55^{NS}) Bathinda (0.11^{NS})		F.G. Sahib (1.42*) Jalandhar (0.55^{NS}) SBS Nagar (0.7^{NS})	Amritsar (1.35^{NS}) Roopnagar (0.64^{NS}) Tarn Tarn (0.69^{NS}) Bathinda (0.70^{NS}) Sangrur (0.84^{NS}) F.G. Sahib (0.38^{NS})
Negative growth districts	Kapurthala (-3.48*) Ferozepur (-1.23^{NS})	Ludhiana (-0.93**) Bathinda (-1.82^{NS}) Patiala (-0.47^{NS})	Gurdaspur (-1.36^{NS}) Patiala (-2.14^{NS})		Amritsar (-4.37^{NS})	Gurdaspur (-4.29^{NS}) Jalandhar (-0.10^{NS}) SAS Nagar (-1.95**) Hoshiarpur (-0.24^{NS}) Ludhiana (-7.34*) Fazilka (-9.83**) Patiala (-8.02*)

Table 5: Values of parameters used for estimation of economic surplus

Parameter	Value	Source
Minimum Support Price (Rs./tonne) (Avg of TE 2022-23) at constant 2022-23 prices	16325.11	CACP
Yield change per ha (%)	0.18	FGDs, experts consultation
Variable cost change per ha (%)	0	FGDs, experts consultation
Maximum Adoption rate	5%, 10%	Expert consultation
Supply elasticity	0.37	Kumar *et al*. (2010)
Demand elasticity	0.48	Kumar *et al*. (2010)
Discount rate (%)	5	Review of literature
Probability of success (%)	100	Expert opinion

indicating a fall in yield. Jalandhar, Kapurthala, Faridkot, and Ferozepur districts experienced yield growth of more than four percent during the post-green revolution period, whereas Gurdaspur and Patiala experienced negative growth. The release and subsequent widespread adoption of hybrid varieties of maize by maize growers throughout the Punjab state occurred during Liberalization Period I, or the period following economic reforms, which led to increase in the yield. As a result, the decade from 1995 to 2005 saw the highest growth in yield, and all the maize-growing districts experienced growth rates of at least two percent per annum in this period. Only the Amritsar district (-4.37%) had experienced negative growth during liberalization period II. Similar to this, in neo-liberalization period, Pathankot, Kapurthala, and SBS Nagar showed high growth with yield growth ranging from 4.4% to 11.6%, while Amritsar, Tarn Tarn, Roopnagar, Bathinda, Sangrur, and Fatehgarh Sahib showed low growth with yield growth only up to 1.9 %.

Economic Surplus Estimation of Maize Variety PMH 14

The secondary data were used for ex-ante evaluation of maize variety PMH 14 in Punjab. The secondary data were compiled from various published sources like Statistical Abstracts of Punjab, Package of Practices (PAU), Agricultural Statistics at a Glance, *etc*. for finding out the values of parameters used for the estimation of the economic surplus model. The values of parameters used in the economic surplus modeling are given in Table 5. The MSP of maize has been taken as the TE of MSP for 2022-23 (estimated at 2022-23 prices) and was estimated at Rs. 16325.11/tonne. A yield enhancement of 18 per cent is observed for PMH 14 variety in comparison to PMH 1 as this new variety PMH 14 gives productivity of 62 qtls./ha in contrast to 52.5 qtls/ha in PMH 1.

The elasticities of supply and demand are derived from Kumar *et al*., (2010). The demand elasticity of maize is taken as 0.48 and the supply elasticity as 0.37. As the maize variety (PMH 14) has been recently introduced and is picking up fast, so, the success rate in the economic surplus model is assumed as 100%. The research costs were computed by considering the salaries of the scientists and other researchers and extension workers working on the varieties of maize and some other related costs in PAU during 2012 to 2030. The farmers cultivating variety PMH 1were experiencing the same per hectare cost of cultivation as PMH 14, so in the model we assumed cost reduction to be zero. The range of discount rates that can be employed to calculate the economic surplus has been suggested by numerous studies. 3-5% was suggested as the discount rate by Alston et al. in 1998. For agricultural projects in India, Kula (2004) suggested a discount rate of 5.2 percent. Therefore, we likewise employed a 5 percent discount rate for this investigation.

Ex-ante Assessment (2023- 2030)

This table represents the economic benefits likely to arise with the expansion of maize area under variety PMH 14 (Table 6). These benefits will accumulate as a result of increased adoption and higher productivity than earlier released variety PMH 1. The benefits comprise both producer and consumer surplus as a result of closed economy model and sum of both will yield total surplus. The economic benefits have been estimated for the eight year period i.e.

Table 6: Consumer, producer and total surplus from adoption of Direct Seeded Rice for the period 2023- 2030 (Ex-ante)

Adoption rates	Value (Rs.crore)	
Five percent	Consumer surplus	18.16
	Producer surplus	23.56
	Total surplus	41.71
Ten percent	Consumer surplus	36.39
	Producer surplus	47.21
	Total surplus	83.61

2023-2030 by using ex-ante framework. The cumulative economic surplus for the adoption of maize variety PMH 14 during 2023-2030 with five percent adoption rate amounted to Rs 41.71 crore. The total surplus will accrue to Rs 83.61 crores at the maximum adoption rate of 10%. The increase in economic surplus is due to yield enhancement of 18%. Thus with the adoption of maize variety PMH 14 reaching 10% of total maize area in state will double the total surplus giving producer surplus of Rs 47 crore.

Conclusions and Policy Implications

The acreage planted to maize in 2022–2023 is down more than 83 percent from 1970–1971; the crop's production has also decreased significantly over time. However, the introduction of hybrid varieties has resulted in a discernibly higher crop yield. Districts like Kapurthala, Jalandhar, Ludhiana, Bathinda and Ferozepur which registered high growth rate in area under maize during the pre-green revolution period has shifted to negative growth rates in the neo-liberalization period. Findings of the ex-ante economic surplus estimation of newly released variety PMH 14 suggests that assuming maximum adoption rates of five percent and ten percent, the total surplus generated will be Rs 42 crore and Rs 84 crore, respectively over the period 2023-2030. Considering the potential of maize as an alternative for paddy in Punjab, the study suggests that policy makers may frame suitable measures to promote the area under the crop in the state by giving adequate price or MSP and assured procurement. Public sector procurement of maize may be introduced like paddy in order to ensure fair price of maize for the farmers. Appropriate procurement policy may be introduced like paddy will help stabilizing maize price and farmer's interest toward maize production. Regular extension services should be provided to maize growers so as to build up their knowledge about moisture content, various diseases/ insect-pest attack and their control and regulations. Establishment of maize based agro industries in Punjab is the need of hour. As the maize is used in more than 500 products as an ingredient like in shell of capsule, in textiles, in alcohol industries, in tyre industries, bio-fuels like ethanol etc. government should establish industries which uses maize as a raw material for better marketing and high prices for farmers and in addition it also generate employment in the state.

References

Alston J M, Norton G W and Pardey P G 1998. Science under scarcity: Principles and practices for agricultural research evaluation and priority setting. Wallingford: CAB International. file:///C:/Users/CS/Downloads/p15738coll11_6.pdf.

Bembi D K, Nayyar V K and Brar J S 2006. The green revolution in Punjab: Impact on soil health. *Indian Journal of Fertilizers*. **2**: 57-66. https://www.researchgate.net/publication/321300227_The_green_revolution_in_Punjab_impact_on_soil_health.

GoP 2013. Statistical Abstract of Punjab. Economic and Statistical Organization, Government of Punjab. https://punjab.gov.in/wp-content/uploads/2019/04/Abstract-2013.PDF.pdf.

GoP 2022. Statistical Abstract of Punjab. Economic and Statistical Organization, Government of Punjab. https://punjab.gov.in/wp-content/uploads/2019/04/Abstract-2022.PDF.pdf.

Gulati A, Roy R and Hussain S 2021. Punjab agriculture back on high growth path: sources, drivers and policy lessons. Indian Council for Research on International Economic Relations. 1-51. https://icrier.org/publications/getting-punjab-agriculture-back-on-high-growth-path-sources-drivers-and-policy-lessons/..

Kula E 2004. Estimation of a social rate of interest for India. *Journal of Agricultural Economics*, **55**: 91–99. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1477-9552.2004.tb00081.x.

Kumar A, Kumar S, Dahiya K, Kumar S and Kumar M 2010. Productivity and economics of direct seeded rice (*Oryza sativa* L.). *Journal of Applied and Natural Science,* **7**: 410 -416.http://dx.doi.org/10.31018/jans.v7i1.625.

Kumar R, Srinivas K and Sivaramane N 2013. Assessment of the maize situation, outlook and investment opportunities in India. Country Report – Regional Assessment Asia (MAIZE-CRP), National Academy of Agricultural Research Management, Hyderabad, India. https://naarm.org.in/wp-content/uploads/2016/07/Assessment-of-the-Maize-Situation-outlook-and-investment-opportunities-in-India.pdf.

Kumar P, Kumar S and Joshi L 2015. Socioeconomic and environmental implications of agricultural residue burning, springer briefs in environmental science, http://dx.doi.org/10.1007/978-81-322-2014-5.

Nirupma S, Rajendran R A, Shekhar M, Jat S L, Kumar R and Kumar R S 2012. Rabi Maize Opportunities Challenges, Directorate of Maize Research, Pusa Campus, New Delhi -110 012, Technical Bulletin, **9**: 32.https://krishi.icar.gov.in/jspui/bitstream/123456789/2136/1/Rabi%20Maize-Opportunities%20and%20Challenges.pdf.

Rakshit S, Singh N P, Khandekar N and Rai P K 2021. Diversification of cropping system in Punjab and Haryana through cultivation of maize, pulses and oilseeds. Policy paper. ICAR-Indian Institute of Maize Research.1-37. https://iisrindore.icar.gov.in/pdfdoc/Policypaper1.pdf.

Singh N, Rajendran R A, Shekhar M, Jat S L, Kumar R and Kumar R S 2003. *Maize opportunities and challenges*: A Report. Directorate of Maize Research, New Delhi. https://krishi.icar.gov.in/jspui/bitstream/123456789/2136/1/Rabi%20Maize-Opportunities%20and%20Challenges.pdf.

Tuli M D, Rapolu M K, Sreedevi B, Bandumala N, Kuchi S, Bandeppa S, Saha S, Parnar B, Rathod S and Ondraset G and Sundaram R M 2022. Sustainable diversification of a rice-maize system through conservation agriculture to enhance system productivity in southern India. *Plants.* **11**:1229. https://doi.org/10.3390%2Fplants11091229

Vatta K and Sidhu R S 2007. Income diversification among rural households in Punjab: Dynamics, impacts and policy implications. *The Indian Journal of Labour Economics.* **50**: 723-736. https://www.researchgate.net/publication/293058964_Income_diversification_among_rural_households_in_punjab_Dynamics_impacts_and_policy_implications.

Received: September 00, 2022 Accepted: January 00, 2023