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Abstract

The present investigation was undertaken to evaluate the growth in area, production and productivity and resource use efficiency of maize in various agro-climatic zones of Bihar. The growth pattern in production and productivity were also observed to be positive and statistically significant. The trends in area, production and productivity were also observed positive for both the growth models, linear and compound. The resource use efficiency was evaluated zone-wise and for state as whole levels using Data Envelopment Analysis (DEA) technique for the block period 2008-09 to 2010-11. Technical efficiencies at state level in maize production were found to be 64% for kharif maize and 71% in rabi maize. Allocative mean efficiencies for kharif and rabi maize were calculated 68% and 65%, indicating that farmers could reduce costs by 32% and 35% by using optimum proportions of inputs considering it's prices while selecting it's quantities. Farmers of zone-II of Bihar are well known for large scale production of rabi maize, but still there exist technical inefficiency by 24% and AE by 9%. The value of cost efficiency (CE) emphasizes the reduction of cost by 30% to produce exiting level of output at least cost. The farmers of zone-III are more technically sound as compared to zone-I, zone-II and thus, even at state level too, the TE was observed 88% and 87% for kharif and rabi maize, respectively but AE is very less as compared to other zones i.e. 52% for rabi maize

Keywords: *Maize, Resource Use Efficiency, Compound Growth Rate, Cost Efficiency, Technical Efficiency, Bihar*

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Introduction

Maize (*Zea mays* L.) is an important cereal crop in the world after wheat and rice. The importance of maize lies in its wide industrial uses besides serving as human food and animal feed and fodder. It is the most versatile crop with wider adaptability to varied agro-climatic regions and has highest genetic yield potential among the food grain crops. As the demand for maize is growing globally due to its multiple uses for food, feed and industry sectors, we need to produce more from a given level of resources. New production technologies offer great promise for increasing productivity to meet the growing demands of world consumers. For decades, corn growers have worked for continuous improvement and greater efficiency.

Maize is called 'queen of cereals' as it is grown throughout the year due to its photo-thermo insensitive character and highest genetic yield potential among the cereals. It has tremendous potential for increasing in productivity, profitability, stability and sustainability and is currently being produced in most of the countries of the world. In India, maize is cultivated throughout the year in most of the states of the country for various purposes including food, feed, fodder, green cobs, sweet corn, baby corn, pop corn and industry. It is the third most important food crop in India after rice and wheat. It is nutritious for human consumption because of the presence of carbohydrates, fats, protein, some of vitamins and minerals. That is why; maize has now been placed under nutria-cereal group. The presence of a mixture of carotenoids (beta-carotene, cryptoxanthin, and beta-zeacarotene having pro Vit A activity) provides maize a specific place among cereals. Maize contains 79% starch, 10% protein, 4%fat, 4% fiber and 3% minerals (ICAR Annual Report). The high quality of protein in Quality Protein Maize (QPM) varieties is another attraction, catching the eyes of scientists, planners, policy makers and extension workers to tackle the problem of protein malnutrition prevalent in the world. On the other hand, maize in baby corn stage is a boon for the people, especially weaning infants, old age people and patients under stress condition. Maize is used for three main purposes; as a staple human food, as feed for livestock and as raw material for many industrial products. In India, current consumption pattern of maize is poultry, pig, fish feed 52%, human consumption 24%, cattle feed and starch 11% and seed and brewery industry 1% .Hence, an urgent need is to exploit the potential of maize for the promotion of the health of our population especially the vulnerable segment of the society. It is possible only when maize is utilized in a more diversified ways by converting them into a variety of products such as infant food, health foods/beverages, emergency ration etc. Besides being utilized in normal and therapeutic nutrition, maize has many industrial uses, which will render this crop profitable for farmers..

Maize is cultivated on nearly 185.12 million hectare in the world and its production is about 1018.11 million tonnes with a productivity of 5500 kg/ha during 2013-14. India occupies 6th rank in area and production in the world. At global level its share in total area and production is about 5.13% and 2.29%, respectively. The major maize producing countries are USA, China, Brazil, Argentina, Ukraine, India, Mexico, Indonesia, France and Canada. In India major maize growing states are Karnataka, Andhara Pradesh, Maharashtra, Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, Gujarat and Tamil Nadu.

India is the sixth largest producer of maize in the world contributing 2.29% in total maize production of the world. Bihar was ranked 7th in area under maize among different maize producing states in the year 2013-14. In Bihar Maize is grown in almost all the districts of all the three agro-climatic zones of Bihar. But Zone-I and Zone-II are major maize producing agro-climatic zones of Bihar. In area Khagaria occupies first rank followed by Samastipur, East Champaran, Muzaffarpur and Begusarai and in production, Katihar is at the top followed by Madhepura, Khagaria, Muzaffarpur, Araria and Samastipur. Productivity was found highest in Katihar (6510 kg/ha) followed by Madhepura (5285/kg/ha) Saharsa (4636 kg/ha) Araria (4272 kg/ha) Supaul (4096 kg/ha), Vaishali (4067 kg/ha) and Muzaffarpur (3935 kg/ha). Zone-wise data showed 0.27 million hectare area under maize in zone-II with a production of 12.05 million tones. The productivity was found to be 4397 kg/ha in zone-II which is known for its Rabi maize production while in zone-I area under maize was 0.33 million hectare and production 9.72 million tones. Zone-III recorded only 0.10 million hectare under maize (mainly kharif maize) with a production of 3.01 million tones. The area, production and productivity of maize in the state of Bihar have shown increasing trend over time. The price of maize has also been observed increasing in the recent past.

Methodology

In the light of above observations, present study was undertaken to estimate the growth in area, production and productivity of maize in Bihar using linear and compound growth functions. Assessing resource use in agricultural production is an important issue from sustainability point of view, since it gives pertinent information useful for making sound management decisions, resource allocations and profit maximization. The resource use efficiency of various inputs used in the cultivation of Maize in different agro-climatic zone was also been worked out using Data Envelopment Analysis (DEA).

Data pertaining to area, production and productivity of maize was collected from various issues of Economic *Survey of Bihar and Bihar through figures* from 1971-71 to 2014-15 for the period of 45 years. Growth rates of area, production and productivity of maize were calculated for every 15 years and 45 years as a whole by using the following functions

(a) $$y = a + bt + e$$

Where,

t is the time in years, independent variable
y is dependent variable in terms of area, production and productivity
a is constant
b is regression coefficient and
e is random error

The linear growth rate is calculated by the formula

Linear growth rate (LGR) in percent = (b/$\bar{y}$)x100

(b) $Y = ab^t$ or Log y = log a + t log b
where,

t is the time in years, independent variable
Y is dependent variable in terms of area, production and productivity
a is constant
b is regression coefficient

CGR (%) = (antilog(b)-1)x100

The significance of the growth rates was tested by using student's't' test

i.e. t= r/SE(r) with (n-2) degree of freedom

Where,

r is the Compound growth rate
n is the number of years under study
SE(r) is the standard error of growth rate.

Resource Use Efficiency

For calculating resource use efficiency plot level data of Comprehensive Cost of Cultivation Scheme for the block period 2008-09 to 2010-11 collected from 450 farmers from 45 clusters in Bihar were used. DEA is a well established approach for measuring the relative efficiency of peer decision making units (DMUs) that have multiple inputs and outputs, proposed by Charnes *et al.* (1978) and extended by Banker *et al.* (1984). Performance analysis is a relative concept (Coelli *et al.* 1998). It relates to production analysis and measures the production with a ratio.

Efficiency of resource use which can be defined as the ability to derive maximum output per unit of resource is the key to effectively addressing the challenges of achieving food security. There are various techniques and methods to examine resource use efficiency such as Data Envelopment Analysis (DEA), Stochastic Frontier (SF) production function etc. In the present study, DEA method has been used which is given below:

Data Envelopment Analysis (DEA) approach

Resource use efficiency under different crop production is estimated on the basis of DEA. DEA is a Linear Programming technique for constructing a non-parametric piece wise linear envelop to a set of observed output and input data. Efficiency is defined as a measure of how efficiently inputs are employed to produce a given level of output producing same level of output, with lower level of inputs or more output with the same level of inputs means higher level of efficiency. The technique of DEA has been used to find the relative efficiency score of each farm in relation to farms with minimum input output ratio for all inputs. The score of the most efficient farms being one, the score of each farm will lie between zero and one.

In the present study the DEA approach has been used to analyze the data for optimizing the performance measure of each production unit and determining the most preferable ones. The information obtained included the amount of input costs which incurred during crop production such as human labour, fertilizer seed etc. and the yield as an output.

In order to specify the mathematical formulation of model, we assume that we have K farmers Decision Making Units (DMU) using N inputs to produce M outputs. Inputs are denoted by x_{jk} (j=1,2,….. n) and output are represented by Y_{ik} (i=1,2,3…..m) for each farmer k (k=1,2,…. K). The technical efficiency (TE) of the farmers can measured as:

$$TE_k = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk}$$

Where, $Y_{ik}$is the quantity of i^{th} output produced by k^{th} farmer, $x_{jk}$is the quantity of j^{th} input used by the k^{th} farmer, u_i and v_i are the output and input weights respectively. The farmer maximizes the technical efficiency, TE_k subject to

$$TE_k = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk} \leq 1$$

Where, u_i and $v_j \geq 0$

The above equation indicates that the technical efficiency measure of a farmer cannot exceed one, and the input and output weights are positive. The weights are selected in such a way that the farmer maximizes its own technical efficiency which is executed separately. To select optimal weights, the following linear programming model is specified:

Min TE_k

Subject to

$$\sum_{i=1}^{m} u_i y_{ik} - y_{jk} + \omega \geq 0$$

Where k=1,2,………..k

$$x_{jk} - \sum_{j=1}^{n} u_j x_{jk} \geq 0$$

and u_i and $v_j \geq 0$

The above model shows TE under constant returns to scale (CRS) with an assumption if w=0 and it changes into variable returns to scale (VRS) if w is used unconstrained. In the first case it leads to technical efficiency (TE) and in second case pure technical efficiency (PTE) is estimated. Here the analysis is concerned with the first case.

Technical Efficiency (TE): It can be expressed generally as the ratio of sum of the weighted outputs to sum of weighted inputs. The value of technical efficiency varies between zero and one; where a value of one implies that the DMU is the best performer located on production frontier and has no reduction potential. Any value of TE lower than one indicates that DMU uses inputs inefficiently.

Cost or Economic Efficiency (CE): one can measure both technical and allocative efficiencies to verify the behavioral objectives such as cost minimization or revenue maximization.

Cost minimization DEA is expressed as

$\text{Min}Y_{Xk}{}^{*} w_k{}^{'} X_k{}^{*}$,

Subject to $-y_k+YY\geq 0$,

$X_k{}^{*}-XY\geq 0$,

$Y\geq 0$,

Where $w_k{}^{'}$ is a vector of input prices for the kth farmer and $X_k{}^{*}$ (which is calculated by LP) is the cost minimizing vector of input quantities for the kth farmer, given the input prices w_k and the output level y_k.

Total cost efficiency (CE) or economic efficiency of the kth farmer can be calculated as

$CE= w_kX_k{}^{*}/w_kX_k$

That is the ratio of minimum cost to the observed cost.

While the allocative efficiency (AE) is calculated as the ratio of cost efficiency to technical efficiency

$$AE=CE/TE$$

DEA is well established approach for measuring the relative efficiency of decision making units (DMUs) that have multiple inputs and outputs. We have used this method to investigate the technical efficiency (TE), allocative efficiency (AE) and cost efficiency (CE) or economic efficiency (EE). In this study, we use input-oriented efficiency measures because they reflect local reality where a decrease in scarce resources (inputs) makes use more relevant.

Efficiency or performance analysis is a relative concept relates to production analysis and measures the production with ratio. TE relates the degree to which a farmer produces maximum output from a given bundle of inputs, or uses the minimum amount of inputs to produce a given level of output when the technology exhibits constant returns to scale but is likely to differ otherwise. These two definitions of TE are known as output-oriented or input-oriented efficiency measures, respectively. AE or price efficiency reflects the ability of a farm to use the inputs in optimal proportions, given their respective price EE or CE is distinct from the other two; even though it is the product of TE and AE and reflects the ability of a production unit to produce a well-specified output at minimum cost. An economically-efficient might be both technically and allocatively efficient.

Results and Discussion

Growth Trends in Maize

The trend of growth in area, production and productivity in Bihar during 1970-71 to 2014-15 is presented in Table 1.

In Bihar, the average area under maize during 1970-71 to 2014-15 was 636.78 hectare. The coefficient of variation during this period was found to be 10.09% and linear and compound growth rates were recorded to be -0.072 percent and -0.023 percent per annum respectively. The area of maize exhibited a negative growth trend in state and it was found non-significant in both the cases linear and compound growth rates. The negative growth might be due to decline in kharif maize area due to diseases and pest attack as well as high cost of irrigation due to erratic rainfall.

The average production of maize was found to be 1236.11 thousand tonnes with a coefficient of variation 47.88%. The linear and compound growth rates were computed to be 3.22 percent and 1.367 percent annually and these were found significant at 5% level of probability. The higher growth in maize production might be due to adoption of new technology i.e. high yielding varieties of maize including improved package of practices.

In case of productivity, the average productivity was recorded 1931.52 kg/ha with a coefficient of variation 43.54%. The productivity of maize could increase at 1.385% compound growth rate per annum. The enhanced productivity may be attributed to adoption of new technology as mentioned above.

The whole investigation period consisting of 45 years was divided into three periods 1970-71 to 1984-85, 1985-86 to 1999-2000 and 2001-02 to 2014-15 each of 15 years. The growth rates for each period under investigation were worked out. During the first 15 years coefficient of variation (CV) for area was found to be 9.54% and the area under the crop declined as it was evidenced by negative compound growth rate (0.35%) but on the other hand, the growth rates for production and productivity were found to positive i.e. 0.25% and 1.35% for linear growth and 0.24% and 0.59% for compound growth, respectively.

Table 1. Growth rates of area, production and productivity of maize in Bihar

Period	Area			Production			Productivity		
	LGR	CGR	CV	LGR	CGR	CV	LGR	CGR	CV
Period-I (1970-71 to 1984-85)	-0.82	-0.35	9.54	0.25	0.24	16.40	1.35*	0.59	16.96
Period-II (1985-86 to 1999-2000)	1.39*	0.62*	7.37	4.11*	1.91*	20.64	2.75*	1.26*	14.64
Period-III (2001-02 to 2014-15)	1.20*	0.52*	6.09	5.34*	2.22*	27.87	4.09*	1.71*	21.92
Overall Period (1970-71 to 2014-15)	-0.072	-0.023	10.09	3.22*	1.367*	47.88	3.09*	1.385*	43.54

* Significant at 5% level of probability
LGR = Linear Growth Rate, CGR=Compound Growth Rate, CV= Coefficient of variation

During the second period (1985-85 to 1999-2000) the effect of technical change on area of maize was comparatively observed as it was reflected in positive growth rates being 0.62 CGR per annum with moderately stable CV(7.37%). The growth pattern in production and productivity were also observed to be positive and statistically significant. The production jumped up 1.91% CGR per annum whereas the productivity rose at 1.26% CGR during the period under study. The reason for impressive growth in area, production and productivity of maize during this period may probably be assigned to the fact that technological changes in the crop production technology and increasing demand of maize with better returns.

During the third period (2001-02 to 2014-15), the trends in area, production and productivity were also observed positive in both the growth models, linear and compound. In this period high yielding varieties of maize particularly rabi maize, and high demand of \maize for making different processed items like poultry feed, corn flex etc fetching higher profit may be the causes for rising trend in area, production and productivity of the crop in this period.

Resource use efficiency

Summary statistics for the measures of technical, allocative and economic or cost efficiencies are presented in Table 2. Technical efficiencies at state level in maize production were found to be 64% for kharif maize and 71% in rabi maize, indicating thereby production changes by 36% and 29% in kharif and rabi maize are possible to increase with the available technology. Allocative mean efficiencies for kharif and rabi maize were calculated 68% and 65%

indicating that farmers could reduce costs by 32% and 35% by using optimum proportions of input considering it's prices while selecting it's quantities. The combined effect of TE and AE showed the average CE score 44% and 46% for kharif and rabi maize, this means that according to Farrell's principle, the farmers can potentially reduce their overall cost of maize production on an average by 56% and 54% to produce the existing level of output at least cost. However, farmer's objective and skill might influence their potential and desire to achieve overall CE or EE.

Perusal of zone-wise analysis indicated, technical inefficiency of 16% for kharif maize and 36% for rabi maize. Cost efficiency (CE) of kharif and rabi maize in zone-I provides guidance to farmers that there is scope to reduce cost by 37% and 55 % producing kharif and rabi maize to arrive at least cost point.

Farmers of zone-II of Bihar are well known for high production of rabi maize, but still they have technical inefficiency by 24% and AE by 9%. The value of cost efficiency (CE) emphasizes the reduction of cost by 30% to produce exiting level of output at least cost.

A perusal table of reflected that the farmers of zone-III are more technically sound as compared to zone-I, zone-II and thus even at state level too, the TE was observed 88% and 87% for kharif and rabi maize but AE is very less as compared to other zones i.e. 52% for rabi maize. The estimated value of cost efficiency revealed the fact there is ample scope to reduce the cost of production by 55% to achieve the objective of optimization of income.

Table 2: Zone-wise resource use efficiency of maize in Bihar, TE 2010-11.

Crop	(Sample size) (n)	Technical Efficiency (TE)	Allocative Efficiency (AE)	Cost Efficiency (CE)
Agro-climatic Zone-I				
Maize(Kharif)	69	0.84	0.74	0.63
Maize (Rabi)	21	0.64	0.70	0.45
Agro-climatic Zone-II				
Maize (Rabi)	24	0.76	0.91	0.70
Agro-climatic Zone-III				
Maize (Kharif)	17	0.88	0.84	0.74
Maize (Rabi)	21	0.87	0.52	0.45
Bihar				
Maize (Kharif)	86	0.64	0.68	0.44
Maize (Rabi)	66	0.71	0.65	0.46

Source: Author's calculation

Note: Variables used: working hours of human labour/ha, quantity of NPK used/ha, quantity seed/ha and ground water draft (cum/ha) with their unit prices and output produced per hectare.

Conclusions

Present investigation was undertaken to evaluate the growth in area, production and productivity and resource use efficiency of maize in Bihar and its various agro-climatic zones. The growth in area, production and productivity was evaluated in three study periods as well as for overall period in the state. During the first period, coefficient of variation (CV) for area was found to be 9.54% and the area under the crop declined as it was evidenced by negative compound growth rate (0.35%) but on the other hand, the growth rates for production and productivity were found to be positive i.e. 0.25% and 1.35% for linear growth and 0.24% and 0.59% for compound growth, respectively. During the second period (1985-85 to 1999-2000), the effect of technological change on area of maize was observed as it was reflected in positive growth rates being 0.62 CGR per annum with moderately stable CV(7.37%). The growth pattern in production and productivity were also observed to be positive and statistically significant. The production went up by 1.91% CGR per annum, whereas, the productivity rose at 1.26% CGR during the period under study. During the third period (2001-02 to 2014-15), the trends in area, production and productivity were also observed positive in both the growth models, linear and compound.

The resource use efficiency was evaluated for different zones and state as whole using plot level data collected under cost of cultivation scheme for the block period 2008-09 to 2010-11. Various inputs like human labour, NPK use, seed quantity, groundwater and their cost per hectare were used to estimate the efficiency by applying Data Envelopment Analysis (DEA) technique.

Technical efficiencies at state level in maize production were found to be 64% in kharif maize and 71% in rabi maize, indicating thereby changes in production in kharif and rabi maize are possible by 36% and 29% respectively with the available technology. Allocative mean efficiencies for kharif and rabi maize were calculated 68% and 65%, indicating that farmers could reduce costs by 32% and 35% respectively by using optimum proportions of inputs considering it's prices while selecting it's quantities. Zone-wise analysis indicated the technical inefficiency by 16% for kharif maize and 36% in rabi maize. Cost efficiency (CE) of kharif and rabi maize in zone-I provides guidance to farmers that there is scope to reduce the cost by 37% and 55 % for producing kharif and rabi maize respectively to arrive at least cost point. Farmers of zone-II of state are well known for large production of rabi maize, but still there exist technical inefficiency by 24% and AE by 9%. The value of cost efficiency (CE) emphasizes the reduction of cost by 30% to produce existing level of output at least cost. The farmers of zone-III are more technically sound as compared to zone-I, zone-II and thus even at state level too, the TE was observed 88% and 87% for kharif and rabi maize respectively but AE was very less as compared to other zones i.e. 52% for rabi maize. The estimated value of cost efficiency revealed the fact there is ample scope to reduce the cost of production by 55% through efficient use of resources to achieve the objective of optimization of income. It is important to mention here that rabi maize has been observed as low as around 45% in zone-I, Zone-III and for the state as a whole. Thus, it opined that there is ample scope to minimize the cost at least cost a given level of input (rational use of resources) to produce a given level of output with available technology so as to optimize the net income of maize cultivating community.

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