Total Factor Productivity And Returns To Investment In Paddy Research in Western Maharashtra

Kulkarni, A. R.*, Sanap D. J.** and NirgudeR. R.***

Department of Agricultural Economics, Post graduate Institute,
Mahatma PhuleKrishiVidyapeeth, Rahuri,
Dist-Ahmednagar, Pin code-413722, Maharashtra

ABSTRACT

*Any growth in output that is not explained by some index of input growth is attributed to changes in technology or more broadly Total Factor Productivity. TFP measures the net growth of output per unit of total inputs. In this study, estimation of total factor productivity in paddy crop and returns to investment in paddy research in Western Maharashtra is attempted.For the study, the time series data on cost of cultivation of paddy was collected (1993-94 to 2014-15) from official records of state cost of cultivation scheme to fulfill the objectives. The output index of paddy increased from 0.88 in 1993-94 to 1.60 in 2013-14. The average output index for twenty one years was 1.48. The highest output index was observed in 2006 (2.15).The average input index of paddy was 0.80 for twenty one years.The highest TFP index was observed in 2006-07 (3.33). The result indicates that total factor productivity index of paddy grew at 5.98 per cent per annum. Public research significantly contributed (0.27***) to TFP growth in paddy. The additional investment of one rupee in paddy research generated additional income of `3.04, indicating substantial rate of returns to investment with internal rate of return of 19.10 on research in paddy in Maharashtra.The total factor productivity in paddy crop registered a substantial growth with profitable returns in Western Maharashtra. Hence the Government should allocate substantial funds to public research in paddy for productivity improvement of paddy crop providing food security to masses.*

Keywords: *Total Factor Productivity, Paddy, Estimated Value of Marginal Product, Internal Rate of Return*

Authors affiliations: Kulkarni, A. R.*, Ph.D. Scholar, Department of Agricultural Economics, MPKV, Rahuri.,Sanap D. J.** Junior Research Assistant, MPKV, Rahuri and Nirgude R. R.***, Assistant Professor and Incharge of State Cost of Cultivation Scheme, MPKV, Rahuri.

INTRODUCTION

The year 2004 was declared the “International Year of Rice” because rice is the staple food for more than half of the world's population. Rice has a large influence on human nutrition and the fight against hunger all over the world. Rice cultivation and post-harvest activities provide employment for several hundred million people in rural areas, particularly in developing countries.

More than four-fifths of the world’s rice is produced by small-scale farmers and consumed locally. Rice is a central part of many cultures and it is used in festivals, paintings, songs and religious ceremonies as a symbol of life, fertility and abundance. Some Asian countries even credit rice cultivation with the development of their civilization. It is remarkable that almost every culture has its own way of eating rice and that these different recipes are, in fact, part of the world's cultural heritage.For all of these reasons, “Rice is Life” (FAO, 2004).

Indian agriculture has undergone technological change at different rates across regions and among different crops. Rapid growth in rice production has resulted in substantial increases in the marketable surplus of rice. Many of the benefits of higher efficiency in the use of inputs and lower unit costs of production that technological change has generated have been passed on from farmers to consumers in the form of lower prices. Rice is a principal food crop, which nearly one-fourth of the gross irrigated area in India occupies. Majority of agricultural and food policy initiatives over the period were largely centered on rice and also wheat. However, the public sector Research and Development (R&D) wing has given a top priority to the rice improvement in terms of resource allocation of both capital and human resources (Adlas and Achoth 2006).

Production growth for coarse grains has not been as high: since technological change has been limited for these crops, yields have grown relatively slowly and land has been diverted to more profitable crops like rice and wheat. Of more concern, total factor productivity growth (TFP, or the growth in the amount of output generated by a unit of input), declined in the 1980s compared with the 1970s due to the declining real investments in agriculture (Kumar, 1995). As against India's average yield of paddy of 3.62 tonnes per ha., the world average stands at 4.53 tonnes per ha. The yields per hectare are as high as 6.74 tonnes (in China), 5.75 tonnes (in Vietnam), 5.13 tonnes (in Indonesia) and 4.42 tonnes (in Bangladesh) (Dalwai, 2017).

Paddy is the major food grain consumed in most of the Indian states and plays a major role in Indian economy. Paddy is an important cereal crop consumed by most of the people across the globe and its cultivation provides livelihood security for more than two billion people. India today is not only self-sufficient in respect of demand for food, but is also a net exporter of agri-products occupying seventh position globally. It is one of the top producers of cereals (wheat & rice), pulses, fruits, vegetables, milk, meat and marine fish. However, there remain some chinks in the production armoury, when evaluated against nutritional security that is so important from the perspective of harvesting the demographic dividend of the country. The impressive agricultural growth and gains since 1947 stand as a tribute to the farmers' resilience to multiple challenges and to their grit and determination to serve and secure the nation's demand for food and raw material for its agro-industries (Dalwai, 2018).

A total 209 new varieties/hybrids tolerant to various biotic and abiotic stresses with enhanced quality have been developed for Cereals, Pulses, Oilseeds, Commercial and Forage crops.117 high yielding varieties/ hybrids of cereals comprising 65 of rice, 14 of wheat, 24 of maize, 5 of finger millet, 3 of pearl millet, 1 each of sorghum, barley, foxtail millet, kodo millet, little millet and proso millet were released for cultivation in different agro-ecologies of the country during 2017(Economic Survey, 2017-18).

The area, production and productivity of paddy in Maharashtra during 1960-61 was 1300 ('000'ha), 1369 ('000' MT) and 1054 (Kg/ha) while in 2016-17 it was 1535 ('000'ha), 3581 ('000' MT) and 2333 (Kg/ha). Per cent change in in area, production and productivity of paddy showed positive growth in area by 18.07 per cent, while positive growth was reported in production and productivity by 161.57 per cent and 121.34 per cent, respectively.Area under paddy in Maharashtra was 1572 ('000' ha), while in India it was 43667 ('000' ha). In comparison with India area under paddy in Maharashtra was 3.6 per cent.(Area under principal crops, average for years 2012-13 to 2014-15, Economic Survey of Maharashtra, 2017-18).

MATERIAL AND METHODS

Methodologies of Measuring (TFP) Total Factor Productivity

Total factor productivity concept implies an index of total output per unit of total factor inputs. TFP growth measures the increase in output i.e. not accounted for by the increase in total inputs. Thus total factor productivity index that measure the growth in net output i.e. not accounted for by the growth in basic factor input such as land, labour, capital. It is superior to partial approach as it is composite measure of productivity, which related output to all inputs, simultaneously.

There are three main approaches for estimating the TFP, namely the Production Function Approach (PFA), Growth Accounting Approach (GAA) and the most recent one being the Non-parametric Approach. Growth Accounting Approach (GAA) was used to measure the TFPG.Solow (1957) was the first to propose a growth accounting framework and then Denison (1967 and 1985) refined the approach. In this approach, TFP is measured as a residual factor, which attributes to that part of growth in the output that is not accounted for by the growth in the basic factor inputs. This approach approximates the technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen, 1975). The TFP index is measured as the ration of the index of net output and the index of total factor inputs. The index of total factor inputs is derived as weighted average of indices of labour inputs, capital inputs and land inputs with relative income shares of the three factors as respective weights. The key feature of the GAA is separation of change in production on account of changes in the quantities of factors of production from residual influences, which include technological progress, learning by doing, etc.

The output index, input index and TFP index are constructed separately for paddy crop. To construct output index the time series data (1993-94 to 2013-14) on main product, by product and prices used, where as to construct input index, the time series data with regard to inputs like seeds, manure, chemical fertilizer (NPK), human labour, bullock labour, machine labour, plant protection chemicals, irrigation and prices of inputs are used. Finally the TFP index is computed by dividing output index by input index. We have specified that the index is equal to 1.00 in a particular year i.e. here we considered 1993-94 as base year and TFP chain index constructed as it provides annual changes in productivity over a period of time.

The Chain-linking index takes into account the changes in relative values/costs throughout the period of study. This procedure has the advantage that no single period plays a dominant role in determining the share weights and biases are likely to be reduced. The TFP indices computed using the software TFPIP version 1.0, which developed by Tim Coelli, Centre for Efficiency and Productivity Analysis, University of Queensland, Australia. Time series data on Costs and returns of Paddy crop for the years 1993-94 to 2013-14 collected and compiled from the State Cost of Cultivation Scheme, Department of Agricultural Economics, MPKV, Rahuri. All the data was calculated in real terms by deflating the time series

data on investment using the consumer price index with 2011-12 as a base year.
TFP indices computed as follows:

Tornqvist- Theil TFP index

This index is the commonly used index for measuring TFP growth.It is a superlative index, which can approximate any smooth production or cost function byassociating small changes in relative prices for a commodity with small changes in the quantity of it used.

Tornqvist- Theil TFP index :

Total output index:

(TOI) = $TOI_t/TOI_{t-1}=\prod_j(Q_{jt}/Q_{jt-1})^{(Rjt+Rjt-1)1/2}$

Total input index:

(TII) = $TII_t/TII_{t-1}=\prod_j(Xjt/Xjt\text{-}1)^{(Sjt+Sjt-1)1/2}$

Total factor productivity index (TFPI) of t[th] year is 100 times the ratio of TOI, to the TII and is given by,

$TFPI_t$= (TOI_t/TII_t) x 100

Input price index is given by,

$$\frac{IPI_t}{IPI_{t-1}} = \prod_j \left[\frac{P_{it}}{P_{it-1}} \right]^{(S_{jt}+S_{jt-1})\frac{1}{2}}$$

Where,

R_{jt} = Share of j[th] output in total revenue
Q_{jt} = Output 'j'
S_{jt} = Share of i[th]input in total input cost
X_{it} = input 'i'
P_{it} = Price of i[th] in period 't'

By specifying TOI t-1, TIIt-1 and IPIt-1 equal to 100 in the initial year, the above equation provides the total output, total input, total factor productivity and input price indices for the specified period 't'.

Chain-linking index takes into account the changes in relative values/costs throughout the period of study. This procedure has the advantage that no single period plays a dominant role in determining the share weights and biases are likely to be reduced. The above equations provide the indices of total output, total input, and TFP for the specified year 't'.

Returns to research investments

The time series data from the different years was used. Using the elasticity of TFP with respect to research and development investment, one can estimate the value of marginal product of research and development investment.

EVMP(R) = b*(V*TFP share/R)

Where,

R : Research
B : TFP Elasticity of research investment
V : Value of production associated with TFP
EVMP : Estimated value of marginal product

Internal rate of return to cereal research and development

Internal rate of return also known as Marginal efficiency of capital 'or' Yield on the investment. In economic terms, the IRR "is the interest rate earned on the unrecovered balance over an investment's life so that the unrecovered balance at the end of that time is zero. 'IRR' is the discount rate at which the NPV (Net present worth) of an investment becomes zero. In other words discount rate which equates the present value of future cash flows of an investment with the initial investment. It is one of the several measures used for investment appraisal.

Formula used for internal rate of return:

IRR = (Lower Discount Rate)+(Difference Between The Two Discount Rates)* (Present Worth of Cash Flow At The Lower Discount Rate/Absolute Difference Between The Present Worth of the Cash Flow At The Two Discount Rates)

RESULTS AND DISCUSSION

Indices of input, output and TFP index of paddy

Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production. The output, input and TFP indices of paddy crop are presented in Table 1.

The TFP for paddy increased from 0.80 in 1993 to 2.54 in 2014.The highest TFP index was observed in 2006-07 (3.33). The average TFP index for 21 years was 1.97.The TFP index was quite promising from the year 2005 onwards. The output index of paddy increased from 0.88 in 1993-94 to 1.60 in 2013-14.

The output growth fell to1.26 in 1998 and reached the lowest in 2002 (0.89). It may be due to severe drought conditions in western Maharashtra. The highest output index was observed in 2006 (2.15).The average output index for twenty one years was 1.48. In the case of input index, there were heavy fluctuations, decreasing from 1.10 in 1993-94 to 0.63 in 2013-14.

Table 1 Total Factor Productivity of paddy(1993 to 2014)

Sr. No.	Year	Input	Output	TFP
1	1993	1.00	1.00	1.00
2	1994	1.10	0.88	0.80
3	1995	1.03	1.17	1.13
4	1996	1.01	1.25	1.24
5	1997	0.99	1.32	1.34
6	1998	0.90	1.26	1.41
7	1999	0.84	1.43	1.71
8	2000	0.76	1.37	1.80
9	2001	0.83	1.35	1.63
10	2002	0.68	0.89	1.30
Period I	**Mean**	**0.91**	**1.19**	**1.34**
11	2003	0.79	1.43	1.81

12	2004	0.82	1.53	1.86
13	2005	0.66	1.68	2.55
14	2006	0.65	2.15	3.33
15	2007	0.70	1.96	2.79
16	2009	0.76	1.82	2.38
17	2010	0.67	1.75	2.60
18	2011	0.62	1.70	2.74
19	2012	0.64	1.79	2.81
20	2013	0.62	1.65	2.68
21	2014	0.63	1.60	2.54
Period II	**Mean**	**0.69**	**1.73**	**2.55**
Overall	**Mean**	**0.80**	**1.48**	**1.97**

The average input index of paddy was 0.80 for twenty one years.TFP mean (2.55) increased over first decade signals productivity increased. While, it may take longer gestation period to reflect in compound growth rates of input, output and TFP.

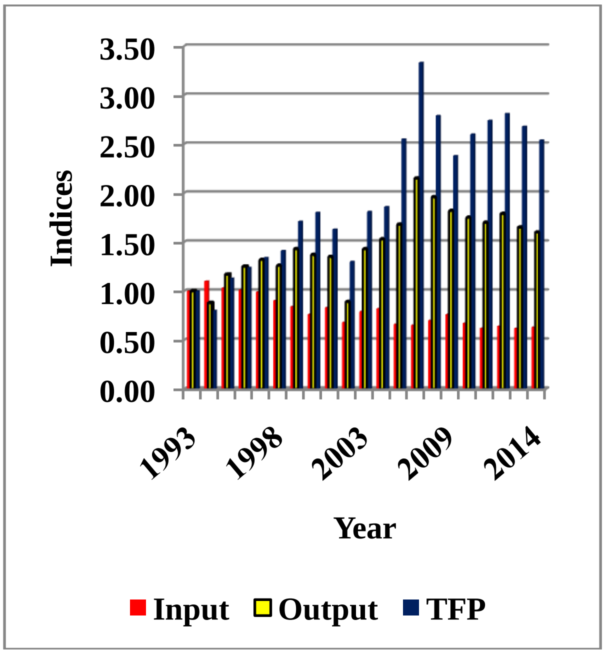


Fig. 1. Input, output and TFP index of paddy

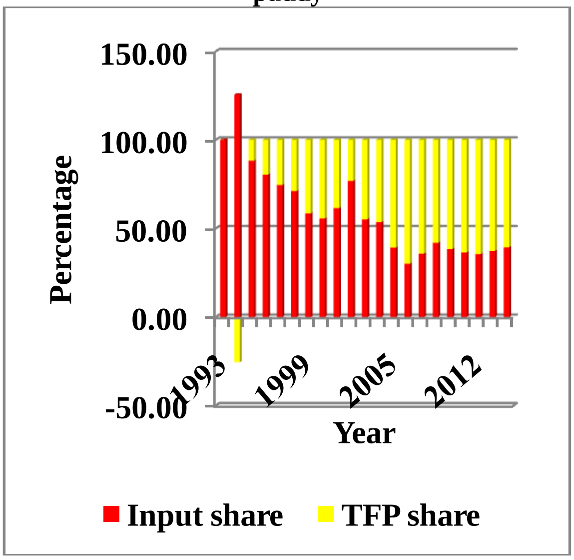
Share of Input and TFP in Total Output of Paddy

Share of input and TFP in total output of paddy is presented in Table 2.Share of input was calculated by dividing input index to output index. TFP share was calculated by subtracting input share from 100. The contribution of technology was low upto the year 2004 and it has increased from 2005 onwards, it may be due suitable climatic conditions in the region and production technology that generates paddy crop output.

Table 2Share of input and TFP in total output of paddy

Year	**(%)**		
	Input Share	**TFP share**	**Total**
1993	100.00	0.00	100
1994	125.48	-25.48	100
1995	88.23	11.77	100
1996	80.43	19.57	100
1997	74.56	25.44	100
1998	71.13	28.87	100
1999	58.50	41.50	100
2000	55.63	44.37	100
2001	61.54	38.46	100
2002	76.84	23.16	100
2003	55.19	44.81	100
2004	53.62	46.38	100
2005	39.19	60.81	100
2006	30.07	69.93	100
2007	35.86	64.14	100
2009	41.99	58.01	100
2010	38.42	61.58	100
2011	36.51	63.49	100
2012	35.59	64.41	100
2013	37.37	62.63	100
2014	39.38	60.62	100

Fig. 2.Share of input and TFP in total output of paddy



Compound Growth Rates of Input, Output and TFP Index of Paddy

In order to assess productivity performance of TFP of paddy in western Maharashtra, the compound growth rates of output, input and TFP indices were estimated for 21 years from 1993-94 to 2013-14 and for two sub-periods viz. period I (1993-94 to 2002-03) and period II (2003-04 to 2013-14).The growth rates in TFP was analyzed to quantify the contributions of various factors to TFP growth such as research expenditure, rural literacy, rainfall, road density, N to P ratio, net irrigated area on TFP of paddy.A perusal of Table 3 reveals that over the entire period of study (1993-94 to 2013-14), TFP grew at the rate of 5.98 per cent per annum. During the same period, output index increased by 3.04 per cent per annum and input index decreased by 2.77 per cent per annum.In sub-periods also the results are more revealing. The input index declined at the rate of 4.5 per cent per annum during period I and output index increased at the rate of 1.88 per cent per annum. The TFP index was increased at the rate of 6.68 per cent during period I. During, period II, the input index was declined at the rate of 2.24 per cent per annum, whereas output index increased at the rate of 0.43 per cent per annum and TFP increased by 2.73 per cent per annum. It clearly indicates that there is contribution of technology in output of paddy.

Table 3 Compound growth rates of input, output and TFP of paddy

Period	CGR (%)		
	Input	Output	TFP
Period I (1993-2002)	-4.5***	1.88	6.68***
Period II (2003-2013)	-2.24***	0.43	2.73
Overall Period (1993-2013)	-2.77***	3.04***	5.98***

*,** and *** indicate significance at 10, 5 and 1 per cent level

Sources of Total Factor Productivity (TFP) Growth of Paddy

The TFP is influenced by research, extension, human capital, intensity of cultivation, application of plant nutrient, infrastructural development and climatic factors.In order to assess the sources of TFP, the TFP index was regressed against the variables *viz*., research investment, rural literacy, rainfall, road density, N to P ratio and net irrigated area. The model specified in log-linear form as:

$$\ln(TFP) = a + b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6$$

Where,

Y = Total factor productivity index (TFP)
A = Intercept/Constant term
X_1 = Research (lakh rupees)
X_2 = Rural Literacy (%)
X_3 = Average rainfall (mm/year
X_4 = Road density (km)
X_5 = N to P ratio
X_6 = Net irrigated area (%)
T = Time variable (years 1, 2, 3….n)
U = Error term

The results indicate that public research (0.27), rural literacy (1.62) significantly contributed to TFP growth in paddy. The rainfall (0.079) is a crucial determinant of TFP in paddy. The ratio of nitrogen to phosphorus nutrients (0.54) was taken as proxy for the balanced use of fertilizer. The road density (1.90) was considered as a proxy for infrastructure. Non-significant and negative contribution by net irrigated area (0.68%) to TFP calls for better irrigation management and technology adoption in the farms. The coefficient of these variables was positive and significant. The estimated 'R' square value was 0.89 indicating that 89 per cent of variation in TFP was explained by the factors included in the model and 'F' value was statistically significant indicating a good fit of the model.

The hypothesis *i.e.* Contribution of agricultural research output and adoption of technology has significant impact on increase in output has been proved. Similar results corroborated with Suresh K. and ChandrakanthM.G. [18] (2015).

Table 4Sources of Total Factor Productivity (TFP) growth of paddy

Variables	Coefficients
Intercept	-10.40(3.20)
(X_1) Research investment (`)	0.27***(0.08)
(X_2) Rural literacy (%)	1.62**(0.71)
(X_3) Rainfall(mm)	0.07**(0.03)
(X_4) Road Density(km)	1.90**(1.07)
(X_5) N to P ratio	0.54**(0.26)
(X_6) Net irrigated area (%)	-0.68(0.69)
R^2	0.89
F value	19.20***
N (No. of observations)	21

*,** and *** indicate significance at 10,5 and 1 % level Figures in parenthesis are standard errors

Estimated value of marginal product of research investment and internal rate of return to research in Paddy in Maharashtra: 1993-94 to 2013-14

The estimated value of marginal product of research investment on paddy and internal rate of return is given in Table 5. Using TFP decomposition results, the technical coefficient of research stock (RESTOCK) representing production elasticity, was multiplied by growth rate of research stock to determine its contribution in the growth of TFP index. Thus, share of TFP growth explained by research is equal to product of growth rate and value of technical coefficient of research stock in percentage terms. The research-induced value of production (V) could be estimated when value of percentage share of research in TFP growth multiplied with average value of production (product of production and price). The 'V' is used to derive estimated value of marginal product (EVMP) of research, where EVMPr = br (V/R). br is elasticity of research stock and R is average value of research stock (B. S. Chandel, 2007).

To estimate the marginal value product the regression coefficients should be positive and statistically significant. Thus, in this study, the regression coefficient of research expenditure of paddy was found significant. The Internal Rate of Return (IRR) is the rate of an investment which we equate the present value of benefits and costs.

Table 5Estimated value of marginal product of research investment and internal rate of return to research in paddy in westernMaharashtra (1993-94 to 2013-14)

Period	EVMP (`)	IRR (%)	Research expenditure flexibility (%)
1993-94 to 2013-14	3.04	19.1	3.70

The estimated value of marginal product of research investment for paddy and internal rate of return is given in Table 5.The regression coefficient of research expenditure of paddy was found positive and significant. An additional income of one rupee in paddy research generated additional income of ` 3.04.The inverse of TFP elasticity with respect to research gives flexibility to research expenditure. The estimated value was 3.70 which mean that to achieve one per cent increase in TFP, the investments in research need to be increased by 3.70 per cent for paddy in western Maharashtra.

The internal rate of return for paddy crop during the period 1993-94 to 2013-14 was 19.1 per cent. It means that every rupee invested in paddy research yielded return of 19.1 per cent annually. Similar observations were reported by Chand*et al.*, [3] (2012).

CONCLUSIONS

I. TFP mean increased over first decade signals productivity increased. While, it may take longer gestation period to reflect in compound growth rates of input, output and TFP.

II. The contribution of technology was low upto the year 2004 and it has increased from 2005 onwards.Growth rates of TFP clearly indicates that there is significant contribution of technology in output of paddy.

III. Public research, rural literacy, road density and N to P ratio significantly contributed to TFP growth in paddy. The rainfall is a crucial determinant of TFP in paddy.

IV. An additional income of one rupee in paddy research generated additional income of ` 3.04. The estimated value of research expenditure flexibility was 3.70 which mean that to achieve one per cent increase in TFP, the investments in research need to be increased by 3.70 per cent for paddy in western Maharashtra.

V. The internal rate of return for paddy crop during the period 1993-94 to 2013-14 was 19.1 per cent. It means that every rupee invested in paddy research yielded return of 19.1 per cent annually.

To conclude, the TFP growth consequences are multidimensional and interrelated. The magnitude TFP growth provides better guidance for the future investment for paddy in terms of minimizing the real cost of production and maximizing profitability of farming society.

REFERENCES

[1] Adlas J., Achoth L. (2006): Is the Green Revolution Vanishing? Empirical Evidence from TFP analysis for Rice. Poster paper prepared for presentation at the International Association of Agricultural Economics Conference. Gold Coast, Australia, Aug 12-18, 2006. American Journal of Agricultural Economics. 57(5) : 910-915.

[2] Ananth, G.S. and Chengappa P. G. 2006, Impact of research investment on technology development and total factor productivity in major field crops of peninsular India, Contributed poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006.

[3] Chand, R., Kumar, P. and Kumar S., 2012. Total Factor Productivity and Returns to Public Investment on Agricultural Research in India,NCAP, New Delhi, Agricultural Economics Research Review Vol. 25(2):181-194.

[4] Chandel, B.S. 2007. How sustainable is the Total Factor Productivity of Oilseed in India. Indian Journal of Agricultural Economics. 62(2) : 244-258.

[5] Christensen, L. R. 1975. Concept and measurement of agricultural productivity.

[6] Coelli, J. Timothy, D. S.PrasadaRao, Christopher J O'Donnell and George E Battese, 2005. An Introduction to Productivityand Efficiency Analysis, Second Edition, Springer: USA.

[7] Dalwai A. 2018. Doubling of Farmers' Income: Agricultural Growth and Farmers' Welfare.Kurukshetra - A Journal of Rural Development,(June) 65(8) pp.5-14.

[8] Dalwai A. 2018. Report of the committee on Doubling Farmers' Income."Input Management for Resource Use Efficiency and Total Factor Productivity".Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, Volume VII, March.

[9] Denison E. F.1972. Issues of Growth Accounting: Survey of Current Business 52, no. 5, pt. 2 (May): 65-94.

[10] Diouf J. 2004.The International Year of Rice: Background, Food and Agriculture Organization of The United Nations, 2004.

[11] Economic Survey, 2017. Agriculture and Food Management. Government of India, Ministry of Finance, Department of Economic Affairs, Volume II, pp.116.

[12] Evenson, R.E., Pray C. and Rosegrant M.W. 1999. Agricultural research and productivity growth in India. Research Report 109. International Food Policy Research Institute, Washington, D.C. U.S.A.

[13] Kumar P., Mittal S. And Hossain M. 2008. Agricultural growth accounting and total factor productivity in south Asia. A review and policy implications. Agricultural Economics Research Review, 21, July December, pp : 145-172.

[14] Kumar, P.,Rosegrant M. and Hazell P.1995. Cereals Prospects in India to 2020: Implications for policy. International Food Policy Research Institute, 2020, Brief 23, June 1995.

[15] Rosegrant, M.W. and Evenson, R.E. Agricultural productivity and sources of growth in South Asia. American Journal of Agricultural Economics. 1992; 74(3), 757-761.

[16] Rozelle, S. Jin, J. Huang and R. Hu, (2003) The impact of investments in agricultural research on total factor productivity in China. Crop variety improvement and its effect on productivity. In: The Impact of International Agricultural Research, Eds: R.E. Evenson and D. Gollin. UK: CABI Publishing.

[17] Solow R. M., 1957."Technical Change and the Aggregate Production Function."Review of Economics and Statistics 39: 312-320.

[18] Suresh, K. and Chandrakanth, M.G. 2015. Total factor productivity and returns to investment in Ragi (finger millet) crop research in Karnataka state, India. Indian Journal of Economics and Development. Vol 3 (3): 199-205.