Total factor productivity and returns to investment in Ragi (finger millet) crop research in Karnataka state, India

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Abstract

Background: Total factor productivity indicates the contribution of non inputs to the growth of agricultural productivity. In this study, estimation of total factor productivity in ragi crop and returns to investment in ragi research in Karnataka is attempted.

Method: For the study, the time series data on cost of cultivation of ragi was collected from farm management reports, published by Directorate of agriculture, Government of Karnataka. The Tornqvist Theil index of TFP is used for measuring TFP growth and regression analysis is employed to identify sources of TFP growth.

Findings: The result indicates that The Total Factor Productivity index of ragi grew at 4.75 per cent per annum. Public research significantly contributed to TFP growth in ragi. The additional investment of one rupee in ragi research generated additional income of Rs. 26.84, indicating substantial rate of returns to investment on research in ragi in Karnataka.

Conclusion/Application: The total factor productivity in ragi crop registered a substantial growth in Karnataka. Hence the Government should allocate substantial funds to public research in ragi for productivity improvement of ragi crop providing food security to masses.

***Keywords*:** Total factor productivity, ragi, returns to research investment, public research

1. Introduction

The green revolution during mid-60's and mid 70's enabled India to become self-sufficient in food production by 1982. Agricultural research in developing high yielding varieties and improved technologies was largely responsible. Thus, the contributions of agricultural research helped to improve welfare gains and reduce poverty in rural and urban areas by lowering prices of food commodities due to increased production and productivity. Agricultural sector is the first to experience diminishing marginal returns compared to any other sector due to low capital per unit of land. The level of investment in public agricultural research extension and irrigation is of such an order that India is one of the largest publicly funded systems in the world [1]. Research has been the prime mover of agricultural growth in India. The National Agricultural Research System (NARS) of India is one of the largest in the world, investing about 0.3% of agricultural gross domestic product (GDP) [2].

The research in agriculture, horticulture, veterinary, fishery, animal husbandry and allied fields is largely carried out by the researchers of State Agricultural Universities (numbering 65) and the research institutes of the Indian Council of Agricultural Research. The SAUs have the mandates of teaching, research and extension, while the ICAR institutes are largely research oriented. The extension component is concentrated in the Krishi Vignana Kendra's (KVK) and every district of the country has to have a KVK, where funding comes from 'plan' and 'non plan' components. Resources for agricultural research for development are scarce.

Note: This study is a part of Ph.D. Research carried out by the first author under the chairmanship of second author

Therefore, the efficient resource allocation and prioritizing investments requires the assessment of economic impacts of research. Without the economic analysis it would be difficult to assess the the social value of scientific knowledge and technologies and to make judgments about the trade-offs in the allocation of scarce resources in research [3].

A significant volume of research comes out from the All India Coordinated Research Projects on different crops. Currently there are 61 AICRPs spread all over India. The 'non plan' component of the ICAR is through the All India Coordinated Research Projects in different crops and innovations. The research component budget for the SAUs is modest. At UAS Bangalore the AICRP on small millets has the national centre and national sub centre of AICRP on pigeon pea. Research conducted by both these centres is the subject matter of this study, with the intention of measuring their economic contribution.

Finger millet (ragi) is considered as important millet grown in the world and it ranks fourth after sorghum, pearl millet and foxtail millet. It is largely cultivated in Africa, South Asia and China. Africa is the native home of ragi especially the high lands of Ethiopia and Uganda. The area under small millets was coming down and showing a declining trend in the country. In the case of finger millet also it was true; the area under finger millet was around 2.6 million hectares during 1970's has gradually declined to 1.286 million hectares during 2010-11. However, the production of ragi has maintained around 2.193 million tonnes and it was mainly due to the significant increase in productivity from 10.40 quintals per hectare during 1970's to around 17.05 quintals per hectare during 2010-11. The finger millet cultivation is normally observed in states like Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Gujarat, Jharkhand, Madhya Pradesh, Orissa, Uttarkhand and Uttar Pradesh. It is cultivated as rainfed crop largely during kharif season. In irrigated areas this crop occupies very small proportion especially in Karnataka, Tamil Nadu and Andhra Pradesh. The crop is extremely hardy and more or less devoid of major pests and diseases. The crop exhibits high resilience and capable of withstanding climatic vagaries and still ensuring reasonable harvest.

Finger millet is the third most important food and fodder crop after rice and sorghum in Karnataka. It is cultivated largely in southern parts of Karnataka and Karnataka is the largest grower of finger millet in the country accounting for nearly 60% of the total area and 65% of the total production. During 2010-11 finger millet was grown over 7.87 lakh hectares with production of 15.88 lakh tonnes and a productivity of 2122 kg/ha.

In Karnataka since 1966 large number of varieties/technologies released in ragi crop, especially University of Agricultural Sciences, Bangalore contributed high in developing and releasing of technologies in ragi crop. This study undertaken to assess the contribution of ragi research in Karnataka with following objectives

1. To examine the total factor productivity of ragi in Karnataka
2. To identify sources of TFP growth in ragi and to measure rate of return to ragi research

2. Materials and Methods

Total factor productivity measures the increase in total output which is not accounted for by increases in total conventional inputs. The total factor productivity index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth rate in total output less the growth rate in total inputs [4].

2.1. Tornqvist- Theil TFP index

The Tornqvist index of TFP is the commonly used index for measuring TFP growth. It does not require the assumption of neutral technical change and allows for variable elasticity of substitution [1]. The Tornqvist index of TFP is:

$$\ln(TFP_{t+1}/TFP_t) = \tfrac{1}{2}\sum_j (R_{jt+1} + R_{jt}) \ln (Q_{jt+1}/Q_{jt}) - \tfrac{1}{2}\sum_j (S_{it+1} + S_{it}) \ln(X_{it+1}/X_{it}) \quad \ldots\ldots\ldots(1)$$

Where,

R_{jt} is the share of output j in revenues,

Q_{jt} is output j,

S_{it} is the share of input i in total input cost, and

X_{it} is input *i,* in period *t.*

$R_{jt} = (P_{jt} * Q_{jt}) / \sum (P_{jt} * Q_{jt})$,

Here P_{jt} is the price of output of crop Q_j in period t

$$S_{it} = (W_{it}X_{it}) / \sum_{i=1}^{N}$$

Where,

W_{it} is the price of input X_i in period t.

The output index, input index and TFP index are constructed separately for Ragi and Red gram crop. To construct output index the time series data (1990-91 to 2009-10) 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, human labour, bullock labour, machine labour, plant protection chemicals 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 1990-91 as base year and TFP chain index constructed as it provides annual changes in productivity over a period of time [5]. 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 [6].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 ragi crop for the years 1990-91 to 2009-10 collected and compiled from the reports of Farm Management Division, Department of Agriculture, GOK.

2.2. Sources of TFP growth

The TFP is influenced by research, extension, human capital, and intensity of cultivation, application of plant nutrients, infrastructural development and climatic factors. As an input to public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth [7].

In order to assess the determinants of TFP, the TFP index was regressed against the following variables:

Research (research expenditure per ha of crop area);
Rural literacy (proportion of rural population which is literate);
Kharif rainfall (actual rainfall in mm during months of June –September);
Road (road density, km per 100 sq. km);
NP Ratio (ratio of N to P_2O_5 nutrients used).
Regression analysis was attempted using the above variables in both ragi and red gram crops for the study: The model specified in log linear form as:

$$\ln (TFP) = a+b_1\ln X_1+b_2\ln X_2+b_3\ln X_3+b_4\ln X_4+b_5\ln X_5+e \quad \text{.....(1)}$$

a = constant;

X_1 = Research investment (Rs.)

X_2 = Rural literacy (%)

X_3 = Kharif rainfall (mm)

X_4 = Road density (km/100 sq.km)

X_5 = N to P ratio

b1….b5 = regression co-efficients

e = error term

2.3. Returns to Research investments

The value of marginal product for research is estimated as per Equation (1)

EVMP (Research investment) = bi (V/Research investment) ------- (1)

Where,

V is the value of crop production associated with TFP (= value of output for crop multiplied by the share of TFP in total output), Research investment is the research stock and b_i is the TFP elasticity of research investment estimated from TFP model 1. The benefit stream was generated under the assumption that the investment made in research in t–i will start generating a benefit after a lag of five years, at an increasing rate during the next nine years, will remain constant for the next nine years and thereafter, it will start declining (3). According to [8], an investment of one rupee in the year t–i will generate a benefit equal to 0.1 EVMP in the year t–i+6, 0.2 EVMP in the year t–i+7, …..Soon till t–i+13, and it will be 0.9 EVMP in the year t–i+14. After this, the benefit will be equal to EVMP up to the year t–i+23. Then, the benefit from the year t–i+24 onwards will again start declining and will be equal to 0.9 EVMP in the year t–i+24, and 0.8 EVMP in the year t–i+25, and so on. This benefit stream can then be discounted at the rate, say 'r', at which the present value of the benefit is equal to one. Thus, 'r' was considered as the marginal internal rate of return to public research investment [7].

3. Results and Discussion

The output, input and TFP indices of ragi crop are presented in Table 1. Considering the area under ragi in Karnataka, 99 per cent of the area under ragi is in Southern Karnataka. From the Table 1 it is observed that the TFP for ragi increased from 1.27 in 1991 to 2.88 in 2009. The TFP is fell to1.22 in 1994 and 1.17 in 2002 due to drought during that period. The highest TFP index was observed in 2005-06 (3.91). The average TFP index for 20 years was 1.87.The output index of ragi increased from1.45 in 1991 to 1.51 in 2009. The output growth fell to 0.27 in 1994 and reached the lowest in 2002 (0.95). The highest output index was observed in 2005. The average output index for twenty years was 1.47. In the case of input index, there were heavy fluctuations, decreasing from 1.14 in 1991-to 0.53 in 2009. The average input index of ragi was 0.84 for twenty years.

In order to assess productivity performance of TFP of ragi in Karnataka, the compound growth rates of output, input and TFP indices were estimated for 20 years from 1990-91 to 2009-10 and for two periods, viz. period I (1990-91 to 1999-00) and period II (2000-01 to 2009-10). The results of the same have been presented in the Table 2. A perusal of Table 2 reveals that over the entire period of study (1990-91 to 2009-10), TFP grew at the rate of 4.75 per cent per annum. During the same period, output index by 1.05 per cent per annum and input index decreased by 3.52 per cent per annum. In sub periods also the results are more revealing. The input index declined at the rate of 4.31 per cent per annum during period I, while output index increased at the rate of 1.81 per cent per annum. The TFP index increased at the rate of 5.72 per cent during period I. During, period II, the input index continued to decline at the rate of 5.34 per cent per annum, whereas output index increased marginally at the rate of 0.59 per cent per annum. The TFP index witnessed an impressive growth of 6.17 per cent per annum during period II.The improvement in total factor productivity is due to non-inputs such as rainfall, road length, markets, better management practices, research and extension efforts etc. The UAS, Bangalore has released a number of new improved varieties to increase productivity which are tolerant to drought. Hence, agricultural universities played a crucial role in growth of total factor productivity of ragicrop. The results are corroborated the findings of [9], [10][11].

3.1. Sources of total factor productivity growth in ragi

The growth rate in TFP was analysed to quantify the contributions of various factors to TFP growth such as research expenditure, rural literacy, Kharif rainfall, road density, N to P ratio on TFP of Ragi (Table 3). The results indicate that public research (0.142), road density (0.695) and rural literacy (0.530) significantly contributed to TFP growth in ragi. The rainfall is a crucial determinant of TFP in ragi. The ratio of nitrogen to phosphorus nutrients (-0.080) was taken as proxy for the balanced use of fertiliser. This coefficient was negative and non-significant. The road density was considered as a proxy for infrastructure. The coefficient of this variable was positive and significant. The estimated R square value was 0.71 indicating that 71 % of variation in TFP explained by the factors included in the model and F value was statistically significant indicating a good fit of the model.

3.2. Returns to investment on public agricultural research

To estimate the marginal value product and internal rate of return, the regression coefficients should be positive and statistically significant [7]. Thus, in this study, the regression coefficient of research expenditure of ragi was found significant. The inverse of TFP elasticity with respect to research gives flexibility to research expenditure and is presented in the Table 4. The estimated value was 7.05 which mean that to achieve one % increase in TFP, the investments in research need to be increased by 7.05 % for ragi in Karnataka.

3.3. Value of marginal product in ragi

The estimated value of marginal product of research investment on ragi and marginal internal rate return of ragi research is given in Table 4. The results revealed that additional investment of one rupee in ragi research generated additional income of Rs. 26.84, indicating very high rates of returns to public investments in Karnataka. The findings corroborated with the findings of [7], [1].Research is considered as an important factor responsible for productivity enhancement. From the Table 4 it is observed that the marginal internal rate of return for ragi crop during the period 1990-91 to 2009-10 was 42.50%. It means that every rupee invested in ragi research yielded a return of 42.50% annually.

Table 1. Total Factor Productivity of Ragi in Karnataka during 1990 to 2009.

Year	Output Index	Input Index	TFP index
1990	1.00	1.00	1.00
1991	1.45	1.14	1.27
1992	1.35	1.07	1.26
1993	1.58	1.12	1.41
1994	1.27	1.04	1.22
1995	1.61	0.96	1.67
1996	1.54	0.92	1.68
1997	1.16	0.85	1.37
1998	1.56	0.86	1.81
1999	1.24	0.68	1.82
2000	1.80	0.84	2.14
2001	1.68	0.87	1.92
2002	0.95	0.83	1.17
2003	1.22	0.76	1.61
2004	1.87	0.87	2.15
2005	2.20	0.56	3.91
2006	1.06	0.53	1.99
2007	1.95	0.70	2.80
2008	1.49	0.62	2.41
2009	1.51	0.53	2.88
Mean	1.47	0.84	1.87

Table 2. Annual growth rates in input use, output use and TFP growth in Ragi in Karnataka: 1990-91 to 2009-10 (in per cent)

Sl. No.	Period	Total output	Total input	TFP
1	1990-91 to 1999-00 (Period I)	1.81	-4.31	5.72
2	2000-01 to 2009-10 (Period II)	0.59	-5.34	6.17
3	1990-91 to 2009-10 (overall)	1.05	-3.52	4.75

Table 3. Estimated parameters of TFP decomposition for Ragi, 1990-91 to 2009-10

Variables	Ragi	
	Coefficients	Standard Error
Intercept	-5.289***	1.769
Research	0.142*	0.080
Rural literacy	0.530**	0.160
Kharif Rainfall	0.050	0.088
Road density	0.695*	0.366
N to P ratio	-0.080	0.213
R^2	0.71	
F value	6.821***	

Note: ***, ** and * indicate significance at 1, 5 and 10 % levels, respectively

Table 4. Estimated value of marginal product of research investment and marginal internal rate of return to research in Ragi in Karnataka: 1990-91 to 2009-10

Period	EVMP (Rs.)	MIRR (%)	Research expenditure flexibility
1990-91 to 2009-10	26.84	42.50	7.05

4. Conclusion

The total factor productivity in ragi crop registered a substantial growth in Karnataka. Public research is key and significant source of TFP growth in rainfed staple food crop like ragi. An additional investment of one rupee in ragi research generated additional income of Rs. 26.84 and the marginal internal rate of return estimated to be 42.50 indicating investment in ragi research generated substantial returns to the society. Hence the Government should allocate substantial funds to public research in ragi for productivity improvement of ragi crop providing food security to masses as also serving as a climate change crop.

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