ECONOMIC IMPACT OF PUBLIC SECTOR AGRICULTURAL RESEARCH IN RAGI AND REDGRAM IN KARNATAKA

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Affectionately dedicated to

My beloved

Mother, Father, Brother, Sister

and Teachers

DEPARTMENT OF AGRICULTURAL ECONOMICS
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CERTIFICATE

This is to certify that the thesis entitled "**ECONOMIC IMPACT OF PUBLIC SECTOR AGRICULTURAL RESEARCH IN RAGI AND REDGRAM IN KARNATAKA"** submitted by **Mr. SURESH. K, ID.NO. PAK 9004** in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** in **AGRICULTURAL ECONOMICS** to the University of Agricultural Sciences, GKVK, Bangalore is a record of bona-fide research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore,
December, 2013

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ECONOMIC IMPACT OF PUBLIC SECTOR AGRICULTURAL RESEARCH IN RAGI AND REDGRAM IN KARNATAKA

Suresh K

Abstract

In this study, the economic impact of research in ragi and redgram crops in Karnataka is analyzed and quantified using economic surplus, TFP and Partial Budgeting approaches. For this purpose, in Ragi, GPU 28 and in Redgram BRG 2 varieties released by the University of Agricultural Sciences, Bangalore have been considered as they were appreciably performing with increasing adoption over time. The primary data on costs and returns in the cultivation of the main and check varieties have been obtained from farmers. The gross returns realized by the BRG 2 red gram farmers as pure crop per acre was Rs.18, 513, whereas it was Rs.16, 082 by check variety (TTB 7) farmers with a difference of Rs. 2430 per acre, higher by 15 percent. The gross return realised by the GPU 28 farmers were Rs. 18,236 whereas it was Rs. 14,389 by check variety farmers higher by 27 percent.

The estimated economic surplus due to adoption of BRG 2 redgram variety in Karnataka was Rs. 56.47crores for the period 1995 to 2010. The economic surplus due to Ragi GPU 28 variety is Rs. 1540 crores from 1986 to 2010. The economic impact of research in red gram and ragi using partial budgeting technique indicated that the total economic benefit realised by adopting the BRG 2 redgram variety in Karnataka is estimated as Rs.3.84 crores per year and Rs. 115.44 crores per year for GPU 28 variety of ragi.

The Total Factor Productivity index of redgram grew at the rate of 3.31 per cent per annum and that of ragi grew at 4.75 per cent per annum. Thus, 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.

Date:	Major Advisor
Place: Bangalore	(Dr.M.G. Chandrakanth)

ಕರ್ನಾಟಕದಲ್ಲಿ ರಾಗಿ ಮತ್ತು ತೊಗರಿ ಬೆಳೆಗಳ ಸಾರ್ವಜನಿಕ ವಲಯ ಕೃಷಿ ಸಂಶೋದನೆಯಿಂದಾದ ಆರ್ಥಿಕ ಪರಿಣಾಮಗಳು

ಸುರೇಶ ಕೆ.

ಸಾರಾಂಶ

ಈ ಅಧ್ಯಯನದಲ್ಲಿ ರಾಗಿ ಮತ್ತು ತೊಗರಿ ಬೆಳೆಗಳ ಸಂಶೋಧನೆಯಿಂದ ಕರ್ನಾಟಕದಲ್ಲಿ ಆದ ಆರ್ಥಿಕ ಪರಿಣಾಮಗಳನ್ನು ಆರ್ಥಿಕ ಹೆಚ್ಚುವರಿ, ಸಮಗ್ರ ಅಂಶದ ಉತ್ಪಾದಕತೆ ಸೂಚ್ಯಂಕ ಮತ್ತು ಭಾಗಶಃ ಬಜೆಟಿಂಗ್ ಕಾರ್ಯವಿಧಾನಗಳನ್ನು ಬಳಸಿಕೊಂಡು ವಿಶ್ಲೇಷಿಸಲಾಗಿದೆ ಮತ್ತು ಅಳೆಯಲಾಗಿದೆ. ಈ ಉದ್ದೇಶಕ್ಕಾಗಿ ಕೃಷಿ ವಿಶ್ವ ವಿದ್ಯಾನಿಲಯ, ಬೆಂಗಳೂರು ಬಿಡುಗಡೆಗೊಳಿಸಿದ ಜಿ.ಪಿ.ಯು. ೨೮ ರಾಗಿ ತಳಿ ಮತ್ತು ಬಿ. ಆರ್. ಜಿ. ೨ ತೊಗರಿ ತಳಿಗಳನ್ನು ಪರಿಗಣಿಸಲಾಗಿದೆ. ಏಕೆಂದರೆ ಈ ತಳಿಗಳು ಗಮನಾರ್ಹವಾದ ಇಳುವರಿ ಮತ್ತು ಉತ್ತಮ ಪ್ರದರ್ಶನ ತೋರುತ್ತಿವೆ. ತಳಿಗಳ ಅಳವಡಿಕೆ ವರ್ಷದಿಂದ ವರ್ಷಕ್ಕೆ ಹೆಚ್ಚುತ್ತಿದೆ. ಈ ತಳಿಗಳ ಉತ್ಪಾದನೆಗೆ ತಗಲುವ ವೆಚ್ಚ ಮತ್ತು ಆದಾಯದ ಪ್ರಥಮ ಮಾಹಿತಿಯನ್ನು ರೈತರಿಂದ ಪಡೆಯಲಾಗಿದೆ. ತೊಗರಿ ಬಿ. ಆರ್. ಜಿ. ೨ ತಳಿ ಬೆಳೆಯುವ ರೈತರು ಒಂದು ಎಕರೆಗೆ ರೂ. ೧೮,೫೧೩ ರಷ್ಟು ಒಟ್ಟು ಆದಾಯವನ್ನು ಪಡೆದಿರುತ್ತಾರೆ, ಅದೇರೀತಿ ಟಿ.ಟಿ.ಬಿ ೭ ತೊಗರಿ ತಳಿ ಬೆಳೆಯುವ ರೈತರು ಒಂದು ಎಕರೆಗೆ ರೂ. ೧೬,೦೮೨ ರಷ್ಟು ಒಟ್ಟು ಆದಾಯವನ್ನು ಪಡೆದಿರುತ್ತಾರೆ. ಒಂದು ಎಕರೆಗೆ ೨,೪೩೦ ರೂ ಅಂದರೆ ಶೇ. ೧೫ ರಷ್ಟು ಹೆಚ್ಚುವರಿ ವ್ಯತ್ಯಾಸ ಇದೆ. ಜಿ.ಪಿ.ಯು. ೨೮ ರಾಗಿ ಬೆಳೆಯುವ ರೈತರು ಒಂದು ಎಕರೆಗೆ ೧೮,೨೩೬ ರೂ. ಗಳಷ್ಟು ಒಟ್ಟು ಆದಾಯ ಪಡೆದಿರುತ್ತಾರೆ. ಅದೇ ರೀತಿ, ಇಂಡಾಫ್ ೫ ರಾಗಿ ತಳಿ ಬೆಳೆಯುವ ರೈತರು ಒಂದು ಎಕರೆಗೆ ೧೪, ೩೮೯ ರೂ. ಗಳಷ್ಟು ಒಟ್ಟು ಆದಾಯ ಪಡೆದಿದ್ದು, ಇದರಲ್ಲಿ ಶೇ. ೨೭ ರಷ್ಟು ವ್ಯತ್ಯಾಸವನ್ನು ಕಾಣಬಹುದು.

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ಭಾಗಶಃ ಬಜೆಟ್ ತಂತ್ರವನ್ನು ಬಳಸಿಕೊಂಡು ಕರ್ನಾಟಕದಲ್ಲಿ ತೊಗರಿ ಮತ್ತು ರಾಗಿ ಬೆಳೆಗಳ ಸಂಶೋಧನೆಯಿಂದ ಆದ ಆರ್ಥಿಕ ಪರಿಣಾಮಗಳೆಂದರೆ ಬಿ. ಆರ್. ಜಿ. ೨ ತೊಗರಿ ತಳಿ ಅಳವಡಿಸಿದ್ದರಿಂದ ಕರ್ನಾಟಕದಲ್ಲಿ ರೂ. 3.84 ಕೋಟಿಗಳಷ್ಟು ಆರ್ಥಿಕ ಲಾಭವನ್ನು ಅಂದಾಜಿಸಲಾಗಿದ್ದು, ರಾಗಿ ತಳಿ ಜಿ.ಪಿ.ಯು. ೨೮ ಅಳವಡಿಕೆಯಿಂದ ವರ್ಷಕ್ಕೆ ಸುಮಾರು ರೂ. 115.44 ಕೋಟಿಗಳಷ್ಟು ಆರ್ಥಿಕ ಲಾಭವನ್ನು ಅಂದಾಜಿಸಲಾಗಿದೆ. ಕರ್ನಾಟಕದಲ್ಲಿ ತೊಗರಿಯ ಸಮಗ್ರಾಂಶ ಉತ್ಪಾದಕತೆ ಸೂಚ್ಯಂಕವು ವರ್ಷಕ್ಕೆ ಶೇ. ೩.೩೧ ರಷ್ಟು ಬೆಳೆದಿದ್ದು, ಅದೇ ರೀತಿ ರಾಗಿಯು ವರ್ಷಕ್ಕೆ ಶೇ. ೪.೭೫ ರಷ್ಟು ಬೆಳವಣಿಗೆ ಕಂಡಿದೆ. ರಾಗಿ ಸಮಗ್ರಾಂಶ ಉತ್ಪಾದಕತೆ ಬೆಳವಣಿಗೆಯಲ್ಲಿ ಸಾರ್ವಜನಿಕ ಸಂಶೋಧನೆಯು ಗಮನಾರ್ಹ ಕೊಡುಗೆ ನೀಡಿದೆ. ಕರ್ನಾಟಕದ ರಾಗಿ ಸಂಶೋಧನೆಯಲ್ಲಿ ಪ್ರತಿ ಒಂದು ರೂಪಾಯಿ ಹೆಚ್ಚುವರಿ ಬಂಡವಾಳದ ಹೂಡಿಕೆಯಿಂದ ,ರೂ. ೨೬.೮೪ ಗಳಷ್ಟು ಹೆಚ್ಚುವರಿ ಆದಾಯ ಬರುತ್ತಿದ್ದು, ಈ ಆದಾಯವು ಕರ್ನಾಟಕ ರಾಗಿ ಸಂಶೋಧನೆಗೆ ಗಣನೀಯ ಪ್ರಮಾಣದ ಆದಾಯವೆಂದು ಪರಿಗಣಿಸಲಾಗಿದೆ.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Measuring contribution of agricultural innovations has been a challenging task for economists and generators of technology especially when the policy makers seek information on macro level impacts. Most often linear extrapolation of on farm benefits is resorted to on *ad hoc* basis. The linear extrapolation of micro level experimental result/s realized per plot by scientists discounts the operation of the law of diminishing marginal returns to land, the common denominator. The, linear extrapolation of benefits from new technology is thus incorrect as the impact depends also on factors *inter alia*, probability of performance of innovation or technology in the field, rate of adoption of the technology by farmers (as farmers may not fully adopt the new technology and may make on farm adjustments), rate of depreciation of technology.

Economists are often asked to find the economic impact of new technologies in SAU/ICAR context. The discipline of economics provides the rationale and the methodology to compute the impacts considering tangible and intangible benefits of research. Valuation of intangibles continues to be a challenging task. Policy makers seek answers from recipients of research funds like the SAUs / ICAR institutes for a reflection of economic impact of their technologies / innovations. Scientists endeavor in generating new technologies and upon generation, release them following the official codes of research procedures through their respective Zonal Research and Extension Councils. However, on the other hand, farmer acceptance and adoption rates seem to be lower than expected.

Under estimation of costs and over estimation of returns

The causes for the widening gap in the transfer of technologies include *inter alia* the economic viability of and the economic impact of new technologies. The scientists often use direct costs and benefits of their technologies and use the BC Ratio for the findings from experiments conducted and extrapolate the same to the district or State level. Thus the costs are underestimated since implicit costs as well as opportunity costs such as return to land, cost of farm produced inputs, family labour, capital, management, risk premium are not accounted. In addition, the public investment on research and extension, the probability of adoption of new technology, probability of performance of new technology, depreciation of technology involved are not accounted for. In the linear extrapolation of economic gains or benefits, the returns are obviously overestimated, since the law of diminishing marginal returns which is the major limiting factor in agriculture is discounted in estimation.

Quantification of research benefits is complex

The benefits from research may be from a new variety, or new practice, or processing, a new process, a new product, a new market, a new value chain, a new institution. Some research may be basic in nature and may not have immediate application. The research benefits and costs are spread horizontally over areas, and vertically over years and hence time lags in quantification exist. There may be externalities generated in the process. Some research may aim at capacity building, integrated farming systems, and social science research, which are not easily quantifiable. The time lengths of benefits from research are often indicated arbitrarily by scientists and there are no proven theories to estimate the same. This introduces bias in the estimation of rate of return to research investment. Further, the uncertainty and variations in the (1) impact and adoption of research, (2) political, natural and economic environments which influences commodity supplies, (3) the market conditions such as cob-webs, (4) the availability of quality infrastructure over time and space in adequate quantity, (5) availability of extension to meet client needs, (6) impact of technology at different locations, farm situations, adoption patterns, (6) efficiency of extension system, (7) receptivity of farmers exist. Considering the costs of research and extension, as the researchers and extension specialists are simultaneously and over time involved in several studies / projects, the research and extension costs are available at aggregate levels and are not available crop wise, technology and innovation wise. In addition there are synergies in research and extension system, responsible for adoption, which is also difficult to quantify. Intervening variables such as literacy, awareness, proactive role, education, capacity building, substantially contribute to adoption, which are difficult to measure.

The agricultural universities in India are established on the pattern of the land grant colleges of the United States. The contributions made by SAUs as partners of the National Agricultural Research System (NARS), are immense. Green revolution, with impressive social and economic impact, was due to significant contributions of agricultural universities, by capacity building and generation of new technologies. While the contributions have made the country food secure, the sustainability of the system has been at stake. The decline in public investment in agriculture, infrastructure and agricultural education and research has resulted in sluggish performance of agriculture. In addition, agriculture research is also influenced by the diminishing marginal returns. While the agricultural universities continue to perform well, high academic standards set earlier, are suffering a setback.

Measurement of technological contributions in rainfed crops is challenging as accounting for rainfall has no universally approved procedure. For instance, whether to consider the annual rainfall, number of rainy days, variation in rainfall, result in different results. In addition, considering the macro data on productivity of different crops due to input use, seldom considers the data on how irrigation water is provided for and measured. These complexities exacerbate the predicament of over estimation.

In India the State Governments and the ICAR have been funding for agricultural research through the established network of research organizations in the country. This was made possible through committed and continued support to agricultural research, and the ability of research managers to visualize research challenges and evolve appropriate institutional responses to them (Pal *et al.*, 2005). Agriculture is considered as state subject under Indian constitution

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 (Evenson *et al* 1999). 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) (Ranjitha and Mruthyunjaya., 2005).

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 Kendras (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. 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 (Alston *et al.*, 1998).

AICRP (All India Coordinated Research Projects)

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 center and national sub center of AICRP on pigeon pea. Research conducted by both these centers is the subject matter of this study, with the intention of measuring their economic contribution. In this study, the two crops selected for measuring the economic contribution of research are rainfed crops of Ragi (*Eleusine coracana*) and red gram (*Cajanus cajan*). While ragi, the finger millet provides staple food, redgram, the legume provides staple source of protein. UASB researchers have been forerunners in the release of promising varieties of ragi and redgram since green revolution.

Finger millet (*Eleusine coracana)*

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).

Redgram (*Cajanus cajan*)

Redgram is an important pulse crop in India. Redgram is also known as Tur, Arhar and Pigeonpea. It is largely cultivated and consumed in developing countries and this crop is widely grown in India. India ranks first in the production and consumption of redgram in the world. Redgram accounts for about 20 per cent of the total production of pulses in the country. Redgram is a staple food and rich in protein. It contains about 22 per cent of protein, which is almost three times of cereals.

Redgram is consumed in the form of split pulse as dal, which is an essential supplement of cereal diet. It also plays a crucial role in sustaining soil fertility by improving physical properties of soil and fixing atmospheric nitrogen. It is resistant to drought and suitable for dry land farming and predominately grown as an intercrop with other crops.

Redgram is grown throughout the tropical and subtropical countries of the world especially in South Asia, Eastern and Southern Africa, Latin America, Caribbean countries and Australia. In India, Red gram is one of the most widely grown pulse crops. It was cultivated over an area of 4.36 million hectares with a production of 2.86 million tonnes and productivity of 655 kgs per hectare in 2010-11. Maharashtra is the largest producer of redgram accounting for nearly 34.11 per cent of the total production followed by Karnataka (18.49%), Uttar Pradesh (10.80%), Gujarat (9.54%), Andhra Pradesh (9.26%) and Madhya Pradesh (5.75%). These six major states together contribute about 88 percent of the total production and about 90 percent of the total area in the country in 2010-2011. Among the major red gram growing states, Maharashtra state occupied largest area under the crop and accounts 29.82 percent of the total area in the country followed by Karnataka (20.40%), Andhra Pradesh (14.63%), Madhya Pradesh (11.16%), Uttar Pradesh (7.88%) and Gujarat (6.34%). The productivity of red gram is highest in Delhi (1750 kg/ha) followed by Kerala (1489 kg/ha), West Bengal (1422 kg/ha) and Bihar (1403 kg/ha).

Redgram in Karnataka is largely grown in Northern parts of Karnataka which accounts nearly 90 percent of total red gram area in the state. during 2010-11 the red gram was grown over 8.91 lakh hectares with a production of 5.29 lakh tonnes and a productivity of 625 kg/ha.

Need for impact assessment of research in ragi and redgram

In Karnataka state after green revolution the production of food grains increased substantially over the decades. A large number of new technologies, practices and innovations in agriculture developed and released by the Agricultural Universities for the benefit of farmers of the state to enable them to produce sufficient quantity and quality of agricultural produce and also ensure to get remunerative returns for the betterment of socio economic life of farmers. The new technologies like improved varieties, improved package of practices, new implements and machineries enabled to achieve sustainable growth in agriculture. In this direction, public funded institutes like State Agricultural Universities, ICAR Institutes, International Institutes have played tremendous role. In Karnataka, the University of Agricultural Sciences, Bangalore is a primier institute established in 1963 contributing substantially to modern technologies for the benefit of farmers.

As India faced the problem of food shortage immediately after independence, Karnataka too faced with no exception. This shortage was taken care by developing HYVs and hybrids. In Ragi, the towering breeders were late Dr. Ragi Lakshmanaiah, who contributed developing improved cultivars, Prof Seetharam, for enriching the diversity of cultivars, Professor Mallanna, Professor Shankare Gowda, Prof Krishne Gowda who recommended improved agronomic practices and developed and improved Indaf ragi varieties helping farmers of Karnataka to produce more solving food shortage.Thus, using Indaf as a parent, agricultural scientists developed improved varieties in ragi. Among the ruling improved varieties, GPU 26 and GPU 28 are performing well not only in Karnataka but also in other states (notably Bihar). According to scientists' estimates the variety GPU 28 covered more than half of the ragi area in Karnataka. This variety was released in 1997 after a prolonged research of 11 years by scientists in UAS, Bangalore. In this study, GPU 28 variety of ragi, is chosen for economic impact assessment of the research contribution.

Red gram has been another crop, where UASB has been developing and releasing high yielding varieties for both dhal and vegetable purposes. Redgram is an important pulse crop as it is commonly consumed as a rich source of protein and is essential for human nutrition. Redgram has 22 per cent protein which is three times that of cereals. Red gram is popularly taken as an intercrop in rainfed areas in southern Karnataka, while cultivating as a pure crop in northern Karnataka. UAS B has released BRG 2 (Bangalore Red Gram Variety 2) suitable for southern agro climatic zones in Karnataka in 2006 after a prolonged research effort of 11 years. The variety is spreading fast due to quick adoption and is in process of showing rapid increase in area as it is in high demand by farmers. Due to its quick popularity in southern districts, for this study on economic impact assessment of new technologies, BRG 2 variety of redgram was purposively selected.

This study focuses on estimating the economic impact of agricultural research in ragi and redgram in order to provide policies and design programmes for the University technologists and the State to evolve research strategies towards sustainable food and livelihood security. Towards this endeavor, the estimation of economic efficiency of technologies released and economic benefits due to the new technologies (varieties) in ragi and redgram is attempted with the following specific objectives:

1. To document the economic history of technological innovations in redgram and ragi
2. To analyse the economic efficiency of selected redgram and ragi varieties
3. Estimation of economic surplus (social gain) due to innovations in redgram and ragi
4. To estimate the total factor productivity in redgram and ragi

Hypotheses

The following hypotheses were proposed

1. Over the years the crop germplasm research innovations have dominated research in other cultural practices.
2. The improved variety released are economically efficient than check varieties
3. Substantial social gains are generated due to adoption of improved variety in redgram and ragi in Karnataka.
4. There is a positive TFP growth in ragi and redgram
5. Public research contributed significantly for TFP growth in ragi and redgram.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

A review of studies is essential to look into the relevant studies conducted on the problems so far. It helps in identifying the conceptual and methodological approaches and interpreting the empirical results of the present study. In this chapter, keeping in view the objectives of the study, relevant literature is reviewed in the areas related to the present study. The chapter has been organized under following heads.

2.1 Studies on technical efficiency, allocative efficiency and economic efficiency

2.2 Studies on economic surplus approach

2.3 Studies on total factor productivity

2.4 studies on ragi and redgram crops

2.1 Studies on technical efficiency, allocative efficiency economic efficiency

Bisaliah (1977) decomposed the yield difference between the two wheat production technologies in Punjab into its constituent sources. He found that improved production technology contributed 15 per cent of the total change in output (40.50 per cent). The increased use of inputs under Mexican wheat contributed about 25.50 per cent to the total difference in output. Among the different inputs the contribution of fertilizer, capital and labour was 15, 8 and 2 per cent, respectively.

Kalirajan (1984) examined the importance of efficient use of technology in achieving the higher production using the stochastic production function. The results indicated a wide variation in technical efficiency among the sample farmers. Deficient extension system was identified as an important factor causing the variation.

Deshmukh *et al* (1991) used Cobb-Douglas production function to study resource use efficiency under different farming systems. Production elasticities of gross cropped area and expenditure on manures and fertilizers were relatively higher on irrigated farms as compared to rainfed farms under the Bajra-based farming system.

Kumar and Bisaliah (1991) studied the economic performance of contact and fellow farmers under new agricultural extension project in Karnataka state, India using the concept of technical and allocative efficiency. Data were collected from small and large contact farmers (SCF, LCF) and small and large fellow farmers (SFF, LFF). The results showed the small contact farmers (SCF) were marginally better off (92.4 per cent technical efficiency) than their fellow farmers, which was 91.8 per cent and 91.6 per cent in case of SFF and LFF respectively. LCF were slightly better off (90 per cent technical efficiency) as against 88.42 per cent and 87.95 per cent by SFF and LFF respectively.

Kalirajan and Shand (1994) measured the influence of technical and allocative risks on production by using the stochastic frontier production function approach. The frontier production function was estimated by the Maximum Likelihood Estimates (MLE) method. The total sample of 64 farmers using a high-yielding variety of cotton in Tamil Nadu state, India was selected. The results showed that the farmers had not achieved their potential outputs on their frontiers. The mean economic efficiency with technical and allocative risk was 68.3 per cent. The results also indicated that an average, about 20 to 25 per cent of economic efficiency appears to have been lost by the farmers owning to their perceived technical risk and about 6 to 7 per cent to their perceived allocative risk.

Badal and Singh (2001) examined the nature of technological change in maize production through the measurement of productivity differences between high-yielding varieties and traditional varieties in the Bihar State, India. Primary data was collected from 180 farming households in 12 villages of three districts in Bihar for the agricultural year 1996-97. The Cobb-Douglas type of production function was employed to estimate the elasticities of factors of production. The production elasticities of all the inputs were relatively higher in high-yielding varieties technology as compared to traditional varieties technology.

Dileep *et al* (2002) examined resource use efficiency of contract farms and non-contract farms of tomato in Haryana state, India. Data was collected from total sample size of 100 farmers of different size groups of Ellenabad block of Sira district during 1999-2000; they fitted Cobb-Douglas production function and obtained allocative efficiency based on marginal value productivity. The results showed that there existed a scope to increase the production of tomato by increasing the use of critical inputs particularly fertilizer, irrigation and plant protection chemicals in the case of non-contract farms whereas the contract farms made excessive use of plant protection chemicals.

Gaddi *et al* (2002) using output decomposition model, estimated contribution of different sources to yield gap in cotton. The variables included in the model explained more than 87 per cent of the variation in cotton production in demonstration field. Human labour, bullock labour and seeds turned out to be the most important variables governing production. Capital input did not exert any significant influence in cotton production, while the plant nutrients were excessively used. The production elasticities of all inputs on all the farmers' fields were invariably lower than unity implying diminishing marginal productivity with respect to each of these inputs.

Mondal *et al* (2002) conducted study on Impact of Watershed Development Programmes on Farm-Specific Technical Efficiency in Bundelkhand Region of Madhya Pradesh. The study revealed that the mean technical efficiencies of the farmers range between 0.45 and 0.76 in watersheds and 0.33 and 0.66 in control villages, which indicate that there is a scope for further increase in production by efficient use of existing inputs and technology. The socio-economic factors like education, irrigation facilities, extension contacts, marketing contacts, etc. have been observed to be the significant determinants of farm-specific technical efficiency.

Hosamani *et al* (2004) conducted a comparative analysis of organic and inorganic farms in cotton in Gadag district of Karnataka. Per acre cost of production was found Rs. 7682.59 and Rs. 7317.24 under organic and inorganic conditions, respectively. Results of regression analysis indicated that seeds, plant nutrients and plant protection chemicals had a positive influence on cotton yield. Total estimated growth in output under organic farms when compared to inorganic farms was 13.19 per cent. Difference in the input use levels between organic and inorganic farms contributed to the extent of 25.96 per cent. Timmer's measure of technical efficiency indicated that excess use of nutrients under organic conditions was in the range of 10.62 per cent to 12.04 per cent. This magnitude was still higher under inorganic condition. The efficiency level achieved by farmers under organic conditions was relatively high (94.35 per cent), as compared to farmers under inorganic condition.

Kunnal *et al* (2004) studied the effects of technical change in cotton production on output and employment generation in Karnataka using production function analysis and decomposition analysis. Results of the study revealed that bullock labour, machine labour and capital in case of hybrids and seeds, FYM, and capital in local varieties were the important inputs conditioning cotton output. Cultivation of hybrids resulted in 121 per cent of more cotton output than under local varieties. The contribution from the increased input use was 99.28 per cent and that of technology was 21.72 per cent.

Nasurudeen and Mahesh (2004) analysed technical efficiencies on paddy farms in karaikal region of union territory of Pondicherry. The farm specific technical efficiency estimated and it revealed that in the case direct sown paddy farms, 10 per cent were most efficient (91-99%) and 72 per cent were least efficient (64-80%) with mean technical efficiency of 63 per cent. In the case of transplanted paddy, about 25 per cent farms have high efficiency and 22 per cent were least efficiency with mean technical efficiency of 79 per cent.

Talathi and Hiremath (2004) analysed technical and water use efficiency in methods of irrigation in Thane district of Maharashtra. The Cobb Douglas production function analysis on per hectare basis has showed that human labour (0.0613) has a significant and positive influence on output in traditional method of irrigation. The average Timmer technical efficiencies have been found as 49.97 per cent in traditional method of irrigation and 58.37 per cent in modern method of irrigation for the irrigated crop production.

Pouchepparadjou *et al* (2005) studied green technology adoption in Irrigated Rice in Pondicherry union Territory using econometric analysis Frontier production function is used to assess resource use efficiency. The average level of technical efficiency was 0.35 among adopters and 0.37 among non-adopters. Allocative efficiency was 0.27 for adopters and 0.88 for non-adopters. Economic efficiency was 32 percent among non-adopters and 9 percent among IPM adopter thus have greater potential than that of non-adopter farmers, they show that the adopter farmers can boost output through the use of best practice technologies of IPM. Output decomposition analysis was used to assess the impact of IPM on rice production the average output among the IPM adopter farms was higher than the non-adopter farms. It was 1583.81 Kgs/acre in IPM farms and 1313.76 Kgs/acre in non-adopter farms. Contributions of input and technology to the output difference reveled that a change due to neutral technology was -468.48 per cent and that due to non-neutral technology is 521.22 per cent and the net change is attributed to technology accounts for 52.74 per cent.

Bhende and Kalirajan (2007) estimated the technical efficiency of major food and cash crops in Karnataka. The researchers used both ordinary least square estimates and maximum likelihood estimates for frontier production function and estimated farm specific technical efficiency for rice, sorghum, groundnut and cotton. The results revealed that the higher value of MLE estimates compared with OLS estimates were observed in all the crops. The analysis of technical efficiency indicated that land (area), human labour and plant protection chemicals influence the output of food and cash crops under the study. The average efficiency levels for growing rice ranged from 79 per cent on marginal farms to 86 per cent on semi medium farms. The technical efficiency for growing sorghum varied 80 per cent on semi-medium farms to 86 per cent on medium farms. On an average, ground and cotton growers are operating at 80 per cent and 85 per cent level of efficiency, respectively. And also researchers made one policy implication was that the strengthening of extension and educating the farmers may improve the efficiency of the farmers.

Hassan (2008) studied economic efficiency of maize production in the Northern region of Bangladesh. The study was conducted at the Sadar upazila of Dinajpur and Panchagarh.The study revealed that the returns of scale of the selected inputs were 0.72 and 0.68 for Dinajpur and Panchagarh respectively. The technical efficiency was found on an average 0.84 at Dinajpur and 0.80 at Panchagarh.

Ayinde *et al* (2009) studied determinants of technical efficiency and varietal gap of rice production in Nigeria. To examine the technical efficiency and varietal-gap of rice production study used the concept of meta-frontier function. A random sample of 675 farmers was selected from three out six geographical zones in Nigeria.

The farmers in this study were classified into three groups according to the variety of rice they planted. The three main varieties of rice planted are local (Ofada), improved (Mai-Nasara) and New Rice for African (NERICA). The technical efficiency indices were computed using the meta frontier approach because production varieties and technologies were expected to differ between the three varieties. This method allows the measure of the varietal-differences which is the Technology Gap Ratio (TGR). Estimates of the frontier were obtained assuming a translog functional form. The study revealed that the mean technical efficiency of 55%, 58% and 57% for Ofada, Mai-Nasara and NERICA varieties, respectively. Farm size, hired labour, fertilizer, seed, age, gender, household size and amount of credit are the determinants of technical efficiency of farmers in Nigeria rice production. The average values of varietal technology gap are more than 0.83 in all the varieties. The researcher concluded that to increase efficiency in rice production in Nigeria, farm size, fertilizer usage, seed quantity and credit need to be increased.

Murthy *et al* (2009) analysed technical efficiency in tomato production in Karnataka using Data Envelopment Analysis (DEA) approach. The technical efficiency was estimated under the assumption of both constant returns to scale and increasing returns to scale. The analysis revealed that the efficiency was observed more in medium farms (66.7 per cent). The average technical efficiency score was 0.7767, which indicated tomato farms could reduce the use of inputs by up to 22 per cent of the present usage level. Overall the study found that nearly 90 per cent of the farms were attained optimum efficient.

Onu and Edon (2009) studied the comparative economic analysis of improved and local Cassava varieties in selected local Government areas of Taraba State in Nigeria. The study revealed that the elasticity of output with respect to land (0.2013 and 0.0912), hired labour (0.5444 and 0.2555) were significant at 1% level for the improved and locals varieties respectively, while family labour (0.1597 and 0.1629), fertilizer (0.2314 and 0.1766), stem cutting (0.1944 and 0.3291) and land preparation (0.3416 and 0.1090) were significant at 5% level respectively. It was also revealed that the level of technical efficiencies varied widely across farms with 88% and 81% been the mean technical efficiency of the improved and local varieties. The result revealed further that on the average, the output of cassava fell by 12.64% and 18.72%

from the maximum level due to inefficiency of the improved and local cassava varieties.

Srivastava *et al* (2009) examined the groundwater extraction and water-use efficiency under different water market regimes in the Central Plain Zone (CPZ) of Uttar Pradesh. The researchers used Data Envelopment Analysis (DEA) to analyse the water use efficiency. The analysis revealed that both buyers and owners of water extraction mechanisms (WEMs) are technically inefficient in water–use, as the actual use of irrigation water has been found much higher than the optimum level. However, 'Buyers have been found comparatively more efficient than 'Owners' in water utilization.

Narala and Zala (2010) analysed technical efficiency of rice farms under irrigated conditions in central Gujarat. A stochastic frontier production function has been estimated to determine technical efficiency of individual farms and variance. The study has revealed that the farm-specific technical efficiencies range from 71.39 per cent to 99.82 per cent, with the mean of 72.78 per cent, which indicates that on average, the realized output can be raised by 27 per cent in the region with the available technology and resources, without any additional resources.

Dung *et al* (2011) has evaluated the technical efficiency of farmers engaged in rice-wheat cropping systems in North-eastern India, who are using Resource-Conserving Technologies (RCTs) such as Zero Tillage (ZT) and Direct Seeded Rice (DSR). The data used in this study have been derived from the socio economic surveys conducted in Eastern Uttar-Pradesh and Bihar in North-eastern India during the *kharif* season of 2009 and *rabi* season of 2010. A stochastic frontier analysis was carried out to investigate and compare the determinants of technical efficiency among the farmers receiving intervention and those who are not. The study has revealed that farmers receiving CSISA intervention have realized higher levels of technical efficiency. Additionally, farmers who are receiving subsidies and farmers who are planting more diversified crops have higher levels of technical efficiency.

Baloyi *et al* (2012) used Cobb-Douglas production function to analyse the technical efficiency among small-scale maize producers in Ga-Mothiba of the Limpopo province in South Africa. The results of the estimation showed that there were significant positive relationships between farm size and fertilizer with technical efficiency. The results of the study also revealed that there was a significant negative relationship between cost of tractor hours (the proxy for capital) and technical efficiency. The study further revealed that small-scale maize producers in Ga-Mothiba are experiencing decreasing returns to scale indicating that small-scale farmers are experiencing technical inefficiency in maize production. Therefore, the study generally suggests that government should adopt the strategy of on-farm training to small-scale farmers since these farmers mainly depend on trial and error when it comes to allocation of scarce resources such as fertilizer and seed.

Gedara *et al* (2012) studied the factors affecting the technical efficiency (TE) of irrigated rice farmers in village irrigation systems (VIS) in Sri Lanka. For their study Primary data were collected from 460 rice farmers in the Kurunagala District, Sri Lanka, to estimate a stochastic translog production frontier for rice production and the mean TE of rice farming in village irrigation was found to be 0.72, although 63% of rice farmers exceeded this average

Srinivas *et al* (2012) studied Technical Efficiency of Seed Potato Farmers of Badakshan Province of Afghanistan. In this study, the economic benefits and technical efficiency levels of farmers were estimated using the data collected from the participating and non-participating farmers in the intervention. The study found that a high degree of inefficiency (76%) in the production of seed potato was observed indicating that there is scope for farmers to increase the potato production by 76% just by way of realizing technical efficiency.

2.2 Studies on Economic surplus approach

Bantilan and Joshi (1996) in their study on Returns to Research and Diffusion Investments on Wilt Resistance in pigeonpea used economic surplus model. The researchers considered the elasticity of demand and elasticity of supply is -0.5 and 0.2 respectively. The results of the study showed that the cost of developing the wilt resistance variety was estimated at Rs. 5 million. The unit cost reduction as a result of adoption of ICP 8863 as compared to local varieties was 42%. The large-scale adoption of the variety generated Rs. 1850 million surpluses with a high internal rate of return (65%). The producers' shared larger benefits (72%) than the consumers' (28%).

Kristjanson *et al* (1999) used the economic surplus model to measure potential returns to international livestock research: the case of Trypanosomosis vaccine research. The study found that the net present value of the vaccine research is estimated at US$ 288 million, with an internal rate of return of 33%, and a benefit cost ratio of 34:1. The results of this study will assist in research priority setting and have highlighted the need for further research aimed at better understanding who the beneficiaries of the vaccine will be, and how it will reach them.

Yapi *et al* (1999) in their study used the economic surplus approach to evaluate returns to S 35 sorghum variety research and diffusion investments. The study revealed that the net present value (NPV) of benefits from the adoption of S 35 is estimated at US$ 15 million at a discount rate of 10% and an internal rate of return (IRR) of 95%.

Khatkar *et al* (2004) has assessed the impact of value addition in pearl millet in terms of monetary benefits and nutritional values. The study revealed that the value addition in pearl millet in all the baked, traditional and diabetic products has brought positive changes in total economic surplus in both the rural and urban households in the state of Haryana. The benefits by the total economic surplus method have been estimated as Rs. 157.72 lakh within a period of ten years after the implementation of the project and it will provide the net present value of Rs. 259.52 lakhs within ten years. The internal rate of return has turned out to be as high as 45 per cent. The researchers concluded that project has high economic viability and suggested that there is a need to gear up the extension agencies to encourage the adoption of this upgraded technology to the target domain.

Kumar *et al* (2004) studied socio-economic impact of fisheries technology in india and used economic surplus approach to estimate the social gains to both producers and consumers. The study revealed that the internal rate of return to investment on fish research and development has been projected to be in the range of 42 to 55 per cent under different TFP scenarios.

Mrunthyunjaya *et al* (2004) studies the impacts of selected technologies refined under NATP. In their study to estimate the economic benefits of the technologies upgraded/ developed under NATP used economic surplus model. The model has been applied in a closed economy framework with the assumption of no spillover effects. The data regarding technology and economic parameters used to estimate economic surplus generated by a technology. The researchers collected the technological data from the principal investigators of the selected projects/technologies with the help questionnaire and the data on economic variables were obtained from published sources. The NPV of incremental benefits from the selected technologies/projects ranged from Rs. 34 million for hybrid vegetables to Rs. 264 million for IPM. The benefit- cost ratios were 7.7 and 2.1, respectively for IPM and hybrid vegetables. The IRR for these technologies ranged from 19 to 43 per cent. The study concluded that returns to investment on dissemination of available technologies are enormous and therefore should receive immediate attention.

Wander *et al* (2004) conducted a study on using the economic surplus method to assess economic impacts of new technologies - Case studies of EMBRAPA. Researchers assessed economic impact for four technologies and found positive net present values for all four considered technologies, internal rates of return of 26.2% (a), 13.8% (b), 52.8% (c) and 31.0% (d) and the benefit-cost-ratios of 2.92 (a), 1.19 (b), 11.64 (c) and 3.37 (d). The study concluded that Economic impacts of new technologies are measurable and give important information for decision making on resource allocation options. Research institutions should concentrate their efforts on research activities that may lead to technologies which increase productivity, reduce costs and improve quality. Funding institutions may include the assessment of economic impacts of research activities as a condition to analyze future applications for research funding in order to ensure a more efficiently use of scarce resources.

Krishna and Qaim (2007) in their study on potential impacts of bt eggplant on economic surplus and farmers' health in India estimated the aggregate economic surplus gains of Bt eggplant hybrids and it could be in a magnitude of Rs. 4.9 billion (US $108 million) per year. More than 50% of the overall gains will be captured by consumers, who will benefit from a technology-induced decrease in eggplant prices.

Kostandini *et al* (2009) have estimated ex-ante yield and risk benefits from the adoption of improved drought tolerant varieties of maize, rice and wheat in selected countries of Asia and Africa, and have found that on average, risk benefits comprised one third of total benefits. For India, they have estimated producer benefits from variance reduction as much as two thirds of total benefits in the case of rice, 44 per cent in maize and 18 per cent in wheat. The study also revealed that there is a significant benefit to consumers from the reduction in yield variance.

Palanisami *et al* (2009) conducted a study on Evaluation of Watershed Development Programmes in India using Economic Surplus Method. For their study, the major data were derived from the completed study on Comprehensive Assessment (CA) of Watersheds Programmes in India implemented by the ICRISAT- led consortium team. For the purpose of the study, the data were drawn from a cluster of 10 watersheds implemented in the Coimbatore district of Tamil Nadu. The study revealed that using economic surplus method the net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) were worked out assuming 10 per cent discount rate and 15 years life period. The BCR is worked out to be more than one, implying that the returns to public investment such as watershed development activities were feasible. Similarly, the IRR worked out to be 25 per cent, which is higher than the long-term loan interest rate by commercial banks indicating the worthiness of the government investment on watershed development. The NPV worked out to be Rs. 2271021 for the entire watershed.

Kostandini *et al* (2011) in their study on ex ante evaluation of drought tolerant varieties in eastern and central Africa used economic surplus method to estimate potential benefits of drought tolerant varieties of maize, sorghum and millet in Kenya, Uganda and the Amhara region of Ethiopia. Ex ante results reveals that the total benefits to producers and consumers from mean yields increases and yield variance reductions in Kenya, Uganda and the Amhara regions of Ethiopia was found $ 86, $7.5 and $ 5.5 million benefits from the potential adoption of drought tolerant maize, sorghum and millet respectively.

Kumar *et al* (2011) conducted a study on the potential benefits of Bt brinjal in India –an economic assessment. The economic surplus approach applied to estimate the gains to producers and consumers of Bt brinjal. The study revealed that the that adoption of Bt brinjal hybrids would provide yield gain of 37 per cent and reduction in total insecticide-use of about 42 per cent over non-Bt hybrids. The simulation using economic surplus method results reveals that country may gain aggregate direct economic benefits between Rs.577 crore and Rs. 2387 crore annually at 15 per cent and 60 per cent adoption levels of bt brinjal hybrids, respectively. The major gains will accrue to consumers (66% of total) and rest would go to the farmers. The researchers concluded that Bt brinjal offers a large scope to increase income of farmers, reduce its cost to consumers, improve food safety and reduce health hazards and environmental pollution.

Moussa *et al* (2011) conducted a study on the economic impact of cowpea research in West and Central Africa: A regiona limpact assessment of improved cowpea storage technologies. In their study Surveys in seven countries were used to estimate storage technology adoption. Economic surplus was used to estimate annual benefits and internal rate of return (IRR), and net present value (NPV) were calculated to summarize the net benefits. The IRR, is found to be much greater than the cost of capital. The regional IRR was found to be about 29%, much higher than the real interest rate on government bonds in West Africa at the time. The net present value of the investment amounts to more than 295 million US dollars which yields an annualized value of about 17 million.

Ashok *et al* (2012) studied economic and environmental impact of Bt cotton in India and used economic surplus model to estimate total benefits of new technology and its distributional impact. In their study producer surplus and consumer surplus were estimated under three supply elasticity scenarios of cotton. Under relatively inelastic supply assumption, 0.31 and 0.13 producer surplus was found to be Rs. 254.53 and Rs. 292.36 respectively where as consumer surplus was found to be Rs. 98.63 and Rs. 47.51 respectively and at elastic supply consumer surplus more than the producer surplus.

Birthal *et al* (2012) analysed economic benefits from adoption of improved drought tolerant groundnut variety one of the most drought-prone districts in the semi-arid tropics of India. The study revealed that at farm level, the variety had 23 per cent yield advantage, required 17 per cent less variable cost and had 30 per cent less variability in its yield compared to the ruling variety and at the aggregate level, potential benefits from the adoption of high yielding, drought tolerant variety are substantial.

2.3 Studies on Total Factor Productivity

Patil and Jha (1978) analysed the pattern of output, input and productivity growth in 25 districts of Maharashtra from 1951-52 to 1971-72. They employed the index number approach and solow's gepmetric index of total factor productivity to measure the productivity.

Dey and Evenson (1991) studied the Economic Impact of Rice Research in Bangladesh and estimated the TFP growth for rice at 0.98 per year for the period 1951- 71 and a little higher (1.15 per cent) during 1973-89, the era of use of HYVs. The contribution of TFP to agricultural output growth was 40-60 per cent, which was quite high. For wheat crop, TFP growth rate was estimated at 0.93 per cent per year during the period 1952-71 and 0.83 per cent during 1973-89. It has contributed only 11 - 19 per cent in the growth of wheat production. For the crop sector, TFP growth rate was 0.72 per cent during the period 1952-71, which slightly improved with the adoption of HYVs and improvement in irrigation infrastructure.

Dolakia and Dolakia (1991) observed that in developing countries the agricultural output had increased drastically in the later half of the 20th century, which was largely attributed to higher productivity of land and labour. The study, which focused on agricultural modernization of India, questioned whether it has actually raised agricultural growth rates and productivity levels. The nature and extent of modernization were evaluated taking into account the impact of Government policy. The authors contend that there was evidence to suggest that the green revolution in the primary sector in India had led to significant increases in total factor productivity (TFP).

Evenson (1992) estimated the determinants of changes in TFP in US agriculture over the period 1950-1982. Separate measures for growth of crop and livestock sectors were estimated. The TFP growth in each sector and investments in public sector agricultural research and extension programme, private sector research and development, schooling of farmers, geo-climatic factors, off farm employment opportunities and farm policy regimes was carried out. The researcher found that the states which have research systems with highest investments in pre-technology sciences research contributed the most to growth in TFP. Further, the public sector investment in agricultural extension and farmers' education contributed to TFP. Similarly, research and development by private sector also contributed to TFP growth in agricultural sector.

Kumar and Mruthyunjaya (1992) assessed the total factor productivity (TFP) growth in wheat production for the states of Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Rajastan. The Tornqvist-Divisia index was used to compute the total output, total input, TFP and input price indices for wheat grown in the major states of India based on micro-level farm data for the post-green revolution period (1970-71 to 1988-89). The results showed that the technical change in wheat production benefited consumers relatively more than producers. The total factor productivity or technical change was found to contribute more than one third to total output growth. Market infrastructure, research and mechanization were indicated as the most important sources of growth in TFP. It was opined that the area under modern varieties had already reached the ceiling levels particularly in front-line states. Thus, the need for evolving new varieties was emphasized to achieve breakthrough in yield levels.

Kumar and Rosegrant (1994) estimate TFP growth for rice. They find that the TFP index has risen by around 1.85 per cent annually in the southern region, 0.76 per cent in the northern and 0.36 per cent in the eastern region. In the western region, due to wide fluctuations in weather wide variation in the TFP index was observed and the estimated annual growth was negative (-0.98), but insignificant.

Kalirajan and Shand (1997) decomposed output growth into input growth, technical change and efficiency change for the period 1980-83, 1984-87, and 1988-90, and estimated technical change as a shift in production function frontiers. Allowing technical progress to be non-neutral, they estimated TFPG the stochastic varying coefficient frontier using Cobb-Douglas technology function for the period 1980-90. Their analysis shows that TFPG was negative in 4 out of 15 states in 1980-83 to 45.24 and that, by the end of the decade, it was small for those states where the contribution of TFPG was positive. For the front runner states like, Punjab and

Haryana the TFP growth declined from 64.45 per cent and 54.82 per cent during 1980-83 to 45.24 per cent and 33.22 per cent respectively, whereas for Uttar Pradesh, Rajasthan, and Madhya Pradesh it slumped from 56.41 per cent, 53.35 per cent, and -28.42 per cent during 1980-83 to 38.58 per cent, 32.55 per cent, and -32.67 per cent during 1988-90 respectively. While input growth contributed more than 50 per cent to the output growth, the contribution of technology to output growth declined substantially, particularly from 1988 to 1990. The share of fertiliser and electricity in the consumption of core inputs, which enjoy heavy subsidies in Indian agriculture, increased from 16.8 per cent in the seventies to 29.2 per cent in the eighties. An average of only around 18 per cent could be attributed to technological change in the pre-reform period but more to gains in technical efficiency. Importantly, the contribution of increasing technical efficiency to output growth remained more or less at the same levels in most states in the pre-reform periods.

Fan *et al* (1998) estimated TFP for agriculture at state-level using Tornqvist-Theil index for the period 1970-1994. The study finds that total factor productivity for India grew at an average annual rate of 0.69 percent between 1970 and 1995. In the 1970s, total factor productivity improved rapidly, growing at 1.44 percent per annum, grew faster in the 1980s at 1.99 percent per annum. But since 1990, total factor productivity growth in Indian agriculture has declined by 0.59 percent per annum. The study also reports state-level estimates- for the whole period 1970 to 1994, the states with TFP growth rate in the range 0-1 percent per annum are Andhra Pradesh, Karnataka, Uttar Pradesh, Himachal Pradesh and Kerala; with TFP growth rate greater than 1 are Punjab, Bihar, Orissa, Maharashtra, West Bengal and J&K. The states with negative TFP growth are Haryana, Madhya Pradesh, Gujarat, Assam and Rajasthan.

Birthal *et al* (1999) have estimated the trend in TFP for the livestock sector in India. The livestock output grew at the rate of 2.6 per cent per year over the period 1950-51 to 1995-96. The input index increased by 1.8 per cent per year and the TFP grew at about 30 per cent, implying that technical change contributed about 30 per cent to the overall growth over the past 45 years. Period-wise results revealed that there was no TFP growth during the first period (1950-51 to 1970-71), implying no progress in productivity but it started rising during the 1980s when sector's output touched nearly 4 per cent and the TFP growth jumped to nearly 1.8 per cent, contributing 45 per cent to the total output growth.

Evenson *et al* (1999) conducted study on agricultural research and productivity growth in India. To estimate total factor productivity researchers used Tornqvist- Theil TFP index. Data were collected for the period 1956/57 to 1987/88 in 271 districts covering 13 states. The study revealed that India has made significant gains in TFP. The high- yielding varieties of wheat and rice introduced in the late 1960s certainly contributed to these gains. Growth in TFP has contributed 1.1–1.3 per cent per year to crop production growth in India. Conventional inputs have contributed about 1.1 per cent per year since 1956. TFP and conventional inputs have thus contributed roughly 2.3 per cent per year to the growth of crop production.

Murgai (1999) uses Tornqvist-Theil Index to estimate TFP growth in Punjab at district level during 1960-1993. TFP growth averaged 1.9 percent from 1960 to 1993. Productivity growth in Punjab is found to be lowest during the green revolution years, even as farmers moved from traditional varieties of wheat and rice to modern hybrid seed varieties and the agricultural sector experienced high growth rates in production. The study attributes most yield improvements to rapid factor accumulation, particularly that of fertilizers and capital. Contrary to widespread belief, the contribution of productivity growth to economic growth is found to be small.

Mukherjee and Kuroda (2001) use Törnqvist-Theil methodology to construct the TFP index for Indian agriculture in fourteen states from 1973 to 1993. They find TFP index to be 1.73 for 1973-79, 2.51 for 1980-89, 1.34 for 1990-1993 and 2.19 for entire period 1973-2003.

Forstner *et al* (2001) compute Malmquist TFP index using Data Envelopment Analysis to estimate productivity change over about two decades for 32 Least Developed Countries. They find an overall decline in total factor productivity (TFP), pointing to technology as a major problem area in the growth of these countries.

Joshi *et al.* (2003) carried out a study on a comprehensive productivity analysis in the irrigated agro-ecosystem concentrated in the Indo- Gangetic Plains

(IGP) for the rice and wheat crops. The TFP growth of rice and wheat in the IGP has been found quite impressive during the past three decades, 1970- 1999. The annual compound growth rate of TFP was 2.43 per cent for rice and 2.99 per cent for wheat during this period. The contribution of TFP to output growth was 56 per cent in rice and 70 per cent in wheat. This shows that technology played a key role in increasing the rice and wheat output in IGP.

Nin *et al* (2003) estimate TFP growth for 20 countries during 1961-1994 using non parametric Malmquist TFP index with an alternative definition of technology- Sequential technology and find that the earlier results reverse and most of the developing countries experience productivity growth.

McKinsey and Evenson (2003) have analysed the impact of crop genetic improvement on Indian agriculture and observed that the productivity impacts of state research, private research, extension, and market development were positive. Extension and market development would not have made large impacts in the absence of modern varieties. Extension is productive when the extension service has new technology to extend. Similarly, the improvement of markets is important as it facilitates adoption and diffusion of modern varieties. The role of each sources of growth is complementary.

Ananth (2004) conducted a study on returns to investment on agricultural research in major field crops of Karnataka state. For the study data has been collected from the secondary sources for a period of 25 years (1970-71 to 1994-95). The study revealed that the agricultural research investment registered a growth rate of 14.7 per cent per annum during the period of 25 years. The crop wise analysis showed that the growth in research investment was highest for tur (15.10%) followed by sunflower (10.45%), groundnut (8.8%) and ragi (7.5%) in real term. The total factor productivity index showed increasing trend in case of rice, ragi, cotton and sugarcane. The decreasing trend noticed in case of tur and sunflower. The study also revealed that the returns on the agricultural research investment were highest in rice followed by sugarcane, ragi, cotton and jowar. The returns were negative in case of tur, groundnut and sunflower.

Aliva and Evenson (2004) in their study measured the changes in TFP for crop production, livestock production and aggregate agricultural production in India for two periods, 1961-1980 and 1981-2001 using FAO published data on cropland, pastureland, human labour, fertilizers, seeds, tractors and combine harvesters and animal stocks. Use of modern varieties, increase in the years of schooling of labour force, and enhances in dietary energy were reported as sources of TFP growth in this study. The contribution of TFP was maximum of modern varieties (64 per cent), followed by years of schooling (22 per cent) and nutritional security (14 per cent).

Kumar *et al* (2004) observed that the TFPG of the crop sector in the indo-gengetic plains had risen at the rate of 1.2 per cent per annum during the period 1980-81 to 1996-97. The analysis has confirmed that contribution of TFPG to output growth had started declining and was, in fact showing a tendency of further deterioration in the process.

Thirtle *et al* (2004) estimated the total factor productivity growth in UK agriculture, from 1953-2000 by using Tornqvist-Theil index. The study reveals that prior to 1984 TFP grew at 1.68 per cent per annum and after that date at only 0.26 per cent per annum. The study also reveals that the decline in TFP growth is mainly due to cuts in R&D, fewer patents, less growth in farm size and the demise of public extension.

Rao (2005) computed TFP using Tornqvist-Theil index in the crop sector, food grain crops and nor food grain crops in Andhra Pradesh during 1980-81 to 1999-2000 period. The analysis revealed that the average annual total factor productivity index during post reform period has been found five per cent less than that during pre-reform period in the state in the crop sector as a whole. The contribution of total factor productivity to yield growth has been found to be healthy 31 per cent in the pre reform period. An absolute decline (-37) has been noted during the post reform period in the crop sector.

Thorat *et al* (2006) have analysed total factor productivity in horticultural crops in Konkan Region of Maharashtra. The comparative picture of TFP growth by sub period wise has revealed that the magnitude of TFP growth varied from 1.3 per cent per annum during the 1990s to 6.2 per cent per annum during the 1980s. During the entire period under study (1981-2000), TFP has been found growing at the rate of 5.4 per cent per annum. The researchers also noticed that the returns to horticultural research were high pay-off to the tune of IRR 119 per cent.

Kumar *et al* (2004) estimated the total factor productivity for the inland and marine fisheries using Divisia-Tornqvist index. the estimates revealed that the TFP annual growth has been estimated to be 4.0 per cent for the aquaculture sector and 2.0 per cent for the marine sector.

Bhushan (2005) uses Data Envelopment Analysis to estimate Malmquist TFP index for major wheat producing states in India- Punjab, Haryana, Madhya Pradesh, Uttar Pradesh and Rajasthan. He finds TFP growth rate to be highest in Punjab and Haryana which is attributed to technical progress in these two states. Rajasthan (with no efficiency change) and Uttar Pradesh (with improvement in efficiency and negative growth in technological progress) have positive TFP growth rate while Madhya Pradesh (no change in efficiency and negative growth of technical progress) is reported to record negative TFP growth rate. As compared to 1980s, mean growth of TFP is found to be higher in 1990s and the primary source of TFP growth is technical progress and not efficiency improvements.

Kumar and Jha (2005) estimated TFP growth and return to research of rice in India. The TFP growth of rice across the states estimated and revealed that the high growth was observed in Uttar Pradesh and Punjab. The marginal internal rate of return varies from 32 per cent in Karnataka to 74 per cent in Uttar Pradesh.

Ranjitha and Mruthyunjaya (2005) analysed total factor productivity growth in Indian crops and the livestock sector for the period 1964-65 to 1991-92 and also attempted the decomposition of TFP growth. The analysis revealed that the growth rate of TFP has been falling over the years in Indian crops and livestock sector during the study period and research factor contributed 48 per cent to TFP growth.

Kumar and Mittal (2006) estimate crop-specific TFP growth across different states for paddy and wheat. They find TFP of paddy has started showing deceleration in Haryana and Punjab but TFP of wheat is still growing in these two Green Revolution states. About 60 per cent of the area under coarse cereals is facing stagnated TFP. Similarly, the productivity gains which occurred for pulses and sugarcane during the early years of Green Revolution, have now exhausted their potential.

Arega (2009) analysed total factor productivity growth in African agriculture under contemporaneous and sequential technology frontiers over the period 1970–2004. The study further investigates the sources of agricultural productivity growth using a fixed-effects regression model and a second-degree polynomial distributed lag structure for agricultural research. The conventional estimates show an average productivity growth rate of only 0.3% per year over the period 1970–2004. In contrast to conventional measures, however, the improved measures under sequential technology show that agricultural productivity grew at a higher rate of 1.8% per year. Technical progress, rather than efficiency change, was the principal source of productivity growth. Researcher concluded that Agricultural research has turned out to have positive and significant impacts on productivity. The estimated productivity elasticity with respect to agricultural research is 0.04 and suggests that doubling research investments would lead to a 4% increase in total factor productivity. Consistent with the induced intensification hypothesis, population pressure has a positive and significant effect on agricultural productivity.

Bryce *et al* (2009) in their study analysed the productivity growth in Canadian prairie primary agriculture from 1940 to 2004. Total factor productivity (TFP) is measured using Tornqvist- Theil indexing procedures for the Prairie Provinces. It was found that during the 1940 to 2004 period, productivity growth in prairie agriculture grew at a rate of 1.56% a year. During this time, agricultural output increased at a rate of 2.43% per annum thus increasing productivity accounted for 64% of output growth. It was also found that the productivity growth in crops (2.85%) is considerably higher than productivity growth of livestock (1.56%).

Chand *et al* (2011) estimated the total factor productivity and returns public investment on research in India. The Divisia Tornqvist index was used in this study for computing TFP indices for major crops, viz. cereals, pulses, edible oilseeds, sugarcane, cotton, and jute grown in different states of India. The estimates of TFP reveal considerable variations across crops in different states and at all-India level during the period 1975-2005. The public investment in research has been a significant source of TFP growth in rice, wheat, maize, sorghum, pearl millet, chickpea, redgram, groundnut, rapeseed and mustard and cotton. During the period 1975-2005, the overall internal rates of return (IRR) to public investment in agricultural research were highest for red gram (57%), followed by sorghum and cotton (39% each), wheat (38%), chickpea (34%), pearl millet (31%), rice (29%), maize (28%), and were lowest for groundnut (18%).

2.4 Studies on ragi and redgram crops

Balappashivaraya *et al.* (1998) evaluated the economics of IPM for redgram crop. They indicated that the farmers who followed IPM technology used more human and bullock labour, manures, fertilizers and less of chemical fertilizers. Whereas non-IPM farmers used more of chemical pesticides and imbalanced nutrients. The Non-IPM farmers incurred relatively higher costs for plant protection measures through the indiscriminate use of chemical pesticides. The IPM farmers obtained higher yields (1.24qtl/ha) and net income (19.45%) despite relatively higher costs of cultivation as per the farm management concept as compared to non-IPM farmers. The B: C ratio in IPM farm was marginally higher than that of Non-IPM farm.

Benagi *et al* (2004) reported that in large scale demonstration of IPM of redgram on an area of 125 acres in Gulbarga district, the seed yield in IPM fields was 7.69 Qtl /ha and in non-IPM field wad 7.30 Qtl/ha the per cent pod damage in IPM field was 10.8 compared to 17.1 in non- IPM fields further they estimated by adopting the IPM module an additional income of Rs 1457 .00 was obtained.

Biradar (2007) in their study of economics of redgram based cropping systems in Bidar district medium farmers incurred highest total cost in cropping system (Redgram + blackgram, redgram + Soyabean, redgram + green gram) and large farmer in cropping system (Redgram + Jowar, redgram sole). Net return obtained by small farmers were highest in cropping system (Redgram + Jowar, redgram sole) highest net return obtained by large farmers in cropping system (Redgram + black gram, Redgram + Soyabean, Redgram + greengram). From the above review it is observed that, the cost of production was high for large farmers followed by medium and small farmers due to higher level of use of fertilizer and quality seeds, but net returns was high for small farmers followed by medium and large farmers due to lower cost and high gross return and efficient utilization of family labour. Under irrigated condition, net return from sugarcane was high and under rainfed condition net return from redgram was found to be high.

Apoorva *et al.* (2010) conducted a field experiment on “Integrated plant nutrient supply on growth, yield and economics of finger millet” was conducted under red sandy loam soils (Alfisols), during *kharif* 2007 at Zonal Agricultural Research Station, G.K.V.K., Bangalore, India. The study reveals that the application of fertilizers and FYM on STCR (Soil Test Crop Response) basis along with dual microbial inoculation recorded higher grain yield (3740.5 kg ha-1) and straw yield (9485.9 kg ha-1) of *finger millet* (Finger millet). Further a higher Gross Returns, Net Returns, Value added Cost Ratio (VCR), Unit Cost of Production (UCP) and Productivity Index (PI) were observed when compared to the other treatment combinations carried out during the experiment.

METHODOLOGY

CHAPTER III
METHODOLOGY

This chapter deals with the description of the study area, the sampling procedure followed and techniques used for data analysis. It has been organized under the following heads

1. Description of the study area
2. Sampling design and collection of data
3. Analytical tools and techniques employed

3.1 Description of the study area

The geographical, social and economic features of the study area are presented in this section.

Karnataka is the eighth largest state of India in terms of geographical area with 30 districts, 176 taluks,775hoblies and 29406 villages as per 2001 census.

The population of Karnataka is 6.11 crores, ranking as the 9th most populated state forming 5.05 per cent of the population (2011 with the sex ratio of 968 females for 1000 males. Literacy rate was 75.60 per cent with male literacy of 82.85 per cent and female literacy of 68.13 per cent.

The soils of Karnataka are classified into nine groups (1) shallow black soils, (2) medium black soils (3), deep black soils, (4) red sandy soils, (5) mixed red and black soils, (6) red loamy soils, (7) laterite soils, (8) laterite gravelly soils and (9) coastal alluvial soils.

3.1.5 Climate

The state receives rains from south west monsoon during June to October and North east monsoon during October to January. During the period between February to May, the state experiences dry summer spells.

Fig 3.1 Map of Karnataka

Districts of Sample farmers

Chitradurga district Central dry agro climatic zone:

Chikkaballpur district (chinatmani) Eastern dry agro climatic zone:

Bangalore rural district (doddaballpur) Eastern r dry agro climatic zone:

Ramanagara district (Magadi) Eastern r dry agro climatic zone:

3.1.6 Rainfall

Karnataka receives normal annual rainfall of 1198 mm, mainly through southwest monsoon (June to September) and Northeast monsoon (October to December). A small quantity of rainfall is received during winter and summer seasons. The actual annual rainfall during the year2010 and 2011 was 1500 and 1375 mms respectively.

3.1.7 Cropping pattern

The cropped area in 2010-11 is 11841677 ha (Table 3.3). The largest area is under cereals and millets (5349202 ha) constituting 45.17 per cent of cropped area followed by pulses (23.42 %) and Oil seeds (13.64%). Commercial crops (1312178ha) cover about 11per cent of the total cropped area, while area under fruits and vegetables is 353728 ha and 437931 ha respectively (Table 3.1).

3.2.1 Data base

Sampling framework

For this study the sample of farmers included those cultivating ragi, redgram as pure crops and redgram as intercrop in rainfed areas of Karnataka. For this, 35 farmers cultivating GPU 28 variety of ragi as rainfed crop in eastern dry agroclimatic zone (in Chintamani and Doddaballapura), 35 farmers cultivating BRG 2 variety of red gram (Pigeon pea) as pure crop as under rainfed conditions in Eastern dry agroclimatic zone (in Magadi and Doddaballapura) have been chosen purposively. For comparison, 35 farmers each under each of these crops cultivating the corresponding local check variety Indaf - 5 in Ragi and TTB-7 variety of redgram have been chosen in the same areas as counterfactual. In addition, 35 farmers cultivating redgramvariety BRG-2 as intercrop under rainfed conditions are chosen in central dry agroclimatic zone (Chitradurga district - Hiriyur and Hosadurgataluks). Another 35 farmers cultivating redgram variety TTB 7 are chosen purposively in Chitradurga district as counterfactual. In all, 210 farmers have been chosen for this study (Table 3.2).

The data needed for the study was collected from the farmers by personal interview method using pre-tested schedule prepared during 2011-12. At the time of interview, personal bias of the sample farmers was minimized by convincing them about the genuinely of the purpose for which the data were collected.

Secondary data was collected from the annual research reports, publications of Directorate of Economics and Statistics, Department of Agriculture, Government of Karnataka, National Seeds Project, National Seeds Corporation, Karnataka State Seeds Corporation and by also consulting with scientists, administrators and extension personnel.

The data on costs and returns of ragi and redgram crops over the years 1990-91 to 2009-10 have been collected from the annual Farm Management Survey reports published by the Directorate of Agriculture, Government of Karnataka. The area, production and productivity of ragi and redgram crops have been collected for the period 1990-91 to 2010-11 from the reports published by the Directorate of Economics and Statistics, Government of Karnataka.

The data on research cost incurred to develop new variety and extension expenditure for spread of new variety in ragi and redgram crops, area covered, duration of research project, probability of performance of new technology were collected by consulting respective scientists. The seed distribution data was collected from National Seeds Project, National Seeds Corporation, Karnataka State Seeds Corporation. The whole sale price index over the years from the reports published by Reserve Bank of India was obtained. The farm harvest prices of ragi and redgram crops over the years were compiled from the reports of the Directorate of Economics and Statistics, Government of Karnataka.

The data on release of varieties and their special features were collected and documented from the reports published by Director of research, University of Agricultural Sciences, since its inception.

Table 3.1 Area under principal crops in Karnataka (2010-11)

Sl.No.	Crops	Area (ha)	%
I	Cereals and Millets		
1	Paddy	1532261	12.94
2	Jowar	1242071	10.49
3	Bajra	309227	2.61
4	Maize	1260018	10.64
5	Ragi	750588	6.34
6	Wheat	254755	2.15
7	Other Cereals and Millets	282	0.00
	Sub total	5349202	45.17
II	Pulses		
1	Tur	889005	7.51
2	Horse gram	216449	1.83
3	Black gram	126762	1.07
4	Green gram	397766	3.36
5	Avare	80370	0.68
6	Cowpea	93606	0.79
7	Bengal gram	958704	8.10
8	Other pulses	11126	0.09
	Sub total	2773788	23.42
III	Total fruits	353728	2.99
IV	Total vegetables	437931	3.70
V	Oilseeds		
1	Ground nut	838026	7.08
2	Sunflower	407950	3.45
3	Safflower	55038	0.46
4	Castor	18553	0.16
5	Sesamum	85538	0.72
6	Niger seed	23112	0.20
7	Soyabean	168033	1.42
8	Linseed	11358	0.10
9	Other oil seeds	7242	0.06
	Sub total	1614850	13.64
VI	Commercial crops		
1	Cotton	545288	4.60
2	Sugar cane	644610	5.44
3	Tobacco	122280	1.03
	Sub total	1312178	11.08
	Total	11841677	100.00

Source: DES, Karnataka at a glance 2010-11

Table 3.2 Details of sample farmers selected for the study

Area covered	Redgram as mono crop		Redgram as intercrop		Ragi crop	
	BRG2 Variety	TTB7 variety	BRG2 Variety	TTB7 variety	GPU 28 variety	Indaf 5 variety
Eastern dry agro climatic zone (Magaditaluk and Doddaballapurtaluk)	35	35				
Easter dry agro climatic zone (Doddaballapurtaluk and Chintamanitaluk)					35	35
Central dry zone (Hiriyurtaluk and Hosadurgataluk)			35	35		
Total	35	35	35	35	35	35

3.3 Analytical tools and techniques employed

To address the specific objectives of the study, the data generated was subjected to econometric analysis as under:

1. Growth rate model
2. Production function analysis
3. Data envelopment analysis
4. Economic surplus approach
5. Total factor productivity index

Objectives	Analytical Tools/methods	Data
1. To document the economic history of technological innovations in Red gram and Ragi		Sourced from Director of Research, UAS, Bangalore
2. To analyse the economic efficiency of selected red gram and ragi varieties	Cobb-Douglas and Data Envelopment Analysis (DEA)	Primary data collected from farmers used for analysis
3. Estimation of economic surplus (social gain) due to innovations in red gram and ragi	Economic Surplus Approach and partial budgeting	Data on area, production and productivity of redgram and ragi over the years. Area spread computed using seed distribution data. Research and extension cost used. Whole sale price index sourced from RBI website and used to deflate the price in real price.
4. To estimate the total factor productivity in red gram and ragi	Tornqvist -Thiel TFP index. compound growth rate and regression analysis	Time series data on Cost of cultivation of ragi and redgram(1990 to 2009)

The socio-economic profile of respondents was obtained and costs and returns of ragi and redgram crops were worked out. Simple statistical tools like averages and percentages were used to compare, contrast and interpret results.

3.3.2 Growth model

To estimate the annual growth rates in output use, input use and TFP growth, exponential function for the study of the following form,

$$Y = ab^t$$

On applying natural logarithm we will get the equation of the form,

$\ln Y = \ln a + t \ln b$

Where,

Y is TFP, Output and input indices,

a is the intercept and

b is the regression coefficient and

t is the time period , the total period (1990-91 to 2009-10). Here compound growth rate is = antilog of (Ln b) -1.

3.3.2 Production function analysis

3.3.2.1 Cobb-Douglass production function

The Cobb-Douglas production function is the most widely used form of production functions for fitting agricultural production data, because of its mathematical properties like ease of interpretation and computational simplicity. One of its serious limitations is that it accommodates either constant or increasing or decreasing marginal productivity and does not allow an input-output curve embracing all the three relationships.

$$\ln (y) = a + b_1\ln(x_1)+ b_2\ln(x_2)+ b_3\ln(x_3)+ e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

Y = Gross returns (Rs/farm)

a = Intercept

x_1 = Area under crop variety (acres)

x_2 = Labour (Rs/farm) includes human labour cost, bullock labour cost and machine labour cost

x_3 = Capital (Rs/farm) includes seed cost, FYM cost, chemical fertilizer cost, PPC and miscellaneous cost

b_i = Elasticities of production (i = 1to n)

e = Error term

3.3.3 Data Envelopment Analysis (DEA) approach

Data envelopment analysis (DEA) is the non-parametric mathematical programming approach for frontier estimation (Coelli, 1996).This approach was first used by Farrell (1957) as a piecewise linear convex hull approach to frontier estimation and later by Boles (1966) and Afriat (1972). The term data enveloped analysis coined by Charnes*et al* (1978) after publication of their paper. DEA method has the disadvantage that it does not explicitly accommodate the effects of data noise (Murthy *et al.*, 2009).

The DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level (Murthy *et al.*, 2009). In this study, to estimate the technical efficiency, allocative efficiency and economic efficiency input oriented and cost minimization DEA were used.

Constant returns to scale

The linear programming model for measuring the efficiency of farms under constant returns to scale is (Coelli, 1996):

$\mathrm{Min}_{\theta,\lambda}\theta$,

Subjected to,

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0$$

Where,

θ is ascalar, the efficiency score whose value will be the efficiency measure for the i^{th}farm. If θ =1 the farm will be efficient; otherwise, it will be inefficient,

y_i is a vector (m x 1) of output of the ith farm,

x_i is a vector (k x 1) of inputs of the ith farm

Y is a output matrix (n x m) for n farms

X is a input matrix (n x k) for n farms

λ is a vector (n x 1) of constants whose values are estimated to obtain the optimum solution.

The constant returns to scale is only appropriate when the farms are operating at an optimal scale (Murthy et al. 2009).

Variable returns to scale

Banker *et al* (1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) conditions because of imperfect competition, finance constraint, etc. all farms not to be operating at optimum scale (Coelli, 1996; Johansson, 2005; Baris and Nilgun, 2007). Hence, when not all farms are operating at the optimal scale, we use VRS to avoid scale efficiency effects in calculation of technical efficiency.

The CRS linear programming problem can be easily modified by imposing a convexity constraint (N1'λ = 1) to account for VRS. The following linear programming model estimated is:

$\text{Min}_{\theta\lambda}\theta$,

Subjected to,

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0,$$

Where,

$N_1$is a vector (n x1) of ones.

The VRS approach forms a frontier of intersecting planes which envelope the data points more tightly than the CRS frontier. Therefore, it provides efficiency scores which are higher than or equal to those obtained using the CRS specification (Coelli, 1996; Manjunatha*et al.*, 2009).

Allocative efficiency and cost efficiency

If we have price information and our objective is to cost minimisation, then we can measure both technical and allocative efficiencies. The cost minimization DEA formulated as follows

$$Min_{\lambda,xi^*}\ W_i'\ X_i^*,$$

Subjected to,

$$-y_i + Y\lambda \geq 0,$$

$$X_i^* - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

Where, W_i is the vector of input prices for the i^{th}farm and X_i^* is the cost minimizing vector of input quantities for the i^{th} farm, given the input prices W_i and output levels y_i. The total cost efficiency or economic efficiency (EE) of the i^{th} farm is calculated as

$$\mathrm{EE} = W_i'\ X_i^* / W_i'\ X_i$$

That is, the ratio of minimum cost to observed cost, for the i^{th} farm. The allocative efficiency is calculated residually by

AE = CE/TE

The DEAP version 2.1 software developed by Tim Coelli (1996), Centre for Efficiency and Productivity Analysis, University of Queensland, Australia, was used in this study to compute the efficiency levels of ragi and red gram farms separately by taking input oriented method.

The main product and by product per acre considered as outputs in the present study and seeds (kgs), farm yard manure (tons), human labour (mandays), bullock labour (pairdays), machine labour (hours), chemical fertilisers (kgs), plant protection chemicals (in redgram) were taken as inputs. The prices of inputs used for cost minimization problem to estimate the economic efficiency.

3.3.4 Economic surplus approach

Economic surplus by far has been the most popular approach in assessing the impact of investments in agricultural research. This method measures the aggregated social benefit of a research project by calculating consumer and producer surplus due to technological change due to research. The economic surplus along with information on research costs are used to calculate the net present value (NPV), the internal rate of return (IRR) and the benefit-cost-ratio (BCR) (Maredia*et al* 2000).

Here for impact assessment, the situation with research is compared with the situation without research. This is further dealt using 'with and without' research approach as against 'before and after' research approach for impact assessment of research (Masters *et al.*, 1996). Economic surplus method provides a relatively simple, flexible approach for economic impact assessment of research, by comparing the situations with and without research.

Figure 3.2 illustrates the impact of a successful research effort on the supply curve, the equilibrium price and quantity, and the economic surplus. The research innovation shifts the original supply curve S_0 down to the right to S_1. This shift in supply moves the equilibrium price from P_0 to a lower level $P_1$and a higher quantity from Q_0 to Q_1.

For farmers, the impact of research is reduction in cost of production. This in terms of producer surplus is given by an increase in area between (S_0) and (S_1) supply curves + the area under the new price line P_1 given by ERBF. Further, research reduces the price received by farmers, and this reduces producer surplus by the extent of area between two price lines, above S_0given by P_1BNP_0

For consumers, the effect of research is that they always a gain. They receive whatever was lost by producers due to lower prices, plus the economic surplus on the increased quantity. Consumers gain because they are able to consume a larger amount (Q_1) at a lower price (P_1). The area P_0NRP_1 (Fig 1) gives the change in consumer surplus (ΔCS). The change in producer surplus (ΔPS) is given by areaERBF.

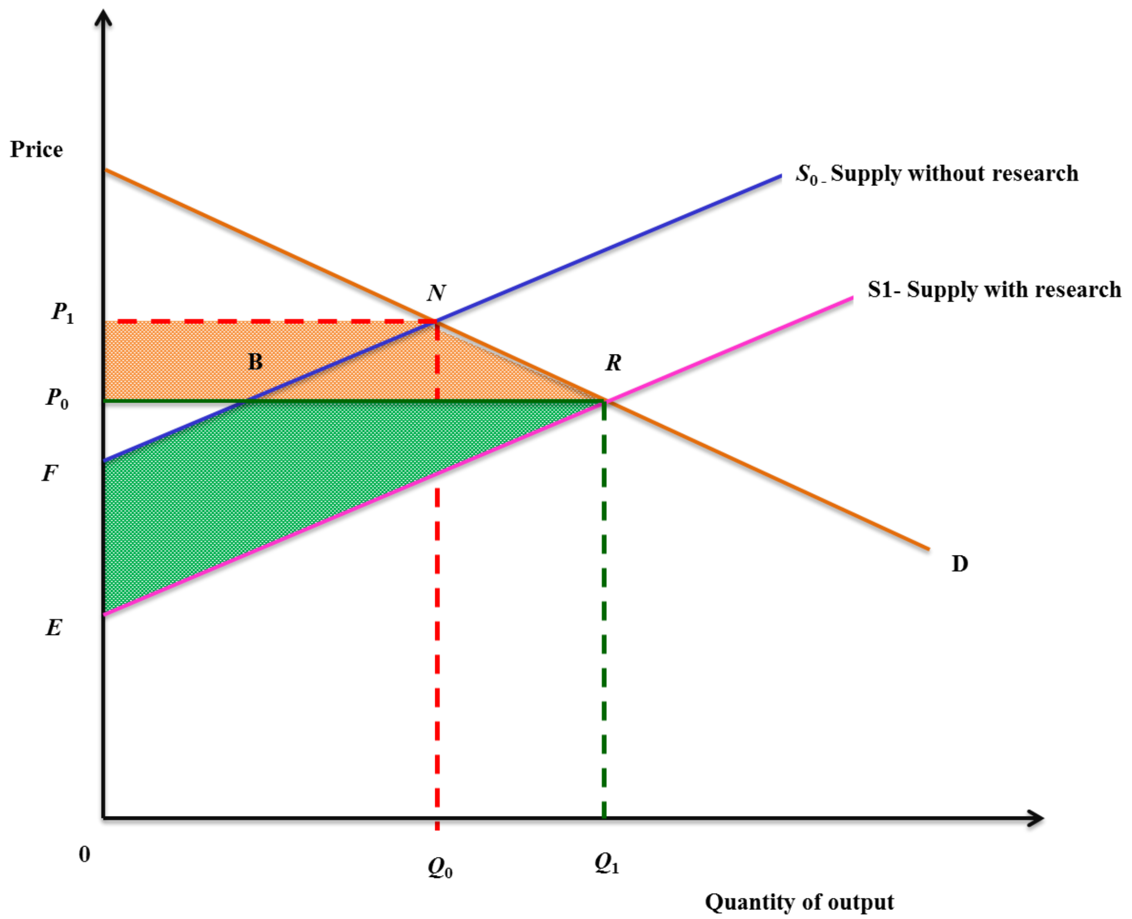


Fig.3.2. Graphical representation of impact of research on economic surplus

Source: Alston *et al* (1995)

The impact of agricultural research is a gain of the area ERBF and area P_0NRP_1 for the whole economy is concerned (Masters et al., 1996). The social gain from research is the sum of additional producer surplus and additional consumer surplus.

Ex-ante impact assessment

Figure 3.3 illustrates a situation in which the observed price and quantity do not include effects of research as they are not in the market and hence not yet adopted. So the observed quantity and price are on the without research supply curve (Q_0 P_0). In this situation the social gain we wish to measure is a parallelogram or rectangle (area R) plus a triangle (area T). The area R represents the value of cost reduction at the without research level of output (Q_0) while area T shows the social benefits from increased production (Q_0 to Q_1). Usually lower production costs are of more economic value. Therefore, area R is almost always much larger than area T, indicating that gains from research should not be measured in terms of increased production levels (Masters et al., 1996).

Ex-post impact assessment

In this situation**,** the observed price and quantity already included the effects of research which results in shift in supply, as the technology is adopted. In the figure 3 the social gain we wish to measure is area R minus area T. area R shows the social gain due to the reduction in production costs at the observed level of production (Q_0), while area T represents a correction for the change in quantity caused by the research(Fig 3.4). The height of area R is measured in terms of money per unit of output. Specifically, the effects of research are observed in terms of quantity of output per unit of input, such as an increased crop yield per hectare. For a given cost of inputs, increased quantities represent a horizontal shift of the supply curve. To adopt the research results we may require additional investment in new inputs. For a given level of output, this increased cost represents vertical shift (Masters et al., 1996). Therefore, it is necessary to combine data on increased quantities (horizontal shift) and increased inputs costs (a vertical shift), to obtain a net shift in terms of costs per unit of output.

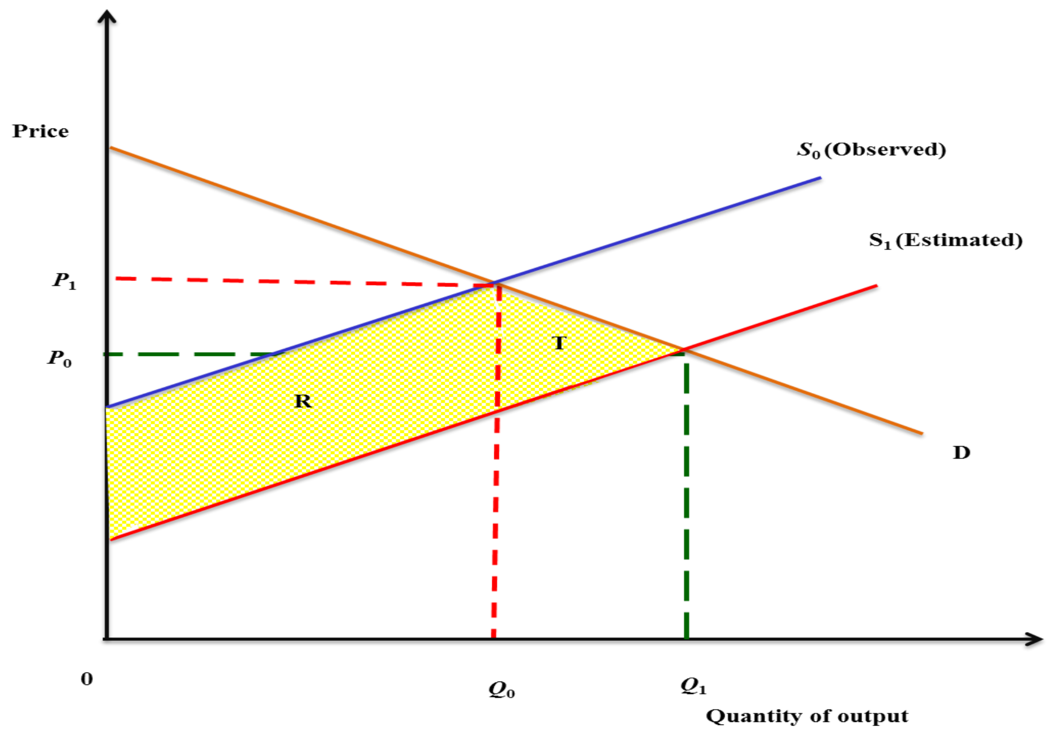


Fig. 3.3.Graphical representation of An ex-ante impact assessment

Source: Masters *et al* (1996)

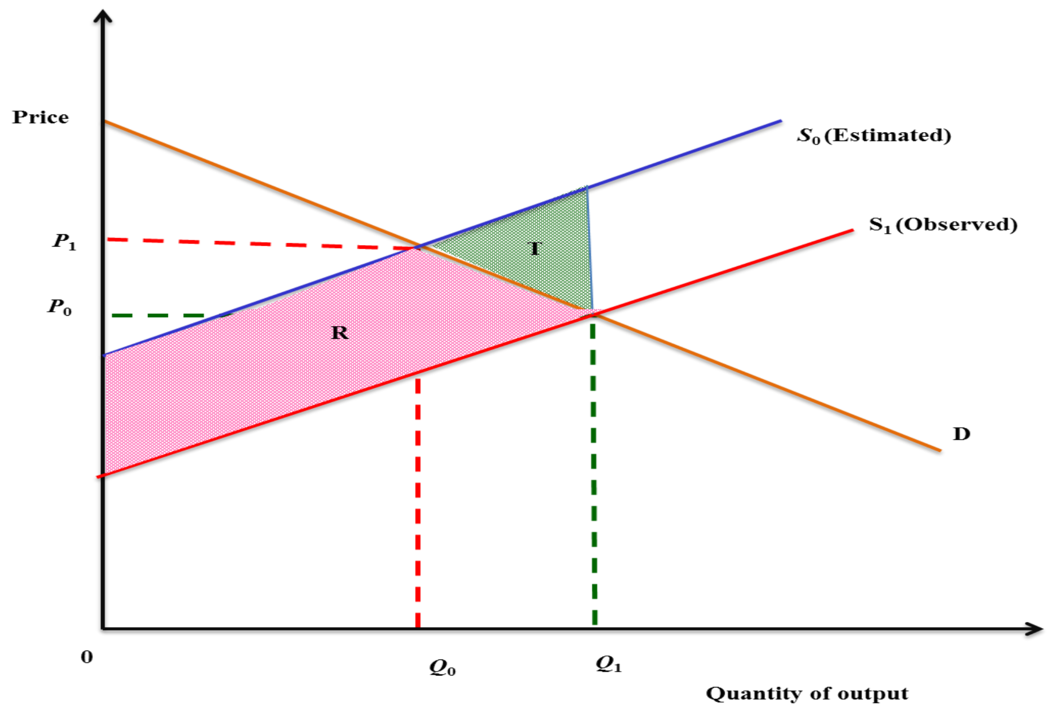


Fig. 3.4 Graphical representation of an ex-post impact assessment

Source: Masters *et al* (1996)

Data requirement for measurement of social gain or economic surplus

1. Data on area, production and productivity of crop over the years at http://eands.dacnet.nic.in/fhprice/FHP-2010-11/karnatak.pdf on 25/02/2013, 2 pmThe farm harvest Prices for years 1997 to 2010 for Ragi and 2006 to 2010 for red gram, are obtained from the website http://eands.dacnet.nic.in/fhprice/FHP-2010-11/karnatak.pdf on 25/01/2013.

2. Whole sale price indices for India to deflate the nominal priceswere obtained from the website http://rbidocs.rbi.org.in/rdocs/Publications/PDFs/039T_BST130913.pdf (on 24 Jan 2013);

3. The data on yield due to adoption of new technology and the cost of adoption of new technology was obtained in field work collecting data from sample farmers cultivating check variety and the improved variety The data on quantity of GPU 28 ragi seeds sold for the years 1997 to 2010 and the data on quantity of BRG 2 redgram seeds sold for the years 2006 to 2010 were obtained by adding the sales data from the Karnataka state seeds Corporation, Hebbal, The National Seeds Corporation, Hebbal and the National Seeds Project, UAS, GKVK, Bangalore.Economic parameters – price elasticity of demand and price elasticity of supply for a commodity were obtained from Rosegrant*et al*. (2012).

4. Data on research and extension costs incurred for developing the new technology. In the Table 3.3 and Table 3.4, the details of research costs and costs incurred in extension by the University of Agricultural Sciences, Bangalore in the release of BRG 2 variety of red gram and the GPU 28 variety of Ragi. The figures are provided the concerned scientists Professor A Seetharam for GPU 28 Ragi variety, and Professor M Byregowda for BRG 2 redgram.

Table 3.3 Research and extension cost for GPU 28 ragi variety

Year	Resear cost (Rs.)	extension cost (Rs.)
1986	84350	
1987	84350	
1988	84350	
1989	94350	
1990	104350	
1991	144350	
1992	184350	
1993	194350	
1994	264350	
1995	320350	
1996	364350	
1997		260300
1998		260300
1999		50000
2000		50000
2001		60000
2002		45000

Figures are in nominal prices

Source: collected from annual budget books UAS, Bangalore, and consulting scientists in AICRP onsmall millets

Table 3.4 Research and extension cost incurred for BRG 2 redgramvareity

Year	Research cost (Rs.)	extension cost (Rs.)
1995	510000	
1996	510000	
1997	510000	
1998	510000	
1999	561000	
2000	561000	
2001	589200	
2002	278000	
2003	370800	
2004	804600	
2005	441400	
2006		525600
2007		635000
2008		146000
2009		298000
2010		298000

Figures are in nominal prices

Source: collected from UAS,B annual budget books and consulting scientists in AICRP on pigeonpea

In order to estimate the social gains illustrated in Figure 2 (ex-ante), the difference between supply curve observed and supply curve estimated gives the welfare. Since the supply curve observed is at original quantity Q_0 and price P_0, for computing the welfare effect, the effect of shifted quantity of output Q_1 at Price P_1 is given by the area under parallelogram R plus the area under the triangle T. Thus the area R + area T gives the welfare effects of new technology in ex-ante analysis. Accordingly

Social Gain SG = kPQ + ½kPΔQ. Here K = difference between the original supply curve and the new supply curve due to new technology at optimum use of inputs. Since in ex-ante, the new supply curve due to optimal use of inputs is estimated, considering the demand to be perfectly inelastic, the area T is added to the area of parallelogram R.:

The Social Gain accordingly is $SG = kPQ \pm \frac{1}{2}kP\Delta Q$. (1)

ΔQ is the change in quantity of output due to research contribution (i.e. = Q_0-Q_1 in ex-ante studies)

In Ex-post, which is attempted in this study, = $\Delta Q = Q_1 - Q_0$, and k to be the vertical shift in supply. Here Q_0 and Q_1 are as defined earlier. The Social Gain is obtained by the formula

$SG = kPQ - \frac{1}{2}kP\Delta Q$.

(Masters *et al*., 1996).

To compute k, ΔQ, I, J and K parameters

The steps involved including estimation of welfare gain according to Masters *et al*., (1996) are as under:

Step 1: Data on total production (Q, quintals) of Ragi /Redgram and price per quintal of (P, rupees per quintal), for years 1997 to 2010 are obtained for variety GPU28 of Ragi since the variety released during 1997 and for years 2006 to 2010 for BRG 2 of redgram variety since it is released in 2006 . As the prices obtained are nominal prices, they are deflated to obtain price in real terms by dividing nominal price by wholesale price index. The wholesale price index for different years with base year of 2010 is given in Table appendix V.

Step 2: The data on yield of check variety (TTB 7 for redgram and INDAF 5 for GPU28 Ragi per hectare were collected from n = 35 farmers under each crop variety (including check) through field survey for the year 2011-12.The secondary data on area, production and productivity of ragi and redgram is available upto 2010-11. Therefore the research benefits estimated upto 2010-11. The shift in yield ΔQ is the difference between the yield of check variety (Yc) and (Ym) the improved variety due to research.

Step 3: Estimation of J parameter

The J parameter is the total increase in production that is due to adoptionof the improved variety (BRG 2 of redgram or GPU 28 of ragi), assuming that the costs of production / prices of output do not change with the new variety, which is a reasonable assumption.

J is obtained by

$\Delta Y^* t^* A$ ---(2)

Here,

ΔY = the yield change = Yc-Ym (in quintals or kgs/ha)

t = adoption rate , assumed / obtained from scientist / breeder concerned

A = Gross area sown in the State under the Ragi / Redgram crop obtained from the Directorate of Economics and Statistics for each of the years 1997 to 2010 for Ragi and 2006 to 2010 for Redgram.

Step 4: J-parameter can also be estimated as the change in quantity of output as a share of total output given by j = J/Q .... (3)

This expression gives the estimate of the supply shift in parameter (j) in terms of the increase in yield, rate of adoption and the overall average yield (Y)

i.e. $j = (\Delta Y^* t)/Y$. Here, Y is the overall average yield i.e total production/total area under crop for each year.

step 5: Computation of adoption costs:

The parameter I is the increase in per unit input cost required to obtain the increase in total production or total output J (Masters et al., 1996Given by I = $[\Delta C * t/Y]$ .... (4)

Here,

ΔC = adoption costs per ha incurred to adopt the improved variety. This is obtained as the additional cost involved to adopt the new technology variety including all items of additional costs from seed to harvesting.

The proportional cost increase parameter (c) is given by,

$c = I/P= [(\Delta C * t)/Y]*1/P$ ……….. (5)

Step 6: K parameter, or shift in supply curve to be estimated. The K-parameter is the net reduction in production costs induced by the technology and can be obtained from combining the effects of increased productivity (J) and adoption costs (I) (Masters., et al., 1996). Given J andI, it can be computed using the slope of the supply curve (b_s) as

$K = (J * b_s) – I$ .... (6)

Step 7: The slopes of supply curves (b_s) areassociated with units of measurement. Therefore supply elasticity (€), which is independent of units of measurement (Masters., *et al.*, 1996) is computed as follows:

€ = % $\Delta Q/\%\Delta P$

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

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

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

b_s = €*Q/P

K = J/(€*Q/P) – I K = [JP/ €Q] –I

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

k = K/P = [JP/€QP] - I/P = (j/€) (7)

where,

€ = price elasticity of supply

To estimate social gains, the elasticity of demand (e) price elasticity of supply and demand were obtained from Rosegrant et al. (2012).

Step 8: The Estimate equilibrium output quantity change: ΔQ

The equilibrium situation without improved variety/technology would be that price and quantity, which satisfy both, demand and supply (Masters., et al., 1996):

$Q_d = Q_s$

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

Similarly

$P1 = (as - ad + b_s K)/(b_d - b_s)$

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

the change in quantity is given by

$\Delta Q = b_d \Delta P$ .... (8)

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

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

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

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

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

$= b_d (P/Q)$

$b_d = e(Q /P)$

Thus $\Delta Q = (eQ/P) \times (€Q/P) K / [eQ/P) + [€Q/P]$

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

$\Delta Q = Qe €k/ (e+€)$ ……….. (9)

Step 9: Next step is to estimate social gains. It is computed using the formula

$SG = (kPQ) \pm ½(kP\Delta Q)$ ………………(10)

Step 10: we incorporate the costs of research and extension, in real terms (adjusted for inflation), to obtain social benefits for each year. This is done by dividing nominal expenditures by the wholesale price index. The net social benefits are computed by subtracting research and extension costs from the total social gains obtained.

Step 11: Net social gain = SG-Research and Extension costs

The producer surplus and consumer surplus is computed by decomposing the Social Gains (SG) given by the equation as follows

$$\Delta TS = \Delta CS + \Delta PS = P_0Q_0k(1+0.5Ze) \quad \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$\Delta CS = P_0Q_0Z(1+0.5Ze) \quad \ldots\ldots\ldots\ldots\ldots(12)$$

$$\Delta PS = P_0Q_0(k\text{-}Z)(1+0.5Ze) \quad \ldots\ldots(13)$$

$$\text{Where } Z = k^* \frac{€}{e+€} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

The net social gains obtained from deducting total research and extension costs and it is used to estimate NPV (Net Present Value) and IRR.(Internal Rate of Return).

$$NPV = \sum_{i=1}^{n} \frac{B_i}{(1+r)^i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

Where,

Bi = net social gains

r = discount rate, taken as 5 percent(Alston*et al.*, 1995)

i = year 1 to n.

n = total numbers of years of research

Software for computation: Excel spread sheets are used for computation assessing the Impact through Economic surplus approach.

Advantages of using economic surplus method

- The economic surplus method needs less information than other models.
- It is easy method to assess the impact of research and development
- We can estimate both producer surplus and consumer surplus by decomposing the total economic surplus
- Besides the net social gain, we also compute the NPV (Net Present Value) and IRR (Internal Rate of Return)
- This method used for both ex-ante and ex-post impact assessment

Limitations

- Here we assume constant price elasticity of demand and price elasticity of supply. But, elasticities for linear supply and demand curves would change as the equilibrium moves along the curve.
- We assume supply curve as straight line and parallel shift, normally supply curve can take any form (straight line or a curve)

3.3.5 Total factor productivity index

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 (Rosegrant and Evenson, 1995).

3.3.5.1Tornqvist- Theil TFP index

The Tornqvistindex 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 (Evenson*et al.*, 1999). 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

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

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 (Coelli, *et al* 2005). 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 (Kumar *et al.*, 2008).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.

Data: Time series data on Costs and returns of ragi and redgram crops for the years 1990-91 to 2009-10.

Source: Farm Management Division, Department of Agriculture, GOK,

Software for analysis: The TFPIP version 1.0, which developed by Tim Coelli, Centre for Efficiency and Productivity Analysis, University of Queensland, Australia.2005

3.3.5.2 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 (Chand *et al* 2011).

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 redgram crops for the study: The model specified in log linear form as:
$\ln(TFP) = a+b_1\ln X_1+b_2\ln X_2+b_3\ln X_3+b_4\ln X_4+b_5\ln X_5+e$ …………………..(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

3.3.5.3 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 (Chand *et al* 2011). According toEvenson and Pray (1991), 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 (Chand *et al* 2011).

3.4 Definition of concepts and terms used

Input and cost concepts

The total costs were divided into two broad categories:

a. Variable Costs
b. Fixed Costs

Variable costs: The variable costs include cost of seeds, manure, fertilizers, wages of human and bullock labour, machine labour, plant protection chemicals, miscellaneous charges interest on working capital and repair and maintenance charges.

Seeds: The cost of purchased seeds was based on the actual amount paid by the respondents.

Farm yard manure: The quantity of FYM used in the cultivation of paddy was measured in terms of. The cost was imputed at the market price in the village including cost oftransportation and other incidental charges if any.

Fertilizers and plant protection chemicals: The cost of fertilizers and plant protection chemicals was based on the actual prices paid by the farmers including the cost of transportation and other incidental charges, if any.

Labour: The cost of hired labour was calculated at the prevailing wage rates paid per day (8 hours) in the study area for Men, Women and Bullock labours and Machine labour during the study period. The cost of family labour human, animal and machinery) was calculated considering the prevailing market rate in this region through imputation.

Miscellaneous charges: This includes the expenses incurred by sample farmers for procuring input materials and marketing of produce in the market and other expenses.

Interest on working capital: The working capital consists of the expenditure on seeds, labour, farm yard manure, chemical fertilizers and plant protection chemicals, Interest on operational capital was calculated at the rate of 7 per cent per annum (the rate at which commercial banks advance short term loans).

Fixed costs: These include depreciation on farm implements and machinery, interest on fixed capital, land revenue.

The measurement and definitions of fixed cost components are as follows.

Depreciation charges: Depreciation on each capital equipment and machinery owned by the farmers and used for land cultivation was calculated for individual farmer based on the purchase value using the straight line method. Thus the

Annual depreciation = <u>Purchase value –Junk value</u>

Useful life of the asset

The average life of the asset as indicated by the experts (Agril. Engineers) was used in the computation of the depreciation. The depreciation cost of each equipment was apportioned to the crop based on its percentage use.

Interest on fixed capital: Interest charges on fixed capital were calculated at the rate of 09 per cent, as the fixed deposits in commercial banks would fetch this rate of interest. The items considered under fixed capital are implements and machinery. Interest was considered on the value of these assets after deducting the depreciation for the year.

Land revenue: Actualland revenue paid by the farmers was considered.

i. **Rental value of land:**It was imputed by taking the prevailing rents in the study area per acre per annum.

Cost of cultivation: It is the sum of variable costs and fixed costs and expressed on per acre basis.

Gross return: The gross returns were computed by multiplying the quantity of main product and by-product obtained with respective prices received.

Cost of cultivation for redgram intercropping with maize and groundnut

To estimate cost of cultivation of redgram intercrop row ratios considered according to that the proportion of cost incurred for redgram cultivation estimated. In the study area farmers followed 8: 1 ratio for maize+ redgram. Therefore, here we considered 1/9th of cost of cultivation maize+ redgram to estimate cost of cultivation of redgram separately excluding the seed cost of intercrop and labour cost incurred for harvesting and threshing of redgram intercrop. In the case of groundnut+ redgram, the ratio was 10:1. Hence, 1/11th of cost of cultivation of ground nut +redgram considered for estimation.

RESULTS

CHAPTER IV

RESULTS

In consonance with the objectives of the study concerning the economic impact of agricultural research in Ragi (finger millet) (*Elusine coracana*) and Red gram (*Cajanus cajan*), in Karnataka, the field data and secondary data collected were analysed and the results are presented under the following headings:

4.1 New varieties/technologies released in Ragi (finger millet) and Red gram crops by UAS, Bangalore, since inception and area under selected varieties of ragi (finger millet) and redgram in Karnataka

4.2 Socio-economic characteristics

4.3 Cropping pattern of sample farmers

4.4 Costs and return structure of red gram and ragi (finger millet) production

4.5 Economic efficiency of selected varieties of ragi (finger millet) and red gram

4.6 Economic surplus of improved variety in ragi (finger millet) and red gram in Karnataka

4.7 Estimation of economic impact of agricultural research in red gram and ragi (finger millet) using partial budgeting technique

4.8 Total Factor Productivity in ragi (finger millet) and red gram in Karnataka

4.1 New varieties/technologies released in Ragi (finger millet) and Red gram crops by UAS, Bangalore, since inception

The varieties developed and released by University of Agricultural Sciences, Bangalore, Karnataka were presented in the Table 4.1.From 1966 to 2008, 22 varieties of ragi (finger millet) were released in Karnataka. In the case of red gram, 5 varieties were released from 1987 to 2012 in Karnataka.

4.1.2 Area under ragi (finger millet) and GPU 28 variety in Karantaka

From the table 4.2, it is observed area under ragi (finger millet) was 1055330 ha during 1990 and it decreased to 787894 ha in 2010. The area under GPU 28 variety

Table 4.1 New varieties/technologies released in Ragi and Redgram by UAS, Bangalore, since inception

Sl. no.	Name of the variety	Important features	Release year
I	**Ragi (finger millet)**		
1.	Purna	Short duration, highly yielding variety (42 q/ha) can be grown throughout the year. Except during winter. Suitable for rainfed and irrigated conditions.	1966
2.	Hamsa	Matures in 110-112 days, can be grown in summer, and kharif. It has creamy white grains unlike other ragi varieties with a yield potential of 48q/ha.	1967
3.	Shakti (ROH-2)	Suitable for both rainfed and irrigated conditions, yielding 49 q/ha, grown between May and August.	1972
4.	Indaf-1	High yielding (49q/ha) variety suitable for rainfed conditions.	1976
5.	Indaf-3	High yielding (50q/ha) variety suited to rainfed condition and rainfed condition	1976
6.	Indaf-5	High yielding (51q/ha) variety suited to irrigated conditions.	1977
7.	Indaf-7	Duration of 115-120 days, has good cooking quality yielding 45-50q/ha.	1981
8.	Indaf-8	Variety resistant to drought and blast disease, yielding upto 50q/ha under rainfed conditions and 60 q/ha under irrigated conditions.	1982
9.	Indaf-9	For pre-monsoon, late kharif, rabi and summer irrigated areas except for June and July sowing. Duration of 100-110 days, tolerant to water logging and salinity. Has dormancy for two months after maturity with yield potential of 35 q/ha.	1985
10.	HR-911 (KBR-1)	Released for kharif and summer irrigated conditions, matures in 115-120 days, recorded 20 %higher grain yield over Indaf-8, for sowing between July and August in kharif season, and between January and February in summer season. It is moderately resistant to diseases with yield potential of 39 q/ha, with fodder yield upto 85 q/ha.	1985
11.	MR-1	For pre-monsoon and kharif ragi areas of Agro climatic zone -III, tolerant to drought, matures in 120 days, yielding 40 q/ha under rainfed conditions.	1990
12.	Indaf-15	For rabi under irrigated conditions as a supplement to Indaf-7. Fairly tolerant to neck and finger blast than Indaf-7. Matures in 125-135 days. Produces 10-12% higher yield than Indaf-7 yielding 34.5 q/ha of grain and 10.1 t/ha of straw.	1993
13.	MR-2	Yielding 40 q/ha (12% grain, 18% straw higher than Indaf-8). Recommended for rainfed areas of zone-7, matures in 125-130 days.	1994
14.	GPU-28	Grain yield 52q/ha. Blast tolerant. Matures in 125-130 days.	1996
15.	GPU-26	Grain yield 3 to 4 t/ha and fodder yield 6 to 7 t/ha. Duration 95-100 days. Suitable for kharif season, recommended for zones 4,5 and 6	1997

16.	L-5	Grain yield 49 q/ha (15% higher than Indaf-8). Matures in 115-120 days, tolerant to rust and blast diseases.	1998
17.	MR-6	High yielding, light brown coloured ragi with a duration of 120 days and yield potential of 45-50 q/ha under irrigated, 30-35 q/ha under rainfed condition. This is highly tolerant to neck and finger blast, recommended for both Kharif and late kharif in Southern and Eastern Dry Zone.	2004
18.	GPU-48	A short duration variety (100 days), with 22 % higher yield (37 q/ha) thanGPU-26 (31 q/ha) with profuse tillering, tolerant to blast, ideal for late sowing under rainfed conditions and suitable for catch crop (time and space) under irrigated conditions. The variety was identified at GKVK and recommended for cultivation in zones -4,5,6 and 7.	2005
19.	GPU- 21	Proso-millet variety with bold grains maturing in 70-75 days, with a yield potential of 15 q/ha released at the national level for cultivation in Karnataka and Tamil Nadu.	2003
20.	ML-365	Short duration (100-105 days) ragi variety, moderately tolerant to neck blast and finger blast, with grain yield potential of44q/ha under rainfed condition, offering 23 % higher yield over the check GPU 28. It is recommended for cultivation in zone-5.	2007
21.	KMR- 204	Grains are brick red in clour, medium bold, matures in 100-105 days. Resistant to blast, yields 35-40 q/ha under irrigated condition, 30-35 q/ha under rainfed situation for zone-5 and 6.	2012
22.	GPU -66	Medium duration (108 – 110 days) ragi variety yielding 35 q/ha, 21% higher yield over check GPU-28 (29 q/ha) under rainfed condition. Variety is tolerant to neck blast and finger blast diseases, suitable for cultivation in kharif, late kharif and summer season, recommended for zone-4, 5 and 6.	2008
23.	KMR-301	HYVragi variety with grain yield of 55 q/ha compared to check MR-6 (50 q/ha) under irrigated condition, 35-40 q/ha under rainfed condition. It matures in 120 days, tolerant to neck blast and finger blast diseases. Grains are bold and brick red in colour, recommended for kharif and late kharif in zone-6.	2008
II	**REDGRAM**		
1.	TTB-7	For red soils yielding better than HY-3C, medium sized, matures in 140-150 days, highly tolerant to sterility mosaic disease. Fits well for intercropping with groundnut, ragi, cowpea and sesamum, with yield potential of 10 q/ha.	1987
2.	BRG-1	Both vegetable and dal purpose variety, maturing in175 to 190 days, yielding14 q/ha. It gives 11% higher grain yield than the check variety HY-3C and 20% higher green pod yield. The green pods are long and thick with bold seeds. The variety is resistant to major diseases and pests and is recommended for eastern dry zone.	2003

3.	BRG-2	For late sowing with a duration of 145 days, yielding13q/ha compared with check variety TTB-7 (12q/ha) recommended for Zone 5.	2006
4.	ICP-7035	Dual purpose, medium duration (160-140 days) variety yielding on par with TTB-7 recommended for cultivation in sterility mosaic disease prone areas of zone-5.	2004
5.	BRG-10-2	HYV and early duration variety for normal and late planting. Matures in 140-145 days, yields 14 q/ha on par with BRG-2, recommended for zone -5.	2012

Source: Research Accomplishment and Research Highlights, UAS, Bangalore, Directorate of Research, UAS GKVK, Bangalore 560065, (2007, 2008, 2009, 2010, 2011-12.

increased substantially over the years accounting almost 50 per cent of area of ragi (finger millet) in the state duing 2010. Since the variety released during 1997 the area under GPU 28 was 1880 hectares in 1997 and it increased to 393947 hectares during 2010.

4.1.3 Area under redgram and ragi (finger millet) in Karnataka

It is observed from the table 4.3 that, the area under redgram was 423856 hectares during 1995 and increased to 891535 hecares in 2010. During 2010, the area under BRG 2 vareity estimated as 28901 hectares. In Southern Karnataka this variety occupied 40 per cent of redgram area.

4.2. Socio-economic characteristics of the sample farmers

The details of family type, age, family size, literacy status and size of land holdings of sample respondents are presented in the Table 4.4.

4.2.1 Family profile of sample farmers

Majority of sample farmers (83%) cultivating ragi (finger millet), belonged to nuclear family while, in the case of red gram, as pure and as intercrop, farmers 70 % belonged to nuclear family. Thus, nuclear families were a rule than an exception in dry land agriculredgrame in Karnataka.

4.1.2 Education level of sample farmers

The levels of literacy for farmers cultivating ragi (finger millet) / red gram were impressive as the level of literacy was around 97%. It was observed that farmers completing up to secondary school education were higher in ragi (finger millet) (74.29 %) followed by red gram as intercrop (60%) and red gram as pure crop (50%). Within ragi (finger millet), 20 %of farmers completed college education and 5.71 %studied up to primary school. In the case of red gram farmers, 30 % completed their studies upto primary school and 13%studied up to college level and 4%studied up to degree level. In the case of red gram intercrop farmers, 31.43 % educated upto primary school followed by college (4.29%) and degree (1.43).

Table 4.2 Area under ragi and area under GPU 28 variety in Karnataka

Year	Area under ragi (ha)	Area under GPU 28 (ha)
1990	1055330	-
1991	1118145	-
1992	1038411	-
1993	1028508	-
1994	944155	-
1995	1019932	-
1996	1035204	-
1997	938546	1880
1998	1030679	12790
1999	916328	80040
2000	1022701	157060
2001	953430	159940
2002	767148	182590
2003	998266	196510
2004	892841	184570
2005	938630	192690
2006	605771	203700
2007	832722	239490
2008	841124	282960
2009	764374	318560
2010	787894	393947

Table 4.3 Area under redgram and area under BRG 2 variety in Karnataka

Year	Area under red gram (ha)	Area under BRG 2 (ha)
1995	423856	-
1996	445381	-
1997	421810	-
1998	475396	-
1999	508086	-
2000	582763	-
2001	482100	-
2002	513739	-
2003	532251	-
2004	562127	-
2005	599884	-
2006	595697	1000
2007	681136	3500
2008	596622	8400
2009	604305	18000
2010	891535	28901

4.2.3 Age distribution

About 73% of ragi (finger millet) farmers belonged to middle age followed by old age farmers (24.29%) and young farmers (2.86%). On the other hand, in the case of red gram as intercrop, middle aged farmers constituted 71% followed by old aged (26%) and young aged farmers (2.86%).

Among the red gram farmers, about 61% were middle aged, while 34.29% were old aged and 4.29% were young aged.

4.2.4 Land holding

The average size of land holding for red gram farmers, ragi (finger millet) farmers and red gram intercrop farmers was 4.51 acres, 3.98 acres and 4.20 acres respectively.

4.2.5 Distribution of land holdings and Family size

About half the red gram farmers were belonged to small category land holding and 30 % and 24.29 % who belonged to medium farm category and marginal farm category. In the case of ragi (finger millet) farmers, about 42.86 % belonged to small farm category followed by marginal and medium farmers category. In the case of red gram intercrop farmers, majority were small farmers (47%) followed by medium (24.29%) and marginal farmers (22.86%).The average size of family or both ragi (finger millet) and red gram farms was six members and 7 members in the case of red gram as intercrop

4.3.1 Cropping pattern of ragi (finger millet) farmers in Eastern Dry agro climatic zone

The cropping pattern in the three seasons (Kharif, rabi and summer) in Eastern Dry agro climatic zone are in the Table 4.5. The sample farmers in rainfed land cultivate ragi (finger millet) as major crop (48.7%) followed by maize (20.3%) and red gram (12.4%). In the case of irrigated land, most of the farmers cultivated vegetables such as tomato (60.8%) followed by Beans (17.72%), perennial crop mango (12.6%) and Mulberry (6.3%).

Table 4.4 Socio-economic characteristics of sample farmers

Sl. No.	Particulars	Redgram farmers	Ragi farmers	Farmers with Redgram as intercrop
1.	Type of family			
	a. Nuclear family	49 (70.00)	58 (82.86)	48 (68.57)
	b. Joint family	21 (30.00)	12 (17.14)	22 (31.43)
	Total	70 (100.00)	70 (100.00)	70 (100.00)
2.	Literacy level			
	a. Illiterate	2 (2.86)	0 (0.00)	2 (2.86)
	b. Primary	21 (30.00)	4 (5.71)	22 (31.43)
	c. Secondary	35 (50.00)	52 (74.29)	42 (60.00)
	d. College	9 (12.86)	14 (20.00)	3 (4.29)
	e. Degree	3 (4.29)	0 (0.00)	1 (1.43)
	Total	70 (100.00)	70 (100.00)	70 (100.00)
3.	Age distribution			
	Young (<35 years)	3 (4.29)	2 (2.86)	2 (2.86)
	Middle (35-50 years)	43 (61.43)	51 (72.86)	50 (71.43)
	Old aged (>50 years)	24 (34.29)	17 (24.29)	18 (25.71)
	Total	70 (100.00)	70 (100.00)	70 (100.00)
4.	Average land holding (acres)	4.51	3.98	4.20
5.	Distribution of land			
	Marginal farmers (<1ha)	17 (24.29)	20 (28.57)	16 (22.86)
	Small farmers (<2 ha)	27 (38.57)	30 (42.86)	33 (47.14)
	Medium farmers (2 to 4 ha)	21 (30.00)	17 (24.29)	17 (24.29)
	Large farmers (> 4 ha)	5 (7.14)	3 (4.29)	4 (5.71)
	Total	70 (100.000	70 (100.00)	70 (100)
6.	Average Family Size	6	6	7

Figures in parentheses indicate percentage to respective total

4.3.2 Cropping Pattern of red gram sample farmers in Eastren dry agro climatic zone (Magadi taluk and Doddaballapur taluk)

The cropping pattern in (Kharif, rabi and summer) in eastern dry agro climatic zone (Table 4.6) indicated that, in rainfed areas ragi (finger millet) occupied 34% of gross cropped area of sample farmers while the area under red gram occupied 33% and maize (28%). In the case of irrigated area beans occupied 40 % of area followed by tomato (21%) and coconut (14%).

4.3.3 Cropping Pattern of Redgram (as mixed crop) sample farmers in Central dry agro climatic zone (Chitradurga district)

Table 4.7 portrays the cropping pattern of sample farmers in central dry zone. In rainfed areas most of the farmers grow red gram as intercrop with groundnut (35.41%) and maize (26.49%) followed by ragi (finger millet) (14%), maize, sunflower, cotton and groundnut. In irrigated area onion occupied highest area (31.43%) followed by pomegranate, maize and arecanut.

4.4. Costs and return structure of red gram and ragi (finger millet) production

4.4.1 Costs and return structure of BRG 2 variety and Check variety of red gram farmers

The details of the cost of cultivation, as well as the gross and the net returns from an acre of red gram cultivation on BRG 2 and Check variety farms during the crop year 2011-12 are given in Table 4.8.

Farmers of BRG 2 variety used 21.10mandays of human labour, 1.51 pairdays of bullock labour, 5.20 kg of seeds and 2.22 tonnes of farm yard manure. Whereas check variety(TTB 7) farmers used 19.53 mandays of human labour, 1.25 pairdays of bullock labour, 4.86 kgs of seeds and 2.14 tonnes of farm yard manure. Check variety Redgram farmers incurred higher cost of Rs 501 towards plant protection chemicals compared with BRG 2 farmers (Rs.429.78). The machine labour (2.04 hours) used was nearly same by both categories of farmers. BRG 2 and check variety farmers incurred a total cost of Rs. 12,883.84 and 12,146.10 respectively. Human labour cost accounted maximum share in total cost of cultivation in both categories of farms (34.57% and 33.86%) respectively. The variable cost was higher in the case BRG 2 farms (Rs. 9,274.50) than Rs.8, 637.58 incurred by check variety farmers. The

Table 4.5: Cropping pattern of Ragi farmers in in Eastren Dry agro climatic zone

Chintamani taluk+ Doddaballapur taluk (n= 70)				
Crops	**Rainfed area (acres)**	**%**	**Irrigated area (acres)**	**%**
Ragi	130.80	48.77	0.00	0.00
Cowpea	20.00	7.46	0.00	0.00
Tur	33.25	12.40	0.00	0.00
Maize	54.5	20.32	1.00	2.53
Fieldbean	24.75	9.23	0.00	0.00
Mulbery	0.00	0.00	2.50	6.33
Tomato	0.50	0.19	24.00	60.76
Ragi+tur	3.00	1.12	0.00	0.00
Beans	0.00	0.00	7.00	17.72
Mango	0.00	0.00	5.00	12.66
Carrot	1.00	0.37	0.00	0.00
Eucalyptus	0.40	0.15	0.00	0.00
Total	268.20	100.00	39.50	100.00

Table 4.6 Cropping Pattern of Tur farmers in Eastren dry zone of eastern dry zone.

Magadi taluk + Doddaballapur taluk (n = 70)				
Crops	**Rainfed area (acres)**	**%**	**Irrigated area (acres)**	**%**
Tur	101.00	33.33	0	0.00
Ragi	103.80	34.26	0	0.00
Maize	85.00	28.05	1	4.72
Filed bean	5	1.65	1	4.72
Groundnut	7	2.31	0	0.00
Paddy	0	0.00	2	9.43
Beans	0	0.00	8.50	40.09
Tomato	0	0.00	4.50	21.23
Horsegram	1	0.33	0	0.00
Ridgeguard	0.20	0.07	0.20	0.94
Coconut	0	0.00	3	14.15
Banana	0	0.00	1	4.72
Total	303.00	100.00	21.20	100.00

Table 4.7 Cropping Pattern of redgram Mixed crop farmers in Central dry zone of Karnataka (Chitradurga district)

Chitradurga district (n=70)				
Crops	Rainfed area (acres)	%	Irrigated area (acres)	%
Maize+Redgram (8:1)	68.60	26.49	0.00	0.00
Groundnut+Redgram (10:1)	91.70	35.41	0.00	0.00
Ragi	36.20	13.98	0.50	1.43
Maize	22.50	8.69	8.00	22.86
Jowar	1.00	0.39	0.00	0.00
Cotton	9.00	3.47	2.00	5.71
Sunflower	12.00	4.63	0.00	0.00
Horsegram	1.00	0.39	0.00	0.00
Groundnut	7.00	2.70	2.00	5.71
Onion	0.00	0.00	11.00	31.43
Redgram	10.00	3.86	0.00	0.00
Paddy	0.00	0.00	0.50	1.43
Arecanut	0.00	0.00	3.00	8.57
Pomegranate	0.00	0.00	8.00	22.86
Total	259.00	100.00	35.00	100.00

fixed cost was uniform in BRG 2 farms and check variety farmers. The share in total cost was 29% in check variety farms and 28.01 % in BRG 2 farms.

The BRG 2 farmers obtained higher yield in both main product (5.02 quintals/acre) and by-product (3.65 quintals of stubbles) compared to check variety farmers who obtained 4.50 quintals of red gram as main product and 3.24 quintals of stubbles as by-product. The gross return was Rs.18, 513 and Rs.16, 082 in BRG 2 farms and check variety farms respectively with a difference of Rs. 2430.36 per acre. The net return was the highest being 5,629in the case of BRG2 red gram variety as against Rs. 3936 in the case of check variety farms with a difference of Rs. 1,692

4.4.2 Economics of GPU28 and Check variety Ragi (finger millet) farmers

From Table 4.9, it can be seen that GPU 28 ragi (finger millet) farmers used higher human labour (19.78 mandays), machine labour (2.22 hours), seeds (4.80 kgs), farm yard manure (2.16 tonnes) and chemical fertilisers (89.26 kgs) over the check variety (17.63 mandays of human labour, 2.13 hours of machine labour, 4.46 kgs of seeds, 1.92 tonnes of farm yard manure and 83.86 kgs of chemical fertilisers) farmers. In GPU 28 ragi (finger millet) farms, the cost of human labour was the highest of Rs. 3,553.69 accounting 30.72 % of total cost of cultivation whereas as it was Rs. 3230.83 (29.27) in check variety farms. The cost of chemical fertilisers accounted 9.80 % and 9.45 % of total cost in GPU 28 ragi (finger millet) farms and check variety per acre respectively. The expenditure incurred on farm yard manure was Rs.961.48 in GPU 28 ragi (finger millet) farms and it was Rs. 637.11 in check variety farms. However, the cost of bullock labour was found to be higher in check variety farms (Rs. 620) compared with that of GPU 28 farmers (Rs. 773.97). The total variable cost was Rs. 7,728.33 (66.81%) and Rs.7, 221.85 (65.43%) for GPU 28 ragi (finger millet) farms and Indaf 5 check variety farms respectively. The total fixed cost was 34.57 % (Rs. 3816.33) % of total cost in check variety farms whereas it was 33.19 % (Rs.3839.51) of total cost in GPU 28 ragi (finger millet) farms. The rental value of land in both categories of farmers was nearly the same.

The ragi (finger millet) grain yield obtained by GPU 28 farmers was 12.45 quintals as against 10.49 quintals by check variety farmers. The by-product straw was

Table 4.8 Economics of BRG 2 variety of redgram as main crop and check variety of redgram cultivation (Rs./ acre)

Sl.No.	**Particulars**	**Unit**	**BRG 2 Variety**		**TTB 7 (Check variety)**	
			Quantity	**Value (Rs.)**	**Quantity**	**Value (Rs.)**
A	**Variable costs**					
1	Human labour	Mandays	21.10	4453.97 (34.57)	19.53	4112.81 (33.86)
2	Bullock labour	Pairdays	1.51	760.95 (5.91)	1.25	626.19 (5.16)
3	Machine labour	Hours	2.04	526.67 (4.09)	2.04	521.90 (4.30)
4	Seed	Kgs.	5.20	408.52 (3.17)	4.86	378.76 (3.12)
5	FYM	Tons	2.22	884.10 (6.86)	2.14	701.43 (5.77)
6	Chemical Fertilisers	Kgs.	83.55	1168.68 (9.07)	84.07	1165.25 (9.59)
7	Plant protection chemicals	Rs.		429.78 (3.34)		501.00 (4.12)
8	Miscellaneous	Rs.		328.19 (2.55)		338.14 (2.78)
	Sub total			8960.87 (69.55)		8345.49 (68.71)
9	Interest on working capital at 7%			313.63 (2.43)		292.09 (2.40)
	Total variable cost (A)			9274.50 (71.99)		8637.58 (71.11)
B.	**Fixed costs**					
10	Land Revenue and Taxes	Rs.		15.00 (0.12)		15.00 (0.12)
11	Depreciation	Rs.		143.77 (1.12)		94.81 (0.78)
12	Rental value	Rs.		3295.14 (25.58)		3247.62 (26.74)
13	Interest on fixed capital at 9%			155.43 (1.21)		151.08 (1.24)
	Total fixed cost (B)			3609.34 (28.01)		3508.52 (28.89)
	Total cost of cultivation (A+B)			12883.84 (100.00)		12146.10 (100.00)
C.	**Returns**					
1	Main product	Qtls	5.02	17140.81	4.50	14941.90
2	By-product	Qtls	3.65	1372.05	3.24	1140.60
	Gross return	Rs.		18512.86		16082.50
D	Net return	Rs.		5629.02		3936.40

also higher in the case of GPU 28 ragi (finger millet) farms (2.38 tonnes) compared with that of check variety farms (1.70 tonnes).

The gross return realised by the GPU 28 farmers were found to be Rs. 18,235.79 whereas it was Rs. 14,389.21 by check variety farmers. The net return realised by GPU 28 farmers and check variety farmers were Rs. 6,667.94 and Rs. 3,351.03 respectively.

4.4.3 Economics of BRG 2 variety of red gram as intercrop with maize, groundnut in central dry agro climatic zone of Karnataka

The costs incurred and return realised by the farmers by adopting red gram as intercrop with maize and groundnut during the year 2010-11 are presented in the Tables 4.10 and 4.11.

Farmers who cultivated BRG 2 variety of redgram as intercrop with maize incurred human labour cost of Rs.425 accounting 32% of total cost of cultivation as against Rs. 440 (32.39%) incurred by check variety farmers. the quantity of red gram seed used was 2.20 kgs in the case of BRG 2 farms and 2.43 kgs in check variety farms. the cost of plant protection chemicals, bullock labour, machine labour, farm yard manure and seeds of red gram were higher in check variety farms compared with BRG 2 farms. The cost incurred on chemical fertilisers was Rs. 112 (8.5%) in BRG2 farms and Rs.105 (7.77%) in check variety farms. Miscellaneous cost and interest on working capital were found nearly same in both categories of farms.

The total variable cost was high in check variety farms contributing 76% (Rs.1041) to the total cost of cultivation whereas it was Rs. 998 (75%) in BRG 2 farms. The return realised by the BRG2 red gram farmers was observed to be higher compared with that of check variety farmers. The BRG2 red gram farmers obtained 1.26 quintals of red gram yield as against 0.97 quintals obtained by check variety farmers. The gross return and net return on BRG2 red gram farms were Rs. 4,103 and Rs.2778 per acre, respectively as against Rs. 3,058 and Rs. 1,698 per acre, on the check variety farms.

The Table 4.11 portrays costs incurred and return realised by the farmers by adopting red gram as intercrop with groundnut. The BRG2 red gram farmers and check variety farmers used 1.91 kgs and 2.31 kgs of red gram seed for intercropping

Table 4.9 Economics of cultivation of (GPU 28) ragi and check variety inEastren dry zone of Karnataka (Rs./acre)

Sl No	Particulars	Unit	GPU 28 Variety		INDAF 5 Check Variety	
			Quantity	Value (Rs.)	Quantity	Value (Rs.)
A	**Variable costs**					
1	Human labour	Mandays	19.78	3553.69 (30.72)	17.63	3230.83 (29.27)
2	Bullock labour	Pairdays	1.24	620.00 (5.36)	1.55	773.97 (7.01)
3	Machine labour	Hours	2.22	664.71 (5.75)	2.13	637.71 (5.78)
4	Seed	Kgs.	4.80	101.59 (0.88)	4.46	92.65 (0.84)
5	FYM	Tons	2.16	961.48 (8.31)	1.92	759.81 (6.88)
6	Chemical Fertilisers	Kgs.	89.26	1133.09 (9.80)	83.86	1043.08 (9.45)
7	Miscellaneous	Rs.		432.43 (3.74)		439.59 (3.98)
	Sub total			7466.99 (64.55)		6977.63 (63.21)
8	Interest on working capital at 7%			261.34 (2.26)		244.22 (2.21)
	Total variable cost			7728.33 (66.81)		7221.85 (65.43)
B	**Fixed costs**					
9	Land Revenue and Taxes	Rs.		15.00 (0.13)		15.00 (0.14)
10	Depreciation	Rs.		78.70 (0.68)		69.66 (0.63)
11	Rental value	Rs.		3580.48 (30.95)		3567.33 (32.32)
12	Interest on fixed capital at 9%			165.34 (1.43)		164.34 (1.49)
	Total fixed cost			3839.51 (33.19)		3816.33 (34.57)
	Total cost of cultivation (A+B)			11567.85 (100.00)		11038.18 (100.00)
C	**Returns**					
	Main product	Qtls	12.45	14949.60	10.49	12284.97
	By-product	Tons	2.38	3286.19	1.70	2104.24
	Gross return	Rs.		18235.79		14389.21
D	Net return	Rs.		6667.94		3351.03

Table 4.10 Economics of BRG 2 variety of redgram intercropping with maize (ratio 8:1) Rs./acre

Sl.No.	Particulars	Unit	BRG 2 Variety		TTB 7 Check variety	
			Phy.Units	value	Phy.Units	Value
A						
1	Human labour	Mandays	2.68	425.46 (32.11)	2.93	440.68 (32.39)
2	Bullock labour	Pairdays	0.10	50.18 (3.79)	0.12	62.39 (4.59)
3	Machine labour	Hours	0.19	94.50 (7.13)	0.20	101.11 (7.43)
4	Seed	Kgs	2.20	166.05 (12.53)	2.43	194 (14.30)
5	FYM	Tons	0.15	80.09 (6.04)	0.17	72.31 (5.31)
6	Fertiliser	Kgs.	8.69	112.96 (8.53)	8.38	105.68 (7.77)
7	Pesticides	Rs.		13.28 (1.00)		17.47 (1.28)
8	Miscellaneous	Rs.		22.55 (1.70)		11.97 (0.88)
	Interest on working capital at 7%			33.78 (2.55)		35.22 (2.59)
	Total variable cost			844.16 (75.39)		1041.41 (76.54)
	Land revenue and taxes	Rs.		1.50 (0.11)		1.50 (0.11)
	Depreciation	Rs.		14.38 (1.09)		9.48 (0.70)
	Rental value	Rs.		296.13 (22.35)		294.44 (21.64)
	Interest on fixed capital at 9%			14.04 (1.06)		13.74 (1.01)
	Total fixed cost			326.04 (24.61)		319.17 (23.46)
	Total cost			1324.89 (100.00)		1360.58 (100.00)
	Returns					
	Main product of inter crop	Qtls	1.26	3832.16	0.97	2833.67
	By product of intercrop	Qtls	0.78	271.61	0.65	225.07
2	Gross income	Rs.		4103.77		3058.73
3	Net income	Rs.		2778.88		1698.15

Table 4.11 Economics of BRG 2 variety of redgram intercropping with groundnut (ratio 10:1)

(Rs./acre)

Sl. No.	**Particulars**	**Unit**	**BRG 2 Variety**		**TTB 7 Check variety**	
			Phy.Units	value	Phy.Units	Value
A						
1	Human labour	Mandays	2.22	351.39 (30.83)	2.31	366.73 (32.51)
2	Bullock labour	Pairdays	0.10	51.83 (4.55)	0.12	58.28 (5.17)
3	Machine labour	Hours	0.08	41.94 (3.68)	0.10	47.51 (4.21)
	Seed	Kgs	1.91	152.63 (13.39)	2.31	185.43 (16.44)
5	FYM	Tons	0.17	82.71 (7.26)	0.14	61.46 (5.45)
6	Fertiliser	Kgs.	4.78	78.43 (6.88)	4.23	53.92 (4.78)
7	Pesticides	Rs.	0.00	22.20 (1.95)		19.46 (1.72)
8	Miscellaneous	Rs.		21.32 (1.87)		17.84 (1.58)
	Interest on working capital at 7 %			28.09 (2.46)		28.37 (2.52)
	Total variable cost			830.55 (72.86)		839.00 (74.38)
	Land Revenue and Taxes	Rs.		1.35 (0.12)		1.35 (0.12)
	Depreciation	Rs.		12.94 (1.14)		8.53 (0.76)
	Rental value	Rs.		281.74 (24.72)		266.70 (23.64)
	Interest on fixed capital at 9%			13.32 (1.17)		12.45 (1.10)
	Total fixed cost			309.35 (27.14)		289.03 (25.62)
	Total cost			1139.90 (100.00)		1128.03 (100.00)
	Returns					
	Main product	Qtls	1.34	4056.21	0.94	2754.12
	By product of intercrop	Qtls	0.80	274.63	0.80	274.94
	Gross income	Rs.		4330.84		3029.06
	Net income	Rs.		3190.94		1901.03

Note: Figures in parentheses indicates percentages to the total in groundnut farm respectively. The BRG2 red gram and check variety famers incurred a total cost of cultivation of Rs. 1140 and 1128 per acre respectively. In the both categories of farms human labour cost was found high constituting 30% and 32% of total cost of cultivation in BRG2 red gram and check variety farms respectively.

With regard to returns is concerned BRG2 red gram farmers realised higher returns compared with check variety farmers. The BRG2 red gram farmers obtained 1.34 quintals of red gram from an acre of farm by following intercropping system with groundnut crop whereas check variety farmers obtained 0.94 quintals of red gram main product. BRG2 red gram farmers obtained 40 kgs of red gram per acre higher than check variety farmers. The gross return and net return realised by BRG 2 farmers were Rs. 4,330 and 3,190 respectively whereas it was Rs. 3,029 and 1,901 in check variety farms respectively.

4.5 Economic efficiency of ragi (finger millet) and red gram

4.5.1 Resource use efficiency in red gram

The per farm gross returns from red gram cultivation were regressed on the explanatory variables such as land, labour and variable capital. The ordinary least square estimates of the BRG 2 red gram farms and the check variety farms are presented in Table 4.12.In the case of BRG2 red gram farmers, the coefficient of multiple determination (R^2) is 0.98 indicating that 98% variation in gross returns is explained by the explanatory variables included in the model. The estimates of OLS showed that coefficients of the land and capital were statistically significant at 1 % level. This indicated that for 1 % increase in land and capital expenditure, the gross return increases by 0.870% and 0.125% respectively. The F value was statistically significant at one % level.

In the case of check variety farms (TTB 7), all the three variables are jointly contributing for 95% of variation in gross return from check variety of red gram. The coefficient of land being 0.942 was statistically significant at 1 % meaning that for a one per cent increase in land area, gross return increases by 0.942 per cent. The coefficients of labour and capital are positive and non-significant. The F-value shows that the regression model fitted is statistically significant at one % level.

Table 4.12 Estimated variety wise Cobb-Douglas production function for redgram cultivation

Dependent variable: Gross returns per farm in BRG 2 farms = Rs. 29057.77
Gross returns per farm in TTB 7 farms = Rs. 19060

Sl No.	Particulars	Variety: BRG 2 redgram (n = 35)	Geometric mean level	Variety: TTB 7 (n = 35)	Geometric mean level
1.	Intercept	8.642*** (0.739)	Anti log of 8.642= 5665	8.388*** (1.237)	Anti log of 8.388 = 4394
2.	Crop sown Area (acres) (land)	0.870*** (0.047)	1.57	0.942 *** (0.107)	1.19
3.	Labour (Rs.)	0.020 (0.090)	8611	0.001 (0.126)	6033
4.	Capital (Rs.)	0.125*** (0.048)	4830	0.158 (0.130)	3427
5.	Returns to scale = ∑bi	1.01		1.10	
6.	R^2	0.98		0.95	
7.	F value	630.17***		210.87***	

Note: ***, ** and * indicate significance at 1, 5 and 10 % levels, respectively
Figures in parentheses are standard errors

The sum of elasticities of the three inputs was around unity in both BRG 2 farms (1.01) and check variety farms (1.10) however indicating constant returns to scale. . The constant term (intercept) was significant at 1 % in both the BRG 2 Farms (8.642) and check variety farms (8.388).

The MVP to MFC ratios in both the farms indicated that the resources labour and capital are used in the rational zone of the production. The MVP to MFC ratios for these resources were less than one but higher than zero. The MVP to MFC ratio of land area in both varieties was higher than unity indicating that land is underutilised and there was scope to increase area for red gram crop of both the varieties (Table 4.14).

The distribution of farmers according to MVP to MFC ratio presented in the Table 4.15. The Table reveals that the MVP to MFC ratio for capital resource was higher than one in 28.57 % of TTB 7 farms and 2.86 % in BRG 2 farms which indicated the capital input was underutilised by TTB 7 Farmers than BRG 2 farmers. The land input was underutilised by both the farmers. The MVP to MFC ratio for labour input was less than unity in both the farms indicating the almost all farms were over used the labour input in the production of red gram crop.

4.5.2 Resource use efficiency in ragi (finger millet)

The ordinary least square estimates of the GPU 28 ragi (finger millet) farms and the check variety farms are presented in Table 4.13.

From the Table it is observed that the intercept, which represents the contribution of the factors that are not included in the model, was found to be higher in the case of check variety farms (8.349) compared to the GPU28 ragi (finger millet) farms (8.765). The coefficient of multiple determination (R^2) was 0.99 and 0.97 for GPU 28 and check variety farms respectively, indicating adequacy of fit of the model, as 99 % and 97 % variability in gross returns were explained by the variables considered in the model. The regression coefficients of area (0.794) and capital (0.175) of the GPU 28 ragi (finger millet) farms were significant and a regression coefficient of labour of the GPU 28 ragi (finger millet) farms was positive but not significant. In the case of check variety farms the regression coefficient of area is

Table 4.13 Estimated variety wise Cobb-Douglas production function for Ragi cultivation Dependent variable: gross returns per farm (Rs),

Geometric mean Gross returns in 'GPU 28' farms= Rs. 31065
Mean gross returns in 'Indaf 5' farms= Rs. 19328

Sl. No.	Particulars	Variety: GPU 28Ragi (n=35)	Geometric mean level of inputs	Variety: Indaf 5 Check variety, (n = 35)	Geometric mean level of inputs
1	Intercept	8.349*** (0.725)	Anti log = Rs. 4226	8.765*** (1.678)	Anti log = Rs. 6406
2	Crop sown Area (acres)	0.794*** (0.062)	1.71	0.898** (0.143)	1.35
3	Labour (Rs.)	0.012 (0.047)	7460	0.040 (0.153)	5705
4	Capital(Rs.)	0.175*** (0.060)	4410	0.060 (0.153)	1448
5	Returns to scale = ∑bi	0.98		0.99	
6	R^2	0.99		0.97	
7	F value	967.03***		285.91***	

Note: ***, ** and * indicate significance at 1, 5 and 10 % levels, respectively
Figures in parentheses indicates standard errors

Table 4.14 MVP to MFC ratios of resources in BRG 2 and check variety of Redgram cultivation

Inputs	BRG 2 Variety				TTB 7Variety			
	Mean	MVP	MFC	MVP/MFC Ratio	Mean	MVP	MFC	MVP/MFC Ratio
Area(acre)	1.57	16067	5560	2.89	1.19	15078	4183	3.60
Labour (Rs)	8611	0.07	1.00	0.07	6033	0.004	1.00	0.004
Capital (Rs.)	4830	0.75	1.00	0.75	3427	0.88	1.00	0.88

Table 4.15 Distribution of farmers according to resource use efficiency (MVP TO MFC Ratio) in Redgram cultivation

MVP to MFC Ratio	BRG 2			TTB 7		
	Inputs			Inputs		
	Land	Labour	Capital	Land	Labour	Capital
> 1	35 (100.00)	(0.00)	1 (2.86)	35 (100.00)	0 (0.00)	10 (28.57)
<1	0 (0.00)	35 (100.00)	34(97.14)	0 (0.00)	35 (100.00)	25 (71.43)
Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)

Note: Figures in parentheses are the percentages to the total significant and other inputs were positive but not significant. The sum of elasticities was 0.98 and 0.99 in the case of GPU 28 ragi (finger millet) farms and check variety farms respectively, indicating decreasing returns to scale. The F value in both the case found significant.

The MVP to MFC ratio for the labour was less than one in both the GPU 28 and Indaf 5 farms indicating over used of resource and scope for reduce the labour input cost. The MVP to MFC ratio for the capital and land input were higher than 1 in the case of GPU 28 ragi (finger millet) farms indicating under use of these resources and there was scope for increase in use of capital and area under GPU 28 ragi (finger millet) farms. In the case of Indaf 5 (check variety) farms the MVP to MFC ratios for capital was less than one indicating over use of the input (Table 4.16).

The distribution of farmers according to MVP to MFC ratios were presented in the Table 4.17. The perusal of the Table portrays that majority of the farms in both the farms were under used the land input in the production of ragi (finger millet) crop. All most all the farmers in both the farms were over used the labour input in the production of ragi (finger millet). The use of capital resource is concerned, about 91.43 % of the GPU 28 farmers were underutilised the capital resource and 40 % of Indaf 5 farmers were underutilised and higher scope was there to these farmers to higher use of capital input.

4.5.3 Efficiency of red gram farms- A DEA approach

In order to analyse efficiency levels of individual farms as decided by the physical inputs (quantities) and their prices, DEA model (input oriented) were used at different production scales under assumption of constant returns to scale and variable returns to scale. The results on efficiency measures with constant and variable returns for red gram farms are in Table 4.18. The farms that operated at 90 or higher were considered ‘efficient farms’.

It is evident from the Table 4.18 that in the case of BRG 2 farms, all most all farms (97%) under the assumption of constant returns to scale, performed with technical efficiency level equal to score0.9 and above i.e. 34 of 35 farms and under the assumption variable returns to scale all farms performed technical efficiency level

Table 4.16 MVP to MFC ratios of resources in GPU 28 and check variety of ragi Cultivation

Inputs		GPU 28 variety				Check variety		
	MEAN	MVP	MFC	Ratio	Mean	MVP	MFC	Ratio
Area (acre)	1.71	14451	6806	2.12	1.35	12868	5843	2.20
Labour (Rs)	7460	0.05	1	0.05	5705	0.14	1.00	0.14
Capital (Rs.)	4410	1.23	1	1.23	1448	0.35	1.00	0.35

Table 4.17 Distribution of farmers according to resource use efficiency (MVP TO MFC Ratio) in ragi cultivation

MVP to MFC ratio	GPU 28			Check variety		
	Inputs			Inputs		
	Land	**Labour**	**Capital**	**Land**	**Labour**	**Capital**
> 1	35 (100.00)	0 (0.00)	32 (91.43)	34 (97.14)	0 (0.00)	14 (40.00)
<1	0 (0.00)	35 (100.00)	3 (8.57)	1 (2.86)	35 (100.00)	21 (60.00)
Total	35 (100)	35 (100.000	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)

Note: Figures in parentheses are the percentages to the total equal to 90and above. The average technical efficiency score was 0.98 and 0.99 under the assumptions of constant returns to scale and variable returns to scale respectively. Whereas in the case of check variety farmers, about 77.14 % performed with technical efficiency level higher than equal to 90 % under the assumption of constant returns to scale. The average technical efficiency score was 0.95 and 0.98 under the assumptions of constant returns to scale and variable returns to scale respectively. It was evident that BRG 2 farmers have greater technical efficiency than check variety farmers under the both CRS and VRS.

With regard to allocative efficiency and economic efficiency is concerned about 22.86 % of both BRG2 red gram farmers and check variety farmers attained efficiency level 90 and above under VRS assumption. Thus, their performances with the allocative and economic efficiency level of 90 and above under the assumption of VRS. The average allocative efficiency and economic efffícency score was 0.74 and 0.72 for BRG 2 farmers under the assumption of CRS respectively, whereas, it was 0.73 and 0.70 for check variety farms under the assumption of CRS respectively.

Economic efficiency score for BRG 2 farmers was 0.77 and 0.76 under the assumption of VRS respectively, whereas as in the case of check variety farms it was 0.5 and 0.74 under the assumption of VRS respectively. It was evident from the analysis that farmers of BRG 2 have greater economic efficiency, allocative efficiency than check variety farmers using inputs such as seed, farm yard manure, chemical fertilisers, human labour, bullock labour, machine labour and plant protection chemicals.

4.5.4 Efficiency (EE) of ragi (finger millet) farms – A DEA (Data Envelopment Analysis) approach

The results on efficiency measures with constant and variable returns ragi (finger millet) farms are given presented in Table 4.19. In the case of GPU 28 ragi (finger millet) farms about 88.57 % of farms achieved the technical efficiency level 90 % and above under CRS, whereas in the case of check variety farms about 80 % of farms achieved the technical efficiency under CRS. When it comes to under the assumption of VRS the efficiency scores were increased in both the cases. The technical efficiency level achieved higher than or equal to 90 % were found higher in

Table 4.18 Distribution of Red gram famers according to technical efficiency, allocative efficiency and economic efficiency scores

Sl. No.	levels of efficiency (%)	BRG 2 farmers					
		Constant returns to scale			**Variable returns to scale**		
		Technical efficiency	**Allocative efficiency**	**Economic efficiency**	**Technical efficiency**	**Allocative efficiency**	**Economic efficiency**
1	90 and above	34 (97.14)	4 (11.43)	4 (11.43)	35 (100.00)	8 (22.86)	8 (22.86)
2	80 to 89.99	1 (2.86)	10 (28.57)	8 (22.86)	0 (0.00)	8 (22.86)	7 (20.00)
3	70 to 79.99	0 (0.00)	8 (22.86)	7 (20.00)	0 (0.00)	7 (20.00)	8 (22.86)
4	60 to 60.99	0 (0.00)	8 (22.86)	9 (25.71)	0 (0.00)	9 (25.71)	7 (20.00)
5	50 to 50.99	0 (0.00)	2 (5.71)	4 (11.43)	0 (0.00)	1 (2.86)	3 (8.57)
6	<50	0 (0.00)	3 (8.57)	3 (8.57)	0 (0.00)	2 (5.71)	2 (5.71)
7	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.98	0.74	0.72	0.99	0.77	0.76
	Check variety farmers						
1	90 and above	27 (77.14)	6 (17.14)	6 (17.14)	35 (100.00)	8 (22.86)	8 (22.86)
2	80 to 89.9	5 (14.29)	6 (17.14)	4 (11.43)	0 (0.00)	6 (17.14)	5 (14.29)
3	70 to 79.9	3 (8.57)	9 (25.71)	8 (22.86)	0 (0.00)	8 (22.86)	6 (17.14)
4	60 to 70.9	0 (0.00)	4 (11.43)	4 (11.43)	0 (0.00)	5 (14.29)	7 (20.00)
5	50 to 50.9	0 (0.00)	8 (22.86)	9 (25.71)	0 (0.00)	7 (20.00)	7 (20.00)
6	<50	0 (0.00)	2 (5.71)	4 (11.43)	0 (0.00)	1 (2.86)	2 (5.71)
7	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.95	0.73	0.70	0.98	0.75	0.74

*Note:*figures in parentheses are percentages to the total

GPU 28 ragi (finger millet) farms (97.14) compared with that of check variety farms (91.43%). The average technical efficiency score was 0.98 in both GPU 28 ragi (finger millet) farms and check variety farms but under the assumption of CRS it was 0.97 and 0.94 for GPU 28 and check variety farms respectively.

As regard to allocative efficiency and economic efficiency, 20 % of BRG 2 farmers achieved efficiency level 90 % and above under assumption of VRS, whereas in the case of check variety farmers about 40 % and 34.29 % of farmers achieved allocative efficiency 90 % and above under VRS respectively. The average allocative efficiency score was 0.76 and 0.81 for GPU 28 ragi (finger millet) farms and check variety farms respectively under VRS. The average economic efficiency score was 0.75 and 0.79 for GPU 28 ragi (finger millet) farms and check variety farms respectively under VRS. It was evident that in the case of ragi (finger millet) farms the GPU 28 farmers achieved low allocative efficiency and economic efficiency than check variety farmers under the assumption of variable returns to scale. But under the assumption of constant returns to scale both allocative efficiency and economic efficiency of GPU 28 farmers (0.73 and 0.71) were greater than check variety farmers (0.74 and 0.70).

4.6 Economic benefits due to improved variety in ragi (finger millet) and red gram in Karnataka using economic surplus approach.

Economic surplus method is an approach to measure economic benefits of new technology. The Manual prepared by Masters et al. (1996) has been used for estimating the ex-post economic impact assessment of BRG 2 red gram and GPU 28 ragi (finger millet) technologies. For the ex-post study, the costs and returns were considered in real terms using the All India wholesale price index at 2010 constant prices.

4.6.1 Estimation of Economics surplus from red gram BRG 2 variety in Karnataka

The BRG 2 red gram variety was developed by scientists of UAS, Bangalore over from 1995 to 2006 and released during 2006. The check variety forBRG2 redgram variety is TTB 7 and the BRG2 yields 15-20% over the check variety. From the field survey, the estimated yield difference was 0.52 quintals per acre over the check variety. Ex post economic surplus approach was used for the analysis to

Table 4.19 Distribution of ragi farmers according to Technical Efficiency, allocative efficiency and economic efficiency scores

Sl. No.	Levels of efficiency (%)	GPU 28 farmers					
		Constant returns to scale (CRS)			Variable returns to scale (VRS)		
		Technical efficiency	Allocative efficiency	Economic efficiency	Technical efficiency	allocative efficiency	economic efficiency
1	90 and above	31 (88.57)	5 (14.29)	4 (11.43)	34 (97.14)	7 (20.00)	7 (20.00)
2	80 to 89.99	4 (11.43)	5 (14.29)	5 (14.29)	1 (2.86)	6 (17.14)	4 (11.43)
3	70 to 79.99	0 (0.00)	8 (22.86)	5 (14.29)	0 (0.00)	8 (22.86)	7 (20.00)
4	60 to 60.99	0 (0.00)	14 (40.00)	17 (48.57)	0 (0.00)	12 (34.29)	15 (42.86)
5	50 to 50.99	0 (0.00)	3 (8.57)	4 (11.43)	0 (0.00)	2 (5.71)	2 (5.71)
6	<50	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
7	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.97	0.73	0.71	0.98	0.76	0.75
	Indaf5 Ragi Check variety farmers						
1	90 and above	28 (80.00)	10 (28.57)	6 (17.14)	32 (91.43)	14 (40.00)	12 (34.29)
2	80 to 89.9	4 (11.43)	4 (11.43)	6 (17.14)	3 (8.57)	6 (17.14)	6 (17.14)
3	70 to 79.9	2 (5.71)	5 (14.29)	3 (8.57)	0 (0.00)	7 (20.00)	7 (20.00)
4	60 to 60.9	1 (2.86)	7 (20.00)	11 (31.43)	0 (0.00)	4 (11.43)	6 (17.14)
5	50 to 50.9	0 (0.00)	2 (5.71)	2 (5.71)	0 (0.00)	0 (0.00)	0 (0.00)
6	<50	0 (0.00)	7 (20.00)	7 (20.00)	0 (0.00)	4 (11.43)	4 (11.43)
7	Total	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)	35 (100.00)
	Mean	0.94	0.74	0.70	0.98	0.81	0.79

Note: figures in parentheses are percentages to the total measure the economic benefits of BRG 2 redgram variety which is already released and adopted in Karnataka state. The Table 4.20 portrays the economic benefits due to adoption of BRG 2 redgram in Karnataka for the period 2006 to 2010. The change in economic surplus, consumer surplus and producer surplus estimated considering the demand elasticity and supply elasticity for red gram. The demand elasticity and supply elasticity greatly influence the change in consumer surplus, producer surplus and economic surplus.

The stream of net social gains generated by the BRG2 technology over the years was discounted using 5 % discount rate to obtain the net present value. The Internal rate of return (IRR) to research investment for improved variety (BRG2 red gram) was also estimated (Table 4.20). At the price elasticity of demand of 0.15 and price elasticity of supply of 0.45 (Rosegrant et al., 2012), the economic surplus due to BRG 2 variety in Karnataka is Rs. 56.47 crores for 1995 to 2010 period of which producer surplus forms 24.89% and the consumer's surplus forms 75.11%. Thus consumers benefited relatively more than producers in BRG 2 variety. The net present value was Rs. 26.02 crores for the at 5 % discount rate. The IRR worked out to be an impressive 44 % and indicates worthiness of the investment on research of red gram variety BRG 2.

4.6.2 Economics surplus due to adoption of ragi (finger millet) GPU 28 variety

Ragi (finger millet) is an important staple food crop of South Karnataka and is grown in rainfed areas of Karnataka. Karnataka has the second largest drought area next to Rajasthan. In Eleusine coracana, (finger millet)), UASB has been the pioneer in developing and releasing successful varieties since inception. The early successful varieties of ragi (finger millet) belonged to the Indaf series. Using Indaf 5 as the parental variety, the UASB developed GPU 28 with continuous research efforts of 11 years. The GPU 28 was released during 1997. The economic benefits of GPU 28 variety of ragi (finger millet) in Karnataka are presented in Table 4.21. It is evident that with the assumption of price elasticity of supply 0.528 and price elasticity of demand 0.450 (Rosegrant *et al*., 2012), the total economic surplus due to GPU 28 variety is 1540.38 crores from 1986 to 2010. The consumers surplus formed 56.13 per cent while the the producers surplus formed 43.87%. Thus, consumers relatively benefited more than producers

Table 4.20: Estimated Economic Surplus due to Red gram BRG 2 variety in Karnataka for the period 1995-2010

Sl.No.	Partiulars	Supply Elasticity (SE)=0.45 and Demand Elasticity and (DE)=0.15	
		Value	%
1	Change in Consumer surplus (Rs)	42,41,47,912	75.11
2	Change in Producer surplus (Rs)	14,05,59,919	24.89
3	Total Economic surplus (Rs)	56,47,07,831	100.00
4	Net economic surplus (Rs.)	55,25,00,133	
5	NPV at 5% Discount rate (Rs)	26,02,97,238	
6	IRR	44%	

Note: SE=Supply elasticity and DE= Demand elasticity, SE=0.45 and DE=0.15 were taken from IFPRI Impact model data base 2012. Source: Rosegrant et al. (2012)

Table 4.21 Estimated Economic Surplus due to Ragi GPU 28 variety in Karnataka for the period 1985-86to 2009-2010 computed at Price elasticity of demand of 0.45, and price elasticity of supply of 0.53.

Sl.No.	**Particulars**	**Supply Elasticity** (SE)=0.528 **and Demand Elasticity** (DE)=0.45	
		Value	**Share%**
1	Consumer Surplus (Rs.)	864,59,76,227	56.13
2	Producer Surplus (Rs.)	675,78,63,735	43.87
3	Total Economic Surplus (Rs.)	1540,38,39,962	100.00
4	Net economic surplus	1539,69,04,615.	
4	NPV at 5% discount rate (Rs.)	556,90,65,271	
5	IRR	79%	

Note: The demand and supply elasticities were obtained from IFPRI Impact model data base 2012. Source: Rosegrant et al. (2012)

The net present value due to GPU 28 ragi (finger millet) is Rs. 556.91 crores at 5% discount rate yielding an IRR of 79% indicating economic worthiness of investment on ragi (finger millet) research for developing variety GPU 28.

4.7 Economic impact of agricultural research using partial budgeting

In economic surplus approach the elasticity of supply should be pertain to that of new technology which is elasticity of supply of BRG 2 and GPU 28 of ragi (finger millet). Similarly the elasticity of demand to be used in economic surplus approach should pertain to that of BRG 2 of redgram and GPU 28 of ragi (finger millet). However, the demand and supply elasticities have crucial bearing an economic supply estimates which are highly sensitive to elasticities. Studies using economic surplus make use of the existing measures of demand and supply elasticity, which may or may not pertain to the concerned crop innovation. Hence, economic surplus approach suffers from limitations. In addition, economic surplus approach does not involve the concerned researchers who have contributed towards the innovation as entire analysis circles around the elasticities of demand and supply. Hence, as the introduction of new technology through a new variety is only a partial change in the crop budget. An attempt has been made to evolve and use the partial budgeting methodology which explicitly involves the concerned scientists/innovators in quantification of the research impact because the scientist have to indicate what are the items of additional cost due to new technology, what are the items of reduced returns due to new technology (debit side) and what are the reduced costs or savings due to new technology and what are the added returns due to new technology. In the process of obtaining information, the partial budgeting method provide fond of opportunities for excellent blend of scientist/innovators with the economists. In addition, the most of the information for filling the partial budgeting framework comes from field survey of the new variety with the counterfactual and the partial budgeting framework provides economic impact considering the yield gaps which subsume the yield gaps in both research and extension which is precise indicator of the yield gap.

4.7.1 Economic impact of agricultural research in red gram variety BRG 2 using partial budgeting technique

From the Table4.22, it can be observed that in the debit side there is added cost for seeds. The additional cost of seed was Rs. 29.76. However, in order to harvest the additional output from the new technology of BRG 2 variety, the cost labour was Rs. 481.59 over the check variety. The research cost and extension cost incurred for development and diffusion of BRG 2 variety was Rs. 9.62 per acre and Rs.1.39 per acre respectively. Similarly the research and diffusion cost of the check variety needs to be obtained. However, since this could not be traced, and in addition, as the check variety TTB 7 was at least forty years old and hence the research and extension costs are assumed as zero. The total added cost per ha due to BRG 2 variety over the check variety TTB 7 is Rs.704.33 per acre. There is no reduced return due to BRG2 variety as the yield of BRG2 variety is higher than TTB 7. Thus, the total debit works to Rs. 704.33. As there is no reduced cost due to nil savings, the reduced cost due to BRG 2 variety is zero. However the yield of main product increases by 0.52 quintals over the check variety TTB 7 and by-product by 0.41 quintals. The value of this added output is Rs. 2700.36. Thus, the total credit side is Rs. 2700.36, while the total debit side is Rs. 704.33. The difference between credit and debit due to BRG2 variety over TTB 7 is Rs. 1996 per acre.

The benefit obtained per acre when scaled up to cover the area occupied by BRG2 variety of redgram, it is crucial to note that linear extrapolation is fraught with the problems of discounting the operation of the law of diminishing marginal returns (LDMR). Accordingly the LDMR needs to be incorporated into the extrapolation. In this study the LDMR is accommodated by weighing the partial budget estimate of economic impact of Rs. 1196 per acre with the probability of performance, rate of adoption of technology and depreciation. The probability of performance of BRG 2 variety of redgram technology in the field is assumed to be 0.75 since it is estimated that the varietal performance is to the tune of 0.75 as opposed to 1.00 in the controlled conditions. Next, the rate of adoption of the BRG2 varietal technology is estimated to be 0.4 in Southern Karnataka. Any technology will have depreciation because of the product life cycle of technology. A depreciation of 1.00 implies, no depreciation, while that of 0.9 implies depreciation of 10%. For this study, the depreciation rate of 10% is assumed. Thus, the Economic impact of BRG 2 Variety considering field conditions per acre = 1996*0.75*0.4*0.9 = Rs.538.93 per acre, reflecting the operation of LDMR partially. This benefit of Rs. 538.59 per acre is linearly extrapolated to cover all the area under the BRG 2 variety of red gram being 71385 acres in Karnataka, thus totalling Rs. 3.84 crores per year.

Table 4.22 Estimation of Economic Impact of Research in redgram (Variety BRG 2) In Karnataka, using Partial Budgeting

(Rs./acre)

Debit Side (A + B)				**Credit Side (C + D)**		
A. ADDED COSTS DUE TO BRG 2 variety of redgram				**C. Reduced costs due to use of BRG 2 Tur**		
		qty used (kgs)	Cost		qty used (qtls)	Cost
i. Seed cost of check variety (TTB7)		4.86	378.76	C. Reduced costs due to new technology		0
ii. Seed Cost of BRG 2 (new var)		5.5	408.52	Savings in PPC /agro chemicals		0
Added cost due to use of BRG 2 seed			29.76	Savings in weeding, pesticide application		0
Added Labour cost due to improved yield of BRG 2			Cost	D. Added returns due to BRG 2 Tur		Gross return
Extra labor cost to harvest, thresh the increased output due to the new technology BRG 2 variety			481.59	Added yield of Tur by product due to BRG 2 variety	0.41	231.45
Additional cost of FYM, chemical fertiliser, PPC			104.93	Added yield of tur main product due BRG 2	0.52	2468.91
Total additional cost due to seed and labour (additional working capital)			616.28	Added returns due to new technology		2700.36
Interest on additional working capital @ 5% per year for 6 months			15			
Risk premium @ 10% of additional working capital			61.63			
Research cost per acre			9.62			
Extension cost per acre			1.39			
Total of research and extension costs per acre			11.01			
Total of added costs			704.33			
B. Reduced Returns by using BRG 2 variety:			0			
Total Debit side:			704.33	Total credit side		2700.36
Economic worthiness of BRG 2 variety: Credit minus Debit = 2700-704.33 = Rs. 1996 per acre						

Table 4.23: Economic benefits from the cultivation of BRG 2 variety of Tur over the check variety TTB 7 in Karnataka

1	Product life cycle of this technology (years) assumed	10.0
2	Probability of performance of this technology = 0.75	0.75
3	Rate of adoption of this technology = 0.4	0.4
4	Depreciation of technology (if 1, no depreciation)	0.9
5	Economic impact of BRG 2 Variety considering field conditions per acre = 1996*0.75*0.4*0.9 = Rs. 538.93 per acre	538.93
6	Total area adopted =71385.96 acres	71385.96
7	Total economic impact on 71385.96 acre in Rs. = 538.93*71385.96=	Rs.3,84,71,944
8	No. of years for developing BRG 2 tur variety	11
9	Cost of salaries of researchers plus staff for 11 years (Rs)	6171000
10	Amortized research cost of project per year Rs	686996
11	Cost of extension per demonstration (Rs)	5000
12	Total cost of demonstrations (Rs)	500000
13	Amortized cost of demonstration per year (Rs)	55663
14	Salaries of extension workers plus staff (Rs) for 5 years	43500
15	Area under tur in Karnataka acres (2010-11) acres	2202091
16	Assumed area under BRG 2 Tur is 40% in South Karnataka	71385.96
17	Research cost per acre (Rs.)	9.62
18	Extension cost per acre (Rs.)	1.39
19	Total research and extension cost per acre (Rs.)	11.01

Notes:

1. The rental value of land has not been considered as there is no provision to lease out land in Karnataka due to the Karnataka Land Reforms Rules of 1974
2. Management cost is an extra cost due to the new variety
3. Risk premium is the extra cost due reflecting the risk taking cost of farmer for adopting new technology or variety

4.7.2 Economic impact of agricultural research in ragi (finger millet) variety GPU 28 using partial budgeting technique

From the Table 4.24 it can be observed that in the debit side there is added cost for seeds was Rs.8.94. However, in order to harvest the additional output from the new technology of GPU 28 variety, the cost labour was Rs.196 over the check variety. The additional cost of FYM, chemical fertilisers and miscellaneous was Rs.196. The research cost and extension cost incurred for development and diffusion of GPU 28 variety was Rs. 0.12 per acre and Rs.0.09 per acre respectively. Similarly the research and diffusion cost of the check variety needs to be obtained. However, since this could not be traced, and in addition, as the check variety Indaf 5 was at least 30 years old and hence the research and extension costs are assumed as zero. The total added cost per acre due to GPU 28 variety over the check variety Indaf 5 is Rs.551 per acre. There is no reduced cost due to GPU 28 variety as the yield of GPU 28 variety is higher than Indaf 5. Thus, the total debit works to Rs. 551. The reduced costs due to GPU 28 were estimated in credit side.. However the yield increases by 2.26 quintals over the check variety Indaf 5 and also the increase in yield of straw by 0.68 tonnes. The value of this added output is Rs.3846.58. Thus, the total credit side is Rs. 3846.58, while the total debit side is Rs. 551 The difference between credit and debit due to GPU 28 variety over Indaf 5 is Rs. 3295.58 per acre.

The benefit obtained per acre when scaled up to cover the area occupied by GPU 28 variety of ragi (finger millet), it is crucial to note that linear extrapolation is fraught with the problems of discounting the operation of the law of diminishing marginal returns (LDMR). Accordingly the LDMR needs to be incorporated into the extrapolation. In this study the LDMR is accommodated by weighing the partial budget estimate of economic impact of Rs. 3295.58 per acre with the probability of performance, rate of adoption of technology and depreciation. The probability of performance of GPU 28 variety of ragi (finger millet) technology in the field is assumed to be 0.8 since it is estimated that the varietal performance is to the tune of 0.8 as opposed to 1.00 in the controlled conditions. Next, the rate of adoption of the GPU 28 varietal technology is estimated to be 0.5. Any technology will have depreciation because of the product life cycle of technology. A depreciation of 1.00 implies, no depreciation, while that of 0.9 implies depreciation of 10%. For this study, the depreciation rate of 10% is assumed. Thus, the Economic impact of GPU

Table 4.24 Estimation of Economic Impact of Research in ragi (Variety GPU 28) In Karnataka using partial budgeting technique

(Rs./acre)

Debit Side (A + B)			**Credit Side (C + D)**		
A. Added Costs Due to GPU 28 variety of RAGI			**C. Reduced costs due to use of GPU 28 RAGI**		
Added cost due to new seed	qty used (kgs)	Cost	Savings due to GPU 28 Ragi (in terms of fertilizers, FYM, water…)	Qty used	Cost
i. Seed cost of check variety (Indaf 5)	4.46	92.65	Savings in PPC /agro chemicals	0	0
ii. Seed Cost of GPU 28 (new variety)	4.8	101.59			
Added cost due to use of GPU 28 seed		8.94	Reduced costs due to new technology	0	0
Added Labour cost due to improved yield of GPU 28		Cost (Rs.)	D. Added returns due to GPU 28	Qty	Return (Rs.)
Additional cost of FYM, chemical fertiliser and miscellenious		285	Added yield of Ragi due to GPU 28 variety	2.26	2664.63
Additional cost of labour		196	Increase in yield of straw due to GPU 28	0.68	1181.95
Total additional cost due to seed, labour and capital (additional working capital)		489.94	Added returns due to new technology		3846.58
Interest on additional working capital @ 5% per year for 6 months		12.25			
Risk premium @ 10% of additional working capital		50			
Research cost per acre		0.12			
Extension cost per acre		0.09			
Total of research and extension costs per acre		0.21			
Total of added costs		551.00			
B. Reduced Returns by using GPU 28 variety:		0			
Total Debit side: (A+B)		551.00	Total credit side (C+D)		3846.58
Economic worthiness of GPU 28 variety: Credit minus Debit =3846.58-551.00 = Rs. 3295.58 per acre					

Table 4.25 Economic benefits from the cultivation of GPU 28 variety of Ragi over the check variety Indaf 5 in Karnataka

1	Product life cycle of this technology (years)	20.0
2	Probability of performance of this technology = 0.8	0.8
3	Rate of adoption of this technology = 0.5	0.5
4	Depreciation of technology (if 1, no depreciation)	0.9
5	Economic impact of GPU 28Variety of ragi considering field conditions per hectare = 3295.58*0.8*0.5*0.9 = Rs. 1186.4 per acre	1186.4
6	Total area adopted =973049.09	973049.09
7	Total economic impact on 973049.09 acre in Rs. = 1186.4*973049.09	Rs.115,44,34,003
8	No. of years for developing GPU 28variety of ragi	11
9	Cost of salaries of researchers plus staff for 11 years (Rs)	1923850
10	Amortized research cost of project per year Rs	117656
11	Cost of extension per demonstration (Rs)	4000
12	Total cost of demonstrations (Rs)	200000
13	Amortized cost of demonstration per year (Rs)	22265
14	Salaries of extension workers plus staff (Rs)	68250
15	Area under ragi in Karnataka (2010-11) acre	1946098.18
16	Area under GPU28 Ragi is 50%	973049.09
17	Research cost per ha (Rs.)	0.12
18	Extension cost per ha (Rs.)	0.09
19	Total research and extension cost per acre (Rs.)	0.21

Notes:

1. The rental value of land has not been considered as there is no provision to lease out land in Karnataka due to the Karnataka Land Reforms Rules of 1974
2. Management cost is an extra cost due to the new variety
3. Risk premium is the extra cost due reflecting the risk taking cost of farmer for adopting new technology or variety

Table 4.26 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

28Variety considering field conditions per acre = 3295.58*0.8*0.5*0.9 = Rs. 1186.4 per acre, reflecting the operation of LDMR partially. This benefit of Rs. 1186.4 per acre is linearly extrapolated to cover all the area under the GPU 28 variety of ragi (finger millet) being 973049.09 acres in Karnataka, thus totalling Rs. 115.44 crores per year (Table 4.25).

4.8.1 Total factor productivity of ragi (finger millet)

The output, input and TFP indices of ragi (finger millet) crop are presented in Table 4.26. Considering the area under ragi (finger millet) in Karnataka, 99 percent of the area under ragi (finger millet) is in Southern Karnataka. From the Table 4.26 it is observed that the TFP for ragi (finger millet) increased from 1.27 in 1991 to 2.88 in 2009. The TFP 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 (finger millet) 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 (finger millet) was 0.84 for twenty years.

4.8.2 Total factor productivity of red gram

The redgram is a major legume rich in proteins and popularly used in daily consumption. In South Karnataka, red gram crop is cultivated as an intercrop in rainfed areas. The Red gram area is concentrated in Northern districts of Karnataka. In order to improve the productivity of crop, researchers have contributed to the modern technology in red gram. The total factor productivity estimates of red gram are an indication to the policy makers and scientists regarding the contribution of non-conventional inputs in the output. (Table 4.27)

The results obtained employing Tornqvist-Theilindex method for estimating output index, input index and TFP index are presented in the Table 4.27. The TFP index of red gram crop increased from 0.67 in 1991 to 1.24 in 2009 with usual fluctuations in growth. The low TFP index recorded was 0.42in 1997. The highest

Table 4.27 Total Output Index, Total input Index and Total Factor Productivity Index of red gram in Karnataka during 1990-91 to 2009-10.

Year	Total output index	Total Input index	TFP Index
1990	1.00	1.00	1.00
1991	0.85	1.25	0.67
1992	0.70	1.47	0.48
1993	1.41	1.40	1.01
1994	1.33	1.18	1.13
1995	2.69	2.41	1.12
1996	2.50	2.14	1.17
1997	1.06	2.55	0.42
1998	1.28	1.78	0.72
1999	1.41	1.56	0.90
2000	1.63	1.93	0.84
2001	2.26	2.00	1.13
2002	2.34	1.90	1.23
2003	2.02	1.57	1.29
2004	1.87	2.18	0.86
2005	2.53	1.98	1.28
2006	1.53	1.12	1.37
2007	2.40	1.70	1.41
2008	2.00	1.41	1.42
2009	2.32	1.87	1.24
MEAN	1.76	1.72	1.03

TFP index was observed during 2006 (1.37). The average TFP index was 1.03over 20 years. The output index increased from 0.85 in 1991 to 2.32 in 2009, whereas input index increased from1.25 in 1991 to 1.87 in 2009.The lowest output index was in 1992 (0.70) and the highest in 1995 (2.69). The average output index was 1.76 for the 20 year period. The input index was the lowest in 2006 (1.12) and highest in 1997 (2.55). The average input index was 1.72 for the period of 20 years.

4.8.3 Output growth, input growth and TFP growth in ragi (finger millet) crop during 1990-91 to 2009-10.

In order to assess productivity performance of TFP of ragi (finger millet) 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 4.28. A perusal of Table 4.29 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.

4.8.4 Output growth, input growth and TFP growth in red gram crop during 1990-91 to 2009-10.

The compound growth rates of output, input and TFP indices of red gram 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) and presented in the Table 4.29. A perusal of Table 4.29 reveals that over the entire period of study (1990-91 to 2009-10), TFP grew at the rate of 3.31 per cent per annum. During the same period, output index by 1.14 per cent per annum and input index increased by 4.47 per cent per annum. However, in the sub period I, the TFP index registered a negative growth of 0.42 per cent per annum. But the output index and input indices grew at the rate of 7.05 per cent and 6.54 per cent per annum during the same period I. During the period

Table 4.28 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

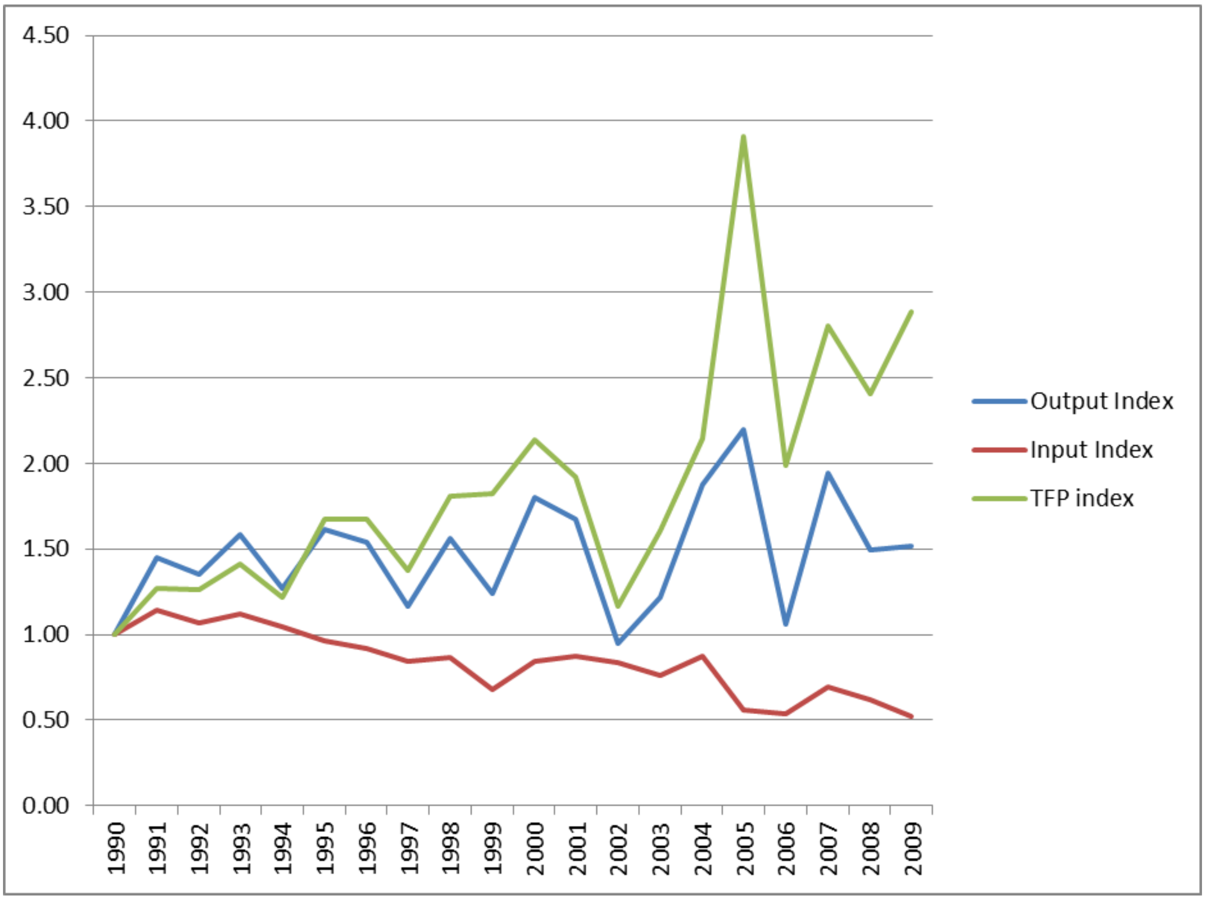


Fig 4.1 Trend in total input, total output and TFP index of Ragi in Karnataka

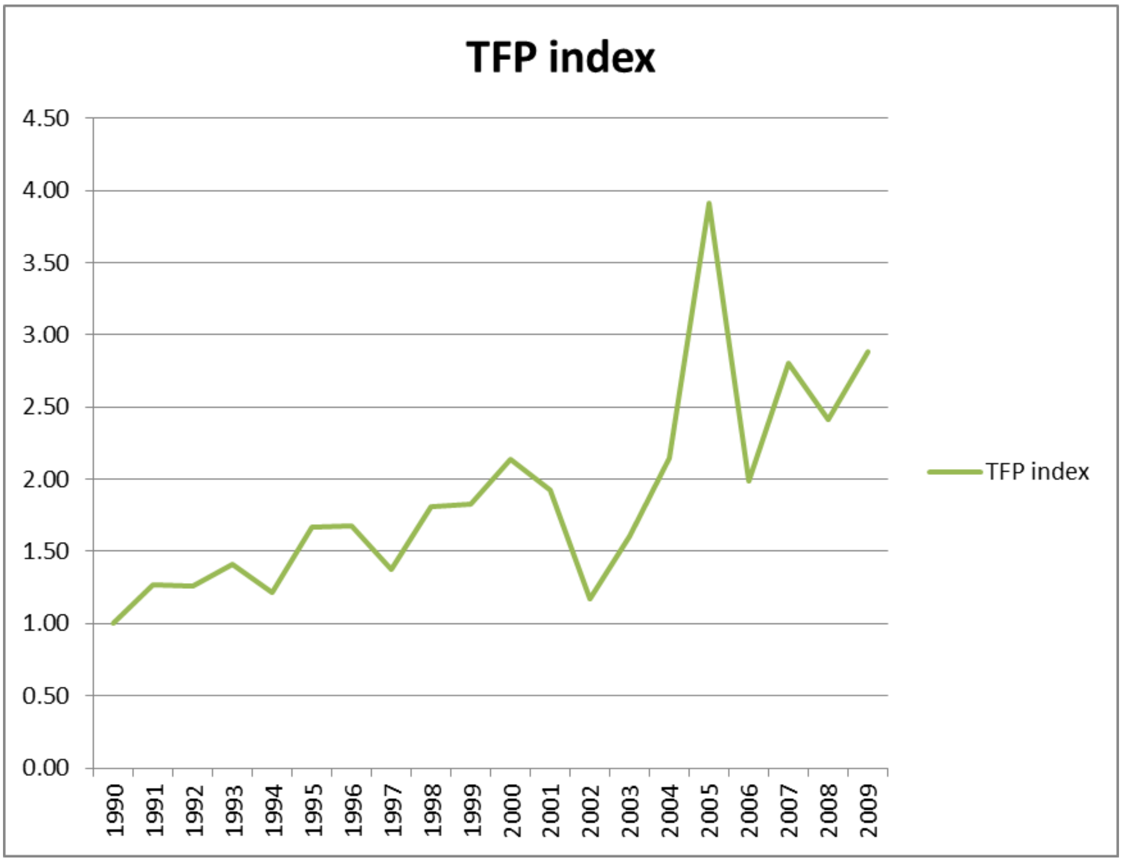


FIG 4.2 Trend in Total factor productivity of Ragi in Karnataka

Table 4.29 Annual growth rates in input use, output use and TFP growth in Redgram 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)	7.05	6.54	-0.42
2	2000-01 to 2009-10 (Period II)	-2.64	1.18	3.92
3	1990-91 to 2009-10 (Overall)	1.14	4.47	3.31

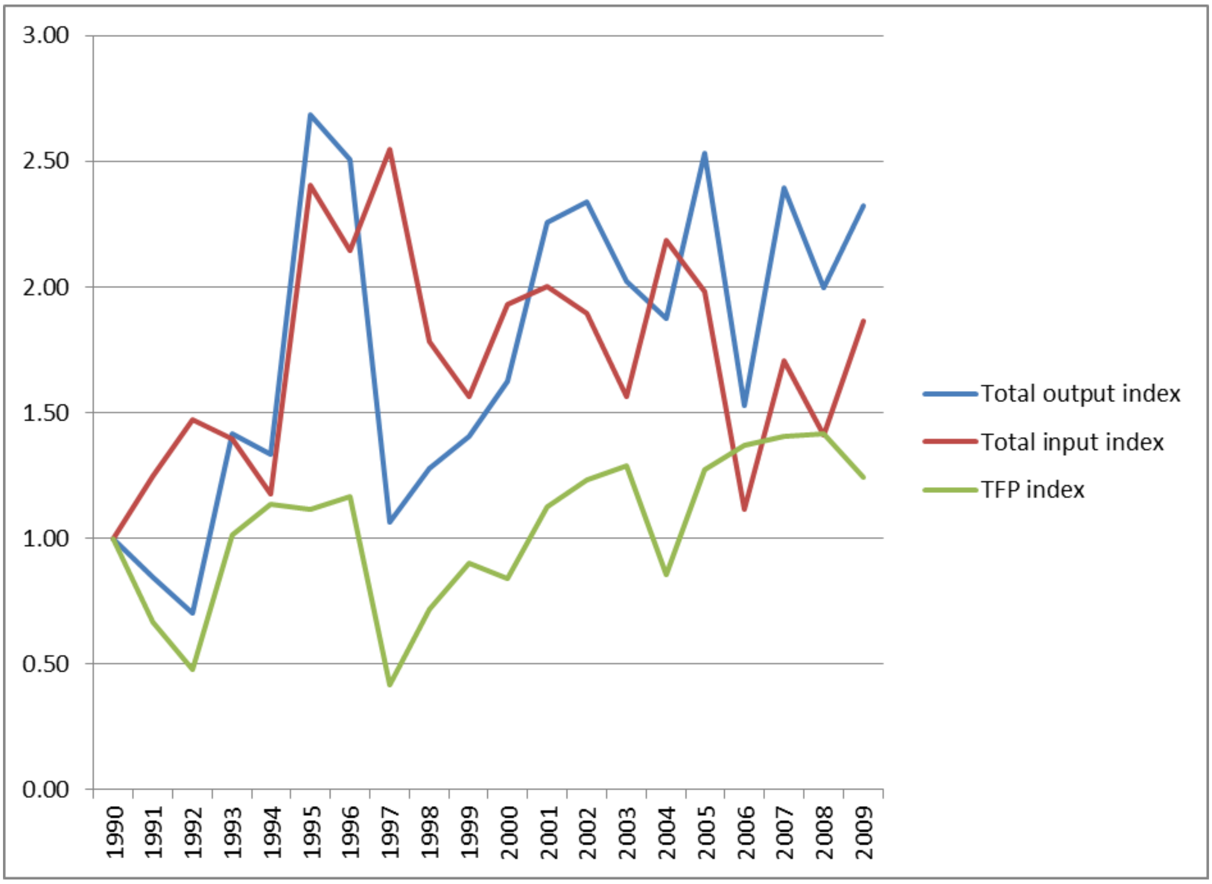


Fig 4.3 Trend in total input, total output and TFP index of Redgram in Karnataka

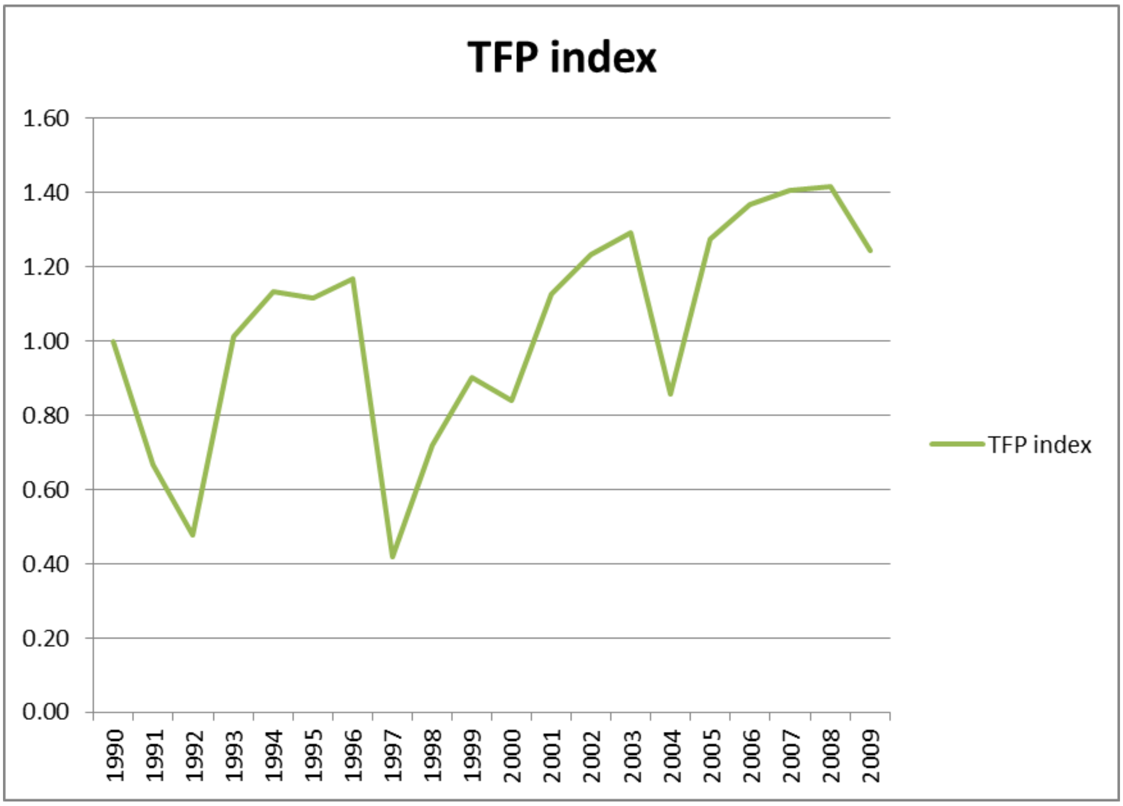


Fig 4.4 Trend in Total factor productivity of Redgram in Karnataka

II, TFP registered an impressive growth of 3.92 per annum. The output index increased by 1.14 per cent per annum and input index increased by 4.47 per cent per annum during the period II.

4.8.5 Sources of Total Factor Productivity growth in ragi (finger millet) and red gram

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 (finger millet) and red gram (Table 4.30). The results indicate that public research (0.142), road density (0.695) and rural literacy (0.530) significantly contributed to TFP growth in ragi (finger millet). The rainfall is a crucial determinant of TFP in ragi (finger millet). 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. In the case of red gram, the R^2value was not significant.

4.9 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 (Chand *et al*., 2011). Thus, in this study, the regression coefficient of research expenditure of ragi (finger millet) was found significant but in red gram it was non-significant. Hence, only ragi (finger millet) crop selected to estimate returns to research investment in the study.

The inverse of TFP elasticity with respect to research gives flexibility to research expenditure and is presented in the Table 4.30. 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 (finger millet) in Karnataka.

Table 4.30 Estimated parameters of TFP decomposition for Ragi, and redgram1990-91 to 2009-10

Variables	Ragi		Redgram	
	Coefficients	**Standard Error**	**Coefficients**	**Standard Error**
Intercept	-5.289***	1.769	-1.903	3.617
Research	0.142*	0.080	0.160	0.220
Rural literacy	0.530**	0.160	0.282	0.277
Kharif Rainfall	0.050	0.088	-0.057	0.138
Road density	0.695*	0.366	-0.128	0.169
N to P ratio	-0.080	0.213	0.156	0.760
R^2	0.71			0.27
F value	6.821***			1.052

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

4.9.1 Value of marginal product in ragi (finger millet)

The estimated value of marginal product of research investment on ragi (finger millet) and marginal internal rate return of ragi (finger millet) research is given in Table 4.31. The results revealed that additional investment of one rupee in ragi (finger millet) research generated additional income of Rs. 26.84, indicating very high rates of returns to public investments in Karnataka.

4.9.2 Marginal Internal rate of return in ragi (finger millet)

Research is considered as an important factor responsible for productivity enhancement. From the Table 4.31 it is observed that the marginal internal rate of return for ragi (finger millet) crop during the period 1990-91 to 2009-10 was 42.50%. It means that every rupee invested in ragi (finger millet) research yielded a return of 42.50% annually.

Table 4.31 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

DISCUSSION

CHAPTER V

DISCUSSION

In this chapter, the results of the study are discussed under the following headings.

5.1 New varieties/technologies released in Ragi and Redgram crops by UAS, Bangalore, since inception and area under selected variety of ragi and redgram in Karnataka

5.2 Socio-economic characteristics

5.3 Cropping pattern of sample farmers

5.4 Costs and return structure of redgram and ragi production

5.5 Economic efficiency of selected varieties of ragi and redgram, using Data Envelopment Analysis

5.6 Social cost benefit of improved variety in ragi and redgram in Karnataka using Economic surplus approach.

5.7 Estimation of economic impact of agricultural research in redgram and ragi using partial budgeting technique

5.8 Total Factor Productivity in ragi and redgram in Karnataka

5.1.1 New varieties/technologies released in Ragi and Redgram crops by UAS, Bangalore, since inception

From 1966 to 2008, 22 varieties of ragi were released in Karnataka. In the case of red gram, five varieties were released from 1987 to 2012 in Karnataka. The University of Agricultural Sciences, Bangalore, since its inception, with its contributions in research and extension has impressive performance in both Ragi and Tur. Most of the varieties developed in ragi and red gram are suitable for Southern agro climatic zones of Karnataka.

5.1.2 Area under ragi and GPU 28 vareity in Karnataka

From the table 4.2, it shows that the area under ragi drastically decreased over the years but area under GPU 28 increased substantially over the years. This indicates that productivity improvement in ragi led to higher production in lesser land. The area under GPU 28 is increased mainly due to it is performing well in dry lands and ensuring higher yield.

5.1.3 Area under redgram and BRG 2 variety in Karnataka

It is revealed from the table 4.3 that, area under redgram increased over the years. Area under BRG 2 vareity in also increasing over the years, since it is released in 2006 the adption rate is increasing over the years as it suitable to southern Karnataka.

5.2 Socio-economic characteristics of sample farmers

5.2.1 Type of family of sample farmers

Majority of sample farmers lived in nuclear family facilitated by subdivision and fragmentation of holdings which is also responsible for division of joint family to nuclear family.

About 30 per cent of redgram farmers, 17.14 per cent ragi farmers and 31.43 per cent of redgram intercrop farmers belong to joint family and the rest belong to nuclear family.

5.2.2 Education level of sample farmers

Education plays a crucial role in management capacity and efficiency of farmers to undertake agricultural enterprises. The results from the Table 4.4 reveal that majority of farmers completed their education up to secondary school. More than 95 per cent of farmers were literate. This facilitated farmers to follow new practices and methods of cultivation and adopt new technologies.

5.2.3 Age of sample farmers

About 73 per cent of ragi farmers, 61 per cent of redgram farmers, 71 per cent of redgram intercrop farmers belonged to middle aged group (35-55 years) Thus, a majority of sample farmers were middle aged and young aged farmers were less than 5 per cent of the total. Perhaps young farmers/ youths are losing interest in agriculture and migrating to urban areas for livelihood.

5.2.4 Land holding

The average size of land holding for redgram farmers was 4.51 acres, for ragi farmers 3.98 acres and for redgram intercrop farmers, 4.20 acres. The break away of joint families is also responsible for the small land holding.

5.2.5 Distribution of land holdings and family size

About 40 per cent of redgram farmers belonged to small farmers and 30 per cent and 24 per cent belonged to medium and marginal holding category. About 43 per cent of ragi farmers were small farmers. In the case of redgram intercrop farmers, majority were small farmers (47 %) followed by medium (24.29%) and marginal farmers (22.86%). Thus, majority of sample farmers belonged to small and marginal farmers due to division of joint family into nuclear family and fragmentation of land holding.

5.3 Cropping pattern of sample farmers

5.3.1 Cropping pattern of ragi farmers in Eastern Dry agro climatic zone

The cropping pattern in Eastern Dry agro climatic zone (Table 4.5) reveals that majority farmers grow ragi in rainfed conditions (48.7%) followed by maize (20.3%)and redgram (12.4%). In this area, ragi is the staple food crop and used for daily consumption which provides both carbohydrates and nutrition. . Also ragi is a hardy crop and comes up in moisture stress conditions compared with other cereal crops. Ragi thus is continuing as a popular rainfed crop in dry agro climatic zones in Karnataka. Redgram is cultivated on 12.4 per cent of gross cropped rainfed area. The reason for cultivating Redgram crop in the study area is due to location of tur dal (dal processing) mills in Gauribidanur taluk which is in proximity to study area. In addition there is great demand of vegetable redgram from Bangalore city.

Most of the farmers in irrigated areas grow vegetables in Eastern Dry agro climatic zone, as the effective demand emanates from Bangalore city as well as Chennai ensuring remunerative prices for their produce.

5.3.2 Cropping Pattern redgram farmers in Eastern Dry agro climatic zone (Magadi taluk and Doddaballapur taluk)

In Eastern Dry agro climatic zone among the sample farmers ragi and redgram occupied large area under rainfed areas. This indicates farmers of the region use ragi as staple food crop for their daily consumption. Redgram crop is also grown because most of the farmers consume redgram and a little is marketed. Red gram provides the major source of protein for farm households.

5.3.3 Cropping Pattern of Tur (as mixed crop) sample farmers in Central dry agro climatic zone (Chitradurga district)

The normal rainfall of the Chitradurga district is 495 mm per annum. In the rainfed region most of the farmers cultivate groundnut crop intercropping with redgram followed by Maize intercrop with redgram and ragi. In irrigated area, majority of the farmers grow onion, pomegranate, maize and areca nut.

5. 4 Costs and return structure of redgram and ragi production

5.4.1Costs and return of BRG 2 variety and Check variety farmers

Farmers cultivating BRG 2 variety employed 21.10 mandays of labour, 1.51 pairdays of bullock labour, 5.20 kg of seeds and 2.22 tonnes of farm yard manure. The check variety (TTB7) farmers employed 19.53 mandays of labour, 1.25 pairdays of bullock labour, 4.86 kgs of seeds and 2.14 tonnes of farm yard manure.

Check variety redgram farmers incurred higher cost on plant protection chemicals (Rs.501) compared with BRG 2 farmers (Rs.429.78). Thus, BRG 2 farmers used higher quantity of inputs compared with to the check variety famers and incurred higher cost on inputs compared to check variety farmers. The BRG 2 variety farmers incurred a total cost of Rs. 12,833 per acre while check variety farmers incurred around Rs. 12,146.10, which indicated that BRG 2 variety farmers incurred relatively higher cost than check variety farmers incurring additional Rs. 688. The human labour cost formed 34.57% of total cost in BRG 2 and 33.86% in the check variety. The higher proportion on BRG 2 farms was due to the extra labour for harvesting of the main product and by-product

The BRG 2 farmers obtained higher yield in both main product (5.02 quintals/acre) and by-product (3.65 quintals of stubbles) than the check variety farmers who obtained 4.50 quintals of redgram and 3.24 quintals of stubbles as by-product. The gross return was Rs.18, 513 and Rs.16, 082 BRG 2 farms and check variety farms respectively with a difference of Rs. 2430 per acre. The net return was the higher (Rs.5, 629) for BRG2 redgram than (Rs. 3,936) for check variety farms, with a difference of Rs. 1,692, higher by 30 per cent. Thus, economically BRG 2 variety performed better than the check variety TTB 7, offering higher net returns of 30 per cent over the check variety.

5.4.2: Economics of GPU 28 variety and Check variety of Ragi farmers

The cost of cultivation of GPU 28 ragi farms (Rs. 11,568 per acre) was higher than the cost incurred by the check variety ragi farmers (Rs. 11,038.18 per acre) due to higher cost incurred towards human labour, machine labour, seeds, farm yard manure and chemical fertilisers. The human labour cost was high in GPU 28 farms since these farmers used more labour for harvesting and threshing of ragi. The expenditure incurred on farm yard manure was Rs.961 in GPU’s 28 farms and it was Rs. 637 in check variety farms. Thus, as higher quantities of farm yard manure are applied in GPU 28 farms, compared to check variety farms. Though the per acre total cost of cultivation was higher, the net return (Rs.6, 668) realised by GPU-28 farmers was higher than check variety farmers mainly in GPU28 farms. The yield of both main product (12.45 quintals/acre) and by product (2.38 tons/acre) of ragi was higher for GPU 28 farmers than the check variety farmers. The net returns per acre for GPU 28 farmers were higher than the check variety farmers by 49 per cent, emphasizing the financial performance.

5.4.3 Costs and return structure of redgram intercropping with maize and groundnut

Quantity of redgram seeds used 2.2 kgs in BRG-2 farms and 2.43 kgs in check variety farms. Thus, the cost of seed was less in BRG-2 farms than the check variety farms. The cost of cultivation in BRG 2 farms (redgram+maize) was lesser compared to that of check variety farms (redgram+maize) because of the cost incurred on human labour, bullock labour, machine labour, seeds, farm yard manure and plant protection chemicals in check variety farms. The BRG -2 farmers obtained 1.26 quintals of redgram as against 0.97 quintals by check variety farmers. The gross return and net return on BRG2 redgram farms were Rs. 4,103 and Rs.2778 per acre, respectively as against Rs. 3,058 and Rs. 1,698 per acre, for the check variety farms. In the intercropping system with maize, BRG 2 variety performed well compared with check variety TTB 7 in the study area.

The BRG2 variety farmers incurred reasonable cost on seeds compared to that of check variety farmers of redgram intercropping in groundnut farm, as less quantity of seeds used by the BRG 2 farmers. The total variable cost was higher in the case of BRG-2 farmers, compared to that of check variety farmers because of high cost incurred by BRG 2 farmers on plant protection chemicals, farm yard manure and miscellaneous charges. The gross return was higher in BRG 2 farms compared with that of check variety farms due to higher yield. The net return was also higher in BRG 2 farms compared to that of check variety farms by 40%. BRG 2 variety intercropping with groundnut crop yielded better than check variety by 30%

5.5 Economic efficiency

5.5.1 Resource use efficiency in redgram

The results of the Cobb-Douglas production function estimated (Table 4.12) indicated that the independent variables considered in the model explained 98 per cent of the variation in CD function. The estimates of OLS showed that coefficients which represent partial elasticities of production (gross returns) were statistically significant at one per cent level. The partial production elasticity indicated that for a 1% increase in land and capital expenditure, the gross return increases by 0.870 % and 0.125 % respectively. In the case of check variety farms (TTB 7), the coefficient of land being 0.942 was statistically significant at one per cent meaning that for a one per cent increase in land area, gross return increases by 0.942 per cent. The coefficients of labour and capital are positive but non-significant. The high and significant F values indicated that the Cobb-Douglas function is adequate in explaining the variations in the gross returns from redgram due to variations in the variables in the model for both BRG 2 and check variety farms. The sum of elasticities of the three inputs was around unity in both BRG 2 farms (1.01) and check variety farms (1.10) however indicating constant returns to scale. The constant term (intercept) was significant at 1

% in both the BRG 2 Farms (8.642) and check variety farms (8.388), which indicated the upward shift in production function due to technological change.
In the case of BRG 2 the land area should be enhanced because area contributing significantly. Capital has to be reduced by 0.75 times and land has to be increased by 2.89 times. Elasticity of labour is not significant, it is close to zero and which implies that labour use has to be drastically reduced.

The MVP to MFC ratios in both BRG 2 and check variety farms indicated that there was a scope for increase in area for redgram crop by 2.89 times, 3.60 times holding capital and labour resources at a constant level. The MVP to MFC ratios of land area in both varieties was higher than unity.

5.5.2 Resource use efficiency in ragi

The results of the Cobb-Douglas production function (Table 4.13) indicate that the independent variables considered in the model explained a large part of the variability in gross returns both in GPU 28 variety (99%) and check variety farms (97%) indicating adequacy of fit of the model. The regression coefficients of area (0.794) and capital (0.175) of the GPU 28 ragi farms were significant. In the case of check variety farms, the regression coefficient of area is significant Therefore, to increase gross return, crop area must be increased, while labour use must reduce drastically, the capital use must increase by 1.23 times the current use. As the labour coefficient is not significant, it is almost zero. Hence labour use has to be drastically reduced in order to increase its marginal productivity to the level where MR=MC. The returns to scale was around one or lower in both the cases. All elasticity or coefficients were between zero and one including the returns to scale. This shows that in both GPU 28 and Indaf 5 farms are in the rational zone of production with respect to all inputs as well as with respect to each inputs The results are in line with the results of Deshmukh *et al* (1991),Onu and Edon (2009) and Baloyi *et al* (2012).

The MVP to MFC ratio for the capital and land input were higher than unity in the case of GPU 28 ragi farms indicating under use of these resources and there was scope for increase in use of capital and land area under GPU 28 ragi farms. In the case of Indaf 5 (check variety) farms the MVP to MFC ratios for capital was less than one indicating over use of the input (Table 4.16).it paves to farmers to increase the area under ragi by 2.12 times in GPU 28 farms and by 2.20 times in Indafd 5 farms.

5.5.3 Efficiency of redgram farms - A DEA approach

Under CRS assumption 97 % of BRG 2 farms achieved technical efficiency of 90 % and above. However, only 11% of the farmers had allocative and economic efficiency of 90% and above. About 23-29 % of the farmers had allocative and economic efficiency between 80 and 90 %. About 20-23% had allocative and economic efficiency between 70 and 80%. And 20-26% of the farmers had allocative and economic between 60 and 70 %. Thus, even though most of the farmers are technically efficient, only around 54 % were economically efficient to the tune of 70 to 80 %.

In the case of check variety farms about 77 % of farms achieved technical efficiency of 90% and above and 17 % of TTB 7 farmers had allocative and economic efficiency of 90% and above.

In the VRS assumption, around 64 % of BRG 2 redgram farmers were allocatively and economically efficient to the tune of 70 to 90%. Similar result hold good for check variety.

Srivastava *et al* (2009), study on extent of groundwater extraction and irrigation efficiency on farms under different water-market regimes in Central Uttar Pradesh also reveals that the water buyers were found more efficiency in production of paddy, wheat, potato and sugarcane than water sellers.

5.5.4 Efficiency (EE) of ragi farms

In the case of farmers cultivating GPU 28, about 90 % of farmers had technical efficiency of 90 % and above under both CRS and VRS assumptions. However, around 40% of the farmers under CRS assumption and 50% of the farmers under VRS were allocatively and economically efficient to the tune of 70 to 90%.

In the case of Indaf 5 farmers, around 85 % of the farmers had technical efficiency of 90% and above under both CRS and VRS assumptions. However, around 50% of farmers under CRS assumption and around 60 % of famers under VRS assumption were allocatively and economically efficient to the tune of 70 to 90 %. The results corroborate the findings of Murthy *et al* (2009).

5.6 Economic benefits due to improved variety in ragi and redgram in Karnataka using economic surplus approach.

5.6.1 Estimation of Economics surplus from redgram BRG 2 variety in Karnataka

The redgram BRG 2 variety is considered as improved variety over the check variety TTB 7. It is developed and released by UAS, Bangalore during the year 2006. The Table 4.20 portrays the economic benefits realised by adopting the new improved BRG 2 redgram variety in Karnataka. It is estimated that the increase in economic surplus due to BRG 2 variety in Karnataka is Rs. 56.47 crores for 1995 to 2010 period of which producer surplus forms 24.89% and the consumer's surplus forms 75.11%. Thus consumers benefited relatively more than producers in BRG 2 variety. The net present value was Rs. 26.02 crores for the at 5 % discount rate. The IRR worked out to be an impressive 44% and indicates worthiness of the investment on research of redgram variety BRG 2. The area adoption is still in progress since it is released in 2006. The results indicate that there is a scope for wide spread of BRG 2 variety in Karnataka to augment tur production in Karnataka. And there is a need of expansion of extension activities to different parts of the State. The results are in line with Mrunthyunjaya *et al* (2004), Kristjanson *et al* (1999) and Bantilan and Joshi (1996).

5.6.2 Economics surplus due to adoption of ragi GPU 28 variety

Using field survey data for this study, the GPU 28 variety yielded 30.75 quintals while the check variety yielded 25.91quintlas per ha with a difference of 4.84 quintals per ha. It is evident from the Table 4.21 that, the total economic surplus due to GPU 28 variety is 1540 crores from 1997 to 2010. The consumers' surplus formed 56.13 per cent of this total, while the producers' surplus formed 43.87%. Thus, consumers relatively benefited more than producers. The net present value due to GPU 28 ragi is Rs. 557crores at 5 % discount rate. The IRR was 79 % indicating economic worthiness of investment on ragi research for developing variety GPU 28. The GPU 28 Variety of ragi has been adopted in more than 50% of ragi area in Karnataka. This is mainly due to the committed and sustainable research and extension efforts of UAS, Bangalore and Department of Agriculture, Karnataka. The increase in economic surplus is mainly due to increased productivity of grain and fodder yield in ragi. The GPU 28 variety not only contributed to productivity of grain but also to productivity of straw. These findings are similar to findings of Krishna and Qaim (2007), Bantilan and Joshi (1996), Yapi *et al* (1999) and Kostandini *et al* (2011)

5.7.1 Economic impact of agricultural research in redgram variety BRG 2 using partial budgeting technique

The partial budgeting technique has been used to assess the economic impact of agricultural research. From the Tables 4.22 and 4.23, it is observed that the total added cost due to BRG 2 variety over the check variety TTB 7 is Rs.704.33per acre. This is mainly due to extra labour cost to harvest increased yield of redgram and extra cost incurred for FYM, chemical fertilisers and PPC. The added return is Rs. 2700 and total benefit due to BRG 2 variety over TTB 7 is Rs. 1996 per acre. These additional advantages are mainly due increase in yield of 0.52 quintals of BRG 2 over the check variety TTB 7. The research cost is Rs. 9.62 per acre extension is Rs. 1.39 per acre. Considering the probability of performance of 0.75, the rate of adoption of 0.4, depreciation of 0.9 on 71385 acres, the Economic impact of BRG 2 Variety is Rs. 538.6 per acre, reflecting the operation of LDMR partially incorporated in probabilities of performance rate of adoption and depreciation of technology. The total economic benefit realised by adopting the BRG 2 redgram variety in Karnataka is estimated to be Rs.3.84 crores per year. This indicates that there is need of area expansion of BRG 2 variety through agricultural departments by extension programme.

5.7.2 Economic impact of agricultural research in ragi variety GPU 28 using partial budgeting technique

From the Table 4.24 it can be observed that the total added cost is Rs. 551 mainly due to extra labour cost harvesting and additional cost for FYM, chemical fertilser. The research cost and extension cost incurred for development and diffusion of GPU 28 variety was Rs. 0.12 Rs.0.09 per acre respectively. GPU 28 variety is spread over 50 per cent of total ragi area in Karnataka and thus, the research cost per hectare is relatively low. The benefit realised by adopting GPU 28 RAGI variety over Indaf 5 is Rs. 3846 per acre. The Economic impact of GPU 28Variety considering a field condition per acre is Rs. per hectare, reflecting the operation of LDMR partially.

This benefit of Rs. 1186.4 per acre is linearly extrapolated to cover all the area under the GPU 28 variety of ragi(973049) in Karnataka, thus totalling Rs. 115.44 crores per year. The results indicate that GPU 28, performing better in field conditions as it is more suitable to rainfed conditions and resistant to blast disease. The seed distribution through Krishi Vigyan Kendras, Raitha Samparka Kendras, UAS, Bangalore and Department of agriculture enabled the high adoption of GPU 28 variety in the state which resulted in increase in economic benefits both to the producers and consumers.

5.8.1 Total factor productivity of ragi

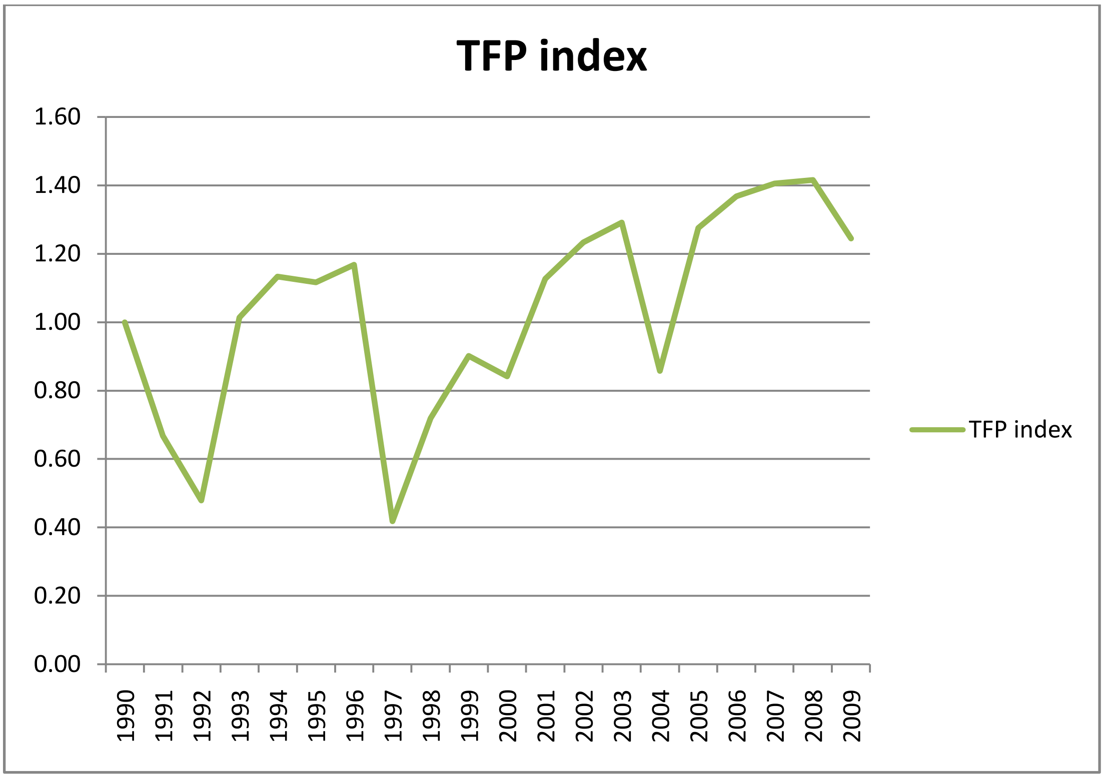
The improvement in total factor productivity is due to non-inputs such as rainfall, road length, markets, better management practices, research and extension efforts etc. The UAS, Bangalore has released a number of new improved varieties to increase productivity which are tolerant to drought. Hence, agricultural universities played a crucial role in growth of total factor productivity of ragi crop.

The TFP for ragi increased from 1.27 in 1991 to 2.88 in 2009. Thus, the contribution of non inputs which was 0.27 in 1991 increased to 1.88 in 2009, which is an impressive performance of Ragi. However the TFP fell to1.22 in 1994 and 1.17 in 2002 due to drought. The highest TFP index was in 2005-06 (3.91), as the rainfall was excellent.

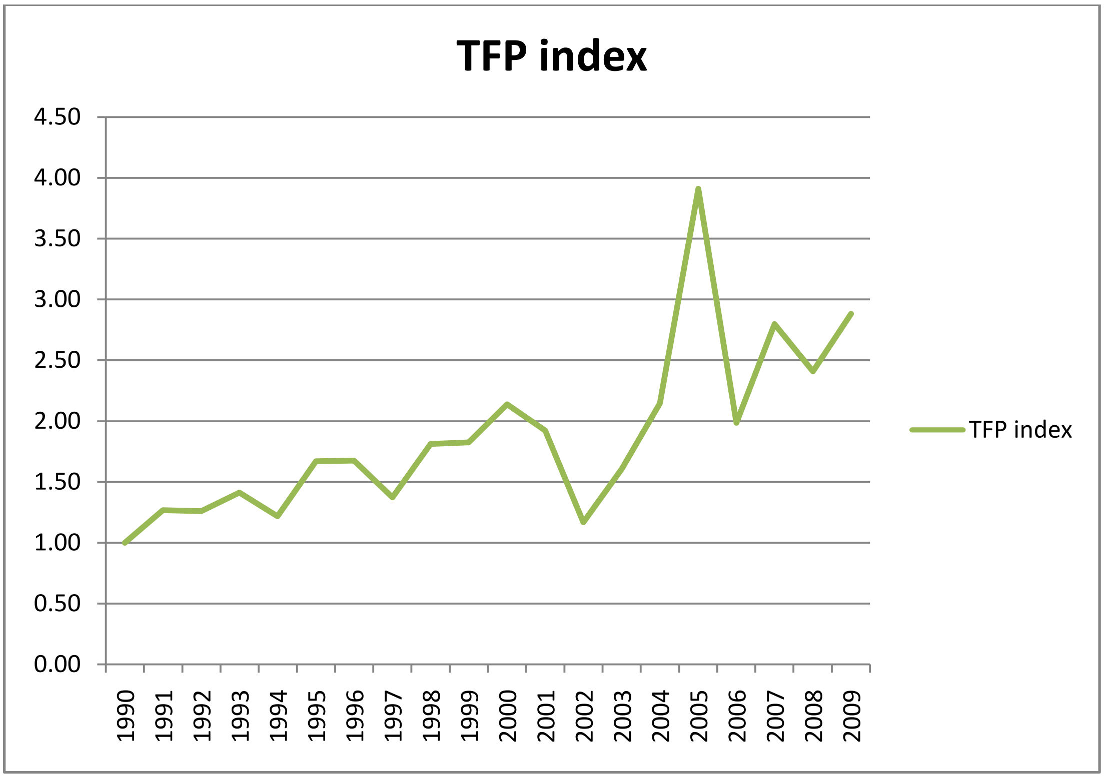
5.8.2 Total factor productivity of redgram

The TFP index of redgram crop increased from 0.67 in 1991-92 to 1.24 in 2009-10 with usual fluctuations in growth. The steady increase in the contribution of technology in Tur production began in 2001, from which point, the TFP was more than unity, but still below 1.42. Thus, the contribution of non inputs in redgram became apparent and visible since 2001. It reached the pinnacle of 1.42 in 2008. This almost coincides with the release of BRG2 variety of redgram which was released in 2006. Considering the fluctuations in TFP for red gram in Karnataka, the coefficient of variation in TFP is around 28.5 per cent with a mean TFP of 1.03, while for Ragi the coefficient of variation in TFP is around 37.7 per cent with a mean TFP of 1.87.

TFP over time for Red Gram crop in Karnataka



TFP over time for Ragi crop in Karnataka



Even though the variation in TFP is higher for Ragi compared with Red gram, Ragi's performance is par excellence, Except for 2002; the TFP of Ragi has surpassed that of Redgram in all the years. While, the TFP of Ragi reached 2.14 in 2000, reaching the pinnacle of 3.91 in 2005, that of Red gram could not even cross 1.5 in any year. The TFP of Ragi has surpassed 2.00 in seven years, while that of Red gram was between 1.00 and 1.5 in 12 years. The TFP in Ragi is not only impressive but also highly varying, while that of Redgram is unimpressive with low variation.

The causes for low TFP in redgram is because it is relatively more prone to pest and disease attack than ragi. The pests like pod borer cause substantial damage to red gram. The area under red gram (8, 91,535 ha) has surpassed that of Ragi (7, 87,894 in 2010) by 13 per cent. Even though the area under red gram is above that of ragi, it is precisely because of the technological contributions in ragi, reflected in its higher productivity, the area under ragi is falling at a compound falling rate of -1.73%. The area under red gram is increasing at the compound growth rate of 2.95%. However, the productivity of Ragi in Karnataka is rising at a compound growth rate of 1.03 %, while that of red gram is rising at 2.78 %.

5.8.3 Output growth, input growth and TFP growth in ragi during 1990-91 to 2009-10.

A perusal of Table 4.28 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 revealing. The input index declined at the rate of 4.31 per cent per annum during period I (1990 to 1999), 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(2000 to 2009), 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 TFP registered an impressive growth during the 1990s and 2000s, which indicates that research and extension contributed along with other non inputs for TFP growth. The results are corroborated the findings of Thorat *et al* (2006), Kumar *et al* (2004) and Bryce *et al* (2009).

5.8.4 Output growth, input growth and TFP growth in redgram crop during 1990-91 to 2009-10.

A perusal of Table 4.29 reveals that over the entire period of study (1990-91 to 2009-10), TFP grew at the rate of 3.31 per cent per annum. During the same period, output index by 1.14 per cent per annum and input index increased by 4.47 per cent per annum. However, in the sub period I (1990 to 1999), the TFP index registered a negative growth of 0.42 per cent per annum. But the output index and input indices grew at the rate of 7.05 per cent and 6.54 per cent per annum during the same period I. During the period II (2000 to 2009), TFP registered an impressive growth of 3.92 per annum. The output index increased by 1.14 per cent per annum and input index increased by 4.47 per cent per annum during the period II. These results indicated that during 2000s, the TFP registered an impressive growth and this mainly due to the research and extension efforts and also improvement in cultivation practices. The results corroborate the findings of Mukherjee and Kuroda (2001), Murgai (1999), Kumar and Rosegrant (1994), Fan *et al* (1998) and Evenson *et al* (1999).

5.8.5 Sources of Total Factor Productivity growth in ragi

The growth in total factor productivity of ragi in Karnataka is mainly due to the factors other than inputs used in raising the crop. The results from the Table 4.30, reveals that public research (0.142), road density (0.695) and rural literacy (0.530) significantly contributed to TFP growth in ragi. Khraif rainfall is crucial factor for ragi production. Investment on public research enabled to develop improved technology in ragi crop and this helped to increase the productivity of ragi crop. The road density is also a key determinant for TFP growth; as it enabled the farming community to access the new technology and marketing of produce in regulated markets through good road connectivity. The rural literacy plays an important role in acquainting knowledge about new improved technology and practices in agriculture. Therefore literacy is contributed in TFP growth.

5.9 Returns to investment on public agricultural research

The inverse of TFP elasticity with respect to research investment gives flexibility to research expenditure (Table 4.31). The estimated value of TFP elasticity with respect to research being 0.14, the inverse will be 7.05. This implies that in order to achieve 1 % increase in TFP, the investment in research needs to be increased by 7.05 % for ragi in Karnataka.

In tur the TFP elasticity with respect to research investment is 0.16, but is not statistically significant. However, in order to achieve a 1 per cent increase in TFP in Red gram, the research investment needs to be increased by 6.25 per cent in Karnataka. However, this coefficient of 0.16 is not statistically significant, which implies that this coefficient is almost equal to zero. Hence in order to achieve a per cent increase in TFP in red gram, substantial investments (infinite) need to increase in research investment on tur.

4.9.1 Value of marginal product in ragi

Considering the EVMP, 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. The value of marginal product higher than one indicates that research in ragi is generating substantial output to economically justify research investment in ragi. Public research investment is a crucial determinant in TFP growth for ragi crop. The findings corroborated with the findings of Evenson *et al* (1999) and Chand *et al* (2011).

5.9.2 Marginal internal rate of return in ragi

The marginal internal rate of return for ragi crop during the period 1990-91 to 2009-10 was 42.50 %. This means that every rupee invested in ragi research yielded a return of 42.50 % annually. The result suggests that further investments on research in agriculture will generate significant returns and enables the development in agriculture in rainfed areas of Karnataka. The results are in line with the findings of Evenson *et al* (1999), Thorat *et al* (2006) Kumar and Jha (2005) and Chand *et al* (2011).

SUMMARY & CONCLUSION

CHAPTER VI
SUMMARY AND CONCLUSION

Estimation of the contribution of agricultural innovations has been a challenging task for economists and generators of technology especially when the policy makers seek information on macro level impacts. Most often linear extrapolation of on farm benefits is resorted to on *ad hoc* basis. The linear extrapolation of micro level experimental result/s realized per plot by scientists discounts the operation of the law of diminishing marginal returns to land, the common denominator. The, linear extrapolation of benefits from new technology is thus irrational as the impact depends also on factors *inter alia*, probability of performance of innovation or technology in the field, rate of adoption of the technology by farmers (as farmers may not fully adopt the new technology and may make on farm adjustments), rate of depreciation of technology.

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. At UAS Bangalore the AICRP on small millets has the national center and national sub center of AICRP on pigeon pea. Research conducted by both these centers is the subject matter of this study, with the intention of measuring their economic contribution. In this study, the two crops selected for measuring the economic contribution of research are rainfed crops of Ragi (*Eleusine coracana*) and red gram (*Cajanus cajan*). While Ragi, the finger millet provides staple food, red gram, the legume provides staple source of protein. UASB researchers have been forerunners in the release of promising varieties of Ragi and red gram since green revolution.

This study focuses on estimating the economic impact of agricultural research in Ragi and Red gram in order to provide policies and design programs for the University technologists and the State to evolve research strategies towards sustainable food and livelihood security. Towards this endeavor, the estimation of economic efficiency of technologies released by the University of Agricultural Sciences, Bangalore, and the prime research institution of India is attempted with the following specific objectives:

1. To document the economic history of technological innovations in Red gram and Ragi
2. To analyse the economic efficiency of selected Ragi and redgram varieties
3. Estimation of economic surplus (net social gain) due to innovations in Ragi and redgram
4. To estimate the total factor productivity in Ragi and Redgram

6.1 Sampling framework

For this study the sample of farmers included those cultivating ragi, red gram as pure crop and red gram as intercrop in rainfed areas of Karnataka. For this, 35 farmers cultivating GPU 28 variety of ragi as rainfed crop in eastern dry agro climatic zone (in Chintamani and Doddaballapura), 35 farmers cultivating BRG 2 variety of red gram (Pigeon pea) as pure crop as under rainfed conditions in Eastern dry agro climatic zone (in Magadi and Doddaballapura) have been chosen puposively. For comparison, 35 farmers each under each of these crops cultivating the corresponding local check variety Indaf - 5 in Ragi and TTB-7 variety of red gram have been chosen in the same areas as counterfactual. In addition, 35 farmers cultivating red gram variety BRG-2 as intercrop under rainfed conditions are chosen in central dry agro climatic zone (Chitradurga district - Hiriyur and Hosadurga taluks). Another 35 farmers cultivating red gram variety TTB 7 are chosen purposively in Chitradurga district as counterfactual. In all, 210 farmers have been chosen for this study.

The data needed for the study was collected from the farmers by personal interview method using pre-tested schedule prepared during 2010-11 and 2011-12. Secondary data was collected from the annual research reports, publications of Directorate of Economics and Statistics, Department of Agriculture, Government of Karnataka, National Seeds Project, National Seeds Corporation, Karnataka State Seeds Corporation and by also consulting with scientists, administrators and extension personnel.

6.2 Analytical tools used

The cost and return analysis was performed to assess the relative economics of red gram and ragi crops for both improved variety and check variety. The Cobb-Douglas production function and stochastic frontier productions were used to assess the resource use efficiency in red gram and ragi cultivation. Data Envelopment Analysis (DEA) used to analyse the technical efficiency, allocative efficiency and economic efficiency in ragi and red gram cultivation. The economic surplus approach and partial budgeting approaches are used to assess the economic impact of red gram BRG 2 variety and ragi GPU 28 variety in Karnataka. The Tornqvist-Thiel index used estimate total factor productivity of red gram and ragi in Karnataka. Compound growth model was employed for finding growth in total output, total input and Total factor productivity of ragi and red gram crops.

6.3 Major findings of the study

- In Eastern Dry agro climatic zone (Chintamani and Doddaballpur taluk) majority of ragi farmers cultivate ragi in rainfed conditions (48.7% of the area). About 20.3% of the sample farmers cultivated maize. About 12.4 percent of the farmers cultivated red gram (as main crop). The majority of red gram farmers in Eastern Dry agro climatic zone grow ragi and red gram in rainfed areas. In irrigated land most of the farmers cultivate tomato and beans crops.
- In central dry zone (Chitradurga district), among rainfed farmers, about 34.41 percent of the rainfed area is devoted to cultivation of groundnut with red gram as intercrop . About 26.49% of the area is devoted to maize and about 14% of the area is devoted to ragi. In irrigated area, onion crop occupied about 31.43% of the total irrigated area.
- Considering farmers cultivating BRG 2 red gram as pure crop, these farmers obtained higher yield in main product (5.02 quintals/acre) by 12 percent, and by-product (3.65 quintals of stubbles) by 13 percent than the TTB 7 red gram check variety farmers who obtained 4.50 quintals of red gram and 3.24 quintals of stubbles as by-product.
- The gross return realized by BRG red gram farmers as pure crop per acre was Rs.18, 513, whereas it as Rs.16, 082 by check variety (TTB 7) farmers with a difference of Rs. 2430 per acre, higher by 15 percent.
- The net return (with red gram as pure crop) was the higher (Rs.5, 629 per acre) for BRG2 red gram farms than (Rs. 3,936 per acre) for check variety farms, with a difference of Rs. 1,692, by 30 per cent.

- The GPU 28 ragi farmers obtained a yield of 12.45 quintals as against 10.49 quintals by check variety farmers, higher by 19 percent. The by-product straw was also higher in the case of GPU 28 ragi farms (2.38 tonnes) compared with that of check variety farms (1.70 tonnes higher by 40 percent).
- The gross return realised by the GPU 28 farmers were Rs. 18,236 whereas it was Rs. 14,389 by check variety farmers higher by 27 percent
- The net returns per acre for GPU 28 farmers (Rs. 6,668) were higher than the check variety farmers (Rs.3, 351) by 49 per cent an impressive financial performance.
- Farmers who cultivated BRG 2 red gram as intercrop with maize obtained 1.26 quintals of red gram as against 0.97 quintals by as intercrop check variety farmers, higher by 30 percent.
- In the intercropping with maize, the gross return and net return from BRG2 red gram farms were Rs. 4,103 and Rs.2778 per acre, respectively as against Rs. 3,058 and Rs. 1,698 per acre, for the check variety farms higher by 34% and 64 percent respectively Thus, with maize, BRG 2 variety performed well compared with check variety TTB 7 in the central dry agro climatic zone.
- BRG 2 variety intercropping with groundnut, crop yielded better than check variety by 30%, and the net return was higher by 40 percent.
- The estimate of OLS with gross returns from BRG 2 red gram regressed on area under the crop, labor and variable capital, showed (Elasticity production), that for a 1% increase in land and capital expenditure, the gross return increases by 0.870 % and 0.125 % respectively. In the case of check variety farms (TTB 7), the coefficient of land being 0.942 was statistically significant at one per cent.
- The sum of elasticities of the three inputs was around unity in both BRG 2 farms (1.01) and check variety farms (1.10) hinting at constant returns to scale.
- The constant term (intercept) was significant at 1 % in both the BRG 2 Farms (8.642) and check variety farms (8.388), which indicated the upward shift in gross returns (production function) due to technological change by Rs. 5664 and Rs. 4397 respectively.

- The MVP to MFC ratio indicates that, in the case of BRG 2, the land area should be enhanced by 2.89 times because the area is contributing significantly to the gross return. Capital has to be reduced by 0.75 times As the Elasticity of labour is not significant and is close to zero, which implies that labour use has to be drastically reduced.
- The MVP to MFC ratios of crop sown area in both BRG 2 and TTB 7 red gram varieties was higher than unity.
- The OLS estimates for Ragi GPU 28 farms and check variety farms showed that, the elasticity of production of area (0.794) and capital (0.175) of the GPU 28 ragi farms were significant. However, in the case of check variety TTB7 farms, the elasticity of production of area alone is significant.
- The returns to scale was around one or lower than unity in both the Ragi GPU 28 farms and the check variety Indaf 5 farms.
- The MVP to MFC ratio for capital and land input were higher than unity in the case of GPU 28 ragi farms indicating under-use of these resources and there is scope for increase in use of capital and land area under GPU 28 ragi farms. In the case of Indaf 5 (check variety) farms, the MVP to MFC ratios for capital was less than unity indicating over use of the input.
- DEA analysis shows that under CRS assumption, 97 % of BRG 2 farms achieved technical efficiency of 90 % and above. However, only 11% of the farmers had allocative and economic efficiency of 90% and above. In the case of check variety farms, about 77 % of farms achieved technical efficiency of 90% and above and 17 % of TTB 7 farmers had allocative and economic efficiency of 90% and above.
- Under VRS assumption, around 64 % of BRG 2 red gram farmers and check variety farmers were allocatively and economically efficient to the tune of 70 to 90%.
- About 90 % of GPU 28 ragi farmers had technical efficiency of 90 % and above under both CRS and VRS assumptions. However, around 40% of the farmers under CRS assumption and 50% of the farmers under VRS were allocatively and economically efficient to the tune of 70 to 90%.
- Around 85 % of the Indaf 5 ragi farmers had technical efficiency of 90% and above under both CRS and VRS assumptions. However, around 50% of farmers under CRS assumption and around 60 % of famers under VRS

assumption were allocatively and economically efficient to the tune of 70 to 90 %.

- The estimated economic surplus due to adoption of BRG 2 redgrm variety in Karantaka is Rs. 56.47 crores for 1995 to 2010 period of which producer surplus forms 24.89% and the consumer' surplus forms 75.11%.
- The estimated net present value due to BRG 2 is Rs. 26.02 crores at 5 % discount rate. The IRR worked out to be an impressive 44 % and indicated economic worthiness of the investment on research of red gram variety BRG 2.
- The total economic surplus due to GPU 28 variety is Rs. 1540 crores from 1986 to 2010. The consumer surplus formed 56.13 per cent of this total, while the producer surplus formed 43.87%.
- The net present value due to GPU 28 ragi is Rs. 557crores at 5 % discount rate. The IRR was 79 % indicating economic worthiness of investment on ragi research for developing the variety GPU 28.
- The economic impact of research in red gram and ragi using partial budgeting technique indicated that the total economic benefit realised by adopting the BRG 2 red gram variety in Karnataka is estimated to be Rs.3.84 crores per year and Rs. 115.44 crores per year for GPU 28 variety of ragi.
- The TFP for ragi increased from 1.27 in 1991 to 2.88 in 2009. The highest TFP index was in 2005-06 (3.91).
- The TFP index of red gram crop increased from 0.67 in 1991-92 to 1.24 in 2009-10 with usual fluctuations in growth.
- The coefficient of variation in TFP of red gram is around 28.5 per cent with a mean TFP of 1.03, while for Ragi the coefficient of variation in TFP is around 37.7 per cent with a mean TFP of 1.87.
- During the period 1990-91 to 2009-10, the TFP of ragi grew at the rate of 4.75 per cent per annum.
- The TFP index of ragi witnessed an impressive growth of 6.17 per cent per annum during period 2000 to 2009.
- The TFP of redgram grew at the rate of 3.31 per cent per annum during the period 1990-91 to 2009-10. However, in the sub period I (1990 to 1999), the TFP index registered a negative growth of 0.42 per cent per annum.

- During the period 2000 to 2009, TFP of redgram, registered an impressive growth of 3.92 percent per annum.
- The sources of TFP growth such as public research (0.142), road density (0.695) and rural literacy (0.530) significantly contributed to TFP growth in ragi.
- The estimated value of TFP elasticity with respect to research in ragi is 0.14, which gives the the inverse value (1/0.14 =) 7.05. This implies that in order to achieve 1 % increase in TFP in ragi, the investment in ragi research needs to be increased by 7.05 % in Karnataka.
- The estimated value of marginal product (EVMP) is computed only for crop research innovations, where the TFP elasticity coefficient for research obtained from regression of TFP on explanatory variables over time, is statistically significant. Accordingly the TFP regressed on research expenditure, road density, rainfall, literacy, N to P ratio, in both the crops ragi and red gram indicated that only ragi, and the TFP was significant. Thus, considering the, (EVMP), 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.
- The marginal internal rate of return for ragi computed using EVMP, during the period 1990-91 to 2009-10 was 42.50 %.

6.4 POLICY IMPLICATIONS

1. The BRG 2 red gram variety and GPU 28 ragi variety are economically performing well in field conditions and offering higher returns to farmers compared to the check varieties. The BRG2 red gram as pure crop offered 30 percent higher net return over the control TTB 7. The GPU 28 ragi offered 49 percent higher net return over its control Indaf 5. The BRG 2 red gram as intercrop with maize offered 64 per cent higher net return over check variety and BRG 2 red gram as intercrop with groundnut offered 40 percent higher net return over the check variety TTB 7.Hence the Department of Agriculture, GOK can popularise and encourage the widespread adoption of these crop varieties for improving the nutritive capacity of farmers and consumers..

2. The BRG 2 variety of red gram is released in 2006. The total economic surplus due to this variety is Rs. 56.47 crores. Thus, there is wide scope for spread of BRG 2 variety and also scope for investment in red gram research to further improve the productivity of the crop, since the elasticity of research investment influencing TFP in red gram is not yet statistically significant.

3. Public research is key and significant source of TFP growth in rainfed staple crop like ragi. 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. .

4. The contribution of public research in TFP growth of red gam is positive but not significant. Hence, priority should be given for research in pulse crops especially red gram crop.

5. Considering the poor spread of BRG 2, efforts and budget allocation for extension of the variety needed.

REFERENCES

CHAPTER VII

REFERENCES

AFRIAT, S.N., 1972, Efficient estimation of production functions, *International Economic Review*, **13**: 568-598.

AIGNER, D., LOVELL, C.A.K. and SCHMIDT, P., 1977, Formulation and Estimation of Stochastic Production Function Models. *Journal of Econometrics*, **6**(1): 21-37.

ALIVA, A. FLAVIO AND EVENSON, R.E., 2004, TFP Calculations from FAO Production Data. Unpublished, Yale University.

ALSTON, J. M., NORTON, G.W AND PARDEY, P.G., 1995, *Science under scarcity: principles and practice for agricultural research evaluation and priority setting.* Cornell University Press, Ithaca, London.

ANANTH, G.S., 2004, Returns to Investment on Agricultural Research in Karnataka- An Economic Analysis of Major field crops. *Ph.D. thesis (*unpublished). University of Agricultural Sciences, Bangalore.

AREGA, D. ALENE., 2009, *Productivity growth and the Effects of R&D in African agriculture.* International Association of Agricultural Economists Conference at Beijing, August.

ASHOK, K.R., UMA, K., PRAHADEESWARAN, M. AND JEYANTHI, H., 2012, Economic and environmental impact of Bt cotton in India, *Indian Journal of Agricultural Economics*, **67** (3): 405-428.

AYINDE O. E., ADEWUMI, M.O. AND OJEHOMON, V.E.T., 2009, *Determinants of Technical Efficiency and Varietal-gap of Rice Production in Nigeria: A Meta-Frontier Model Approach.* International Association of Agricultural Economists Conference at Beijing, August.

AZAM, Q.T., BLOOM, E.A. AND EVENSON, R.E., 1991, *Agicultural research productivity in Pakistan.* Center discussion paper, Economic Growth Center, Yale University. No. 644, V+199.

BADAL, P.S. AND SINGH, R.P., 2001, Technological change in maize production: A case study of Bihar. *Indian Journal of Agricultural Economics*, **56**(2): 211-219.

BALOYI T. R., BELETE A., HLONGWANE J. J AND MASUKU B. M., 2012, Technical efficiency in maize production by small-scale farmers in Ga-Mothiba of Limpopo Province, South Africa, *African Journal of Agricultural Research,* **7** (40): 5478-5482.

BANTILAN, M. C. S AND JOSHI, P. K., 1996, *Returns to research and diffusion investments on wilt resistanc in pigeonpea.* International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

BARIS, Y., AND NILGUN, B. H., 2007, *The use of data envelopment analysis in assessment of irrigation efficiency*. Conference Paper. In International Congress River Basin Management, Antalya, Turkey.

BHENDE, M.J. AND KALIRANJAN, K.P., 2007, Technical efficiency of major food and cash crops in Karnataka (India), *Indian Journal of Agricultural Economics,* **62**(2): 176-191.

BHUSHAN SURYA, 2005, Total Factor Productivity Growth of Wheat in India: A Malmquist Approach", *Indian Journal of Agricultural Economics*, Vol 60, No.1 Jan-March 2005.

BIRTHAL, S.P., KUNAR, A., RAVISHANKAR, A. AND PANDEY, U.K., 1999, *Sources of growth in livestock sector*, policy paper NO.9, National Centre for Agricultural Economics and Policy Research New Delhi.

BIRTHAL, S. PRATAP, NIGAM, N. SHYAM, NARAYANA, A.V AND KAREEM, K.A., 2012, Potential economic benefits from adoption of improved drought tolerant groundnut in India, *Agricultural Economics Research Review,* **25** (1): 1-14.

BISALIAH, S., 1977, Decomposition analysis of output change under new production technology in wheat farming: Some implications to returns on investment. *Indian Journal of Agricultural Economics*, **32** (3)*:* 193-201.

BOLES, J.N.,1966, Efficiency squared – efficient computation of efficiency indexes, *Proceedings of the the 39th Annual Meeting of the Farm Economic Association*, pp. 137-142.

BRYCE STEWART, TERRANCE VEERMAN AND JAMES UNTERSCHULTZ, 2009, Crops and Livestock Productivity Growth in the Prairies: The Impacts of Technical Change and Scale. *Canadian Journal of Agricultural Economics*. **57**(3): 379-394.

CHAND, RAMESH, KUMAR, PRADUMAN and KUMAN, SANT , 2011, Total Factor Productivity and Contribution of Research Investment to Agricultural Growth in India. Policy paper 25, National Centre for Agricultural Economics and Policy Research, Pusa, New Delhi, India.

COELLI, T., 1996, *A guide to DEAP version 2.1: a data envelopment analysis (computer program).* CEPA working papers no. 8/96, University of New England.

COELLI, T.J., 1996, Recent development in frontier modelling and efficiency measurement, *Australian Journal of Agricultural Economics*, **39** (3): 219-245.

COELLI, TIMOTHY J, D S PRASADA RAO, CHRISTOPHER J O'DONNELL and GEORGE E BATTESE., 2005,. *An Introduction to Productivity and Efficiency Analysis,* Second Edition. USA: Springer.

DESHMUKH, P.D., HARGE, D.S., AND PAWAR, J.R., 1991, Resource use efficiency under different farming systems in drought prone area of western Maharastra. *Indian Journal of Agricultural Economics*, **46** (1): 473-474.

DILEEP, B.K., GROVER, R.K. AND RAJ, K.N., 2002, Contract farming in tomato: An economic analysis. *Indian Journal of Agricultural Economics*, **57** (2): 197-210.

DEY, M.M. and EVENSON, R.E., 1991, The Economic Impact of Rice Research in Bangladesh. Economic Growth Center. New Haven: Yale University (Mimeo).

DOLAKIA, B.H. AND DOLAKIA, R.H. 1991, *Modernization of agriculture and economic growth: the Indian experience*, Occasional paper, Center for Development Studies, University of Glasgow. No.9: 20

DUNG TIEN KHONG, SUMALDE M. ZENAIDA, PEDE O. VALERIEN, MCKINLEY D. JUSTIN, GARCIA T. YOLANDA AND BELLO L. AMELIA, 2011, Technical efficiency of resource-conserving technologies in rice -wheat systems: the case of Bihar and eastern Uttar Pradesh in India, *Agricultural Economics Research Review*, **24** (2): 201-210.

EVENSON, R.E., 1992, *Two blades of grass research: research for US Agriculture*, discussion paper, Economic Growth Center, Yale University No. 653: 70.

EVENSON, R. E., CARL, E. PRAY AND MARK, W. ROSEGRANT, 1999, *Agricultural Research and Productivity Growth in India*. Research Report: 109, International Food Policy Research Institute, Washington, USA.

FARRELL, M.J., 1957, The measurement of productive efficiency. *Journal of the Royal Statistical Society*. (Series A, general), **120**: 253-281.

FAN SHENGGEN, HAZELL PETER, and THORAT SUKHADEO, 1998, Government Spending, Growth and Poverty: An Analysis of Interlinkages in Rural India, EPTD Discussion Paper No. 33, Environment and Production Technology Division, International Food Policy Research Institute, USA.

FORSTNER HELMUT and ISAKSSON ANDERS, 2002, "*Productivity, Technology, and Efficiency: An analysis of the world technology frontier when memory is infinite*", SIN Working Paper Series, Working Paper no. 7, February 2002, Statistics and Information Networks branch of UNIDO.

GADDI, G.M., MUNDINAMANI, S.M. AND PATIL, S.A., 2002, Yield Gaps, Constraints and Potential in Cotton Production in North Karnataka-An Econometric Analysis. *Indian Journal of Agricultural Economics,* **57** (4): 722-734.

GEDARA MOHOTTALA KULARATNE, WILSON CLEVO, PASCOE SEAN AND ROBINSON TIM, 2012, Factors affecting technical efficiency of rice farmers in village reservoir irrigation systems of Sri Lanka, *Journal of Agricultural Economics,* **63** (3):627-638.

HASAN FARUQ M., 2008, economic efficiency and constraints of maize production in the northern region of Bangladesh, *journal of innovation and development strategy*, **2** (1): 18- 32.

HOSAMANI, S.B., YADAV, J.S. AND HIREMATH, K.C., 2004, Costs, returns, sources of output growth and technical efficiency in cotton production - a comparative analysis of organic and inorganic farms in Karnataka. *Strategies for sustainable cotton production- A global vision;* University of Agricultural Sciences, Dharwad.

JOHANSSON, H., 2005, *Technical, allocative, and economic efficiency in Swedish dairy farms: the data envelopment analysis versus the stochastic frontier approach*. Poster background paper. In XIth International Congress of the European Association of Agricultural Economists (EAAE), Copenhagen, Denmark.

JOB, E. and GEORGE, M.V., 2002, Technical efficiency in rice production: A Frontier Production Function approach. *Agricultural Economics Research Review,* **15**(1): 50-55.

JOSHI, P.K., 2003, *Impact Assessment of Agricultural Research - Concepts and Measurement.* National Centre for Agricultural Economics and Policy Research, Pusa, New Delhi, India.

JOSHI, P.K., PAL, S., BIRTHAL, P.S. AND BANTILAN, M.C.S., 2005**.** Impact of agricultural research: An overview, Impact of Agricultural Research: Post-Green Revolution Evidence from India, National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics, Patancheru- 502 324, Andhra Pradesh, 1-8.

JOSHI, P.K., JOSHI, L., SINGH, R.K., THAKUR, J., SINGH, K. and GIRI, A.K.,2003, Analysis of Productivity Changes and Future Sources of Growth for Sustaining Rice- Wheat Cropping System. National Agricultural Technology Project ((PSR 15; 4.2), National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, August.

KALIRAJAN, K., 1984, Far specific technological efficiency and development policies. *Journal of Economic Studies*, **11** (3): 33.

KALIRAJAN, K.P. AND SHAND, R.T., 1994, Modeling and measuring Economic efficiency under risk. *Indian Journal of Agricultural Economics*, **49**(4): 580-590.

KALIRAJAN, K.P. and SHAND, R.T., 1997, Sources of output growth in Indian agriculture, *Indian Journal of Agricultural Economics*, **52** (4): 693-706.

KHATKAR, K.R., MITTAL,.B.S. AND SINGH, K.V., 2004, Impact assessment of processing of pearl millet for value-addition and development of heath foods, *Agricultural Economics Research Review*, **17** (Conference No.): 151-162.

KOSTANDINI GENTI, MILLS BRADFORD, OMAMO, S.W. AND WOOD, S., 2009, Ex-ante analysis of the benefits of transgenic drought tolerance research on cereal crops in low income countries, *Agricultural Economics*, **40**: 477-492.

KOSTANDINI GENTI, MILLS BRADFORD AND MYKEREZI ELTON, 2011, Ex ante evaluation of drought tolerant varieties in Eastern and Central Africa, *Journal of Agricultural Economics,* **62** (1): 172-206.

KRISTJANSON, P., ROWLANDS, J., SWALLOW,B., KRUSKA,R., DEE LEEUW,P. AND NAGDA,S., 1999, Using the Economic Surplus Model to measure potential returns to International Livestock Research: the case of Trypanosomosis vaccine research. ILRI Impact Assessment Series 4, Nairobi, Kenya.36 pp.

KRISHNA, V. AND MARTIN QAIM, 2007, Potential Impacts of Bt Eggplant on Economic Surplus and Farmers Health in India. Paper presented at AAEA, WAEA and CAES Joint Annual meeting, July 29-August 1, Oregon, USA.

KUMAR, K.S. AND BISALAIAH, S., 1991, Technical and allocative efficiency of contact and fellow farmers under new agricultural extension project in Karnataka. *The Asian Economic Review*, **23**(1): 103-122.

KUMAR PRADUMAN, MITTAL SURABHI, 2006, Agricultural productivity trends in India: sustainability issues, *Agricultural Economics Research Review*, **19** (Conference No.) pp 71-88.

KUMAR, P. AND MRUTHYUNJAYA, 1992. Measurement and analysis of total factor-factor productivity growth in wheat. *Indian Journal of Agricultural Economics*. **47**(3): 451-458.

KUMAR PRADUMAN, ROSEGRANT MARK W., 1994, Productivity and Sources of Growth for Rice in India, *Economic and Political Weekly,* December 31, 1994, p A-183 to A-188.

KUMAR SANT, LAKSHMI, A. P., PRASANNA AND WANKHADE SHWETAL, 2011, Potential benefits of Bt brinjal in India –an economic assessment, *Agricultural Economics Research Review,* **24** (1): 83-90.

KUMAR PRADUMAN, KUMAR ANJANI AND SHIJI, C.P., 2004, Total factor productivity and socio-economic impact of fisheries technology in India, *Agricultural Economic Research Review,* **17** (conference No.): 131-144.

KUMAR PRADUMAN, KUMAR ANJANI AND MITTAL SURABHI, 2004, Total factor productivityof crop sector in the Indo-Gangetic Plain of India: sustainability issues revisited, *Indian Economic Review*, **39**(1): 169-201.

KUNNAL, L.B., GADDI, M., OLEKAR, J.N. AND DABALI, S.D., 2004, New cotton production technology in Karnataka- An econometric analysis. *Strategies for sustainable cotton production- A global vision*, University of Agricultural Sciences, Dharwad.

KUMAR, P AND JHA, D., 2005, Measurement of total factor productivity growth of rice in India: implications for food security and trade, pp 25-35 in Impact of Agricultural Research:Post-Green Revolution Evidence from India (JOSHI, P.K., PAL, S., BIRTHAL, P.S., AND BANTILAN, M.C.S., eds.), National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics, Patancheru- 502 324.

MANJUNATHA, A. V., SPEELMAN, S., HUYLENBROECK, V., AND CHANDRAKANTH M. G., 2009, Impact of groundwater markets in peninsular India on water use efficiency: A Data Envelopment Analysis approach. *Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22.*

MEEUSEN, W. and VAN DEN BROECK, J., 1977, Efficiency estimation from Cobb-Douglas production function with composed error. *International Economic Review,* **18**: 435-444.

MCKINSEY, J.W. and EVENSON, R.E., 2003, Crop genetic improvement impacts on Indian agriculture. In: Crop Variety Improvement and its Effect on Productivity: The Impact of International Agricultural Research. Eds: R.E. Evenson and D. Gollin. CABI Publishing, UK.

MONDAL BISWAJIT, SINGH ALKA AND JHA KUMAR GIRISH, 2012, Impact of watershed development programmes on farm-specific technical efficiency: a study in bundelkhand region of Madhya Pradesh, *Agricultural Economic Research Review*,**25** (2).

MOUSSA, B., LOWENBERG DEBOER, J., FULTONA, J. AND BOYS, K., 2011, The economic impact of cowpea research in West and Central Africa: A regional impact assessment of improved cowpea storage technologies. *Journal of Stored Products Research,* **30**: 1-10.

MRUNTHYUNJAYA, PAL SURESH, PANDEY, L.M. AND JHA, A.K., 2004, Impacts of Selected Technologies Refined Under NATP. *Agricultural Economics Research Review*, vol. 17 (conference No.): 1-16.

MURGAI RINKU, 1999, *The Green Revolution and the Productivity Paradox- Evidence from the Indian Punjab*, Policy Research Working Paper 2234, The World Bank Development Research Group, Rural Development, November 1999.

NARALA, ANURADHA AND ZALA, C.Y., 2010, Technical efficiency of rice farms under irrigated conditions in Central Gujarat, *Agricultural Economics Research Review*, **23** (2): 375-381.

NASURUDEEN, P. AND MAHESH, N., 2004, Impact of technology on paddy farms in Karaikal region of Union Territory of Pondicherry, *Agricultural Economics Research Review*, **17**(Conference No.): 43-50.

NIN ALEJANDRO, ARNDT CHANNING, PRECKEL PAUL V., 2003, Is agricultural productivity in developing countries really shrinking? New evidence using a modified nonparametric approach, *Journal of Development Economics,* **71**: 395-415.

ONU I. J AND EDON, A., 2009, Comparative economic analysis of improved and local Cassava varieties in selected local Government areas of Taraba State in Nigeria, *Journal of Social Science,* **19** (3): 213-217.

PAL, S., KUMAR, A. AND SINGH, A., 2005, Agricultural research intensity in India, Impact of Agricultural Research: Post-Green Revolution Evidence from India, National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics, Patancheru-502324, Andhra Pradesh, 9-15.

PALANISAMI, K., SURESH KUMAR, D., WANN, S. P. AND GIORDANO, MARK., 2009, evaluation of watershed development programmes in India using economic surplus method, *Agricultural Economics Research Review,* Vol. 22 July-December, pp 197-207.

PATIL R.G. AND JHA, D., 1978, Output growth and technological change in Maharashtra agriculture- a district wise analysis, *Indian Journal of Agricultural Economics,* **33** (3): 31-39.

POUCHEPPARADJOU, A., KUMARAVELU, P. AND ACHOTH LALITH, 2005, An econometric analysis of green technology adoption in irrigated rice in Pondicherry Union Territory, *Indian Journal of Agricultural Economics*. . **60**(4):660-676.

RANJITHA, P AND MRUTHYUNJAYA., 2005. Total factor productivity in Indian agriculture: Impact of research, Impact of Agricultural Research: Post-Green Revolution Evidence from India, National Centre for Agricultural Economics and Policy Research New Delhi, and International Crops Research Institute for the Semi-Arid Tropics, Patancheru- 502 324, Andhra Pradesh, 17-24.

RAO CHANDRASHEKHARA, N., 2005, Total factor productivity in Andhra Pradesh agriculture, *Agricultural Economic Research Review*, **18**(1): 1-19.

ROSEGRANT, M.W. AND THE IMPACT DEVELOPMENT TEAM. 2012. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description. International Food Policy Research Institute (IFPRI), Washington, D.C.

SIDDALINGAPPA, P., 2002, Regional development and agricultural productivity: an analysis across agro climatic zones of Karnataka, *M.Sc. thesis (*unpublished). University of Agricultural Sciences, Bangalore.

SHAMSUDIN, N.M. ABDUL AZIZ, A.R. AND HUSAIN, M.A., 1989. Productivity and sources of growth in Malaysian agriculture: 1960-1986.*The Malaysian Journal of Agricultural Economics.* **6**:35-51.

SRINIVASA MURTHY, D.,HEGDE, M.R. AND DAKSHINAMOORTHY, V., 2009 Technical efficiency and its determinants in tomato production in Karnataka, India: Data Envelopment Analysis (DEA) approach, *Agricultural Economic Research Review*, **22**: 215-224.

SRINIVAS T., RAZVI S.J.H., HASSAN A.W. A., MANAN, R.A. AND KADIAN M.S., 2012, Technical efficiency of seed potato farmers of Badakshan province of Afghanistan, *Potato Journal* **39** (2).

SRIVASTAVA, S.K., KUMAR RANJIT AND SINGH, R.P., 2009, Extent of groundwater extraction and irrigation efficiency on farms under different water-market regimes in Central Uttar Pradesh, *Agricultural Economic Research Review*, **22**: 87-97.

TALATHI, M.J. AND HIREMATH, K.G., Technical and water use efficiency in methods of irrigation in Thane district of Maharashtra, *Agricultural Economics Research Review*, **17**(Conference No.): 115-124.

THIRTLE COLIN, LIN, HOLDING JIM, JENKINS LINDIE AND PIESSE JENIFER, 2004, Explaining the decline in UK agricultural productivity growth, *Journal of Agricultural Economics*, **55** (2): 343-366.

THORAT, A.V., TILEKAR, N.S., DHEKALE, S.J. AND PATIL, K.H., 2006, Total factor productivity in horticultural crops in Konkan Region of Maharashtra, *Agricultural Economics Research Review*, **19** (Conference No.): 113-120.

WANDER, ALCIDO ELENOR, MAGALHAES, MARILIA CASTELO, VEDOVOTO, GRACIELA LUZIA AND MARTINS, ESPEDITO CEZARIO,2004, Using the economic surplus method to assess economic impacts of new technologies-Case studies of EMBRAPA, *Rural Poverty Reduction through Research for Development*, Conference on International Agricultural Research for Development, Deutscher Tropentag, 5-7,October, Berlin.

YAPI, A. M., DEHALA, G., NGAWARA, K., AND ISSAKA, A., 1999. Assessment of the economic impact of sorghum variety S 35 in Chad. (In En. Summaries in En, Fr.) Impact Series no. 6. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi -Arid Tropics, 34 pp.

APPENDICES

Appendix I

Area, production and productivity of ragi in Karnataka: 1990-91 to 2010-11

Year	Area (ha)	Production (tonnes)	Productivity (kg/ha)
1990-91	1055330	976078	973
1991-92	1118145	1472162	1385
1992-93	1038411	1536132	1557
1993-94	1028508	1566564	1603
1994-95	944155	1352668	1508
1995-96	1019932	1618138	1670
1996-97	1035204	1495149	1520
1997-98	938546	1273013	1428
1998-99	1030679	1734076	1771
1999-00	916328	1402162	1611
2000-01	1022701	1835332	1889
2001-02	953430	1539308	1699
2002-03	767148	714489	980
2003-04	998266	1125093	1186
2004-05	892841	1613873	1903
2005-06	938630	1656306	1858
2006-07	605771	664985	1156
2007-08	832722	1368048	1729
2008-09	841124	1232970	1543
2009-10	764374	1196389	1647
2010-11	787894	1588245	2122
CGR	-1.74	-0.72	1.04

Appendix II

Area, Production and Productivity of Redgram in Karnataka:1990-91 to 2010-11

Year	Area (ha)	Production (tonnes)	Productivity (kg/ha)
1990-91	462574	174777	397
1991-92	505962	181984	378
1992-93	450439	86292	202
1993-94	360815	155116	453
1994-95	301923	119287	416
1995-96	423856	201887	501
1996-97	445381	228820	541
1997-98	421810	98473	246
1998-99	475396	221453	490
1999-00	508086	289526	600
2000-01	582763	263533	476
2001-02	482100	147437	322
2002-03	513739	240665	493
2003-04	532251	199627	395
2004-05	562127	291113	545
2005-06	599884	407832	716
2006-07	595697	262673	464
2007-08	681136	451013	697
2008-09	596622	313730	554
2009-10	604305	279760	487
2010-11	891535	529052	625
CGR	2.95	5.82	2.79

Appendix III

Land utilization pattern in Karnataka (2010-11)

Sl no.	**Classification**	**Area in hectares**	**Per cent**
1	Geographical area	19049836	100.00
2	Forest	3071833	16.13
3	Land put to Non Agricultural uses	1430363	7.51
4	Barren and Uncultivable land	786627	4.13
5	Cultivable Waste	414397	2.18
6	Permanent Pasture	912385	4.79
7	Trees and Groves	285986	1.50
8	Other Fallow	426458	2.24
9	Current Fallow	1199134	6.29
10	Net Sown Area	10522653	55.24
11	Area sown More than once	2539510	13.33

Source: DES, Karnataka at a glance 2010-11

Appendix IV

Distribution of Agricultural Land Holding in Karnataka (2010-11)

SL NO.	Agricultural Land Holding	Number	Area (ha)
1	Marginal (<1 Ha)	3848834 (49.14)	1850946 (15.22)
2	Small (1-2 Ha)	2138208 (27.30)	3020002 (24.83)
3	Semi Meduim (2-4 ha)	1266829 (16.17)	3393035 (27.90)
4	Medium (4-10 Ha)	510745 (6.52)	2903686 (23.88)
5	Large (> 10 ha)	67573 (0.86)	993788 (8.17)
	Total	7832189 (100.00)	12161457 (100.00)

Note: Figures in parentheses indicate percentages to total

Source: DES, Karnataka at a glance 2010-11

Appendix V

General wholesale price indices (Base 1981-82 and 2010-11)

Year	Wholesale price indices (base year 1981-82)	Wholesale price indices (Base 2010-11)
1981	100.00	15.04
1982	104.90	15.77
1983	112.80	16.96
1984	120.10	18.06
1985	125.40	18.85
1986	132.70	19.95
1987	143.50	21.58
1988	154.20	23.18
1989	165.70	24.91
1990	182.70	27.47
1991	207.80	31.24
1992	228.70	34.39
1993	247.80	37.26
1994	279.02	41.95
1995	301.32	45.31
1996	315.20	47.39
1997	329.08	49.48
1998	348.65	52.42
1999	360.05	54.14
2000	385.82	58.01
2001	399.70	60.10
2002	413.33	62.15
2003	435.88	65.54
2004	464.13	69.78
2005	485.02	72.92
2006	517.04	77.74
2007	541.17	81.37
2008	584.80	87.93
2009	607.08	91.28
2010	665.10	100.00

Source: Handbook of Statistics on Indian Economy 2011-12, Reserve Bank of India

www.rbi.org.in

Appendix VI

Farm harvest prices of ragi AND red gram of Karnataka (Rs/qtl)

Year	Ragi	Red gram
1997	320	-
1998	381	1878
1999	444	1617
2000	374	1440
2001	374	1539
2002	481	1616
2003	436	1710
2004	282	1715
2005	444	1597
2006	564	1950
2007	668	2219
2008	821	2979
2009	878	4358
2010	965	3567

Source: Director of economics and statistics, Government of India

http://eands.dacnet.nic.in

Appendix VII

Data on nominal and real prices and production of ragi

Year	Production (qtls)	Price	Whole sale price index	Real price
1986	-	-	0.19952	-
1987	-	-	0.215758	-
1988	-	-	0.231846	-
1989	-	-	0.249136	-
1990	9760780	-	0.274697	-
1991	14721620	-	0.312435	-
1992	15361320	-	0.343859	-
1993	15665640	-	0.372577	-
1994	13526680	-	0.419522	-
1995	16181380	-	0.453054	-
1996	14951490	-	0.473918	-
1997	12730130	320	0.494782	646.7491
1998	17340760	381	0.524216	726.7998
1999	14021620	444	0.541354	820.1651
2000	18353320	374	0.580102	644.7138
2001	15393080	374	0.600967	622.3306
2002	7144890	481	0.621458	773.9858
2003	11250930	436	0.655363	665.2802
2004	16138730	282	0.697837	404.106
2005	16563060	444	0.729239	608.8536
2006	6649850	564	0.77739	725.5045
2007	13680480	668	0.813678	820.9639
2008	12329700	821	0.879274	933.7246
2009	11963890	878	0.91277	961.9067
2010	15882450	965	1	965

Appendix VIII

Data on yield with new GPU 28 ragi variety and check Indaf 5 variety

Year	yield of GPU 28 (qtls/ha)	yield Indaf 5 (qtls/ha)	Yield increase (qtls/ha)
1997	30.75	25.91	4.84
1998	30.75	25.91	4.84
1999	30.75	25.91	4.84
2000	30.75	25.91	4.84
2001	30.75	25.91	4.84
2002	30.75	25.91	4.84
2003	30.75	25.91	4.84
2004	30.75	25.91	4.84
2005	30.75	25.91	4.84
2006	30.75	25.91	4.84
2007	30.75	25.91	4.84
2008	30.75	25.91	4.84
2009	30.75	25.91	4.84
2010	30.75	25.91	4.84

Appendix IX

Data on area of adoption of GPU 28, adoption rate, adoption cost and proportional increase in production and cost of adoption

			t	ym	j	dc	dc	c=(dc*t)/(ym*p)
Year	**Area under ragi (ha)**	**Area under GPU 28 (ha)**	**Adoption rate**	**Mean Yield State (qtls/ha)**	**Proportional Production increase**	**Adoption cost**	**REAL adoptin cost (Rs)**	**Proportional increase in cost**
1990	1055330	-	-	9.73	-	-	-	-
1991	1118145	-	-	13.85	-	-	-	-
1992	1038411	-	-	15.57	-	-	-	-
1993	1028508	-	-	16.03	-	-	-	-
1994	944155	-	-	15.08	-	-	-	-
1995	1019932	-	-	16.7	-	-	-	-
1996	1035204	-	-	15.2	-	-	-	-
1997	938546	1880	0.00	14.28	0.00	300.00	606.33	0.00
1998	1030679	12790	0.01	17.71	0.00	350.00	667.66	0.00
1999	916328	80040	0.09	16.11	0.03	370.00	683.47	0.00
2000	1022701	157060	0.15	18.89	0.04	380.00	655.06	0.01
2001	953430	159940	0.17	16.99	0.05	450.00	748.79	0.01
2002	767148	182590	0.24	9.80	0.12	460.00	740.19	0.02
2003	998266	196510	0.20	11.86	0.08	470.00	717.16	0.02
2004	892841	184570	0.21	19.03	0.05	520.00	745.16	0.02
2005	938630	192690	0.21	18.58	0.05	540.00	740.50	0.01
2006	605771	203700	0.34	11.56	0.14	550.00	707.50	0.03
2007	832722	239490	0.29	17.29	0.08	630.00	774.26	0.02
2008	841124	282960	0.34	15.43	0.11	700.00	796.11	0.02
2009	764374	318560	0.42	16.47	0.12	850.00	931.23	0.02
2010	787894	393947	0.50	21.22	0.11	1103.00	1103.00	0.03

Appendix X

Supply shift due to ragi GPU 28 variety, research and extension cost and social gains

Year	Net shift in supply curve k=(j/E)-c	Quantity increased (qtls) Dq = QeEk/(E+e)	Social gains (Rs) (SG=kPQ - .5kPdQ)	Research and extension cost (Rs)	Real cost (Rs)	Net social gains (Rs)
1986	-	-	-	84350	422765.38	-422765.38
1987	-	-	-	84350	390947.50	-390947.50
1988	-	-	-	84350	363819.49	-363819.50
1989	-	-	-	94350	378708.14	-378708.14
1990	-	-	-	104350	379873.64	-379873.63
1991	-	-	-	144350	462015.45	-462015.44
1992	-	-	-	184350	536120.27	-536120.27
1993	-	-	-	194350	521637.12	-521637.12
1994	-	-	-	264350	630122.33	-630122.33
1995	-	-	-	320350	707090.66	-707090.66
1996	-	-	-	364350	768803.95	-768803.95
1997	0.00	3570.01	9502496.67	260300	526090.00	8976406.68
1998	0.01	24347.51	72787503.67	260300	496551.18	72290952.45
1999	0.05	153916.50	516759684.70	50000	92360.93	516667323.80
2000	0.07	295459.50	777763411.25	50000	86191.68	777677219.60
2001	0.08	294042.20	746028425.36	60000	99839.14	745928586.20
2002	0.20	346126.80	1075998574.86	45000	72410.31	1075926165.00
2003	0.13	366967.50	988515832.98	-	0	988515833.00
2004	0.08	311886.10	513767863.19	-	0	513767863.20
2005	0.09	353475.20	876405546.58	-	0	876405546.60
2006	0.24	384952.40	1116306874.91	-	0	1116306875.00
2007	0.14	454632.80	1510776944.82	-	0	1510776945.00
2008	0.18	542964.80	2040861425.96	-	0	2040861426.00
2009	0.21	602988.70	2327286705.83	-	0	2327286706.00
2010	0.19	729495.00	2831078672.01	-	0	2831078672.00

Appendix XI

Data on red gram production, price and yield with new BRG 2 variety and check variety

Year	Production (qtls) Q	Price	Whole sale price index	Real price (P)	Yield of new BRG 2 variety (qtls/ha) Yn	Yield of check variety (qtls/ha) Yt	Yield increase Dy
1995	2018870	-	0.453054	-	-	-	-
1996	2288200	-	0.473918	-	-	-	-
1997	984730	-	0.494782	-	-	-	-
1998	2214530	-	0.524216	-	-	-	-
1999	2895260	-	0.541354	-	-	-	-
2000	2635330	-	0.580102	-	-	-	-
2001	1474370	-	0.600967	-	-	-	-
2002	2406650	-	0.621458	-	-	-	-
2003	1996270	-	0.655363	-	-	-	-
2004	2911130	-	0.697837	-	-	-	-
2005	4078320	-	0.729239	-	-	-	-
2006	2626730	1950	0.77739	2508.393	12.39	11.12	1.27
2007	4510130	2219	0.813678	2727.124	12.39	11.12	1.27
2008	3137300	2979	0.879274	3388.021	12.39	11.12	1.27
2009	2797600	4358	0.91277	4774.476	12.39	11.12	1.27
2010	5290520	3567	1	3567	12.39	11.12	1.27

Appendix XII

Data on red grm area, area adoption by BRG 2 red gram variety, adoption cost due to BRG 2 variety

Year	**Area under red gram (ha)**	**Area under BRG 2 (ha)**	**Adoption rate (t)**	**Mean yield state (qtls/ha)** ym	**Proportional production increase (j)**	**Adoption cost (Rs) =dc**	**Real adoption cost**	**Proportional increase in cost** c=(dc*t)/(ym*p)
1995	423856	-	-	5.01	-	-	-	-
1996	445381	-	-	5.41	-	-	-	-
1997	421810	-	-	2.46	-	-	-	-
1998	475396	-	-	4.9	-	-	-	-
1999	508086	-	-	6	-	-	-	-
2000	582763	-	-	4.76	-	-	-	-
2001	482100	-	-	3.22	-	-	-	-
2002	513739	-	-	4.93	-	-	-	-
2003	532251	-	-	3.95	-	-	-	-
2004	562127	-	-	5.45	-	-	-	-
2005	599884	-	-	7.16	-	-	-	-
2006	595697	1000	0.002	4.64	0.000	518.75	667.30	0.0001
2007	681136	3500	0.005	6.97	0.001	618.75	760.44	0.0002
2008	596622	8400	0.014	5.54	0.003	718.75	817.44	0.0006
2009	604305	18000	0.030	4.87	0.008	818.75	896.99	0.0011
2010	891535	28901	0.032	6.25	0.007	918.75	918.75	0.0013

Appendix XIII

Supply shift due to redgram BRG 2 variety, research and extension cost and social gains

Year	Supply shift k=(j/E)-c	Quantity increased dq = QeEk/(E+e)	SG=kPQ - .5kPdQ)	Research and extension cost	REAL cost	Net social gains
1995	-	-	-	510000	1125694.56	-1125694.56
1996	-	-	-	510000	1076135.68	-1076135.68
1997	-	-	-	510000	1030756.47	-1030756.47
1998	-	-	-	510000	972881.73	-972881.73
1999	-	-	-	561000	1036289.78	-1036289.78
2000	-	-	-	561000	967070.68	-967070.68
2001	-	-	-	589200	980420.40	-980420.40
2002	-	-	-	278000	447334.83	-447334.83
2003	-	-	-	370800	565793.37	-565793.37
2004	-	-	-	804600	1152991.80	-1152991.80
2005	-	-	-	441400	605288.23	-605288.23
2006	0.001	273.29	6093114.07	525600	676108.44	5417005.63
2007	0.002	951.38	23060087.26	635000	780407.38	22279679.88
2008	0.007	2315.04	69693420.48	146000	166046.03	69527374.45
2009	0.016	5071.06	215019686.82	298000	326478.59	214693208.23
2010	0.013	7917.24	250841522.83	298000	298000.00	250543522.83

Appendix XIV

Computation in Excel spread sheet. Example of impact of Redgram BRG 2 variety is provided in excel spread sheet below. The steps and formulas used as follows

Step 1. In the excel spread sheet, data on production of redgram (quintals) is in column B, nominal prices of output are in column D, whole sale price indices are in column E. The nominal prices in column D are converted to real price by dividing nominal price by whole sale price index and given in Fusing D3/E3.

Step 2. Yield of improved variety and check variety per hectare is given in the columns G and H respectively. As the BRG 2 redgram variety is released in 2006, the data entered here is from row cell 12. The price of output data also starts from the cell row 14. The change in yield (Dy) is calculated by subtracting the yield of check variety from yield of improved variety as =G14-H14

Step 3. Data of total area under redgram crop in the State is given in column J and data on area under improved variety of redgram is given in column K. The rate of adoption is calculated using formula in excel sheet as = K14/J14by dividing area under improved variety by total area under crop.

Step 4 The average yield of the Red gram crop for the Karnataka state is the column M for each year. The j parameter is computed using the formula =(I 14*L14)/M14.

Step 5 Data on adoption costs for adopting new improved variety per hectare is given in column O. In the column P, the adoption cost is converted to real terms by performing O14/E14

Step 6 Proportional increase in cost is computed using the formula c = (dc*t)/(ym*p) and in MS Excel is =(P14*L14)/(M14*F14).

Step 7 The data on price elasticity of supply and price elasticity of demand are given in columns R and S respectively and are assumed constant over the years.

Step 8 The increased equilibrium quantity of output (Dq = QeEk/(E+e) is computed in Excel as =(C3*S3*R3*T3)/(R3+S3)

Step 9: Social gain in column V is calculated using the formula =(T3*F3*C3)-(0.5*T3*F3*U3).

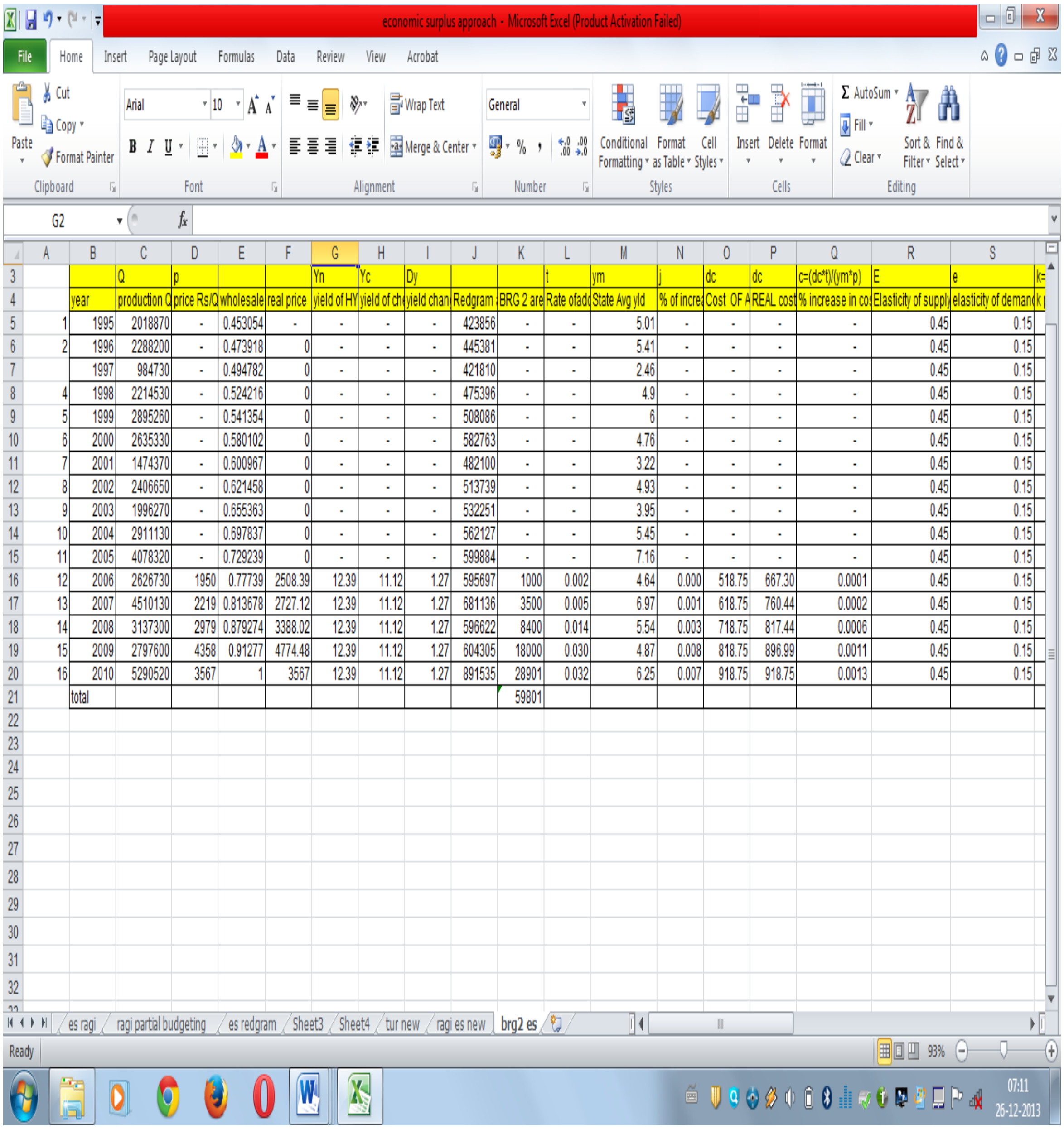
Step 10: Data on research and extension cost incurred to develop new variety are given in column W and converted to real terms by dividing it by whole price index as =W3/E3.

Step 11 The net social gain is computed by subtracting the research and extension costs from the social gains using the formula =V3-X3.

Step 12: The NPV is worked out using the formula =NPV(5%,Y3:Y18) and IRR as =IRR(Y3:Y18, 10%).

Step 13 : In order to compute the producer surplus and consumer surplus, Z parameter is computed in column AB using the formula T3*R3/(R3+S3).

Step 14: The change in consumer surplus is computed as =F3*C3*AB3*(1+0.5*AB3*S3) and producer surplus as =V3-AC3. The sum of consumer surplus and producer surplus is equal to total social gain.



		Q	p			Yn	Yc	Dy			t	ym	j	dc	dc	c=(dc*t)/(ym*p)	E	e	k=
	year	production Q	price Rs/Q	wholesale	real price	yield of HY	yield of ch	yield chan	Redgram	BRG 2 are	Rate ofad	State Avg yld	% of increa	Cost OF A	REAL cost	% increase in cos	Elasticity of supply	elasticity of demand	k p
1	1995	2018870	-	0.453054	-	-	-	-	423856	-	-	5.01	-	-	-	-	0.45	0.15	
2	1996	2288200	-	0.473918	0	-	-	-	445381	-	-	5.41	-	-	-	-	0.45	0.15	
	1997	984730	-	0.494782	0	-	-	-	421810	-	-	2.46	-	-	-	-	0.45	0.15	
4	1998	2214530	-	0.524216	0	-	-	-	475396	-	-	4.9	-	-	-	-	0.45	0.15	
5	1999	2895260	-	0.541354	0	-	-	-	508086	-	-	6	-	-	-	-	0.45	0.15	
6	2000	2635330	-	0.580102	0	-	-	-	582763	-	-	4.76	-	-	-	-	0.45	0.15	
7	2001	1474370	-	0.600967	0	-	-	-	482100	-	-	3.22	-	-	-	-	0.45	0.15	
8	2002	2406650	-	0.621458	0	-	-	-	513739	-	-	4.93	-	-	-	-	0.45	0.15	
9	2003	1996270	-	0.655363	0	-	-	-	532251	-	-	3.95	-	-	-	-	0.45	0.15	
10	2004	2911130	-	0.697837	0	-	-	-	562127	-	-	5.45	-	-	-	-	0.45	0.15	
11	2005	4078320	-	0.729239	0	-	-	-	599884	-	-	7.16	-	-	-	-	0.45	0.15	
12	2006	2626730	1950	0.77739	2508.39	12.39	11.12	1.27	595697	1000	0.002	4.64	0.000	518.75	667.30	0.0001	0.45	0.15	
13	2007	4510130	2219	0.813678	2727.12	12.39	11.12	1.27	681136	3500	0.005	6.97	0.001	618.75	760.44	0.0002	0.45	0.15	
14	2008	3137300	2979	0.879274	3388.02	12.39	11.12	1.27	596622	8400	0.014	5.54	0.003	718.75	817.44	0.0006	0.45	0.15	
15	2009	2797600	4358	0.91277	4774.48	12.39	11.12	1.27	604305	18000	0.030	4.87	0.008	818.75	896.99	0.0011	0.45	0.15	
16	2010	5290520	3567	1	3567	12.39	11.12	1.27	891535	28901	0.032	6.25	0.007	918.75	918.75	0.0013	0.45	0.15	
	total									59801									

economic surplus approach - Microsoft Excel (Product Activation Failed)

	T	U	V	W	X	Y	Z	AA	AB	AC	AD	
3	k=(j/E)-c	Dq = QeEk/(E+e)	SG=kPQ - .5kPdQ)							ΔCS=PQZ(1+0.5Ze)		
4	k parameter	quantity increased	social gains	research and exter	real research a	net social gains	NPV	IRR	Z=k*E/E+e	ΔCS	change in producer sur	total econ surplus
5	-	0	0	510000	1125695	-1125695	₹ 26,02,97,238.00	44%	0.00000	0	0.00	
6	-	0	0	510000	1076136	-1076136			0.00000	0	0	
7	-	0	0	510000	1030756	-1030756			0.00000	0	0	
8	-	0	0	510000	972882	-972882			0.00000	0	0	
9	-	0	0	561000	1036290	-1036290			0.00000	0	0	
10	-	0	0	561000	967071	-967071			0.00000	0	0	
11	-	0	0	589200	980420	-980420			0.00000	0	0	
12	-	0	0	278000	447335	-447335			0.00000	0	0	
13	-	0	0	370800	565793	-565793			0.00000	0	0	
14	-	0	0	804600	1152992	-1152992			0.00000	0	0	
15	-	0	0	441400	605288	-605288			0.00000	0	0	GA
16	0.001	273	6093114	525600	676108	5417006			0.00069	4570311	1522803	
17	0.002	951	23060087	635000	780407	22279680			0.00141	17298714	5761373	
18	0.007	2315	69693420	146000	166046	69527374			0.00492	52308650	17384770	
19	0.016	5071	215019687	298000	326479	214693208			0.01208	161557346	53462340	
20	0.013	7917	250841523	298000	298000	250543523			0.00998	188412890	62428632	
21			564707831		12207698	552500133				424147912	140559919	564707831
24							economic surplus of redgram					
25							supply elasticity and demand elasticity					
26						SE=.45 AND DE=0.15						
27					change in cons	42,41,47,912.07	75.11					
28					change in prod	14,05,59,919.39	24.89					
29					change in econ	56,47,07,831.46	100.00					
30					NPV at 5% dis	26,02,97,238.00						
31					IRR	44%						
32					net economic s	55,25,00,133.48						

es ragi / ragi partial budgeting / es redgram / Sheet3 / Sheet4 / tur new / ragi es new / brg2 es

Ready 93%

07:12 26-12-2013

Appendix XV

Schedule

Research Title: Economic Impact of Public Sector Agricultural Research in Ragi and Redgram in Karnataka

Date of interview: Name of Interviewer: Sri Suresh Naik

I. General information

1. Name of the farmer: Village: Mobile phone No.
2. Age: Caste: SC/ST/OBC/Minority/ General (specify)
3. Education level (qualification):
4. Particulars of family: nuclear family / Joint family:
5.

Name	Relation with Head	Age	Education	Occupation

5. Particulars of land holdings

Sl. No.	Type of land	Owned		Leased in		Leased out	
		Area (Acres)	Market Value of land (Rs.)	Acres (Acres)	Rent paid per season (Rs.)	Acres (Acres)	Rent received per season (Rs.)
1	Dry land						
2	Irrigated land						
3	Current Fallow *(give reason for fallow)						
4	Total						

*Give reasons for fallow (migration, labor shortage, alternative employment)

II. Farm inventory

Farm machinery and equipments

Sl. No.	Particulars	Nos.	Current Value (Rs.)	Year of purchase	Income from custom hiring per year (if any)
1	Bullock cart				
2	Sprayers				
3	Power tiller				

4	Tractor				
5	Irrigation pump (IP set)				
6	Vehicle (2 or 4 wheeler)				
7	Farm building				
8	Others				

Live stock

Sl. No.	Type	Nos.	Output (specify kgs, litres…)	Price per kg/litre / specified unit	Cost involved in rearing (specify per month or year etc)
1	Bullock				
2	Cow local				
3	Cow crossbred				
4	She buffalo				
5	Sheep				
6	Goat				
7	Poultry				

III **Source of irrigation**

Sl. No.	Source	Details of well									Yield of well (in inches)
		Year of drilling	Depth and Dia (feet)	Drilling cost	Casing cost	H P	Pump cost	Electrification cost	Pump Hrs per day	Pump run days in a year	
1	Open well/dug well										
2	Bore well(s)										
	1										
	2										
	3										
	4										
	5										
	6										
3	Irrigation tank										
4	Purchased water (water market)										

For example: Measure the yield of well noting down the time in seconds to fill the water a bucket of known volume

Cropping pattern

Sl. No.	Crops	Variety	Rainfed area (acres)	Output in quintals	Area irrigated by well/s(acres)	Output in quintals	
i.	Kharif						
1							
2							
3							
4							
	5						
ii.	Rabi						
1							
2							
3							
4							
iii.	Summer						
1							
2							
3							
4							
5							
6							
	Perennial crops						Annual cost for perennial crops
1							
2							
3							
4							
5							

Items of expenditure in cost of cultivation data	Season………………… Crop ……………… Variety ……. Area……………………. Date of sowing_________		Season……………………… Crop ………………………. Variety_________________ Area ……………………….	
	Quantity	Value	Quantity	Value
1). Method of irrigation: (beds & channels / ridges & rows / drip / sprinkler/ others)				
2) If well irrigated: Frequency of well irrigation per week				
3) If canal irrigated: Frequency of canal irrigation Per week				
4) If Canal irrigated: No. of inches of water given Per irrigation				
5)If well irrigated, Hours to irrigate the crop each time for the entire area irrigated				
Depth of irrigation in the case of sewage water				
(B) COST PARTICULARS				
1.Human labour for all operations (man days)				
2.Human labor for all operations (woman days)				
3. Bullock labour (bp days)				
4. Machine hours				
5. Seeds / planting material				
6.Manure (cart loads)				
7. Basal dose of N				
Basal dose of Phosphorous				
Basal dose of potash				
Basal dose of any other				
Top dressing of N, P, K				
Date of top dressing (or record days from sowing)				
8. PPCs (including seed treatment)				
9.Packing, grading, marketing costs				
9.Transport cost (Including Hamali)				
10. Main product (Kgs / qntls / tonnes / baskets)				
11. Price at which sold (Rs./qntl)				
12. Place sold				
11. By product (Kgs / qntls / tonnes/ baskets)				
Price of byproduct				
Intercrop name and output				
Price of intercrop				

The major items of labor expenditure are as under Seed treatment, Land preparation, FYM application, Seed bed preparation, Transplanting, Fertilizer application a. basal dose b. top dressing, Hand weeding, Weedicide application, Spraying, Irrigation, Harvesting, Threshing and winnowing Packing, grading, Transport to the market.

Cost of cultivation: Main crop: Variety Intercrop: Variety:

Sowing ratio of row to row: Source of irrigation any: Date of sowing:

a. Labour charges

Particulars	**Human labour**		**Bullock labour**	**Machine labour (hrs)**
	Man day	**Woman day**		
Seed treatment				
Land preparation				
FYM application				
Seed bed preparation				
Transplanting				
Fertilizer application				
a. basal dose				
b. top dressing				
Hand weeding				
Weedicide application				
Spraying				
Irrigation				
Harvesting				
Threshing and winnowing				
Packing, grading,				
Transport to the market				
Wage rate (Rs/day)				

Particulars	**Crop, variety and season**	**Piece wage rate bill**	**Mandays**	**Womendays**
Land preparation				
FYM application				
Seed bed preparation (if any)				
Sowing / dibbling / broadcasting / seed drill sowing				
Transplanting (if any)				
Fertilizer application				
a. basal dose				
b. top dressing				
Hand weeding				
Weedicide application				
Spraying				
Irrigation				
Harvesting				
Threshing and winnowing				
Packing, grading,				
Transport to market				

Wherever piece work rate has been given, fill the following table

Recommended practices/technologies followed

Particular	Time of application	Qty/acre	No. of times		Remarks (reasons for non adoption)
Plowing					
Harrowing					
Seed sowing/planting					
N					
P					
K					
Sulfur					
Zinc sulphate					
Bio fertilizer: rhizobium azospirulum					
Green manure					
FYM					
Soil type					
Soil testing					
Depth of sowing					
Spacing					
Contour bed/ridge and furrow					
Intercultivation					
Irrigation					
Intercropping					
Pheromone trap					
NSKE					
Pesticides :					
Insecticides:					
Weedicides :					
Others if any					
Boran					

Transaction costs:

Inputs / services	When advise was given (during sowing / any operation)	Price per unit	Name and address of seller / distributor from whom input was purchased	Transport cost to purchase inputs and return seeds and return	What specific advise received reg the input*	Name and address of advisor	Did you follow the advise	If not, what were the constraint/s	Your suggestions to fill the gap
Seeds									
Labour									
Fertilizers									
Specific Plant protection chemicals									
FYM									
Machine hiring									
Sowing									
Transplanting									
Fertilizer application									
Intercultural operations									
Weeding									
Harvesting									
Threshing									
Sorting, grading									
Marketing									

*for instance if the scientist recommended a specific chemical or variety or fertilizer or any operation indicate the name of the chemical and dose… details of operation etc

Technology adoption

Crop	Variety used earlier	Variety cultivated at present	Why did you shift to the present variety	Source of information	Subsidy received if any	Major change/s between this variety and previous variety	Yield of previous variety	Yield of present variety	Price per quintal received for previous variety	Cost of cultivation of previous variety