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Impact of research investment on Cassava production technologies in India*

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The present study was an *ex-post* assessment done to validate past funding on cassava research, based on economic surplus approach. Though cassava was introduced as a food crop in Kerala, India from Brazil, it has changed its status to commercial crop at present in Tamil Nadu and Andhra Pradesh states. This was made possible due to intensive research and development efforts of different R&D organizations. Cassava technologies developed enabled in sustaining the crop in the country with the world's highest productivity. All the cassava production technologies considered in the study resulted in an economic surplus of Rs.3585.87 million in the target domain covering Kerala, Tamil Nadu and Andhra Pradesh. Consumers and producers benefited to the tune of Rs.2090.64 million and Rs.1495.23 million respectively. Net present value of economic gains was estimated to be Rs.3548.76 million. Present value of research investment on cassava production technologies was Rs.37.11 million resulting in benefit cost ratio of 96.63:1 with a high internal rate of return of 104 per cent. Thus the study indicated that the research investments incurred on cassava production technologies development was highly economical and provided evidence to the policy makers that supporting the research investment on underground, under exploited tropical root crops like cassava is an economically viable proposition.

Key words: cassava, economic surplus, impact assessment, India, production technologies.

1. Introduction

India's investment in agricultural research and extension has made it one of the largest publicly funded systems in the world (Evenson *et al*. 1999). Economic liberalisation policies of the Government of India since 1991 together with budget constraints and concerns that the returns to public research may be declining have raised questions about the quantum of investment in Public Agricultural Research. Evaluation of benefits due to research has become an integral part of the research management system and is becoming increasingly relevant to planners, policy makers and researchers in recent times. Policy makers who perceive that the benefits to research may be declining are

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Table 1 Comparison of 5 year plan wise average annual research expenditure on tropical tuber crops and potato (in million rupees) in India

Five year plan	Tropical tuber crops	Potato
III	0.07	—
IV	1.28	—
V	3.41	10.94
VI	6.24	19.66
VII	12.05	30.20
VIII	27.06	69.36
IX	51.74	112.04
X	81.76	242.20

advocating a cut back on public spending on research in general and cassava (tuber crop) in particular. The World Bank suggested that each country is required to invest 1 per cent of their agricultural Gross Domestic Product (GDP) on research. Most of the developed countries are investing to the tune of 2.5 per cent of their agricultural GDP while it is only 0.41 per cent in case of developing countries like India. At the time of independence, India was spending less than 0.1 per cent from agriculture. During 1960s, it has reached 0.2 per cent and since early 1980s, it is fluctuating between 0.45 and 0.5 per cent.

A perusal of average annual research expenditure in each 5 year plan on tropical tuber crops and potato (Table 1) clearly indicates that although it is increasing in each 5 year plan on tropical tuber crops, the rate of increase is not the same as that of in potato. Furthermore, this rate of increase is negligible when compared with rate of increase in the average annual research expenditure on rice and wheat in India.

Public allocation of funds/resources to agricultural research is scarce while the expectations are very high from the same. Donors are always interested to know whether the investment in agricultural research has yielded any viable returns or not. It is important to document the returns and/or benefits accrued from the research investment to justify the further investment in agriculture. The donors are seeking evidences on impact of past funding as a basis for future financial support. Research programs demonstrate better historical performance in terms of benefits generated for the society are rated higher for attracting required research resources.

Cassava or tapioca (*Manihot esculenta* Crantz) plant belonging to the family Euphorbiaceae is a native of Brazil. It was introduced in India during the 17th century and it rapidly established itself as an important food crop, especially in Kerala state. Of late, the crop has changed its status from food crop to industrial crop. More than 800 small scale cassava-based industries are under operation producing many values added products viz., starch, sago, chips, flour, wafers etc.

Tropical tuber crops began receiving attention from the Government of India and the Indian Council of Agricultural Research (ICAR) since independence. A number of *ad-hoc* research schemes on these crops, financed from the Agricultural Produce Cess Funds, were launched from 1949 onwards in different tuber crops growing states of India. In Kerala, a combined scheme on tapioca and sweet potato sanctioned for the period 30 March 1951–30 September 1963 was functioning in the erstwhile Travancore-Cochin University (CTCRI 1983).

Dr A. Abraham, Prof. of Botany, in the Travancore-Cochin University served as Special Supervisory Officer of the Tuber Crops Research Schemes in Kerala (Abraham *et al.* 1976). During the third plan, the Main Tuber Crops Research Station was established in July 1963 by the Government of India for intensification of research on the improvement of tuber crops (other then potato) at Sreekariyam, near Trivandrum, terminating the earlier schemes. The material, developed in the schemes formed part of the germplasm. The station was redesignated as Central Tuber Crops Research Institute (CTCRI) with effect from 29th August 1964. The Government of India decided to transfer the administrative control of the Institute to the ICAR, with effect from 1st April 1966. The All India Coordinated Research Project for Tuber Crops (AICRPTC) was started by the ICAR in 1968 to tackle the regional problems.

Systematic efforts on research and development of tropical tuber crops started with the establishment of CTCRI, Thiruvananthapuram and AICRPTC. These are the two major vehicles of the ICAR, India through which both basic and applied research in cassava has been carried out in the country for the past four decades. There is no private investment involved on cassava research and development in India till today.

An attempt was made in this paper to prove that research investment on cassava production technologies could generate high economic returns to the society. This study was an *ex-post* assessment done to validate past funding on research, based on economic surplus approach. It helped in estimating the economic surplus generated as a consequence of research outputs. The information derived through economic surplus approach is used to estimate benefit–cost ratio (BCR), internal rate of return (IRR) and net present value (NPV) of research outputs. Thus present study was conducted with the following objectives.

1. To identify the production technologies developed on cassava and to estimate the expenditure incurred in developing the identified technologies.
2. To quantify the benefits accrued due to the identified technologies to the cassava user's system.
3. Benefit–cost analysis of research investment on cassava in India.

2. Methodology

2.1 Economic surplus approach for computing research benefits

An economic surplus model (Alston *et al.* 1995) was used to measure the potential returns because of the cassava production technologies developed through public funding. The model was applied in a closed economy framework with the assumption of no spillover effects on international market. With relatively bulky, perishable commodities such as cassava, a closed economy model that assumes no or relatively little international trade is appropriate.

The adoption of a cost-reducing or yield-enhancing technology increases the supply of a commodity such as cassava. As there is no or little international trade, the increase in supply reduces both the price of the commodity to consumers and the cost to producers. It was assumed that the output supply function was unitary elastic and linear with a parallel research – induced supply shift and the demand function was linearly inelastic. The assumptions of a simple case of linear supply and demand functions with parallel shift have been applied in most of the earlier studies on research benefits (Alston *et al.* 1995). It may be noted that it is a realistic assumption in the absence of availability of reliable estimates of economies of scale and size in agricultural production influenced by these technologies. When a parallel shift supply was used, the functional form was largely irrelevant and a linear model provided a good approximation to the true functional form of supply and demand functions (Alston and Wohlgenant 1990).

Change in total surplus comprises both the changes in producer and consumer surplus resulting from the shift in supply. Consumers are better off because they consume more at a lower price. Although producers are receiving a lower price for their tubers, they are able to sell more, so their benefits increase, unless supply is perfectly elastic or demand is perfectly inelastic, in which case their revenues remain the same. The change in total surplus can be thought of as the maximum potential benefits to a technology (for example an improved crop variety).

$$\text{Change in total surplus} = K_{\text{t}} P_0 Q_0 (1 + 0.5 Z_t h)$$

where, $Z_t = K_t\ (e/(e+h))$, K_t = vertical shift in supply function, supply shift (K_t) = net cost change × price elasticity of demand (h) × adoption rate × depreciation rate of technology, net cost change = reduction in marginal cost−reduction in unit cost, reduction in marginal cost = relative change in yield/price elasticity of supply (e), where e is the elasticity of supply, h is the elasticity of demand, P_0 = base year output price, Q_0 = base year output quantity, consumer gains/surplus (G_{ct}) = $Z_t\ P_0\ Q_0\ [1 + (0.5 \times Z_t \times h)]$, producer gains/surplus (G_{pt}) = $(K_t - Z_t)\ P_0\ Q_0\ [1 + (0.5 \times Z_t \times h)]$.

Total economic surplus from the target domain is the linear summation of the total gains from each of the 13 technologies estimated for each of the three target domain states. Similarly, consumer and producer gains for the target domain were estimated.

2.2 Estimation of costs

Cassava varieties and production technologies were developed at CTCRI and All India Coordinated Research Project on Tuber Crops since their inception from 1963 to 1979 respectively. Different research programs that lead to the development of cassava varieties and production technologies were identified. There were no Research Project Files available for all these programs which were under operation during 1960s and 1970s. The leader and other associates of these research programs involved in developing these technologies and duration of each program were identified using CTCRI Annual Reports available from 1966 onwards (CTCRI 1966–2000).

As budget for each of the research program was not available, an estimate of the budget for each program was prepared using personal files of the scientists involved in the program for salary details. Agriculture being the state subject and the popularisation of the generated technologies was the responsibility of the State Department of Agriculture. Funds incurred on Roots and Tubers Scheme to popularise tuber crops technologies in Kerala alone was taken into account in the analysis because of the lack of data for states like Andhra Pradesh and Tamil Nadu to arrive at the research cost estimates. Proportionate allocation of funds in AICRPTC budget in each 5 year plan on cassava was also considered in estimating the research cost (CTCRI 1994, 1996 and 2003). Thus research cost incurred in generating cassava production technologies in India from 1966 to 2000 and its present value was estimated.

Stream of costs and benefits were calculated using compounding and discounting technique. A compounding factor of 8 per cent was used for estimating the present value of costs and returns. Economic rates of return viz., NPV, IRR and BCR were calculated as below.

Net present value:

$$\sum_{t=0}^{n}[(B_t - C_t)/(1+r)^t]$$

Benefit–cost ratio:

$$\sum_{t=0}^{n}[(B_t)/(1+r)^t]/\sum_{t=0}^{n}[(C_t)/(1+r)^t]$$

Internal rate of return:

$$\sum_{t=0}^{n}[(B_t - C_t)/(1+r)^t] = 0,$$

where B_t is the benefit (changes in total surplus) in year t, C_t is the cost in year t and r is the discount rate.

2.3 Data and parameters

Estimation of the economic surplus generated by a technology requires data on technological and economical parameters. The technological data include yield and cost advantages, research and development lag (R&D) and adoption pattern. These data were collected from the scientists and farmers with the help of a well-structured questionnaire. A period of 35 years from 1966 to 2000 was considered for developing the cost–benefit stream.

The data on economic variables like cassava prices, area and output quantities in the target domain were obtained from the published sources (Centre for Monitoring Indian Economy 2006 and Season and Crop Reports, Govt. of Andhra Pradesh, Kerala and Tamil Nadu for different years). Farm harvest prices were used for computing the value of production. Percentage adoption of the selected technology, ceiling level of adoption, change in the cost and yield due to adoption of cassava production technologies (Srinivas *et al.* 2006 and Appendix) estimated using the primary data collected from the cassava farmers in the target states with the help of a well-structured questionnaire, were used in this study.

No published figures on price elasticity of demand and price elasticity of supply for cassava in the target states are available. Therefore supply and demand elasticities were estimated using supply response model and demand function respectively for cassava in the target states. Necessary data for the models were collected from published sources for the period from 1960–1961 to 1999–2000.

3. Results and discussion

3.1 Economic gains from cassava production technologies

Among the many cassava production technologies, only important technologies like high yielding varieties, land preparation, sett making, planting method, spacing, recommended quantity of organic manures, NPK fertilizers, retaining two shoots per plant, cassava mosaic disease (CMD) management, irrigation to cassava and storage of planting material were considered in the study. These 13 technologies were developed at CTCRI and recommended as package of practices for cultivating cassava during early 1970s. The package of practices on cassava was disseminated through line departments of cassava growing states like Kerala, Tamil Nadu and Andhra Pradesh. Percentage adoption of cassava production technologies in the target domain states of Kerala, Tamil Nadu and Andhra Pradesh estimated by Srinivas *et al.* (2006) were used in this study.

The economic surplus generated because of adoption of these technologies by cassava farmers of Kerala, Tamil Nadu and Andhra Pradesh are discussed

Table 2 Cassava production technology wise and state wise breakup of economic gains in India (in million rupees)

Technology	Kerala			Tamil Nadu			Andhra Pradesh			Total		
	Consumer gains	Producer gains	Total economic gains	Consumer gains	Producer gains	Total economic gains	Consumer gains	Producer gains	Total economic gains	Consumer gains	Producer gains	Total economic gains
High yielding variety	123.76	84.16	207.91 (5.80)	457.05	354.22	811.27 (22.62)	52.35	24.87	77.21 (2.15)	633.16	463.24	1096.40 (30.58)
Land preparation	44.56	30.30	74.87 (2.09)	20.48	15.87	36.35 (1.01)	2.39	1.14	3.53 (0.10)	67.44	47.31	114.75 (3.20)
Sett making	133.17	90.55	223.72 (6.24)	52.26	40.50	92.77 (2.59)	6.12	2.91	9.03 (0.25)	191.55	133.96	325.51 (9.08)
Planting method	66.42	45.17	111.59 (3.11)	27.20	21.08	48.27 (1.35)	3.18	1.51	4.69 (0.13)	96.80	67.76	164.55 (4.59)
Spacing	188.42	128.12	316.54 (8.83)	97.60	75.64	173.25 (4.83)	0.39	0.19	0.58 (0.02)	286.41	203.95	490.36 (13.67)
Quantity of organic manures	107.32	72.98	180.30 (5.03)	100.65	78.00	178.65 (4.98)	3.45	1.64	5.09 (0.14)	211.42	152.62	364.05 (10.15)
Quantity of N fertilisers	49.36	33.57	82.93 (2.31)	32.85	25.46	58.31 (1.63)	0.12	0.06	0.18 (0.00001)	82.33	59.08	141.42 (3.94)
Quantity of P fertilisers	45.02	30.61	75.64 (2.11)	33.47	25.94	59.42 (1.66)	12.92	6.14	19.05 (0.53)	91.41	62.69	154.11 (4.30)
Quantity of K fertilisers	69.48	47.25	116.73 (3.26)	21.98	17.04	39.02 (1.09)	4.64	2.20	6.84 (0.19)	96.10	66.49	162.59 (4.53)
Retaining two shoots per plant	74.21	50.46	124.67 (3.48)	22.02	17.06	39.08 (1.09)	2.65	1.26	3.91 (0.11)	98.87	68.78	167.65 (4.68)
CMD management	30.58	20.80	51.38 (1.43)	4.48	3.47	7.95 (0.22)	0.00	0.00	0.00 (0.00)	35.06	24.27	59.33 (1.65)
Irrigation	0.00	0.00	0.00 (0.00)	75.11	58.21	133.32 (3.72)	0.00	0.00	0.00 (0.00)	75.11	58.21	133.32 (3.72)
Storage of planting material	103.90	70.65	174.55 (4.87)	20.69	16.04	36.73 (1.02)	0.36	0.17	0.54 (0.02)	124.96	86.86	211.82 (5.91)
Total	1036.21	704.63	1740.84 (48.55)	965.85	748.53	1714.38 (47.81)	88.58	42.07	130.65 (3.64)	2090.64	1495.23	3585.87 (100.00)

Figures in the parentheses indicate percentage to total economic gains.

below. Cassava production technology wise and state wise breakup of economic gains in India is given in Table 2.

3.1.1 High yielding varieties of cassava

H 97, H 165, H 226, Sree Visakham, Sree Sahya, Sree Prakash, Sree Jaya and Sree Vijaya are the important varieties of cassava released from CTCRI to the target domain area of Kerala and these are suitable for cultivation in Tamil Nadu and Andhra Pradesh. Adoption pattern of these varieties is showing different adoption path in Kerala, Tamil Nadu and Andhra Pradesh. Adoption path was constructed based on the adoption studies conducted in these states. Currently only 5.84 per cent of the cassava farmers in Kerala were growing high yielding varieties while 72 and 100 per cent of cassava farmers in Tamil Nadu and Andhra Pradesh respectively were cultivating high yielding and improved varieties of cassava (Srinivas *et al*. 2006).

The large scale adoption of cassava varieties in Tamil Nadu and Andhra Pradesh generated a total economic surplus of Rs.1096.40 million. A major share of this surplus was from Tamil Nadu accounting to Rs.811.27 million. Consumers share in the total economic surplus was 58.3 per cent while 41.7 per cent was estimated to be the producers share in the total economic surplus.

The low economic surplus from Kerala (Rs.207 million) can be attributed to the fact that only 5.84 per cent of cassava area in Kerala was covered with high yielding varieties. H 165 and H 226 are mainly suited for industrial processing and only Sree Visakham, Sree Sahya, Sree Jaya and Sree Vijaya varieties are suitable for edible purpose.

3.1.2 Land preparation

Mound method, flat bed or ridge and furrow method are the recommended land preparation practices for cassava in Kerala, Tamil Nadu and Andhra Pradesh respectively.

Kerala: The entire cassava farming community in Kerala adopted mound method of land preparation as suggested under package of practices of cassava. This technology generated a total economic surplus of Rs.74.87 million in the state with Rs.44.56 and Rs.30.30 million as consumer and producer gains respectively.

Tamil Nadu: All the cassava growing farmers of Tamil Nadu followed the recommended land preparation of ridge and furrow or flat bed method. It was estimated that this technology could generate an impact or total economic surplus of Rs.36.35 million in monetary terms in the state. Consumer gains (Rs.20.48 million) were more than the producer gains (Rs.15.87 million).

Andhra Pradesh: The recommended technology on land preparation was followed by almost all the farmers in Andhra Pradesh resulting in a total economic surplus of Rs.3.53 million with Rs.2.39 million as consumer gains and Rs.1.14 million as producer gains.

Thus, a total economic surplus of Rs.114.75 million were generated with Rs.67.44 as consumer gains and Rs.47.31 as producer gains in all these states put together. High total economic surplus because of land preparation technology can be attributed to maximum adoption of the technology recommended in the target domain.

3.1.3 Sett making

Setts with round edges and a length of 15–20 cm is recommended in cassava cultivation in all the three states. The unit cost reduction as a result of adoption of the recommended technology was 0.33 per cent with an yield advantage of 1.67 per cent.

Kerala: The technology which was adopted by all the cassava growers in the state, resulted in a total economic surplus of Rs.223.72 million with Rs.133.17 and Rs.90.55 million as consumer gains and producer gains respectively.

Tamil Nadu: Entire cassava growing farmers in Tamil Nadu adopted this technology which helped in improving the tuberous root formation and there by improving the yield. The large scale adoption of this technology generated Rs.92.77 million as total economic surplus. Consumers shared larger benefits (Rs.52.26 million) than producers (Rs.40.50 million).

Andhra Pradesh: Large adoption of this technology generated a total economic surplus of Rs.9.03 million with consumers sharing large benefits (Rs.6.12 million) compared to producers sharing only lesser benefits (Rs.2.91 million).

Thus, a total economic surplus of Rs.325.51 million was due to larger adoption of this technology in all the states. Inter state difference in the economic surplus was attributed to the variation in the cassava area and adoption of the technology among the states.

3.1.4 Planting method

Vertical planting of setts in the field was recommended. The unit cost reduction as a result of adoption of this technology was 0.5 per cent and the yield advantage was 1 per cent. The adoption ceiling in the target domain was almost one and the same.

Kerala: Complete adoption of this technology by all the cassava growers in Kerala resulted in generating an economic surplus of Rs.111.59 million in Kerala with Rs.66.42 million as consumer gains and Rs.45.17 million as producer gains.

Tamil Nadu: The adoption of this technology reached the maximum and all the cassava growers followed this technology. This adoption enabled in generating an economic surplus of Rs.48.27 million. The consumers shared larger benefits of Rs.27.20 million compared with producers who gained Rs.21.08 million.

Andhra Pradesh: Adoption ceiling in the state was similar to Kerala and Tamil Nadu and it resulted in an economic surplus of Rs.4.69 million with Rs.3.18 million and Rs.1.51 million as consumer and producer gains respectively.

Thus vertical planting of setts generated total economic benefits of Rs.164.55 million in the target domain with Rs.96.80 million and Rs.67.76 million as the consumer and producer gains respectively.

3.1.5 Spacing

90 × 90 cm is the recommended spacing in the cassava cultivation. The unit cost reduction as a result of adoption of this recommendation was 3.33 per cent and the yield advantage was 5 per cent. The economic surplus generated by this technology in the target domain is given below.

Kerala: Survey on adoption of cassava growers in Kerala showed that 44 per cent of cassava farmers adopted the recommended spacing. This technology generated a total economic surplus of Rs.316.54 million with consumer benefits of Rs.188.42 million and producer benefits of Rs.128.12 million.

Tamil Nadu: Only 58 per cent of cassava farmers in Tamil Nadu adopted this technology. An economic surplus of Rs.173.25 million with Rs.97.60 million of consumer gains and Rs.75.64 million of producer gains were generated by this technology in Tamil Nadu.

Andhra Pradesh: Adoption of this technology in Andhra Pradesh was very less and only 6 per cent of the cassava growers adopted this technology correctly. Most of the cassava growers adopted a spacing of 110 × 110 cm because of the practice of use of an inter cultivator called 'Gorru' in the cassava belt of Andhra Pradesh. This resulted in very low economic surplus of Rs.0.58 million with Rs.0.39 million and Rs.0.19 million as consumer and producer gains respectively.

3.1.6 Organic manures

FYM or compost to the tune of 12.5 Mt per ha is the recommended quantity of organic manures in the cassava cultivation. This technology results in 1.67 per cent of net cost change per tonne of cassava produced with an yield advantage of 4.33 per cent. Kerala, Tamil Nadu and Andhra Pradesh are in the target domain of this technology.

Kerala: Only 56 per cent of cassava farmers adopted this technology resulting in an economic surplus of Rs.180.30 million with Rs.107.32 million as consumer gains and Rs.72.98 million as producer gains.

Tamil Nadu: Adoption was more in Tamil Nadu compared with Kerala. Eighty-six per cent of farmers adopted this technology creating an economic surplus of Rs.178.65 million with Rs.100.65 million as consumer gains and Rs.78.00 million as producer gains.

Andhra Pradesh: Thirty-three per cent of cassava farmers in Andhra Pradesh adopted this technology. As a result of which an economic surplus of Rs.5.09 million could be generated with Rs.3.45 million as consumer gains and Rs.1.64 million as producer gains.

The wide variation in economic surplus generated by this technology was attributed to difference in the adoption levels of the technology owing to institutional and economic constraints. An economic surplus of Rs.364.05 million was generated with Rs.211.42 million and Rs.152.62 million as consumer and producer gains respectively.

3.1.7 Nitrogenous fertilizers

One hundred kilogram per hectare is the recommended dose of nitrogen nutrient application in the target domain of Kerala, Tamil Nadu and Andhra Pradesh. The input cost change by adopting this technology would be 26.67 per cent with an yield advantage of 21.67 per cent. The economic surplus generated in the target states is given below.

Kerala: Percentage of farmers correctly adopting this technology was relatively low in Kerala. It is only 26 per cent of cassava farmers adopting this technology even after 30 years of its recommendation. This technology generated an economic surplus of Rs.82.93 million with Rs.49.36 million as consumer gains and Rs.33.57 million as producer gains.

Tamil Nadu: This technology could generate Rs.58.31 million with Rs.32.85 million as consumer gains and Rs.25.46 million as producer gains till 2005, only 32 per cent of cassava growers adopted this technology.

Andhra Pradesh: Only 1.2 per cent of cassava growers in the state adopted correctly the recommendation there by resulting in an economic surplus of Rs.0.18 million with Rs.0.12 million and Rs.0.06 million as consumer gains and producers gains respectively.

Thus an economic surplus of Rs.141.42 million only could be generated by this technology. Consumer benefits (Rs.82.33 million) are more than the producer benefits (Rs.59.08 million).

3.1.8 Phosphetic fertilizer

Fifty kilogram per hectare is the recommended dose of phosphorous nutrient application in the target domain of Kerala, Tamil Nadu and Andhra Pradesh. The input cost change by adopting this technology would be 14 per cent with an yield advantage of 18.33 per cent. The economic gain as a result of this technology in the target domain is as follows.

Kerala: Only 20 per cent of cassava farmers adopted correctly the application of recommended dose of phosphetic fertilizer. This resulted in an economic surplus of Rs.75.64 million with Rs.45.02 million as consumer gains and Rs.30.61 million as producer gains in the state.

Tamil Nadu: This technology was adopted by only 36 per cent of cassava growers in the state. This technology could generate an economic surplus of Rs.59.42 million with Rs.33.47 million as consumer benefits and Rs.25.94 million as producer benefits in the state.

Andhra Pradesh: Adoption of this technology was similar to Tamil Nadu farmers. Only 34.5 per cent of cassava growers adopted this technology resulting in an economic surplus of Rs.19.05 million with Rs.12.92 million and Rs.6.14 million as consumer and producer gains respectively.

Correct adoption of phosphetic fertilizer recommended dose resulted in an economic surplus of Rs.154.11 million.

3.1.9 Potassic fertilizer

One hundred kilogram per hectare is the recommended dose of potassium nutrient application in the target domain. The unit cost reduction as a result of adoption of this technology was 22.5 per cent with an yield advantage of 23.33 per cent.

Kerala: Only 16 per cent of cassava farmers were correctly following the recommendation on potassium nutrient. This resulted in an economic surplus of Rs.116.73 million with Rs.69.48 million as consumer gains and Rs.47.25 million as producer gains.

Tamil Nadu: Correct adoption of this recommended technology was by only 17 per cent of cassava farmers in the state. As a result of which Rs.39.02 million only could be generated as an economic surplus with Rs.21.98 million as consumer gains and Rs.17.04 million as producer gains.

Andhra Pradesh: Low adoption of correct recommendation of potassium nutrient by cassava growers resulted in a very low economic surplus of Rs.6.84 million with Rs.4.64 million as consumer gains and Rs.2.20 million as producer gains.

An economic surplus of Rs.162.59 million only could be generated by this technology in the target domain.

Even though cassava farmers apply NPK fertilizers, over and above the recommended dose was more compared with correct application because of a disbelief that application of more fertilizers results in more yield.

3.1.10 Retaining two shoots per plant

Recommended package of practice is to retain only two shoots per plant. Adoption of this technology results in change in the input cost to the tune of 1 per cent with an yield advantage of 2 per cent. This technology resulted in an economic surplus of Rs.167.65 million with Rs.98.87 million as consumer gains and Rs.68.78 million as producer gains.

Eighty-nine per cent of cassava farmers adopted this technology in Kerala so far resulting in an economic surplus of Rs.124.67 million. Consumers and producers were benefited to the tune of Rs.74.21 and Rs.50.46 million respectively by this technology.

In Tamil Nadu, an economic surplus of Rs.39.08 million could be generated with Rs.22.02 million and Rs.17.06 million as consumer and producer gains respectively as 81 per cent of cassava growers adopted this technology in the state.

Similar to Kerala and Tamil Nadu, 80 per cent of cassava farmers adopted this technology in Andhra Pradesh generating an economic surplus of Rs.3.91 million.

3.1.11 Cassava mosaic disease management

Rouging of infected plants and using only apparently healthy planting material is the recommended management practice for CMD. Adoption of this technology leads to a unit cost change of 7 per cent with an yield advantage of 13.33 per cent. Economic surplus generated in the target domain because of adoption of this technology was estimated to be Rs.59.33 million with Rs.35.06 million as consumer gains and Rs.24.27 million as producer gains.

This disease was prevalent only in Kerala and Tamil Nadu. 10.4 per cent of cassava farmers in Kerala and 9.7 per cent of Tamil Nadu cassava farmers only adopted this technology. This resulted in an economic surplus of Rs.51.38 million in Kerala and Rs.7.95 million in Tamil Nadu.

3.1.12 Irrigation

Cassava is grown as irrigated crop only in Tamil Nadu. The unit cost change as result of this technology was 11.67 per cent. This technology was adopted by 68 per cent of farmers in Tamil Nadu resulting in an economic surplus of Rs.133.32 million with Rs.75.11 million as consumer gains and Rs.58.21 million as producer gains.

3.1.13 Storage of planting material

Storing the planting materials in shaded region in vertical position is recommended in cassava. The change in the unit cost of input as a result of adoption of this technology was to the tune of 2.67 per cent with an yield advantage of 3.33 per cent. This technology generated an economic surplus of Rs.211.82 million with Rs.124.96 million as consumer gains and Rs.86.86 million as producer gains.

In Kerala almost all the cassava growers adopted this technology resulting in an economic surplus of Rs.174.55 million. While in Tamil Nadu, this technology could generate an economic surplus of Rs.36.73 million because of the fact that 95 per cent of farmers adopted this technology. In Andhra Pradesh only 12.3 per cent of cassava farmers adopted this technology and it resulted in Rs.0.54 million of economic surplus.

3.2 Economic indicators

Net present value of economic gains caused by cassava production technologies was estimated to be Rs.3548.76 million. Present value of research investment on cassava production technologies through different research projects under taken at CTCRI and work carried out by All India Coordinated Research Project on Tuber Crops through its centres in different Agricultural Universities were estimated to be Rs.37.11 million (Table 3). This investment on cassava production technologies resulted in BCR of 96.63:1 with a high IRR of 104 per cent (Table 4).

Table 3 Research cost incurred in generating cassava production technologies in India and its present value from 1966 to 2000

Year	Research cost (Rs.)	Present value of research cost (Rs.)
1966	11 320.00	154 972.00
1967	6680.00	84 676.00
1968	12 752.00	149 671.00
1969	75 866.00	824 486.00
1970	81 762.00	822 743.00
1971	81 578.00	760 084.00
1972	88 738.00	765 552.00
1973	86 850.00	693 763.00
1974	119 228.00	881 852.00
1975	128 812.00	882 166.00
1976	130 630.00	828 346.00
1977	143 756.00	844 058.00
1978	149 119.00	810 693.00
1979	154 948.00	779 982.00
1980	230 008.00	1072 056.00
1981	242 369.00	1 045 993.00
1982	266 683.00	1 065 670.00
1983	269 963.00	998 868.00
1984	276 244.00	946 398.00
1985	363 974.00	1 154 588.00
1986	371 136.00	1 090 098.00
1987	373 725.00	1 016 391.00
1988	413 594.00	1 041 499.00
1989	449 259.00	1 047 510.00
1990	643 858.00	1 390 042.00
1991	706 893.00	1 413 082.00
1992	717 217.00	1 327 519.00
1993	777 475.00	1 332 455.00
1994	897 721.00	1 424 571.00
1995	893 916.00	1 313 456.00
1996	1 055 696.00	1 436 263.00
1997	1 289 165.00	1 623 976.00
1998	1 461 915.00	1 705 177.00
1999	1 631 435.00	1 761 950.00
2000	2 619 302.00	2 619 302.00
Total	17 223 587.00	37 109 910.00

Table 4 Total economic surplus from cassava production technologies

Economic gains	Value (in million rupees)
Total economic gains	3585.87
Present value of research cost	37.11
Net present value of economic gains	3548.76
Benefit–cost ratio	96.63
Internal rate of return (%)	104.00

Table 5 State wise breakup of total economic gains from cassava production technologies in India (in million rupees)

Gains	Kerala	Tamil Nadu	Andhra Pradesh	Total
Consumer gains	1036.21	965.85	88.58	2090.64
Producer gains	704.63	748.53	42.07	1495.23
Total economic gains	1740.84	1714.38	130.65	3585.87

All the 13 cassava production technologies considered in the study resulted in an economic surplus of Rs.3585.87 million in the target domain covering Kerala, Tamil Nadu and Andhra Pradesh. Consumers have gained benefits to the tune of Rs.2090.64 million while producers gained to the extent of Rs.1495.23 million in the system (Table 5).

The total economic gains if observed state wise in the target domain, Kerala benefited highest to the extent of Rs.1740.84 million followed by Tamil Nadu (Rs.1714.38 million) and Andhra Pradesh (Rs.130.65). Even though area under cassava was less in Tamil Nadu compared with Kerala, high productivity enabled it to get economic gains similar to Kerala.

4. Conclusions

All the 13 cassava production technologies considered in the study resulted in an economic surplus of Rs.3585.87 million in the target domain covering Kerala, Tamil Nadu and Andhra Pradesh. Consumers and producers benefited to the tune of Rs.2090.64 million and Rs.1495.23 million respectively. Net present value of economic gains was estimated to be Rs.3548.76 million. Present value of research investment on cassava production technologies through different research projects under taken at CTCRI and work carried out by AICRPTC through its centres in different Agricultural Universities was estimated to be Rs.37.11 millions. This resulted in the BCR of 96.63:1 with a high IRR of 104 per cent. Thus, the study indicated that the research investments incurred on cassava production technologies development was highly economical and provided evidence to the policy makers that supporting the research investment on underground, under exploited tropical root crops like cassava is an economically viable proposition.

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Appendix

State wise and technology wise adoption ceiling of cassava production technologies (as per cent)

Technology	Kerala	Tamil Nadu	Andhra Pradesh
High yielding variety	5.84	72.24	100.00
Land preparation	100.00	100.00	100.00
Sett making	100.00	100.00	100.00
Planting method	100.00	100.00	100.00
Spacing	44.37	58.39	6.08
Quantity of organic manures	56.00	85.92	33.04
Quantity of N fertilizers	26.31	31.74	1.19
Quantity of P fertilizers	19.64	35.82	34.50
Quantity of K fertilizers	16.25	16.77	17.75
Retaining two shoots per plant	89.25	81.36	80.32
CMD management	10.27	9.74	0.00
Irrigation	0.00	68.36	0.00
Storage of planting material	100.00	95.19	12.34

Change in the cost and yield due to adoption of cassava production technologies

Technology	Change in the cost (%)	Increase in yield (%)
Variety	6.00	15.00
Land preparation	1.00	1.00
Sett length	0.33	1.67
Planting method	0.50	1.00
Spacing	3.33	5.00
Application of organic manures	1.67	4.33
Application of N fertilizers	26.67	21.67
Application of P fertilizers	14.00	18.33
Application of K fertilizers	22.50	23.33
Retaining two shoots per plant	1.00	2.00
CMD management	7.00	13.33
Irrigation	11.67	16.67
Storage of planting material	2.67	3.33