Economic impact of cowpea agronomic research in Ghana: The economic surplus approach

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Abstract

The economic surplus approach was used to test the null hypothesis that research findings are not getting to Ghanaian farmers, for them to adopt and lead to productivity increases and attendant economic gains. A case-study crop chosen for this purpose was cowpea, which has enjoyed concerted research and technology transfer activities since some two decades ago. To achieve the objective of the study, a cowpea farmers survey, involving a nationwide random selection of 240 cowpea farmers, was conducted in 1997 to get farm budget data on their operations. The data were used to arrive at the adoption level of the improved technology package of growing improved cowpea seed developed through research, and the recommended attendant spraying with insecticide. The base adoption level was used to derive a logistic curve which gave the adoption rate and cumulative adoption level in the year under consideration. The adoption levels and the economic returns obtained from the farm budget data and price elasticities of supply and demand for cowpea derived for the period under consideration(1980-1996) were used to compute the internal rate of return(IRR) for cowpea research using the economic surplus method. At 61 per cent adoption level in 1996 the IRR was found to be 58 per cent. Sensitivity analysis using 48 and 23 per cent as possible nationwide adoption levels in 1996 yielded IRR of 51 and 19 per cent, respectively. Comparing these IRRs to the opportunity cost of capital in Ghanaian agriculture of 32 per cent and that of donor countries who have greatly funded the research effort at 5-10 per cent makes cowpea research highly profitable. In the process, high monetary payoffs were found to have accrued to the country. The null hypothesis, at least in the case of cowpea agronomic research is, therefore, rejected.

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Introduction

There is a general perception that agricultural productivity of both land and labour in Ghana is generally on a low level. (La-Anyane,1985). This makes it difficult to achieve food self-sufficiency in the basic staples and meat, let alone get marketable surpluses for export, except in a few cases where the crops are not grown for local consumption but basically for export, e.g. cocoa and coffee. In all cases, whether for local consumption or export, crop yields have been shown to be very low compared with what have been achieved in the country in some isolated cases and the average in sub-Saharan Africa (FAO, 1991). Consequently, cases of food deficits and sub-optimal level of nutritional intakes are common.

Where there is a general low level of productivity in agriculture, it is largely attributed to the type, quantity and quality of inputs used, the extension network and inadequate moisture for plant growth (Anderson,1994). To overcome these constraints, research has a role to play in the areas of improved seed development for drought/disease/pest attack, resistance and associated complementary practices like insecticide/fertilizer application (Hayami & Ruttan,1971). The extension system then has the added role of delivering knowledge on the technologies to farmers for them to adopt and improve their productivity (Byerlee,1993).

Productivity enhancing activities have been going on since the colonial era and have received governmental as well as non-governmental organizational support over the years, even though the research outfits complained of inadequate funding of research by Government. Despite these efforts, critics who bemoan the current low state of agricultural development and its growth in the country have attributed this state of affairs to research findings and recommendations not getting to the bulk of farmers, and even where they reached them, their adoption rates being too low (La-Anyane, 1985). A follow-up to these assertions are those who have gone further to say that they doubted if Ghana had reaped any economic benefits from agricultural research.

To test for the null hypotheses that research findings are not getting to farmers for them to adopt and lead to productivity increases and its attendant economic gains, it required a survey of farmers of a case-study crop. This survey, which was undertaken in 1997, had two purposes. Firstly, it was to help determine the full adoption levels and rates of adoption of the farmers of the recommended technology package for increasing yields on their farms. This was to help test for the validity of the assertions made to the effect that the level of improved technology adoption on Ghanaian farms is low. Secondly, the survey was to facilitate the collection of farm budget data, which were to be used to compute the marginal productivity of full technology adoption over other concurrent practices and effects of adoption on farmers' incomes. Derived from these, social gains to the country's socio-economy in terms of economic surpluses to producers and consumers of the crop, arising out of research on it and extension of its recommendations to farmers, were to be evaluated. Concurrently, the return on investment in research and technology transfer on the crop was also to be assessed.

The test crop chosen for the study was cowpea and the technology package was the agronomic recommendation of growing improved cowpea varieties developed through research and its attendant spraying with insecticides. Thus, in the generality of farm-level practices, a farmer who grew improved cowpea seed and also sprayed the farm with insecticide was considered to be a full technology adopter.

Materials and methods

There are a number of analytical methods used by various authors to investigate the effects of research on agricultural productivity. The Cobb-Douglas production function has been used by many researchers who by that method use variables measuring research activities that have been incorporated in the estimation of production functions, (Griliches, 1964; Evenson, 1967). Others like Hanock & Rothschild (1972) and Chavas & Cox (1990) have used the non-parametric analysis with the use of linear programming approach to measure the influence of research on agricultural productivity. A third category of researchers have been using the consumer and producer surplus approach to arrive at the social benefits arising out of research. Notable among these authors are Schultz (1953), Akino & Hayami (1974) and Masters (1996). The national income and nutritional impact approaches can also be found in the literature.

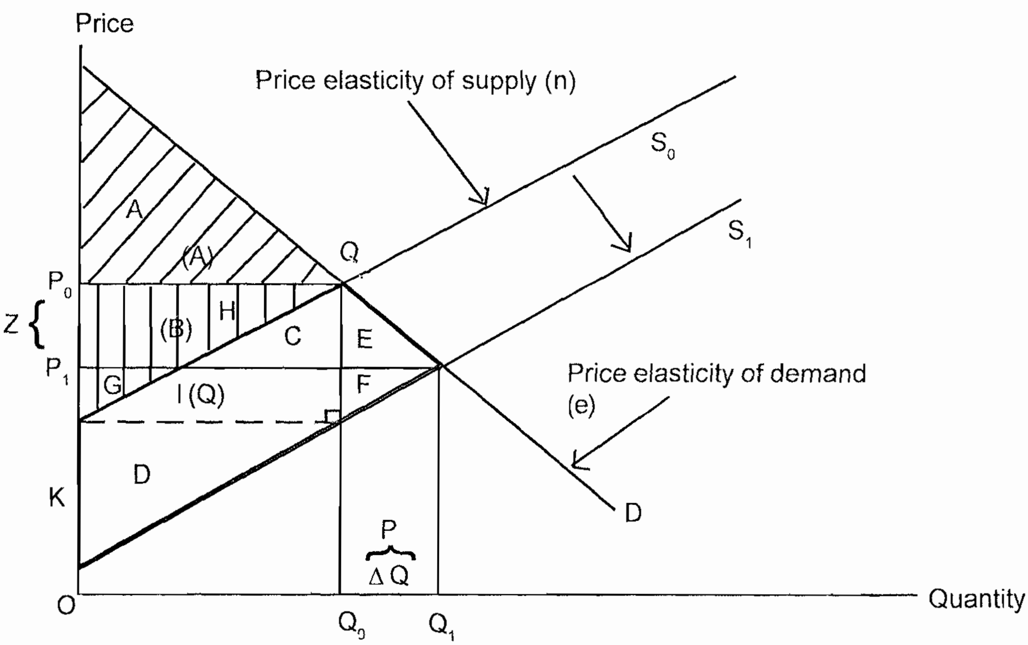
In this study, the concepts of producers and consumers economic surpluses which constitute social gains to the economy are used to derive the economic gains to the country arising out of cowpea research. The economic surplus method helps to specify the value of research by comparing the situations with and without it, and by turning agronomic data into economic values using the concepts of supply, demand and equilibrium conditions. By this method, a cash flow of benefits from research over costs spanning a specified period can be derived. The cash flow is used to compute the returns to investment and makes it more convincing for impact assessment than the linear programming and the Cobb-Douglas approaches, hence its choice for this study. According to Dupuit (1844) and Marshall (1930), the consumer surplus can be measured by the triangle-like area below the demand curve and above the price line. Similarly, since supply represents producers' production costs and price, producers' surplus could be defined as the difference in the price being paid for his product over the unit cost of producing it. The higher this difference, the bigger the economic surplus to the producers and is measured as the triangle-like area above the supply curve and below the price line.

These economic surpluses models have been used elsewhere by authors like Akino & Hayami (1974) and Masters (1996) . Whereas, the Akino & Hayami (1974) model uses the pivotal shift of supply curve due to productivity gains from research and is useful in *ex-ante* impact assessment, the Masters (1996) model uses the parallel shift of the supply curve, which is useful in *ex-post* impact assessment. Fig. 1 and 2 depict the concepts underlying the use of the parallel shift of the supply curve, which is the chosen model in this study. They depict social gains from research that employ the Dupuit-Marshallian concepts of social gains and costs. By this method, social returns to cowpea research in terms of changes in consumers and producers economic surpluses that result from the shift of the supply curve corresponding to a shift in its production function are evaluated.

When social gains are computed and extension costs for getting the improved technology to farmers are deducted, the mathematical model used to compute the returns to investment in cowpea agronomic research is given as:

$$Re = \sum_{t=1980}^{T=1996} \frac{(SG_t - C_t)}{(1+r)^t} = 0 \qquad (1)$$

for the period under consideration which is 1980-



1. Old consumers surplus is shaded area A. New consumers surplus is shaded area A + H + C + E.
Gains in sonsumers surplus ΔCS = (A + H + C + E) -A
= H + C + E
2. Old producer surplus is shaded area (B) = H + G. New producer surplus is G + I + F + D.
Gains in sonsumers surplus ΔPS = (G + I + F + D) - (H + G)
= I + F + D - H

$\Delta TS = \Delta CS + \Delta PS$ = Social Gain = (H + C + E) + (I + F + D - H)
= C + E + I + F + D = (C + I + D) + (E + F)
= KQ + 0.5 KΔQ

Fig. 1. Diagramatic presentation of the concept of social gains from research

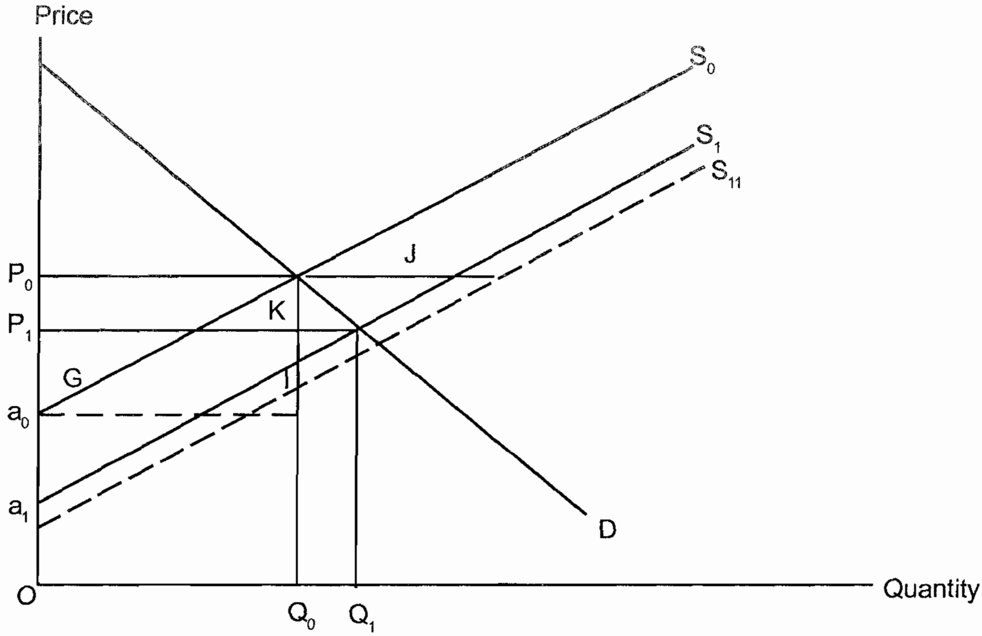


Fig. 2. Estimating supply shift using observed data

1996, and where Re is discounted cash flow at a rate such that the net present value (NPV) = 0

SG_t is social gain in year t.

T is terminal year under consideration.

C_t is research-extension costs on cowpea in year t.

r is discount rate that results in Re = 0.

When r which also is defined as the financial internal rate of return (IRR) for Re is found to be in excess of the opportunity cost of capital in Ghanaian agriculture, then the research effort can be said to have been worth its while and the null hypothesis will be rejected. From this model specification can also be evaluated, as well as the social gains in monetary terms, for the period under consideration.

Survey areas, sample farmers and survey procedure

Cowpea (*Vigna unguiculata* Walp.) is a semi-arid crop which thrives in the Guinea savanna agricultural zone in Ghana comprising the Northern, Upper East and Upper West regions, the transitional forest-savanna middle belt and the coastal savanna areas, where the rainfall is not as high as in the forest belt. Growing the crop in the high rainfall forest belt gives cowpea too much vegetative growth to the detriment of seed formation, making it uneconomical, except if a farmer can well time its cultivation during the minor rainy season (Rachie,1985).

With the help of cowpea research scientists and the Ministry of Food and Agriculture(MOFA) extension personnel advice, six prominent cowpea growing districts in Ghana were selected. The districts were Bawku, Wa/Tumu and Tolon-Kumbugu in the northern savanna zone. Ejura and Wenchi in the forest-savanna transitional zone, and Sogakope/Akatsi in the coastal savanna zone. The exercise had the purpose of getting a sample frame of cowpea farmers that was national in character and representation. From each district, eight cowpea farming villages were randomly selected, and in each selected village, five cowpea farmers were randomly selected. This gave an average of 40 farmers randomly selected per district and 240 farmers nationwide for interviewing with a structured questionnaire. The sampling procedure could, therefore, be classified as a stratified random sampling. The questionnaire sought answers on socio-economic and farm budget data for 1996. The year of the survey was 1997.

Model specification

Going by the concepts of producers and consumers surpluses, it is seen from Fig. 1 that total gains in economic surpluses $\Delta TS = K.Q + 0.5.K.\Delta Q$, where K is the supply shift parameter showing that research has enabled producers to supply the same quantity at the lower cost or to supply more quantity at same prices. Q is the prior to research equilibrium quantity and ΔQ is the addition to quantity as result of research. It can also be shown that consumers surplus $\Delta CS = Q.Z(1 + 0.5.Z.\eta)$, and producers surplus $\Delta PS = Q.(K-Z)(1 + 0.5.Z.\eta)$.

Re-assembling the equations, we have $\Delta CS = Q.Z(1 + 0.5.Z.\eta)$

$\Delta PS = Q.(K - Z)(1 + 0.5.Z.\eta)$

Total surplus $\Delta TS = \Delta CS + \Delta PS = Q.K(1 + 0.5.Z.\eta)$ = Social gains.

$= K.Q + O.5.K.Q.Z.\eta$

$= K.Q + O.5.K.\Delta Q$

where $\Delta Q = Q.Z\eta$, and $Z = K.\eta(\eta + \varepsilon)$ is the reduction in price relative to its initial pre-research value, due to the supply shift, η is the price elasticity of supply, ε is the price elasticity of demand, and $K = [J.P/\eta.Q] - I$.

$J = \Delta Y .t.A$ is production increase shift in supply as result of research.

$I = \Delta C.t/Y$ is the adoption costs as depicted in Fig. 2 whereby it has influenced the supply shift to be reduced from S_{11} to S_{1}.

P is observed market price for the crop; ΔC is adoption cost of the improved technology per hectare; t is adoption rate for the improved technology; Y is yield per hectare; ΔY is yield increase due to research; A is area under the crop.

Substitutions lead to

$\Delta Q = Q.\eta.\varepsilon.K(Q/P)/[(\eta + \varepsilon).(Q/P)]$

which in proportional terms simplifies to

$\Delta Q = Q.\eta.\varepsilon.k/(\eta + \varepsilon)$

where $k = K/P = [J.P/\eta.Q.P] - I/P$

$= (J/\eta) - c$,

where c is ratio of adoption cost and price.

Equation 1 can then be written as

$$Re = \sum_{t=1980}^{T=1996} \frac{[(k.Q + O.5.k.\Delta Q)_t - (R_c + E_c)_t]}{(1 + r)} = 0 \quad (2)$$

with k and ΔQ to be computed as given above and where R_c is costs attributable to cowpea research in the National Agricultural Research System and E_c is cost attributable to extension activities on improved cowpea cultivation.

Q and P were obtained through desk studies at the Ministry of Food and Agriculture and the Crops Research Institute (CRI). Y was obtained partly through desk studies and partly from the farmers survey. C was obtained from the survey farm budget data for 1996 with the consumer price index (CPI) used to calculate it for the other years. The adoption rate (t) figures were derived from the adoption level obtained from the farmers survey for the year 1996 which was used to construct an *f*-shaped logistic curve[1] and which gave the adoption rate and cumulative adoption level in a year under consideration. R_c were obtained from CSIR research activity databases and institutional budgets at the Crops Research Institute, the Savanna Agricultural Research Institute (SARI) and the Ghana Grains and Legumes Development Board (GGLDB) which

[1]The logistic curve was derived from the fomula $Y_t = K/(1 + e^{-a-bt})$ from which is derived $Log(Y_t /K - Y_t = a + b_t$, where Y_t is adoption rate in year t and K is maximum adoption rate considered feasible. The baseline adoption rate was assumed to be 10% and K assumed to be 70%.

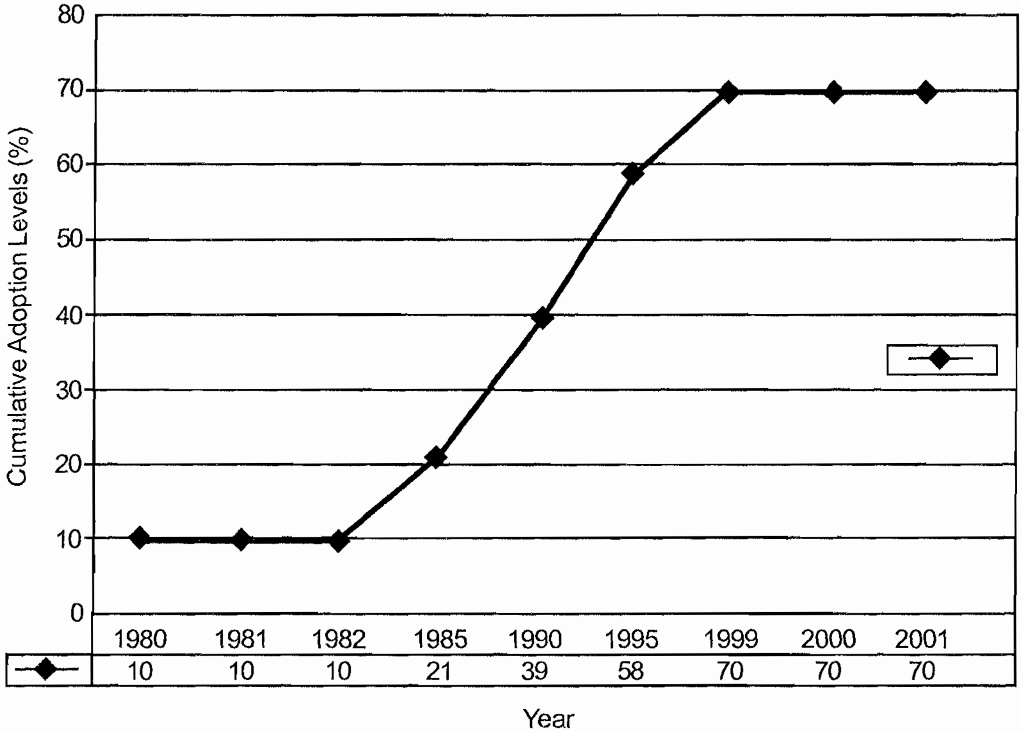


Fig. 3. Logistic curve for improved cowpea technology adoption rates

work on cowpea research and other agronomic aspects on it. E_c were obtained from the Department of Agricultural Extension budgetary allocations and the number of crops that they do extension work on, including cowpea. This allowed a share of the budgets to cowpea extension activities.

Derivation of price elasticities of supply(η) and demand (ε)

Of much importance in the computations for social gains from cowpea research were the price elasticities for the period under consideration (1980-1996). Time series data on production and price trends obtained from the Ministry of Food and Agriculture and Crops Research Institute were used in regression equations specified as:

$LnQc_t = a_0 + a_1 Ln(Pc_{t-1}/PI_{t-1}) + a_2 Ln(Pg_t/PI_t + a_3 RI_t + u_t$ for the supply equation.

$LnQc_t = b_0 + b_1 Ln(Pc_t/PI_t) + b_2 Ln(Pg_t/PI_t) + b_3 Ln(GDP_t/PI_t) + e_t$ for the demand equation;

where Qc_t is quantity of cowpea produced and consumed in year t; Pc_t is average market price of cowpea in year t; Pg_t is average market price of groundnut (competitive crop) in year t; PI_t is consumer price index in year t; RI_t is weather dummy in year t (1 for good weather, 0 for bad weather); GDP_t is national income(Gross Domestic Product) in year t; U_t and e_t are error terms.

Results

Four types of technology practices among the farmers were revealed:

- Use of improved seed + insecticide application (Full adopters)

- Use of improved seed without insecticide application (Partial adopters I)
- Use of local seed + insecticide application (Partial adopters II)
- Use of local seed without insecticide application (Zero adopters).

Gross margin analysis for the derivation of the annual social gains from cowpea agronomic research and extension is shown in Table1. Table 2 shows the distribution by district of the number of farmers who were full adopters and which were used to get the nationwide adoption rate in terms of numbers. Table 3 shows the adoption rates in terms of area under cultivation. Table 4 shows the adoption rates in terms of numbers for the various agro-ecological zones which the districts represent and their respective regional production figures. Table 5 shows adoption rates, relative yields and gross margin per hectare for the various technological practices.

Also used in the spreadsheet analysis are price elasticities of supply and demand which were found to be 1.16 and -0.35, respectively. Arising out of the spreadsheet analysis which showed that the IRR for cowpea agronomic research and extension was 58 per cent for the period 1980-1996, is a summary in Table 6 covering national cowpea production trends, full technology adoption levels and net benefits from cowpea agronomic research and technology transfer through extension. It is seen that in arriving at the IRR of 58 per cent, net social gains totalling ¢5,683 million accrued to the country.

Sensitivity analysis

From Table 4 it is seen that the transitional zone shows the highest levels of adoption. However, cowpea is predominantly grown in the northern savanna zone. The three northern savanna regions produced 78.8 per cent of the total output, with the Northern Region alone producing 44 per cent. It was, therefore, felt that the national average adoption level of 61per cent, in terms of area under cultivation, might have been overstated by the higher adoption levels in the

TABLE 1

Average Gross Margins per Hectare(Cedis) for the Various Technology Practices in 1996

Variable costs	*Full adopters*	*Partial adopters I*	*Partial adopters II*	*Zero adopters*
Seed	30142	30142	20065	20065
Insecticide	40832	0	40832	0
Land preparation	49470	49470	49470	49470
Labour input	174672	174672	174672	174672
Spraying cost	22670	0	22670	0
Total variable costs(TVC)	317786	254284	307709	244207
Yield(kg/ha)-(A)	852.5	482.5	585.0	502.5
Price(¢/kg)-(B)	750	750	715	715
Total Income/ha (A) * (B)	639375	361875	418275	359287
Gross margin per hectare:Total income minus TVC	321158	107591	110566	115080

*Full adopters enjoy both higher yields and higher price for their produce.

TABLE 2

Cowpea Improved Technology Full Adoption levels (Numbers) in 1996

District	*Number of farmers who adopted(n)*	*Total number of respondents (N)*	*Adoption rate (n/N × 100)= % adopting*
Bawku	4	41	10
Wa/Tumu	26	40	65
Tolon-Kumbugu	24	40	60
Wenchi	35	39	88
Ejura	33	36	91
Sogakope/Akatsi	6	40	15
Total	128	236	55

Source: Cowpea Farmers Survey (1996 crop year)

TABLE 3

Cowpea Improved Technology Adoption Levels in Terms of Areas under Cultivation for Different Practices in 1996

Technology level	*Area under the practice(ha)*	*Total area cultivated (%)*
Full adopters	118.4	61
Partial adopters I	4.2	2
Partial adopters II	25.0	13
Zero adopters	30.1	15
Other practices	18.2	9
Total	195.9	100

Source: Cowpea Farmers Survey (1996 crop year)

TABLE 4

Cowpea Full Technology Adoption Levels (Numbers) and Regional Cowpea Production in 1996

District	*Region representing*	*Agro-ecological zone*	*Adoption level(%) (a)*	*1996 Regional production (tonnes) (b)*
Bawku	Upper East	Northern savanna	10	10,772
Wa/Tumu	Upper West	"	65	18,500
Tolon - Kumbugu	Northern	"	60	37,972
Wenchi	Brong Ahafo	Forest savanna transition	88	7,000*
Ejura	Ashanti	"	91	5,000*
Sogakope/Akatsi	Volta	Coastal savanna	15	6,000*
Average/Total	-	-	55 (Average)	85,244 (Total)

Sources:
(a) Cowpea Farmers Survey
(b) PPMED, Ministry of Food and Agriculture, Accra
* Provisionally supplied by PPMED.

TABLE 5

Adoption Levels, Relative Yields and Income in 1996

Type of operation	*Numbers*	*Area*	*Yield kg/ha*	*Gross margin/ha*
Full adopters	55	61	852.5	C321,589
Partial adopters I	3	2	482.5	107,591
Partial adopters II	11	13	585.0	110,566
Zero adopters	23	15	502.5	115,080
Other practices	8	9	670.0	N/A
Total & Average	100	100	Average = 740	-
	N=236		Total area = 195.5 ha	

TABLE 6

National Cowpea Production, Full Technology Adoption and Net Benefits from Cowpea Research and Technology Transfer

Year	*Production (Tonnes)*	*Adoption level (t)**	*Total social gains (¢million)*	*Cost of research and extension (¢million)*	*Net benefits (¢million)*
1980	16,100	0.10	0.97	9.92	-8.95
1981	17,000	0.10	3.10	12.54	-9.44
1982	14,100	0.10	3.74	14.98	-11.24
1983	11,700	0.13	6.94	19.74	-12.80
1984	14,000	0.17	21. 37	24.59	-3.22
1985	11,000	0.21	28.97	32.06	-3.09
1986	19,500	0.24	75.07	43.70	31. 37
1987	23,500	0.28	106.44	55.77	50.67
1988	35,000	0.32	90.32	69.52	20.80
1989	51,000	0.35	232.55	88.10	144.45
1990	48,000	0.39	407.26	109.11	298.15
1991	52,000	0.43	321.13	132.58	188.55
1992	56,316	0.47	496.63	167.14	329.49
1993	60,990	0.50	626.91	178.40	448.51
1994	71,535	0.54	954.10	219.97	734.13
1995	74,472	0.58	1094.34	272.92	821.42
1996	85,244	0.61	801 35	387.49	413.86

* Obtained from Logistic curve shown in Fig. 3.

transitional zone, a lesser production area. It was, therefore, decided to weight the adoption levels with the respective output figures and the extent to which extension was reaching farmers in those zones. Weighting was done by the expression $(f_1x_1/\sum f_1x_1)*100$ to get the weighted adoption rate for the 1^{th} cowpea growing district; where f_1 representes the weighting factor for the original adoption rate x_1 of that district. Forty-eight per cent weighted adoption level for 1996 was arrived at after this exercise. This happened to be the weighted adoption level for the Northern Region, the biggest production area, which was used as a proxy adoption level for the country as a whole.

A logistic curve derived from this figure was used to re-compute the social gains from cowpea agronomic research and technology transfer. It gave an internal rate of return of 51per cent. In the process of achieving this return on investment, there were total social gains of ¢5,508 million as against total research and extension costs of ¢1,838 million with net gains of ¢3,670 million. Going further in the sensitivity analysis, the average weighted adoption level for the three northern savanna regions of 23 per cent was used. Here, the results indicated an internal rate of return of 19 per cent with total social gains of ¢2,171 million as against the same total cost of research and its transfer of ¢1,838 million. This gave net gains of some ¢333 million for the period under review. These computations have been based on the finding from the farm budget data that full technology adopters enjoyed average yield of 852 kg ha^{-1} as against a national average yield of 740 kg ha^{-1} from all the prevailing technology practices. This implies a marginal physical productivity (MPP) of 112 kg ha^{-1} of full adoption over the national average yield and an incremental yield of 15 per cent from full adoption. It is worth noting that national average yields have increased from 132 kg ha^{-1} in 1980 to 740 kg ha^{-1} in 1996, the survey year. The results of the sensitivity analysis is shown in Table 7.

Discussion

The high returns on investment and high pay-offs in monetary terms from cowpea agronomic research in Ghana for the period 1980-1996, when concerted research efforts and technology transfer activities on the crop have taken place, will lead to a rejection of the null hypothesis that research findings are not getting to farmers for the country to derive any economic benefits. This is so, at least, in the case of cowpea research. When the IRR of 58 per cent is compared to the opportunity cost of capital in Ghana's agriculture (the bank lending rate for agriculture) of 32 per cent, it makes agronomic cowpea research a highly profitable venture. Even the lower rate of IRR at 19 per cent, when a much lower rate of adoption was used in the sensitivity analysis will make it justifiable when it is compared to the opportunity cost of capital in the donor countries who have financed, to a large extent, the research effort. The opportunity cost of capital in the USA, for example, was about 5 per cent during 1982 - 1995 as given by its average government long term

TABLE 7

Summary of Sensitivity Analysis Using different Adoption levels

1996 Adoption level (%)	*Total social gains ¢million*	*Total cost of research and extension ¢million*	*Net social gains ¢million*	*IRR*
61	7,521	1,838	5,683	58%
48	5,508	1,838	3,670	51%
23	2,171	1,838	333	19%

bonds.

The study should, therefore, help to dispel the lukewarm attitude in official circles towards agricultural research in Ghana. There is, however, room for more intensification of research and technology transfer efforts, since even the average yield of full adopters in 1996 of 852 $kgha^{-1}$ is far from the optimum achievable yield of 1,500 kg ha^{-1} which has been achieved by the Crops Research Institute in on-farm trials. The study has also revealed that it is not good for cowpea farmers to be partial improved technology adopters. It is better to remain traditional, i.e. zero adopter than to be a partial adopter who either grows improved seed but fails to spray with insecticide or grow traditional seed and spray (Table 1). It is worth noting that there have been studies along these lines for maize and pineapple in recent times. These studies also showed good returns to research and technology transfer. For instance, the IRR of maize research under different scenarios ranged from 50 to 79 per cent (Dankyi, 1999). It is the hope that more of such studies will help boost the prospects of agricultural research in Ghana.

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