

**THE ECONOMIC IMPACT OF PUBLIC INVESTMENTS IN MAIZE
RESEARCH AND EXTENSION IN GHANA, 1979-97.**



BY



**A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL
ECONOMY AND FARM MANAGEMENT, UNIVERSITY OF GHANA, IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
DOCTOR OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS**

SEPTEMBER, 1999.



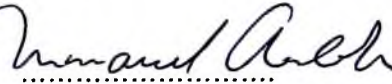
DECLARATION

I do hereby declare that, except for references cited which have been duly acknowledged, this work presented in this thesis was carried out by me as a student at the Department of Agricultural Economics, University of Ghana, Legon. This work has never been presented anywhere either in part or whole for the award of any degree.

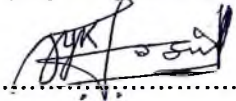


.....
Awere Ansong Dankyi
(Student)

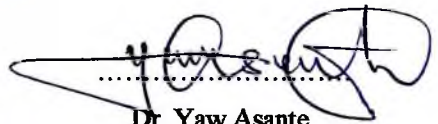
This work has been submitted for examination with our approval as supervisors.



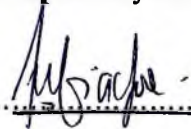
.....
Dr. E. Kweku Andah
Agricultural Economics Department
(Major Supervisor)



.....
K. Yerfi Fosu
Agricultural Economics Department
(Member of Supervisory Committee)



.....
Dr. Yaw Asante
Economics Department
(Member of Supervisory Committee)



.....
Dr. Felix Y.M. Fiadjoe
Agricultural Extension Department
(Member of Supervisory Committee)

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	vii
LIST OF FIGURES.....	x
LIST OF ACRONYMS.....	xi
ACKNOWLEDGMENTS.....	xiii
ABSTRACT.....	xiv
 CHAPTER:	
1 INTRODUCTION.....	1
The Problem.....	5
Objectives of the Study.....	7
Justification of the Study.....	9
Limitations of the Study.....	10
Organisation of the Study.....	11
2 LITERATURE REVIEW.....	12
Impact Assessment.....	12
Impact Assessment Methods.....	12
The Economic Surplus Method of Ex-post Evaluation.....	15
Role of Economic Policy on Returns to Agricultural Research.....	20
Adoption and Diffusion.....	22
Determinants of Adoption.....	24
Chapter Summary.....	26
3 MAIZE TECHNOLOGY DEVELOPMENT IN GHANA.....	28
Agricultural Research in Ghana.....	28
The Ghana Grains Development Project.....	29
Other Collaborating Institutions.....	31
Maize Varieties.....	34
Planting Densities.....	40
Row Planting.....	41
Fertilizer Application.....	42
The Maize Recommendations.....	44
Chapter Summary.....	45
4 THE PRODUCTION ENVIRONMENT.....	46
Ecological Zones.....	46
Rainfall.....	48
Inputs.....	51
Seed Production and Distribution.....	51
Fertilizer.....	54
Marketing and Distribution.....	55
Trends in Fertilizer Imports.....	55
Trends in Fertilizer Prices.....	57
Fertilizer and Maize Prices.....	58

CHAPTER	Page
Chapter Summary.....	61
5 RESEARCH METHODOLOGY.....	62
Data Collection Activities.....	62
The Survey Instrument.....	66
Economics of Maize Production.....	66
Determinants of Adoption of Improved Maize.....	66
Returns to Investment.....	67
Key Assumptions and Critical Parameters.....	71
Baseline Scenario.....	71
Alternative Scenarios.....	73
Scenario 2 (higher research cost).....	73
Scenario 3 (higher extension cost).....	74
Scenario 4 (higher research cost and higher extension cost).....	74
Scenario 5 (lower projected research benefits).....	74
Chapter Summary.....	75
6 THE ADOPTION OF MAIZE TECHNOLOGIES IN GHANA.....	76
Demographic Characteristics of the Farmers.....	76
Adoption of Maize Technologies.....	77
Explaining Adoption.....	89
Extension and Farmers.....	89
Characteristics of Farmers.....	91
Other Factors Associated with the use of Improved Maize Technologies.....	92
Improved Variety.....	92
Row Planting.....	93
Fertilizer.....	94
Maize Utilisation and Storage.....	96
Gender.....	98
Decision-making in Maize Farming Activities.....	99
Impacts of Improved Maize Technologies.....	100
Incomes of Farmers.....	101
Nutrition.....	103
Gender Effects.....	104
Productivity.....	104
Factors Explaining the Adoption Pattern between the Ecological Zones.....	107
Population.....	108
Cropping Intensity.....	109
Markets and Commercial Orientation.....	112
Economics of Maize Technology.....	112
Risks.....	115
Marginal Rate of Return to Maize technology as a Package.....	118

CHAPTER	Page
Logistic Regression Analysis.....	122
TOBIT Analysis.....	126
Chapter Summary.....	129
7 RETURNS TO INVESTMENTS MAIZE RESEARCH AND EXTENSION	130
Scenario 1 (Baseline).....	131
Scenario 2 (higher research cost).....	137
Scenario 3 (higher extension cost).....	138
Scenario 4 (higher research cost and higher extension cost).....	138
Scenario 5 (lower projected research benefits).....	139
Chapter Summary.....	139
8 POLICY IMPLICATIONS AND CONCLUSIONS.....	140
Policy Implications.....	140
Research Policy Issues.....	140
Extension Policy Issues.....	145
Input Policy Issues.....	146
Concluding Remarks.....	147
BIBLIOGRAPHY.....	149
APPENDIX 1: Maize Survey Questionnaire.....	155
2: Theoretical Model for Measuring Net Social Gains.....	168
3: Empirical Parameter Estimates.....	175
4: Derivation of Key Formulae for Net Social Gains and internal Rate of Return.....	184
5: The Logistic Regression and the TOBIT Model.....	195
6: Logistic Growth Curve.....	200
7: Financial Rate of Return (Baseline scenario).....	206
8: Economic Rate of Return (Baseline scenario).....	215
9: Financial Rate of Return with Higher Research Cost.....	224
10: Economic Rate of Return with Higher Research Cost.....	232
11: Financial Rate of Return with Higher Extension Cost.....	240
12: Economic Rate of Return with Higher Extension Cost.....	248
13: Financial Rate of Return with Higher Research and Higher Extension Cost.....	257
14: Economic Rate of Return with Higher Research and Higher Extension Cost.....	265
15: Financial Rate of Return with Lower Projected Research Benefits.....	273
16: Economic Rate of Return with Lower Projected Research Benefits.....	281
17: Area Planted to Specific Improved Maize Varieties in the Ecological Zones of Ghana.....	290

APPENDIX 18: Principal Month for Selling Maize in the Ecological Zones of Ghana..... 291

LIST OF TABLES

Table:	Page
1.1 The Use of Improved Varieties over the Years.....	3
1.2 Comparison of Counterpart Funds Requested and Released in Ghana for Agricultural Research, 1992 to 1996 (in '000 cedis).....	6
1.3 Number of Ghanaian Researchers and Person Years in Commodity Research, 1988.....	10
3.1 Maize Varieties Developed and Released by CRI, 1954-1996.....	32
3.2 The Sources of Released Maize Varieties in Ghana, 1979-1996.....	33
3.3 Average Grain Yield of Full Season Maize Varieties, 1979-84 (in t/ha).....	35
3.4 Average Grain Yield of Maize Varieties, 1981-84 (in t/ha).....	36
3.5 Average Grain Yield of Early Maturing Maize Varieties, 1983-86 (in t/ha).....	36
3.6 Streak resistance levels of some selected varieties.....	37
3.7 Grain Yield of Selected Medium Maturing Maize Varieties (in t/ha).....	38
3.8 Protein and Tryptophan Contents of Obatanpa and Okomasa.....	38
3.9 Grain Yield and other Parameters of Selected Maize Varieties (in t/ha).....	39
3.10 Grain Yield of Local and Improved Maize Varieties (in t/ha).....	40
3.11 Grain Yield of Maize Varieties under Different Densities (t/ha).....	40
3.12 Selected Characters for La posta at Three Densities in Ghana.....	41
3.13 Effect of Time, Placement and Type of Fertilizer on Maize Yield (in t/ha).....	43
3.14 Maize Grain Yield from Farmer-Managed Fertilizer Trials (in t/ha).....	44
3.15 Demonstrated Technological Options for Maize Production in Ghana.....	45
4.1 Comparison of Mean Monthly Rainfall for 1967-1978 and 1979-1880 Periods for some Selected Districts in Ghana.....	50
4.2 Improved maize seed growers and dealers in Ghana since 1990.....	52
4.3 Certified Seed Sales in Ghana (in mt).....	53
4.4 Fertilizer Imports since 1970 (in mt).....	56
4.5 Nominal Fertilizer Prices and Subsidy Rates in Ghana.....	57
4.6 Fertilizer Prices and Subsidies.....	59
5.1 Sampling Procedure for Maize Technology Survey in Ghana.....	63
5.2 Location of Survey Districts.....	64
5.3 Exchange Rates, 1979 to 1997.....	70
5.4 Research and Extension Cost Scenarios.....	75
6.1 Demographic Characteristics of Maize Farmers, Ghana.....	76
6.2 Access to Infrastructure by Survey Household.....	77
6.3 Adoption of Maize Technologies in Ghana, 1997.....	78
6.4 Farmers Stopping Maize Technology Use.....	78
6.5 Proportion of Area under Maize Technology Adoption.....	79
6.6 Area Planted to Specific Maize Varieties.....	80
6.7 Interaction among Maize Technologies in Ghana, 1997.....	80

Table	Page
6.8 Adoption of Improved Varieties in the Political Regions of Ghana.....	81
6.9 Adoption of Row Planting in the Political Regions of Ghana.....	84
6.10 Adoption of Fertilizer in the Political Regions of Ghana.....	84
6.11 Extension Contacts of Adopters and Non-Adopters of Maize Technologies	90
6.12 Level of Education of Farmer and Adoption of Maize Technologies.....	92
6.13 Farmers' Age and Adoption of Improved maize technologies.....	92
6.14 Factors Associated with Improved Varieties.....	93
6.15 Factors Associated with Adoption of Row Planting.....	93
6.16 Factors Associated with Fertilizer Adoption.....	95
6.17 Household Source of Income from Maize.....	97
6.18 Principal Month for Selling Maize.....	97
6.19 Maize Technology Adoption among Male and Female Farmers.....	98
6.20 Male and Female Adopters of Improved Maize Technology.....	99
6.21 Gender and Decision-Making on Maize Farming Activities.....	100
6.22 Use of Increased Income from Maize.....	103
6.23 Descriptive Statistics of Farmers' Estimates of Maize Harvests (in maxibags).....	106
6.24 Estimated Yield Increase Attributable to Improved Varieties and Fertilizer.....	106
6.25 Farmers' Formal Education Level and Household Size.....	109
6.26 Years of Continuous Maize Cropping of Major Maize Field.....	110
6.27 Average Fallow Periods.....	111
6.28 Economic Indices for Estimating Marginal Rate of Return to Maize Technologies.....	113
6.29 Marginal Return Analysis of Adoption of Improved Maize in the Ecological Zones.....	114
6.30 Effect of Yield Reduction in Improved Maize on the Marginal Rate of Return (%).....	116
6.31 Effect of Lower Maize Grain Price on the Marginal Rate of return on Improved Maize (%).....	116
6.32 Marginal Return Analysis On the Adoption of Fertilizer on Maize Production in the Ecological Zones.....	117
6.33 Effect of Yield Reduction and Increase in Fertilizer Price on the Marginal Rate of Return (%).....	118
6.34 Marginal Rate of Return to Adopting Improved Maize, Fertilizer and Row Planting as a Package.....	120
6.35 Changes in Yields on Marginal Rate of Return to Improved Maize Technology (%).....	121
6.36 Marginal Rate of Return to Changes in the Price of Maize (%).....	122
6.37 Definitions of Variables in the Logistic Model.....	123
6.38 Classification Table for MVUSER.....	123
6.39 Indicator Variables for Factors of Adoption of Improved Maize Varieties in Ghana.....	125

Table:		Page
6.40	Correlation Matrix of Variables in the Logistic Model.....	125
6.41	Definitions of the Variables in the TOBIT Model.....	126
6.42	Estimated Results of Factors Affecting Area under Improved Maize Production using Farmer, Farm Specific Variables and Ecological Zones, Ghana.....	127
6.43	TOBIT Marginal Effect for Factors of Maize Technology Adoption.....	128
7.1	Key Indicators Used in Calculating Internal Rate of Return.....	130
7.2	Financial and Economic Rate of Return to Maize Research in Ghana.....	131
7.3	Social Gains and Financial Rate of Return.....	133
7.4	Economic and Financial Net Social Gains.....	135

LIST OF FIGURES

Figure:	Page
1.1 Maize production indicators, Ghana, 1975-1997.....	5
2.1 Economic Surplus with Linear Demand and Supply Curves.....	17
2.2 Benefit-Cost Approach.....	18
2.3 Akino-Hayami Approach.....	19
4.1 Ecological Zones of Ghana.....	47
4.2 Nitrogen-to-Maize Price Ratio, Ghana (1979-1997).....	59
4.3 Kilograms of Ammonium Sulphate that 1kg of Maize can buy (1970-1996).....	60
5.1 Location of Survey Districts, Ghana Maize Technology Adoption Study...	65
5.2 Consumer and Producer Surplus.....	68
6.1 Regional and District Boundaries Showing Adoption Rates for Improved Maize Varieties in the Regions (%).....	83
6.2 Regional and District Boundaries Showing Adoption Rates for Row planting in the Regions (%).....	85
6.3 Regional and District Boundaries Showing Adoption Rates for Fertilizer in the Regions (%).....	86
6.4 First Year Farmer Used Improved Varieties.....	88
6.5 First Year Farmer Used Fertilizer.....	88
6.6 First Year Farmer Planted Maize in Rows.....	89
6.7 Source of Improved Seed in 1997 and in Previous Years.....	91
6.8 Percent of Farmers Indicating Maize as a First Source of Income.....	96
6.9 Percent of Farmers with Increases in Maize Production Indicators.....	102
7.1 Real (Farmgate) Domestic and World of Maize	136
A2.1 Shift and Movement in Production Functions.....	171
A2.2 Production Increases, Supply Shift and Input Expenditure.....	173
A6.1 Logistic Regression.....	204
A6.2 Logistic Growth Curve.....	205

ABBREVIATIONS AND ACRONYMS

CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Centre
CN\$	Canadian dollar
CPI	Consumer price index
CRI	Crops Research Institute
CSIR	Council for Scientific and Industrial Research
EA	Enumeration area
FOB	Freight on Board
GGDP	Ghana Grains Development Project
GLDB	Grains and Legumes Development Board
GSIU	Ghana Seed Inspection Unit
IFAD	International Fund for Agricultural Development
ITA	International Institute for Tropical Agriculture
IRR	Internal Rate of Return
ISNAR	International Service for National Agricultural Research
MOFA	Ministry of Food and Agriculture
MRR	Marginal rate of return
NARP	National Agricultural Research Project
NARS	National Agricultural Research Systems
NGO	Non-governmental organization
NS	Not significant
NSS	National Seed Service

ODI	Overseas Development Institute
OFY	Operation Feed Yourself
OFYI	Operation Feed Your Industry
PPMED	Policy, Planning, Monitoring and Evaluation Division
RER	Real exchange rate
SARI	Savannah Agricultural Research Institute
SG 2000	Sasakawa Global 2000
US	United States of America
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

ACKNOWLEDGMENTS

Many people have helped in the development of this research. My major supervisor, Dr. E. Kweku Andah, deserves special recognition for his untiring guidance from the initial stage through several painful editing to the final copy. I thank my other members of the thesis committee: K. Yerfi Fosu, Dr. Yaw Asante and Dr. Felix Y. M. Fiadjoe for their immense suggestions and time spent on the thesis. I owe a gratitude to Dr. (Mrs.) Ramatu Al-hassan for suggestions at the initial stage of my research. I likewise wish to make mention of Akwasi Mensah-Bonsu, a teaching assistant of the Department for reading through some of the drafts and making useful comments.

I am very grateful to Dr. Michael L. Morris of CIMMYT, Mexico, who was very instrumental in obtaining funding for my visit to CIMMYT as a visiting scientist and for his numerous suggestions and brotherly reception. I also thank the staff of CIMMYT Economics Program especially Dr. Prabhu Pingali, the Director, for hosting me.

My appreciation is due to E. A. Addison, former Director of the Crops Research Institute for nominating me for the National Agricultural Research Project (NARP) award. My research would not have been possible without the financial support from the NARP. I thank all the staff of the NARP secretariat.

I am thankful to Professor John H. Sanders and Dr. Ahmed Mohamed for their suggestions and for playing host to me at Purdue University, USA. To the staff of the Department of Agricultural Economics, Purdue University, I am grateful for their moral support.

For many others whose names I cannot mention, I say thank you very much. Finally, special acknowledgment needs be given to my family for their patience and moral support.

ABSTRACT

Dankyi, Awere Ansong. PhD., University of Ghana. June 1999. **The Economic Impact of Public Investments in Maize Research and Extension in Ghana, 1979-97.**

Major Supervisor: E. Kweku Andah

Maize is the most important cereal in Ghana grown by some 1.74 million households and contributing 67 billion cedis or 14 million dollars to Ghana as at the 1991-92 crop season. Maize is eaten in various forms in most homes. In the late seventies, maize production declined. The Ghana Grains Development Project was established in 1979 to provide research and extension services for maize production in Ghana. Since the inception of the project, maize production has been increasing. These increases in the past two decades have been attributed to the availability and adoption of GGDP-generated improved maize technologies. This study measures the degree to which maize recommendations are taken up by farmers and determines the factors driving the adoption process. It assesses the economics of maize recommendations and analyzes the returns to public investments in Ghana's research and extension activities for maize between 1979 and 1997. The study also makes suggestions for future maize research and extension work in Ghana. It is observed that fifty-four percent of the total area under maize production is cultivated to improved maize varieties and 55 percent of the area is row planted with maize. Only 26 percent of the area are fertilized. Furthermore, the main factors driving adoption of improved varieties are extension contact, farming maize in the coastal savannah zone, transition zone, Guinea Savannah zone, gender and total maize area planted. The financial rate of return on investment in maize research and extension is estimated between 50 and 79 percent and the economic rate of return is 25 to 33 percent. This is a clear indication that maize research and extension activities between 1979 and 1997 have been profitable and have contributed to national food security. This has a number of policy implications for research, extension, input delivery system, agricultural policy makers and donors. Funding, germplasm improvement, crop management recommendations, need for speeding up fertilizer technology dissemination and efficient input supply systems are some of the policy issues needing attention.

CHAPTER 1

INTRODUCTION

Background

Agriculture is the largest and most important sector in the Ghanaian economy. The rate of economic development is closely associated with the performance of the agricultural sector. Agriculture, including forestry, accounts for about 55% of the Gross Domestic Product (GDP) and also employs about 59% of the labour force.¹ The main activity in the rural areas is agriculture and about 70% of the population live in these areas. Poverty is basically a rural phenomenon and about 84% of the National hard-core poverty in the country in 1988 were from the rural areas². Therefore what affects the rural folks has a direct impact on agriculture and consequently on the economy as a whole. Any improvement in agriculture is also likely to improve the welfare of the majority of the rural folks in particular and the whole population in general.

The role of agricultural research in many countries such as Pakistan, Nepal and Japan has been well documented.³ These studies have shown that there are high rates of return to agricultural research investments. By 1997 there were a few of such studies in

¹ Asenso Okyere, W., F.A Asante, L. Oware Gyekye. "Case Studies on Rural Poverty Alleviation in the Commonwealth. Ghana." Food Production and Rural Development Division. Commonwealth Secretariat, London. (1992) pp 1-3.

² Boateng, E.O., K. Ewusi, R. Kanbur, A. McKay. "A Poverty Profile for Ghana, 1987-1988. Social Dimensions of Adjustment in Sub-Sahara Africa". Working Paper No.5. The World Bank, Washington D. C. (1990).

³ Byerlee, D., and P. Moya. "Impacts of International Wheat Breeding Research in the Developing World, 1966-90". Mexico D.F.: CIMMYT. (1993) pp 11-50.

Morris, M.L., H.J. Dubin and T. Pokhred. "Returns to Wheat Research in Nepal". CIMMYT Economics Working Paper 92-04. Mexico, D.F.: CIMMYT. (1992) pp 15-31

Akino Masakatsu and Yujiro Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development" American Journal of Agricultural Economics, vol.57. (1975) pp 1-10.



Africa⁴. The results of the 34 recent studies measuring the impact of agricultural research in Africa indicate that about 70% of these studies estimated a rate of return of more than 20% per year. These high rates of return indicate substantial contribution of agricultural research to national income and economic growth, thus justifying further investments in research in this area.

The Ghana Grains Development Project (GGDP) of the Crops Research Institute (CRI) has been in existence since 1979. Through a systematic research process it has developed improved maize, cowpea and soybean varieties and disseminated recommendations for growing these crops in the country.

Before 1979, some of the improved maize varieties available were the Composites, Diacol 153 and La posta. After 1979, several improved varieties were developed and made available to farmers throughout Ghana.

The performance of the developed improved varieties in on-farm trials was better than the older or local materials. For example, over the 1979-85 period, the average yield of La posta, CRI an improved variety, was 4.3 tons/ha as against a local variety yield of 2.3 tons/ha in the same period - nearly a 100% yield increase⁵ (GGDP Annual Reports 1979-85).

Given the sizeable yield gains and favourable production environment, it is not surprising that there is a dramatic increase in maize production and higher incomes for farmers who have adopted the technology.⁶

⁴ Oehmke, James F., and Eric Crawford. "The Impact of Agricultural Technology in Sub-Saharan Africa: A Synthesis of Symposium Findings". MSU International Paper No. 14. East Lansing: Department of Agricultural Economics, Michigan State University. (1993) pp 2-12 ; Masters W.A., Touba Bedingar and James F. Oehmke. "The Impact of Agricultural Research in Africa: Aggregate and Case Study Evidence". Paper presented at the 23rd International Conference of Agricultural Economists. August 10-16, 1997, Sacramento, California. (1997). Whole Document.

⁵ Estimated by the author from data in various GGDP Annual Reports, 1979 to 1985.

⁶ Dankyi, A.A., V.M. Anchirinah, A.O. Apau. " Profitability and Impact of Extension Test Plot on Maize Production in Ghana". GGDP/SG2000/DAES Collaboration. GGDP Mimeo. (1995) pp 21-29.

Farmers are generally cautious in using recommendations and they normally will test them gradually. This is a "step-wise" adoption or partial adoption. Farmers will continue to use them once the recommendations are appropriate. A 1987 survey⁷ presented in Table 1.1 reveals that a smaller proportion of farmers (44%) who were introduced to improved varieties in 1986 used them whereas for those introduced earlier (1982), a higher percentage (76%) continued to use the improved varieties. This suggests that when a new variety is introduced to farmers, the rate of use of the variety increases over time leading to possible increases in production.

Table 1.1: The Use of Improved Varieties in Ghana over the Years

First year to use improved varieties	Farmers who plant at least half their maize area to improved varieties (%)
1986	44
1985	60
1984	69
1983	75
1982 or earlier	76

Source: Tripp R. *et al.* GGDP 1987, p.18.

A number of surveys conducted by GGDP have shown high rates of adoption of maize recommendations. For example, in 1984, the adoption rate of improved varieties in the transition ecology zone was 53%. In 1986, the adoption in the same zone was 81%⁸.

In Ghana, the amount of money released by the government to finance agricultural research always falls short of the amount requested. For example, between 1993 and 1996, only 12-48% of the counterpart funds requested for agricultural research was released. Nevertheless, the potential high yields of improved varieties among others

⁷ Tripp, R., K. Marfo, A.A. Dankyi, and M. Read. "Changing Maize Production Practices of Small-scale Farmers in the Brong-Ahafo Region, Ghana. Kumasi: Ghana Grains Development Project. (1987) pp 17-19.

⁸ Tripp R., K. Marfo, A.A. Dankyi and M. Read. *Op. Cit* pp 17-19.

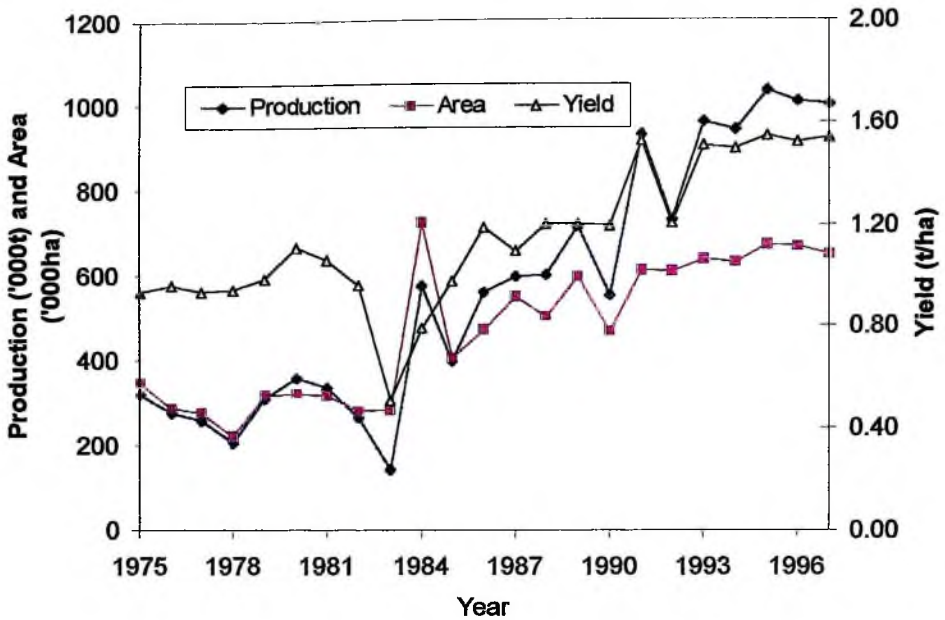
ensured a steady flow of resources to maize research from the Governments of Canada and Ghana. Since limited resources are used to support research in agriculture, it is necessary to show evidence of the returns to public investments in maize research in Ghana to attract more funds. Therefore, it is important to establish whether past maize research has paid off, and whether this pay-off is sustainable

Maize is the most important cereal crop in Ghana. It is grown throughout the country, except in a small portion of the North-eastern part characterised by harsh climatic conditions and rocky soils. Although official production statistics on maize are less accurate than desired, general trends can be established in the pattern of maize production in Ghana (Figure 1.1). Following an extended decline, the area planted to maize and maize yields began to increase in mid-1980s. From 1975 to 1997, maize area grew at an average rate of 2.9% per year, while maize yields grew at an average rate of 2.3% per year. This increase in area planted and yields fuelled overall growth in maize production of 5.3% per year over the same period⁹.

The data for 1983 and 1984 (Figure 1.1) are drastically different from the others. In 1983, there was drought coupled with bush-fires causing low yields and production. In the following year (1984), the area under maize production shot up because there were enough rains, vast bare lands due to bush-fires and jobless Ghanaian deportees from Nigeria who took to farming.

⁹ Estimated by the author.

Figure 1.1: Maize Production Indicators, Ghana, 1975-1997



Source: Compiled and estimated by the author based on data from PPMED, MOFA, Accra, Ghana.

The Problem

Agricultural research in Ghana has sometimes suffered a great deal of embarrassment from some policy makers. Some political-headed institutions in the sixties "publicly declared agricultural research as a waste of time and money, an irrelevant and unproductive activity associated with men who were only competent to talk and write about food but could not produce it themselves"¹⁰. This was probably because there was no study to show the returns to research and there was a communication gap between researchers and decision-makers. A recent study in Ghana on returns to maize research

¹⁰ La-Anyane, S. "Research in Agriculture in Relation to National Economic Development". CSIR/Universities/U.S., Academy of Sciences Workshop, January 18, 1971 pp 1-17.

investment indicated that the internal rate of return to maize research between 1968 and 1991 was 74%¹¹.

Bilateral grants and loans have contributed significantly towards research funding. However, in view of the usual excuse of financial constraints facing the Central Government, the operating budget per scientist has been on the decline. In Ghana, the amount of money actually released to finance agricultural research always falls short of the amount requested. In Table 1.2, the counterpart funds requested and released for agricultural research are compared. Apart from 1992 when about 78% of the request was met, less than 50% of the budget request have been provided since 1993.

Table 1.2: Comparison of Counterpart Funds Requested and Released in Ghana for Agricultural Research, 1992 to 1996 (in '000 cedis).

Year	Budget Requested	Budget Released	% Released
1992	129000	100000	78
1993	845900	100000	12
1994	753500	200000	27
1995	984900	244100	25
1996	1500000	724000	48

Source: World Bank (Aide-Memoire), 1997. pp.9-10.

¹¹ Sanders John H., Taye Bezuneh, and Alan C. Schroeder. (1994). " Impact Assessment of the SAFGRAD Commodity Networks." USAID/AFR/OAU/STRC-SAFGRAD. pp. 1-28.

In recent times, the demand for assessing agricultural research impact has been growing. Some of the reasons for high demand for agricultural research impact assessment are:

1. The steady decline in public and donor funds for agricultural research.
2. Increased pressure for accountability of research funds and better management of agricultural research.
3. Competing demands for available funds.
4. Increased request for evidence of accomplishments and people level impact from such research activities.
5. The shift to market-driven research.

There is the need to continuously provide information on the returns to investments in agricultural research for donors, policy makers and research managers, to justify demand for increases in budget allocations to agricultural research.

Research Questions:

The important questions that therefore, arise are as follows: What is the adoption rate of maize technology in Ghana? What are the factors driving the maize adoption process in Ghana? What pay-off have investments in maize research and extension made on the Ghanaian society? These are the issues that the present study addresses.

Objectives of the Study

The benefits of farmers adopting a new technology are often ascribed to research investments only, with the implicit assumption that related investments of institutions are kept constant. Therefore it is necessary that in evaluating a research programme,

information is provided on the role and sequencing of investments in complementary institutions to avoid over estimation of a particular investment.

To disaggregate the impacts of complementary investments requires other quantitative methods that will demand high quality time series. Unfortunately, such data is not available in Ghana. The general objective of the study therefore, is to determine the economic impact of public investments in maize research and extension in Ghana associated with the GGDP from 1979 to 1997.

The specific objectives of the research are:

1. To describe the biophysical, socio-economic, organisational and policy environment of maize production in Ghana.
2. To determine the factors associated with the adoption of improved maize varieties.
3. To estimate the economic returns to past public investments in maize research and extension in Ghana from 1979 to 1997.
4. To make policy recommendations for improving efficiency of future maize research.

In order to achieve these specific objectives, the study describes and analyses the production environment in Ghana, traces the development of maize research, and measures the pattern and intensity of adoption of improved maize technologies between 1979 and 1997.

Justification of the Study

As indicated earlier, only one detailed study of returns to research in Ghana has been carried out. Donors¹² are eager to find out the rate of return to their investment in maize research and the impact of that on the Ghanaian economy.

Maize has been chosen as the focus for this study for two main reasons. First, maize is Ghana's leading cereal crop and is grown by a large number of rural households. The economic importance of maize in Ghana cannot be overemphasized. During the 1991-92 cropping season, out of two million households engaged in harvesting staple grains and cash crops, 1.74 million grew maize.¹³ In that same period, the value of maize crop totaled approximately 61 billion cedis, or about US \$ 14 million at the prevailing exchange rate. Since research-induced productivity gains in maize are translated directly into increased income for millions of producers and consumers, it is important to know whether maize research and extension efforts are producing tangible benefits. Second, in recent years maize has commanded a large share of Ghana's limited agricultural research resources. The Ghanaian Council for Scientific and Industrial Research (CSIR) and the International Service for National Agricultural Research (ISNAR) have reported that there were many more researchers working on maize than on any crop in the early 1990s in Ghana¹⁴ Table 1.3 shows that there are many more researchers in maize than in cassava or rice. The number of researchers in maize development is more than five times that of rice research and three times that of cassava research. Time spent on maize research by researchers is about ten times that of rice researchers and about six times that of cassava researchers.

¹² Like the Canadian Development Agency (CIDA) and the National Agricultural Research Project (NARP).

¹³ Ghana Statistical Service. Ghana Living Standards Survey 3. 1995. pp. 67-68.

¹⁴ CSIR and ISNAR. "Review of the Ghana Agricultural System". Vol. 1: Report. The Hague: ISNAR. 1991. pp 54-57.

Table 1.3: Number of Ghanaian Researchers and Person Years in Commodity Research, in Ghana, 1988.

Commodity	No. of researchers involved	Person years
Maize	32	10.9
Cassava	10	1.8
Rice	6	1.1

Source: CSIR and ISNAR. Vol.1, 1991, p.55.

The period 1979-1997 was chosen because it is associated with a specific research and extension project. The Ghana Grains Development Project (GGDP), a Canadian International Development Agency (CIDA) funded project, has provided significant support for developing and disseminating the maize technologies between 1979 and 1997. Thus, it is important to establish what impact the level of investment in maize research and extension have achieved so far.

Limitations of the study

As will be noted, a large number of varieties and agronomic recommendations were released by the GGDP between 1984 and 1997 for various ecological zones. Ideally, one should have identified the costs and benefits of each of the recommendations to measure the aggregate net social gains to society. Given the number of technologies developed, the long period of time and poor data availability particularly at the farmer level, it is practically impossible to obtain data on costs and benefits accruing to farmers. The study therefore, combines the range of technologies and estimates the rate of return.

The impact of maize research and extension in Ghana might be more than the estimated internal rate of return (IRR) if other benefits such as nutritional benefits are captured. These are however given qualitative descriptions. Furthermore, several maize technology experiments were conducted in farmers' fields in the research phase of the Project (1979-1983). Hence, actual adoption of the technologies might start earlier than the assumed year (1984) and this will have a positive effect on the IRR.

Research and extension costs and yield gains can affect the outcome of the IRR and since these, in some cases, are estimated, the issue is overcome with sensitivity analysis.

The study realises that unless the effect of the improved technologies at the farm level are monitored and evaluated continuously, it is difficult to obtain reliable estimates for the IRR. The study therefore uses conservative estimates for the assessment of the benefits.

Although it would have been more revealing to ascertain farmers' perception of the risks of the technologies relative to the traditional ones, this was not done because data on this was unavailable. Furthermore, the link between profitability and risk of technologies on one hand and, adoption has not been established for lack of data.

Organisation of the Study

The rest of the study is organised into eight chapters. Chapter Two reviews the literature on research impact. In Chapter Three, maize technology development in Ghana is discussed. This chapter traces the history of agricultural research in Ghana and describes the institutions that have collaborated in the development of maize technology in Ghana. The chapter further looks at how the maize technology was developed from 1979 to 1997, the period under study. It thus reviews the breeding and agronomic experiments underlying the release of varieties and production recommendations. This is to show that a real maize research has occurred; it also shows biological scientists' perceptions of research impact. The Fourth Chapter discusses the production environment and the Fifth Chapter focuses on the methodology of the study. The research results on maize adoption and the determinants of adoption are given in Chapter Six. Chapter Seven presents the results of the returns to maize research, and Chapter Eight summarises the study and its policy implications. Technical details are included in the appendices.

CHAPTER 2

LITERATURE REVIEW

Impact assessment.

Impact assessment is a special form of evaluation that deals with the effects of a project output on target recipients. The basic principles of impact assessment are causality, attribution and increment.

There are two broad categories of interpretation of impact. Biological scientists look at impact as a direct output of an activity. For example, the release of a new variety is an impact. Social scientists, on the other hand, examine the effects of the product on the ultimate users - people level impact.

Impact begins when the behaviour of beneficiaries changes. Thus, impact deals with actual adoption of the research output and subsequent influence on production, income, welfare, the environment or any set development objectives. A project that has an impact must have some movements in the direction of the desired objective.

Impact Assessment Methods

Impact assessment may be done ex-post or ex-ante. The ex-post analysis deals with technologies already in use by farmers while ex-ante is for technologies not yet adopted. In both cases, some of the data required to measure impacts can be observed directly or estimated indirectly from other evidence.

The benefits and costs are transformed into a single number, the internal rate of return (IRR), which is a discounted evaluation measure for a single or a set of projects. The IRR is defined as the discount rate that just makes the net present value of incremental net benefits stream, or incremental cash flow equal to zero. The internal rate of return thus represents the

maximum interest that a project can pay for the resources used if the project is to recover its investments and operating expenses and still break even.¹ A project or program is usually considered economically viable if the internal rate of return exceeds the opportunity cost of capital.

The rate of return to a set of investments can be calculated as a marginal or average rate. The marginal rate of return (MRR) measures the return to the last cedi invested in each component. This can be done with econometric estimation of the relationship between the supply function and program expenditures and requires estimating an aggregate function including research and complementary investments as separate variables. However, estimating MRR requires good time series data. These are problematic in Ghana.

The average rate of return (ARR) looks at the whole expenditure as given and calculates the return to a whole set of expenditures. The ARR indicates whether or not the allocation of resources between investment components is optimal.²

There are various methods for estimating the rate of return for ex-ante and ex-post analysis³. These include:

- A. Ex-ante analysis:
 - i. Benefit cost analysis
 - ii. Simulation models
 - iii. Mathematical programming models

¹ Gittinger Price J. *Economic Analysis of Agricultural Projects*. Johns Hopkins University Press. 2nd Ed. 1982 pp. 299-361.

² Oehmke James F. and Eric W, Crawford. "The impact of Agricultural Technology in Sub-Saharan Africa: A Synthesis of Symposium Findings." Michigan State University International Development Papers. no. 14, 1993. pp 1-12.

³ See Schuh Edward G. and Hellio Tollini. "Costs and Benefits of Agricultural Research." World Bank Staff Working Papers. The World Bank. no. 360. 1979. pp 1-55.

iv. Scoring models

B. Ex-post analysis:

i. Production functions/Econometric method

ii. Surplus approach

a. Benefit-cost approach

b. Input saved approach

c. Index number approach

1. Linear functions with parallel shifts.

2. Linear functions with non-parallel shifts.

3. Non-linear functions with parallel shifts.

4. Non-linear functions with non-parallel shifts.

Ex-ante analysis looks at the future and therefore provides a more realistic and relevant guide for decision-making. Its disadvantage is that it is time consuming and complicated because a series of scenarios must be analysed. Secondly, the quality of data input has effect on judgement and decision-making.

The strengths of ex-post approach are that it draws on prior knowledge of an empirical effect of research on the economy and how the economy functions. It also employs statistical procedures to separate the effect of research and can control other variables affecting research output. This permits a more precise evaluation of the contribution of research. The disadvantage is that a lot of data is required.

Some writers⁴ have reviewed and compared approaches used to evaluate public agricultural research. They follow the procedure of categorising returns to research studies into ex-post and ex-ante evaluations. Ex-post studies fall into two main groups. Those studies

⁴ Norton G. W. and Jeffrey S. Davis. "Evaluating Returns to Agricultural Research: A Review." *American Journal of Agricultural Economics* 63(4) 1981. pp 685-699.

using consumer and producer surplus analyses to estimate average rate of return to research and those using production function analyses to estimate the marginal rate of return to research. Ex-ante studies fall into four categories. These are those using scoring models to rank research activities, those employing benefit-cost analysis, those using simulation models and those employing mathematical programming to select an optimal mix of research activities. They conclude that none of these approaches is superior in all situations.

The Economic Surplus Method of Ex-post Evaluation

By far, the most widely used method for analysing research impact in many situations is a partial equilibrium framework based on economic surplus approach.⁵ The main advantage of the economic surplus approach is that it is relatively flexible. It can be modified to account for a number of side effects of technological change such as price policy and trade. It further provides the means of analysing the distribution of benefits from research to producers and consumers when the demand and supply curves are known. It can also be applied to both closed and open economies.

Some simplifying assumptions are made in the economic surplus method. First, the supply and demand curves are assumed to be linear and to shift in parallel as a result of technological changes. With the assumption of parallel shifts, the choice of functional form has little effect on the size and distribution of benefits. In relation to total benefits, functional forms and elasticity are relatively unimportant compared with the nature of the supply shift. In relation to the distribution of benefits, functional forms are relatively unimportant compared with the sizes and the nature of the supply shifts⁶. Second, a single period (static) model is used and dynamic issues are not included. Third, competitive markets are assumed. Fourth,

⁵ Alston Julian M., George W. Norton and Philip G. Pardey. Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press. 1995. pp.207-208

standard surplus measures are used as measures of welfare change. With these assumptions, qualitative effects and formulae can be computed.

In impact assessment analysis, the main point is to compare a situation without research against a situation with research. It must be based on carefully constructed scenarios of the situations of with and without research.⁷ The economic surplus method provides a relatively simple and flexible approach to valuing research in with and without situations.

In order to turn agronomic data into economic values, the surplus approach employs the concepts of supply, demand and equilibrium. "Supply" represents producers' production cost, and "demand" is the consumers' consumption values. The interaction of the two leads to an "equilibrium". Economic welfare depends on the equilibrium price and quantity, producers' production costs and consumers consumption values.

Generally, the social value of a given production and consumption level can be estimated using the economic surplus concept defined as the area between the supply and demand curves as in Figure 2.1. The equilibrium point is the optimal point because it provides the maximum amount of economic surplus. Total surplus is the sum of the consumer and producer surpluses.

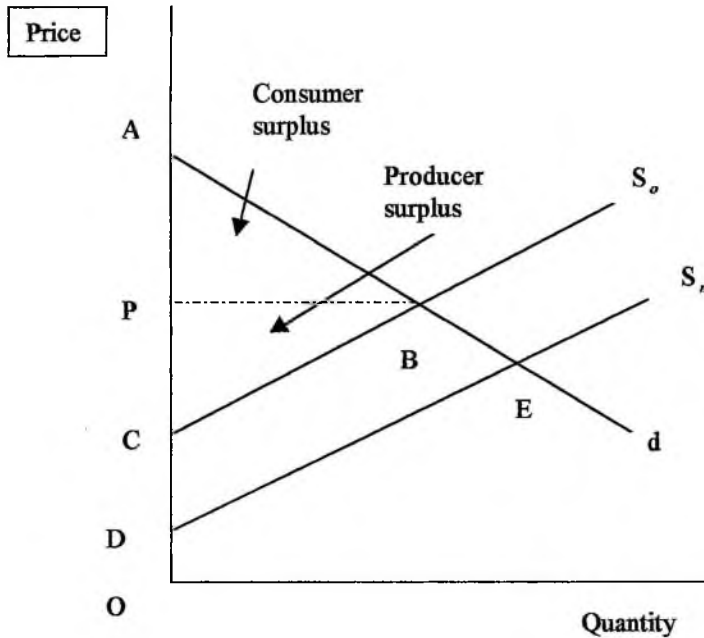
Figure 2.1 assumes a shift to the right in the supply functions from S_0 to S_n that improved technology brings. The benefits from research and extension are estimated by finding the gains and losses in producer and consumer surpluses over time, giving a net gain represented by area BCDE. The shape and the size of this area depend on the functional form of the supply and demand curves and the magnitude of the supply shift. The cumulative benefits are then compared with cumulative research costs by calculating the average rate of

⁶ Alston Julian M, George W. Norton and Philip G. Pardey. Op. Cit.pp.207-234.

⁷ Masters W.A.,Bakari Coulibaly,Diakalia Sanago, Mamadou Sidibe, Anne Williams, John H. Sanders and Jess Lowenberg-DeBoer. The Economic Impact of Agricultural Research: A Practical Guide. Department of Agricultural Economics. Purdue University. 1996.pp.6-12.

return to research expenditures.

Figure 2.1: Economic Surplus with Linear Demand and Supply Curves.

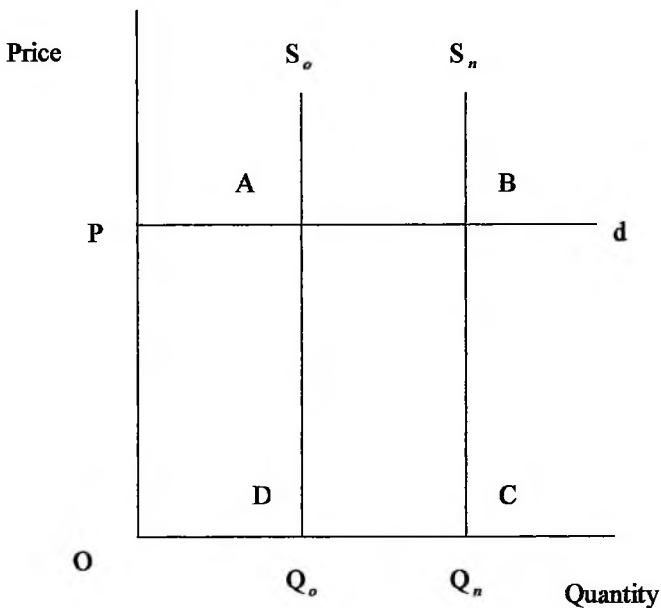


The index number method was used to estimate the impact of increased hybrid corn yields on the net social surplus in the United States by Grilliches (1957). It was hypothesised that the essential impact of agricultural research was to raise productivity, causing the aggregate supply function to shift downward from S_o to S_n (Figure 2.1). Index number approach incorporates elasticity of demand and supply in the analysis.

A simplified version of the economic surplus approach is the Benefit-Cost approach. The Benefit-Cost estimate assumes a perfectly inelastic supply curve and perfectly elastic demand curve. In the Benefit-Cost model, the welfare gains from research and extension are

represented by area "ABCD" in Figure 2.2. This is estimated by multiplying the differences between outputs ($Q_n - Q_o$) by the price, P. A major empirical problem is how to obtain productivity gain that reflects only the output of research. This measure is required to know how much to shift the supply curve. Often, the supply shift is assumed constant but this is usually not the case.

Figure 2.2: Benefit-Cost Approach



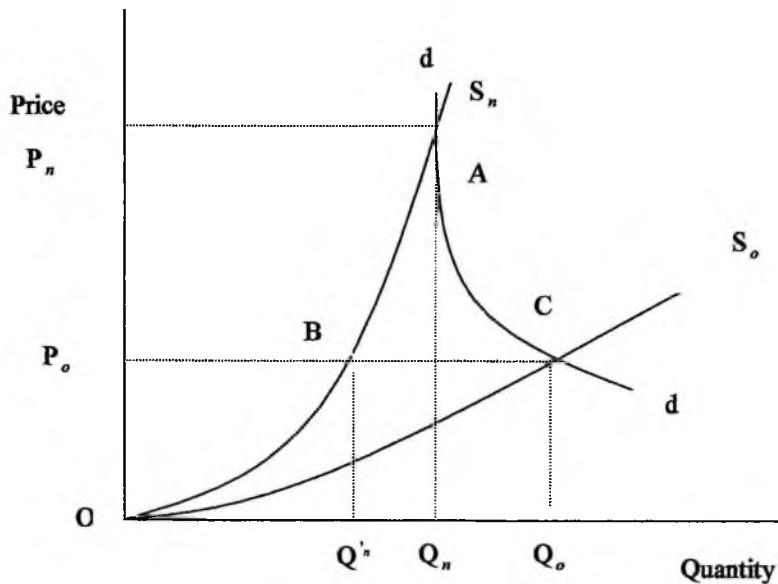
Akino-Hayami Method:

Another method that has been used widely in the assessment of research impact, particularly in developing countries, is the Akino and Hayami method⁸. This requires moderate data. The method assumes non-linear demand and supply curves and a pivotal shift of the

⁸ Akino Masakatsu and Yujiro Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development." *American Journal of Agricultural Economics*. 57(1975).pp 1-10.

supply curve as a result of changes in technology as shown in Figure 2.3. Akino and Hayami developed formulae to quantify the areas of the change in social surplus resulting from investments using Japanese rice breeding research. This method incorporates elasticity of demand and supply and specifies constant elasticity curves.

Figure 2.3: Akino-Hayami Approach



The total benefits (social gains) from research and extension is the area “COB” plus area “ABC.”

Area COB is calculated as:

COB = k-factor x Total Production Value, where:

k-factor = Adoption rate x (Yield gains from improved varieties ÷ Yield of improved varieties).

Or,

k-factor = Adoption rate x {(Yield of improved variety – Yield of traditional variety) ÷ Yield of improved varieties}

Area ABC is calculated as:

$$ABC = \frac{1}{2} \times \text{area COB} \times \{k\text{-factor} \times (1 + \text{price elasticity of supply})\}^2 \div (\text{price elasticity of supply} + \text{price elasticity of demand})$$

The formula for the social gains generally does not include per unit input costs. It is therefore necessary to subtract them separately from social gains, as a separate step in the analysis. The estimated social gains from Akino-Hayami method are considered to be conservative because the social gains estimated with this approach are smaller than those estimated with linear curves. The mathematical relationships of the parameters in the Akino-Hayami approach are however, more complicated than with linear curves. The conservative nature of the results with linear curves can be overcome with sensitivity analysis.

Role of economic policy on returns to agricultural research

A particular economic policy regime can have a major impact on the potential and actual returns to agricultural research. Economic policy affects the benefits and costs of research by distorting the price relatives. It can prevent people from adopting technologies that would have otherwise been adopted. An example is given on Brazil where fertilizer and hybrid corn had low adoption because of government policy that lowered domestic agricultural prices relative to fertilizer prices⁹.

When economic policy distorts relative price ratios, the contribution of a research programme can be either over- or under-stated. In this situation, shadow prices are used to estimate the benefit-cost ratios.

The difference in research impacts between Africa and Asia results from the degree of

⁹ Schuh Edward G, and Helio Tollini. Op. Cit. pp 1-40.

policy intervention.¹⁰ In Africa, restrictions on international trade and domestic marketing have taxed agriculture, transferring funds from farmers to urban dwellers. The implications of agricultural taxation are reduced adoption rates of new technologies and the transfer of whatever gains were achieved with the new technologies to the non-farm sector. Both effects make the returns to past research higher than those implied by conventional methods.

Masters and Sanders (1994) further note that there is a more rapid population growth in Africa than elsewhere. This channels productivity gains into on-farm consumption. If the value of the on-farm consumption is not accurately valued, it may affect the impact results. Cross-border spillover is valuable and critical for investment decisions of donors and international agencies. Attractive rate of return to investment in wheat breeding in Nepal was due in part to her ability to capture spillover benefits from neighbouring countries and from international agricultural centres.¹¹

While any price policy affects the distribution of the research benefits, the net national or world benefits may be reduced, left unchanged or increased, depending on the nature of the policy and the significance of the country in the world market for the commodity.¹² Price distortions may affect research investments and thus economic efficiency. All forms of intervention modify the pattern of benefits from cost-reducing research relative to those obtained under free trade.

Other factors affecting the results of impact assessment studies in Africa include climatic conditions, civil unrest, research system performance, policy affecting input and

¹⁰ Masters William A. and John H. Sanders. "The Impact of Agricultural Research in West and Central Africa: Concepts and Evidence." Paper prepared for discussion at the SPAAR/USAID Workshop on Regionalization of Agricultural Research. Banjul, The Gambia. March 14-18, 1994. pp.1-26.

¹¹ Morris Michael L., H.J. Dubin and Taneswar Pokhrel. "Returns to Wheat Breeding Research in Nepal" *Agricultural Economics* 10(1994) pp.269-282.

¹² Alston Julian M., Geoff W. Edwards, and John W. Freebairn. "Market Distortions and Benefits from Research." *American Journal of Agricultural Economics*. 9(1988). pp. 281-288.

output prices and markets involving input supplies and output markets which tend to support adoption of technologies.¹³

A study of trends in food prices in Ghana between 1970 and 1993 showed that the real wholesale price of food was declining.¹⁴ One of the explanations of this decline was attributed to favourable climate and yield increases for crops such as maize. Another reason is that of falling marketing costs since 1984 because trucks, spare-parts and funds for road construction and repairs were made available.

Evaluation of agricultural research is a complex task that provides a wide range of alternatives and challenges. Although there are various methods to evaluate agricultural research, none of them is ideal in all situations and one has to use the appropriate method suitable for one's condition. Indeed, the method chosen to evaluate research should be shaped by the availability of appropriate data. Often, simple approaches which are less data demanding are more useful than more complicated procedures.

Adoption and diffusion

In the assessment of impact of agricultural research, it is imperative to know the extent of use of the developed technologies. This is needed to compute the benefits of research. In situations where data are unavailable, it is necessary to conduct adoption studies to know the level of adoption of the technologies. Agricultural research has little merit unless it leads to adoption and use of the derived technology by farmers.¹⁵

The adoption of a new technology can be considered in several ways. Depending on

¹³ Oehmke James F. and Eric W. Crawford. Op.Cit. pp 1-12.

¹⁴ Alderman Harold and Gerald Shively. "Economic Reform and Food Prices: Evidence from Markets in Ghana." *World Development*. 24(1996) pp. 521-532.

¹⁵ Ekpere J. A. "Towards a New Orientation to the Challenge of Technology Transfer Systems and Food Production in the 21st Century Africa." Paper Presented at the Regional Workshop. Technology Options and Transfer Systems. Abidjan, Cote D'Ivoire. April 26-28, 1995. pp, 1-26.

one's objective, the adoption of a new technology such as improved variety, may range from using a little bit of the technology to using all the technology.

Information about current and past technology practices should be collected to examine adoption history and diffusion. While adoption is measured at one point in time, diffusion is the spread of the new technology across population and over time.

It is assumed that technology diffusion has an S-shaped curve showing a cumulative proportion of adoption. There is a slow initial growth in the use of the technology. This is followed by a more rapid increase in adoption and then a decrease as cumulative proportion of adoption gets close to a maximum. The logistic function is used to depict the diffusion curve.

The curve can mathematically be described as:

$$Y_t = K / (1 + e^{-a-bt})$$

Where

Y_t = the cumulative percentage of adopters or area at a time

K = the upper limit of adoption.

b = a constant, related to the rate of adoption.

a = a constant, related to the time when adoption begins.

The logistic curve assumes that with the constants, a , and b , infrastructure, relevant price ratio and technology remain unchanged over the period.

Determinants of adoption

The use of discrete choice models such as LOGIT, PROBIT and TOBIT in explaining adoption process is well documented.¹⁶ These studies have variously used farm and farmer characteristics and or farmer perceptions to explain the adoption process. The role of farmers' preferences in adoption decisions has received little attention in adoption studies. A TOBIT model used on sorghum in Burkina Faso and Guinea found that farmers' perception of technology significantly affect their adoption decisions.¹⁷

Several attempts have been made to explain the factors of adoption. Generally, three main issues for explaining adoption decisions can be identified. These are economic constraint, innovation-diffusion and "adopter perception." The economic constraint model argues in favour of the distribution patterns of resource endowments as the major determinants of adoption. The innovation-diffusion model believes that access to information is the main determining factor in adoption decisions.¹⁸ The adopter perception model suggests that the perceived attributes of innovations are the key determinants of adoption behavior¹⁹.

¹⁶ Shively Gerald E. "Consumption Risk, Farm Characteristics and Soil Conservation Adoption among Low-income Farmers in the Philippines." *Agricultural Economics*. 17(1997)pp.165-177.

Nichola Tennassie and John H. Sanders. "A Probit Analysis of the Determinants of Adoption when Inputs are Rationed: The Gezira Experience with Hybrid Sorghum." *Science, Technology and Development*. Vol,14. no.3, 1996 pp.107-119.

Adesina, A. A. and Baidu-Forson, J. "Farmers' Perception and Adoption of New Agricultural: Evidence from Analysis in Burkina Faso and Guinea, West Africa." *Agricultural Economics* 13(1995) pp 1-9.

Adesina Akinwumi A. and Moses M. Zinnah. "Technology Characteristics, Farmers' Perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone." *Agricultural Economics* 9(1993) pp.297-331.

Dankyi, A.A., H.A. Dakurah and J.N. Asafo-Agyei. "Cowpea Technology Adoption in Ghana" Paper presented at the OAU/SAFGRAD Workshop, Abidjan, Ivory Coast. 1993 pp. 1-33

Dankyi, A.A., V.M. Anchrinah and A.O. Apau "The Adoption of the Improved Rice Technologies in the Wetlands of the Ashanti Region of Ghana." Unpublished Paper. West Africa Rice Development Association (WARDA). Bouake, Ivory Coast, 1996 pp 1-39.

¹⁷ Adesinah, A.A. and Baidu-Forson, J. Op. Cit. pp 1-9

¹⁸ Rogers, E.M. "Diffusion of Innovations. Free Press. Glencoe. Illinois. 1962

¹⁹ Kivlin, J.E. and F.C. Fliegel. "Differentiated Perceptions of Innovations and Rate of Adoption." *Rural Sociology* 32 (1967) pp78-91.

In many of these studies, ecological zones are not included as some of the explanatory factors affecting the adoption of improved technologies. Farmers in different ecological zones may adopt improved technologies differently because of the environment in which they live. If technologies developed are not compatible with the conditions prevailing in the ecological zones, adoption may be low. Thus, the type of improved crop varieties and technologies developed may be a response to the environmental conditions prevailing in the ecological zones.

In Ghana, there are four ecological zones running approximately horizontal to each other. Beginning from the coast is the coastal savannah and moving northwards are the forest, transition and the Guinea Savannah in that order. In general, rainfall increases northwards from the coastal savannah zone to the forest zone but decreases from transition zone to the Guinea Savannah zone. Temperatures, on the other hand, increase from the coastal savannah zone to the Guinea Savannah zone. Thus while the Guinea Savannah has one rainfall season, the coastal savannah, the transition and the forest zone have two rainfall seasons. With this ecological distribution, farmers may adopt improved technologies differently. Hence, it is important to include ecological zones when explaining the adoption of improved technologies.

Understanding adoption behaviour goes beyond looking at single relations to multivariate relationships. Multiple regression may be used to analyse such relationships but the dependent variable must be continuous. Since many adoption studies deal with adoption as a "yes" or "no" dependent variable, LOGIT, PROBIT and TOBIT analyses are the appropriate tools.

Both LOGIT and PROBIT techniques use a series of characteristics of the farmer or the farm to predict the probability of adoption. Their analyses give similar results. The



difference between them is that while LOGIT assumes that the dependent variable follows a logistic distribution, PROBIT assumes a cumulative normal distribution. The estimated probability of adoption in the LOGIT model is given by:

$$F(b'X) = 1 / 1 + e^{-b'X}$$

This is the cumulative probability distribution. The expression $b'X$ is defined as:

$$b'X = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_k X_k$$

Where:

b_0 = constant

b_1, b_2, \dots, b_k = other estimated coefficient.

X_1, X_2, \dots, X_k = values of independent variables.

With this expression the probability of adoption of a new technology can be calculated for farmers. The logistic regression gives the same results as LOGIT. The logistic regression can be rewritten in terms of the “odds” of an event occurring. The odds of an event occurring are the ratio of the probability that it will occur to the probability that it will not. When the logistic model is written in terms of the log of the “odds”, it is called a LOGIT. The TOBIT model measures both the probability of adoption and intensity of adoption. The theoretical aspect of the logistic regression and TOBIT are further discussed in Appendix 5.

Chapter Summary

There are several methods for assessing impact of agricultural research but the most widely used method is the economic surplus method. The advantages of this method lie in its relative flexibility, simplicity and less data requirement. One of the parameters needed to estimate the benefits to research and extension activities are the adoption rates of the improved technologies. These can be estimated through adoption studies. A complementary

analysis is to determine the factors affecting the adoption process. This can be done with logistic regression and TOBIT models.

CHAPTER 3

MAIZE TECHNOLOGY DEVELOPMENT IN GHANA

Agricultural Research in Ghana

Organised agricultural research in Ghana did not exist until after the establishment of the Government Botanical Gardens at Aburi in 1890. In the same year, the Aburi Botanical Station became the Department of Agriculture. The original objective was to introduce plants found to be profitable in other countries and to search for other economic plants in Ghana. Serious agricultural research however, began in 1900.

Regional agricultural stations were established between 1903 and 1918 to introduce and distribute new crops and provide training for agricultural officers. The Ministry of Agriculture (MOA), as known at that time, had eight divisions of which the Scientific Services Division was responsible for all research work.

In 1962, the MOA was re-organised and the Ghana Academy of Sciences (GAS) took charge of all agricultural research. Other agricultural stations were given to the State Farms Corporation (SFC) and the United Ghana Farmers Co-operative Council (UGFCC) to produce food. As a government policy, the CSIR was created to replace GAS in 1968. Together with the Universities they carried out agricultural research in Ghana. Presently, five institutes of the CSIR and the Universities carry out agricultural research in Ghana. The CSIR institutes are the Crops Research Institute (CRI), Soil Research Institute (SRI), Animal Research Institute (ARI), Savannah Agricultural Research Institute (SARI) and the Forestry Research Institute (FRI). The Cocoa Research Institute of Ghana (CRIG) and

the Oil Palm Research Institute (OPRI) also carry out research in cocoa and oil palm respectively.

Maize was first introduced in Ghana in the 16th century from the Portuguese¹. In the colonial years, other maize varieties were introduced from Latin America and other African countries. By 1956, the Ghana Government had established maize improvement centre at Kwadaso that in 1963 became part of Crops Research Institute.

The Ghana Grains Development Project

The Ghana Grains Development Project (GGDP), under the CRI, is a bilateral aid venture between the Governments of Ghana and Canada. It was established in 1979 to improve maize and legume production in Ghana. The Crops Research Institute is the executing agency for the Ghana Government and the International Maize and Wheat Improvement Centre (CIMMYT in Mexico) represents the Canadian Government. Other participating institutions are the Grains and Legumes Development Board (GLDB), and the Ministry of Food and Agriculture (MOFA). The International Institute of Tropical Agriculture (IITA) in Nigeria since 1985, participated in the second and third phases of the project.

Initial efforts of the GGDP in Phase 1 (1979-1984) concentrated on training staff, procurement of basic equipment and identifying appropriate improved maize and legume varieties for farmers. Later, emphasis was shifted to crop management research on farmers' fields to develop improved production practices. Effective recommendations were formulated for maize mono-cropping system and later for inter-cropping systems.

¹ Edmeades, G., A.A.Dankyi, K. Marfo and R. Tripp. "On-farm maize research in the transition zone of Ghana." In *Planned Change in Farming Systems*. Edited by R. Tripp. 1991. P.66. Wiley-Sayce Co-Publication.

In Phase 2 of the Project (1985-1990), the advances and methodologies of the previous research were expanded. The research priorities, extension strategies and maize recommendations were refined. There was more collaboration between research, extension and farmers.

In the third and final Phase (1991-1995), the productivity increases in maize by farmers were the main concern of the project. Gender awareness was given priority. As at 1998, nine open-pollinated improved varieties and three hybrids have been released together with their agronomic recommendations.

At the onset of the Ghana Grains Development Project in 1979, the major improved varieties recommended for use in all ecological zones were La posta CRI, Composite 4 and Golden Crystal. These varieties were used in both major and minor rainy seasons. They were very tall and therefore easily lodged, and were susceptible to diseases. Furthermore, on-farm agronomic data to support their planting were very scanty.

The main objectives of maize breeding programme of the GGDP were to:

- i) Increase the grain yield and the yield components.
- ii) Improve lodging resistance.
- iii) Develop specific varieties for the different ecological zones and livestock feeding.
- iv) Develop maize variety for livestock feeding.
- v) Develop varieties for major and minor seasons.
- vi) Improve disease and insect resistance in maize.
- vii) Improve the protein quality of maize.

In 1982, following a mid-term review of the GGDP, the breeding programme was modified in scope and direction for on-farm and extension activities. The varietal requirements for Ghana were determined and grouped into five types. These were based on ecology, season, farmer and consumer preferences².

The varieties were:

- i) 120-day white dent varieties for the transition, forest and Guinea Savannah zones in the major season.
- ii) 110-day yellow flint/dent varieties, for all parts of Ghana in major and minor seasons.
- iii) 105-day white dent varieties for transition, forest and coastal savannah zones in the major season.
- iv) 90-day soft white dent for maritime Volta Region.
- v) 90-day yellow flint varieties for early planting in the Guinea Savannah.

Between 1979 and 1996, nine new varieties were released by GGDP. The released maize varieties by the CRI from 1954 to 1996 and their potential yields are shown in Table 3.1.

Other collaborating institutions

The international agricultural institutions such as CIMMYT, IITA, and the Semi-Arid Food Grain And Development (SAFGRAD) have played various roles in the human development, and the flow of information and materials among National Agricultural

² Ghana Grains Development Project. Fourth Annual Report. Research Results. 1982. pp. 2-7.

Research Systems (NARS). The development of early and extra-early maize varieties was supported by SAFGRAD.

Table 3.1: Maize Varieties Developed and Released by CRI, 1954-1996.

Variety	Year of Release	Special Attributes	Days to Maturity	Grain Yield ton/ha
Nyankariwana I	1954	Yellow	100	2.5
Nyankariwana II	1954	Yellow	100	2.5
GSI, GSII, GSIII	1955-61	White dent	120	3.5
Mexican 17	1961	White dent	110	3.5
Composite 2	1968	White dent	120	4.0
Composite W	1972	White dent	120	5.0
Composite 4	1972	White dent	120	5.0
La Posta CRI	1972	White dent	120	5.5
Golden Crystal	1972, 1984	Yellow Flint/dent	110	5.0
Kawanzie	1984	Yellow	95	4.0
Safita-2	1984	White dent	95	4.0
Dobidi	1984	White dent	120	5.5
Aburotia	1984	White dent	105	4.5
Okomasa	1988	White dent Streak resistant	120	6.0
Abeleehi	1990	White dent Streak resistant	105	5.0
Dorke SR	1990	White dent Streak resistant	95	4.5
Obatanpa	1992	White dent Quality Protein, Streak resistant	110	5.5

Source: Adapted from Twumasi-Afriyie S. "Achievements of the Crops Research Institute." CRI, Ghana, 1995. p.5

CIMMYT is an internationally funded and non-profit scientific research and training organisation. It is involved in world-wide research on maize and wheat. It is one of the thirteen international centres supported by the Consultative Group on International Agricultural Research (CGIAR). CIMMYT has had a long collaboration with the CRI on maize research in Ghana. It played an important role in the establishment and management of the GGDP in 1979. Since 1979, CIMMYT has supported grains development in Ghana with maize germplasm which breeders in the GGDP have further worked on for the release of several maize varieties. The sources of some of the released maize varieties in Ghana are presented in Table 3.2.

Table 3.2: The Sources of Released Maize Varieties in Ghana, 1979-1996.

Released variety	Germplasm source	Institution source
Dobidi	CIMMYT population 43 (La posta)	CIMMYT
Safita 2	CIMMYT Pool 16	CIMMYT, SAFGRAD
Aburotia	CIMMYT population 49	CIMMYT
Kawanzie	CIMMYT population 31	CIMMYT
Okomasa	CIMMYT population 43	CIMMYT
Abelechi	CIMMYT population 49	CIMMYT
Dorke SR	CIMMYT population 16	CIMMYT
Obatanpa	CIMMYT population 63	CIMMYT

Source: Various GGDP Annual Reports. 1979 to 1996

The Savannah Agricultural Research Institute (SARI) was originally known as the Nyankpala Agricultural Experimental Station (NAES). Until 1995, it was part of the CRI. At the moment, it carries out crop research including maize in the northern sector of Ghana.

The Ministry of Food and Agriculture has been one of the main collaborators of the GGDP. Together with the Grains and Legumes Development Board (GLDB), they

carried out on-farm trials, maize technology demonstrations, training of farmers and other extension activities in the transfer of maize technologies.

Sasakawa Global 2000 (SG2000) project in Ghana was started in 1986 in the Upper West and Northern regions of Ghana. Later it spread throughout the whole country. The SG2000 project focuses on teaching farmers how to use improved methods for growing crops like maize, sorghum and cowpea. The project arranges the necessary credit by bridging farmers and banks so that inputs like fertilizer are loaned to farmers to be repaid after harvest. The SG2000 project carries out its extension activities through field demonstration called Production Test Plots (PTP).

Maize Varieties

Some of the very early maize varieties released by the CRI were Ghana Synthetics (eg. GSI, GSII and GSIII). CIMMYT introduced La posta into the country in 1968 and in 1972, it had been released as La posta CRI. Other improved varieties were composite 4 and Golden Crystal.

Since 1979, several improved varieties have been evaluated against local/farmer varieties. These are full season, medium maturing and early maturing maize varieties. Others are streak resistant and protein quality maize.

The average performance of the various recommended full season improved varieties against the local/farmer variety over the years in the various ecological zones are shown in Table 3.3. The full-season maize varieties take about 120 days to mature.

Table 3.3: Average Grain Yield of Full Season Maize Varieties, 1979-84 (in t/ha).

Variety	Ecological zones		
	Transition	Forest	Guinea savannah
La posta CRI	4.21	4.37	3.08
Dobidi	4.05	4.38	3.15
Composite 4	3.98	3.98	2.99
Golden Crystal	4.05	3.54	3.08
Local	2.72	3.07	2.13

Source: Compiled by the author from GGDP Annual Reports, 1979 to 1984.

The GGDP recommended varieties, "Dobidi" and "Golden Crystal", generally out-yielded the local varieties and showed a good level of stability across ecological zones and years. "Dobidi" (originally Ejura-1-7843), was derived from CIMMYT population "La posta" from progeny selected at Ejura, and consistently performed well. For example, it out-yielded the local variety by 49% in the Transition zone, 43% in the forest zone and 48% in the Guinea Savannah zone. In addition, Dobidi has other desirable characteristics like reduced plant height and lodging. It was released in 1984.

To satisfy farmers who plant in the minor season (September-November) or are late in planting in the major season, a medium maturing variety, Aburotia, which matures in 105 days, was developed. Its original name was Tuxpeno P.B. C16, a CIMMYT product. It performed better than the local varieties and was comparable with the full season maize like Golden Crystal. The grain yield from on-farm trials averaged across three years (1981 to 1984) for Aburotia and other varieties are compared in Table 3.4. Aburotia yielded about 0.8 t/ha more than the local variety and has similar yield as Golden Crystal, a full-season maize.

Table 3.4: Average Grain Yield of Maize Varieties, 1981-84 (in t/ha).

Variety	Mean yield (t/ha)
La posta CRI	2.47
Composite 4	2.40
Aburotia	2.32
Golden Crystal	2.38
Local	1.57

Source: Compiled by the author from GGDP Annual Reports (1981 - 1984).

Farmers in the guinea savannah zone in the early years of the project, planted early maturing local maize varieties to fill the hunger gap. Similarly, in the maritime Volta Region, early white local varieties were planted to take advantage of the short and erratic rainfall. Based on these, the GGDP developed a 90-day yellow flint variety, Kawanzie, for early planting in the guinea savannah. In the maritime Volta Region which is a coastal savannah, another 90-day soft white dent variety called Safita 2 was developed and released. Both varieties were released in 1984. The performances of these varieties compared with other varieties in the savannah zones from on-farm trials are presented in Table 3.5. Both recommended varieties, "Kawanzie" and "Safita 2" out-yielded the local variety of about 0.8 t/ha representing about 35% yield increase.

Table 3.5: Average Grain Yield of Early Maturing Maize Varieties, 1983-86 (in t/ha).

Variety	Mean yield (t/ha)
Kawanzie*	3.00
Safita 2*	3.02
Pool 16	2.75
Local	2.23

Source: Compiled by the author from GGDP Annual Reports, (1983-1986).

In the early eighties, particularly in 1983, maize streak virus disease became severe and widespread throughout Ghana as a result of a long drought. Breeding for resistance to maize streak virus disease was considered as the most cost-effective control

option. Streak resistant varieties available from CIMMYT and IITA were obtained for further research. These were to replace susceptible improved varieties like "Aburotia". To insure against further epidemic of the disease, streak resistance germplasm were incorporated in all breeding pools and populations. The GGDP management further decided that only varieties that had a fairly good amount of streak resistance were to be released in Ghana.

As a result of further research, "Okomasa", "Abeleehi" and "Dorke SR" which were all streak resistant varieties were developed to replace "Dobidi", "Aburotia" and "Safita 2", respectively. The new streak resistant varieties had similar yields as their predecessors. In Table 3.6, the results of streak resistance levels of the released varieties evaluated under artificially induced maize streak virus disease pressure are shown. The replacing varieties, Dorke SR, Okomasa and Abeleehi have high streak resistance levels.

Table 3.6: Streak Resistance Levels of Some Selected Varieties.

Non-resitant variety	% Streak resistant plants (8 weeks after planting)	Resistant replacement variety	% Streak resistant (8 weeks after planting)
Safita 2	8	Dorke SR	95
Dobidi	8	Okomasa	94
Aburotia	0	Abeleehi	86

Source: GGDP Annual Report, 1990, p. 7.

Quality protein maize (QPM)³ research began in the early eighties by CIMMYT but was abandoned because of unacceptably soft endosperm. In 1989, however, CIMMYT made available to GGDP, QPM with grain type similar to normal maize.

³ Normal maize, although has about 10% protein, lacks essential amino acids-lysine and tryptophan. QPM has reasonable amount of these essential amino acids and is thus better than normal maize grown in Ghana.

Research efforts by GGDP led to the release of a streak resistant medium maturing white dent QPM variety called "Obatanpa"⁴ in 1992. As presented in Table 3.7, Obatanpa compares favourably with normal maize counterparts across the ecological zones. Across all zones, it yields 3.7t/ha and is 0.5t/ha more than the farmer's variety.

Table 3.7: Grain Yield of Selected Medium Maturing Maize Varieties (in t/ha).

Variety	Ecological zones				Mean
	Forest	Transition	Coastal savannah	Guinea savannah	
Obatanpa	3.9	3.5	4.0	3.5	3.7
Abelechi	3.2	3.7	3.7	4.0	3.7
Aburotia	2.1	3.0	3.5	3.7	3.1
Farmer variety	2.7	3.8	2.2	3.9	3.2

Source: GGDP Annual Report, 1991, p. 109

Quality protein analysis is presented in Table 3.8. Tryptophan, an essential amino acid is about 100% more in the protein and the endosperm of Obatanpa than they are in Okomasa. These make Obatanpa superior to Okomasa.

Table 3.8: Protein and Tryptophan Contents of Obatanpa and Okomasa.

Variety	% Protein	% Tryptophan in:	
		Sample	Protein
Whole grain:			
Obatanpa	9.8	0.08	0.85
Okomasa	10.4	0.05	0.46
Endosperm:			
Obatanpa	8.0	0.06	0.76
Okomasa	10.0	0.38	0.38

Source: GGDP Annual Report, 1991, p.14.

⁴ "Obatanpa" is a vernacular word meaning "good nursing mother" which is given to maize variety because it has quality protein. Obatanpa was released to farmers in 1992.

To further verify the superiority of the improved varieties over local variety, a farmer-managed variety experiment was conducted in 1985. In this trial, farmers were given improved varieties to plant and manage themselves in whatever way they wished. The only conditions were that they also planted their own variety in the same field and under the same management and that researchers could observe and take records. The results of this experiment are presented in Table 3.9. Dobidi and Aburotia, the recommended varieties yielded 0.58t/ha and 0.45 t/ha respectively more than the farmer's variety. The densities and the number of ears harvested from the recommended varieties were more than the farmer's variety. This is evidence that the recommended varieties perform better than the farmers' variety.

Table 3.9: Grain Yield and other Parameters of Selected Maize Varieties (in t/ha).

Variety	Harvest density	Ears at harvest	Grain yield
Dobidi	27000	25400	2.49
Aburotia	27500	25200	2.26
Farmer's variety	25800	22200	1.81

Source: GGDP Annual Report, 1985, p.133.

The yield advantages of improved varieties are further shown in Table 3.10. The table shows that improved varieties are more responsive to fertilizer. For example, the improved variety yields more than the local variety by 0.76 tons/ha at zero fertilizer and by 1.20 tons/ha at higher levels of fertilizer. Thus improved maize gave more yields using fertilizer than local varieties.

Table 3.10: Grain Yield of Local and Improved Maize Varieties (in t/ha).

Maize variety	Fertilizer level		
	Zero	(Difference)	90:60:60 (NPK)
Improved	2.47	(1.50)	3.97
(Difference)	(0.76)		(1.20)
Local	1.71	(1.06)	2.77

Source: GGDP Annual Report, 1980, p.43

Planting Densities

Results from an exploratory survey in Mampong-Sekyedumasi area in 1979 showed that planting densities in farmers' fields varied from 20,000 to 45,000 plants/ha. Using these as guidelines, variety by planting density trial was conducted in 1980. It involved some improved varieties and three planting densities - 25,000, 50,000 and 75,000 plants/ha. The results from the forest, transition and Guinea Savannah zones are presented in Table 3.11. The data indicate that as the density increased beyond 50,000 plants/ha the yield generally decreased as a result of competition for light and soil nutrients. This further means that the resources to the plant - nutrients and water in the soil and light are being used more intensively resulting in negative returns to scale.

Table 3.11: Grain Yield of Maize Varieties under Different Densities (t/ha).

Variety	Density (plants/ha)		
	25,000	50,000	75,000
Forest Zone:			
La posta CRI	4.61	4.89	4.06
Aburotia	3.68	4.04	4.38
Transition Zone:			
La posta CRI	3.85	4.35	3.69
Aburotia	3.55	4.34	4.08
Guinea Savannah:			
La posta CRI	2.87	3.00	2.84
Aburotia	2.59	3.42	3.10

Source: GGDP Annual Report, 1980, p.62.



Planting densities in excess of the optimum caused considerable lodging and barrenness particularly with full season varieties such as La posta. With medium maturing varieties such as Aburotia, total lodging and ears per plant decreased with increase in densities. These results are presented in Table 3.12. Bird damage also generally increased. Taking into consideration a 12% stand loss by farmers, a planting density of about 56,000 plants/ha was recommended for farmers growing full season (120-day) varieties and 62,500 plants/ha for medium varieties such as Obatanpa and also for early varieties.

Table 3.12: Selected Characters for La posta at Three Densities in Ghana.

Variety	Density	Total lodging (%)	Bird damage (%)	Ears per plant
La posta CRI	25,000	15.6	2.9	1.01
	50,000	24.6	7.2	0.87
	75,000	28.8	10.2	0.72
Aburotia	25,000	16.2	4.0	1.02
	50,000	15.8	7.8	0.92
	75,000	8.1	2.0	0.83

Source: GGDP Annual Report, 1980, p.61

Row Planting

In the early 1980s, two recommendations were given. On land free of stumps and projections, ropes were used to mark rows while the use of sighting poles (at least 3) was recommended for lands with stumps and projections. As at 1986, only sighting poles were recommended for making rows. One problem that arose was how to measure the distances in the field since farmers did not carry measuring tapes to their farms. A simple

but very useful method was developed. The normal cutlass used by farmers was used to measure the distance⁵.

Fertilizer Application

On taking off, the GGDP embarked on some fertilizer trials using the existing fertilizers in the country. Between 1982 and 1984 it concentrated on on-farm timing and method of application. This was because farmers were not following the recommendation and usually waited until the emergence of the seedling. Table 3.13 shows some of the results obtained in 1982 and 1983. That experiment looked at applying starter fertilizer at planting or at 3 weeks after planting; burying it or placing it on the surface; using 15-15-15 (NPK) or tripple super phosphate (TSP) or sulphate of ammonia (S/A).

The results show that there was no significant difference in yields between applying the starter fertilizer at planting time and delaying it until three weeks in the transition zone although it was significant in the forest zone. There was also no effect of placement of fertilizer on yield. Furthermore, there was a small but consistent advantage of applying phosphorus fertilizers compared with ammonium sulphate. On potassium, previous experiment had shown that the response of maize to it was very low or non-existent in Southern and Central Ghana.

⁵ The length of this cutlass was about 60cm. Using one-and-a-half times the length of the cutlass gave a distance of 90cm between rows and using two-thirds of the length gave the distance between plants in the row of 40cm apart.

Table 3.13: Effect of Time, Placement and Type of Fertilizer on Maize Yield (in t/ha).

Treatment	1983		
	Forest	Transition	Guinea savannah
Time:			
At planting	3.46	3.68	2.33
	NS ⁶	NS	
At 3 weeks	3.34	3.87	2.38
Placement:			
Burried	3.42	3.92	2.27
	NS	NS	NS
Surface	3.38	3.62	2.44
Types:			
15:15:15 (NPK)	3.54	4.14	2.56
Triple super-phosphate	3.22	3.58	2.17*
Sulphate of ammonia	3.45	3.60	2.34

Source: GGDP Annual Report, 1983, p.74

These findings endorsed the farmer practices of applying compound fertilizer to the soil surface 2-3 weeks after planting. This avoided the loss of fertilizer if crop establishment failed either because of poor seed or predator attack. It also saved him some labour at planting time. Therefore it was recommended that farmers could apply starter fertilizer at planting or up to about 2 weeks after planting without yield loss. For fields that were recently in fallow, little or no fertilizer was required. Higher rates were recommended for more continuously cropped fields and for the guinea savannah zone because of low soil fertility.

To further examine the effect of fertilizer on yield under farmers management, farmer-managed fertilizer experiments were conducted in 1985 in the forest, transition and savannah zones. In these trials, two plots were demarcated. All decisions on the

⁶ NS =not significant

maize variety to plant and all other production decisions were made by the farmer. The only difference between the two plots was that, on one, fertilizer was added at a rate of 250 kg/ha of compound and sulphate of ammonia. The other plot received no fertilizer. The results from those trials are presented in Table 3.14. The yield increase due to fertilizers was between 0.6t/ha in the forest zone and 0.9t/ha in the Guinea Savannah zone. Again, this shows that the Guinea Savannah is more responsive to fertilizer.

Table 3.14: Maize Grain Yield from Farmer-Managed Fertilizer Trials (in t/ha).

Treatment	Ecological Zone			Across sites
	Forest	Transition	Savannah	
With fertilizer	1.97	1.61	2.03	1.89
Without fertilizer	1.37	0.88	1.12	1.11
Difference	0.60	0.73	0.91	0.78

Source: GGDP Annual Report, 1985, p.137.

The Maize Recommendations

Putting all the agronomic trials together and subjecting them to economic analysis, maize production recommendations were made for Ghana. The maize production options are presented in Table 3.15. Option A is recommended for fields that have low soil fertility and option B for moderate soil fertility. These options were demonstrated to several thousands of farmers throughout Ghana by MOFA, GLDB and SG 2000.

Table 3.15: Demonstrated Technological Options for Maize Production in Ghana

Practice	Option A	Option B
Variety	Okomasa, Dobidi, Obatanpa or other improved varieties	Okomasa, Dobidi, Obatanpa or other improved varieties
Planting density	56,000 plants/ha for Okomasa, Dobidi; 62,500 plants/ha for Obatanpa and other early varieties	56,000 plants/ha for Okomasa, Dobidi; 62,500 plants/ha for Obatanpa and other early varieties
Sowing method	Rows using sighting poles	Rows using sighting poles
Between – row distance	90cm for Okomasa and Dobidi; 80cm for Obatanpa and early varieties	90cm for Okomasa and Dobidi; 80cm for Obatanpa and early varieties
In –row distance	40cm	40cm
Seeds per hill	2	2
Starter fertilizer	38:38:38(NPK)	19:19:19(NPK)
Starter fertilizer application time	At planting	At planting
Side-dressing with nitrogen	53:0:0	26:0:0
Side-dressing application time	4 weeks	4 weeks
Hand weeding	Twice at 3 and 6 weeks	Once at 4 weeks.

Source: Maize and Legumes Production Guide. GGDP, 1996. pp.5-16.

Chapter Summary

The chapter has shown that various institutions have collaborated in maize research in Ghana. In a well-planned research and extension activity, maize recommendations were developed and extended to farmers. This was to help increase maize production in Ghana. The chapter has also shown the efforts made by biological scientists in the development and promotion of maize technologies in Ghana.

CHAPTER 4

THE PRODUCTION ENVIRONMENT

Ecological zones

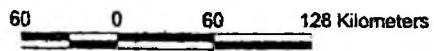
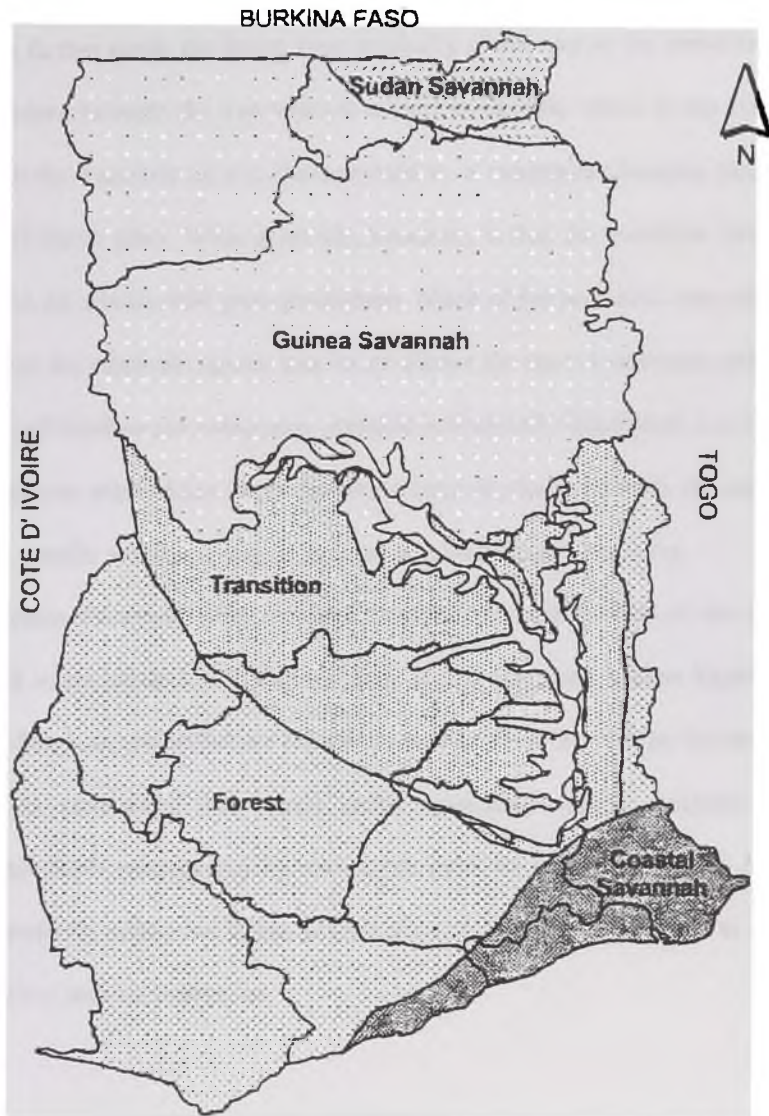
Maize is the most important cereal crop in Ghana. It is grown throughout the country, with the exception of a small portion of the north-east characterized by harsh climatic conditions and extremely rocky soils.

Generally speaking, the climate in Ghana grows hotter and drier as one moves northward and inland away from the Atlantic coast. Maize cropping systems and production technologies vary between the four ecological zones in which significant amounts of maize are cultivated (Figure 4.1).

The coastal savannah zone includes a narrow belt of savannah that runs along the Atlantic coast, widening toward the east of the country. Farmers in this zone grow maize and cassava as their principal staples, often intercropped. Annual rainfall, which is bimodally distributed, totals only 800 mm per year, so most maize is planted following the onset of the major rains beginning in March or April. Soils are generally light in texture and low in fertility, and productivity is low.

Immediately inland from the coastal savannah lies the forest zone. Most of Ghana's forest is semi-deciduous, with a small proportion of high rain forest remaining only in the southwestern part of the country near the border with Cote d'Ivoire. Maize in the forest zone is grown in scattered plots, usually intercropped with cassava, plantain, or cocoyam as part of a bush fallow system. Some maize is consumed in the forest zone, but it is not a leading food staple, and much of the crop is sold. Annual rainfall averages

Figure 4.1: Ecological zones of Ghana



about 1,500 mm, and maize is planted both in the major rainy season (beginning in March) and in the minor rainy season (beginning in September).

Moving further north, the forest zone gradually gives way to the transition zone. The exact boundary between the two zones is subject to dispute, which is not surprising considering that the boundary area is characterized by a constantly changing patchwork of savannah and forest plots. What is certain, however, is that the transition zone is an important region for commercial grain production. Much of the transition zone has deep, friable soils, and the relatively sparse tree cover allows for more continuous cultivation and greater use of mechanized equipment. Rainfall is bimodally distributed and averages about 1,300 mm per year. Maize in the transition zone is planted in both the major and minor seasons, usually as a monocrop or in association with yam or cassava.

The Guinea Savannah zone occupies most of the northern part of the country. Annual rainfall totals about 1,100 mm and falls in a single rainy season beginning in April or May. Sorghum and millet are the dominant cereals in the Guinea Savannah, but maize grown in association with small grains, groundnut and/or cowpeas is also important. Some fields are prepared by tractor, but most are prepared by hand. Maize is grown in permanently cultivated fields located close to homesteads, as well as in more distant plots under shifting cultivation.

Rainfall

Maize is generally grown throughout Ghana under rain-fed conditions. Based on rainfall regimes, the country may be divided broadly into two main regimes. The southern part has two rainy periods and the northern half has one long rainy period.

The major rainy season for the south falls between April and July and the minor season is from September to November. Maize is mostly grown in the major season in the south. However, in some parts of Ghana particularly in the transition and some forest ecological zones, minor season maize has grown in importance lately because of changes in the rainfall distribution. In the northern half of Ghana, the rainfall season is from May to September.

Since maize is grown under rainfall conditions, the importance of rainfall cannot be overemphasised. It is thus important to analyse the rainfall distribution without and with the establishment of the GGDP. This is done in an attempt to isolate the effect of rainfall on production with and without the GGDP research. In this respect two periods are compared. The period of 1967 to 1978 representing "without" the GGDP is compared with 1979 to 1990 period as "with" GGDP. Using data from the Meteorological Services Department, Accra, the mean monthly rainfall is compared for the two periods for some of the selected districts for the maize adoption survey on which rainfall data were available.

The main task is to test whether the mean of casewise differences in monthly rainfall between the two periods (1967-1978 and 1979-1990) differs from zero. Using the paired samples t-test procedure, the mean monthly rainfalls of the two periods are compared. The results are presented in Table 4.1.

Table 4.1: Comparison of Mean Monthly Rainfall 1967-1978 and 1979-1990 Periods for Some Selected Districts in Ghana.

Survey district	Nearest meteorological station	Mean monthly rainfall (mm)		Paired difference	t	Significance (2-tailed)
		1967-1978	1979-1990			
Wa	Wa	86.9	77.3	9.6	1.454	.174
Damango	Dmango	97.1	105.1	-8.0	-0.487	.636
Salaga	Salaga	88.1	97.2	-9.1	-0.815	.433
Nkoranza	Ejura	115.3	108.7	6.6	0.760	.463
Amansie West	Kumasi	116.4	107.0	9.4	0.891	.392
Adansi East	Bekwai	108.3	94.1	14.2	1.437	.179
West Akim	Prankese	124.0	94.1	29.9	1.722	.113
Adidome	Ohawu	75.5	72.0	3.5	0.455	.658
Tema	Tema	62.9	51.8	11.1	1.291	.222
Agona	Agona Swedru	102.1	93.7	8.4	1.093	.298
Jasikan	Hohoe	138.4	122.5	15.9	2.502	.029

Source: Estimated by the author based on data from the Meteorological Services, Accra.

The probability values (p value) associated with the t-statistics in Table 4.1 show that apart from Hohoe which had significantly higher mean monthly rainfall in the 1967-1978 period than the 1979-1990 period, for all the other districts, the mean monthly rainfall was not significantly different between the two periods. This means that the mean monthly rainfall for the periods 1967-1978 and 1979-1990 are apparently the same. The results thus seem to suggest that even if rainfall is an important factor in maize

production in Ghana, it has basically played an unbiased role for maize production in the period prior to the establishment of the GGDP (1967-1978) and with the GGDP existence (1979-90).

Inputs

In maize factor of production trial conducted on-farm by the GGDP in 1980, fertilizer contributed 54% to yield, improved variety was 21%, appropriate plant density 18% and weed control 7%. Fertilizer and seed are thus important inputs in maize technology development. It is thus imperative that their availability, distribution and use are analysed for purposes of policy development.

Seed Production and Distribution

The seed industry is crucial to agricultural development in Ghana, and seed is one of the important forms in which technology can easily be transferred to farmers.

The Seed Multiplication Unit of MOFA used to produce and market different kinds of seeds including maize before 1979. In 1979, however, the Ghana Seed Company (GSC) was established as a parastatal to take over the functions of the Seed Multiplication Unit. During the period of 1979 to 1989, the GSC became a major producer and marketer of certified seed in Ghana. The GSC received maize breeder seed from the GGDP of CRI. It, in turn, produced foundation seed which was then given to contract growers to produce certified maize seeds.

The channels of distribution and sale of GSC seed were direct sales through their offices, sales kiosks, mobile sales, commission agents and extension agents from the Ministry of Food and Agriculture. The Grains and Legumes Development Board also

produced some foundation and certified seeds, side by side, with GSC. It also obtained its breeder seed from the GGDP.

In 1989, as a result of Ghana Government policy favouring privatisation of the seed industry, the GSC was closed down. Since 1989, the Ghana Government has restructured the whole Ghana seed industry. Breeder seed is produced by CRI and made available to GLDB for foundation seed production. Private seed growers then produce certified seeds that were sold either directly to farmers or through seed dealers. The Ghana Seed Inspection Unit (GSIU) and the National Seed Service (NSS) provide technical support of quality control and certification.

Other international bodies such as the United States Agency for International Development (USAID), SG2000, International Fund for Agricultural Development (IFAD) and the World Bank have in various ways supported the whole seed industry.

The establishment of the seed industry has provided employment for entrepreneurs and enterprises engaged in seed production and distribution. For example, the number of seed growers and dealers has increased since 1990. The number of growers has more than doubled from 1990 to 1996, and the number of dealers has increased sixteen folds since 1991 (Table 4.2). These seed dealers are the retailers of improved

Table 4.2: Improved Maize Seed Growers and Dealers in Ghana, 1990-1996

Year	Number of growers	Number of dealers
1990	52	0
1991	65	10
1992	80	80
1993	91	96
1994	108	0
1995	120	160
1996	120	160

Source: Compiled by the author from the National Seed Service records, Pokuase, Ghana.

maize seed and they are found in most areas of Ghana.

The quantity of certified seeds sold by erstwhile GSC, GLDB and seed growers since 1979 are presented in Table 4.3. Between 1979 and 1983, the main maize variety sold was La posta. Since 1984, the newer varieties such as Dobidi, Okomasa and Abeleehi developed and released by GGDP have been some of the major varieties officially on sale.

Table 4.3: Certified Seed Sales in Ghana (in mt)

Year	GSC	GLDB	Seed growers	Total	Estimated area under cultivation (ha)
1979	992	25	0	1017	45200
1980	893	9	0	902	40089
1981	617	46	0	663	29467
1982	711	16	0	727	32311
1983	196	18	0	214	9511
1984	55	26	0	81	3600
1985	41	75	0	116	5156
1986	145	86	0	231	10267
1987	209	86	0	295	13111
1988	227	145	0	372	16533
1989	0	157	0	157	6978
1990	0	145	0	145	6444
1991	0	0	297	297	13200
1992	0	0	326	326	14489
1993	0	0	475	475	21111
1994	0	0	816	816	36267
1995	0	0	1082	1082	48089
1996	0	0	713	713	31689

Source: Compiled by the author from GSC, GLDB Warehouse and National Seed Service records.

In the period between 1984 and 1995 a total of 4,393 metric tons of certified seed were sold to farmers covering a cumulative area of 195,244 hectares. Thus, on the

average 16,270 hectares were under improved maize over the 12 year period (1984 - 1995).

MOFA has tried to encourage farmers to use improved seeds through seed promotional programmes since 1990. The Ministry advertises yearly in the daily newspapers the names of growers and dealers, their addresses, location and varieties of certified maize seed for sale. It also earmarks a day in each year as seed promotion day to remind farmers of the beginning of the maize growing season. As part of seed promotion, MOFA develops fact sheets about seed maize for interested people. The GSIU further organises field days on seed growers' farms for neighbouring farmers.

Certified seed sold by the seed growers and dealers are probably just a small proportion of the total improved maize grown in the country¹. An important point to note is that a conscious effort has been made to make quality improved seeds available for farmers.

Fertilizer

Most of the fertilizers imported into Ghana are used in maize production. Other crops that use fertilizers are rice, cotton and some vegetables. The use of fertilizers in Ghana is generally low. In 1990, for example, Ghana used less than 5 kilograms per hectare of plant nutrients that only replenished about one-seventh of the plant nutrients

¹ .For example, in a maize seed management study in the Brong-Ahafo and Volta Regions of Ghana, 78% and 76% of farmers between 1992-94 farm-saved their seeds. (Tripp 1996. DRAFT REPORT). Of the farmers who acquired seed off-farm only 15% and 18% of the farmers in Brong-Ahafo and Volta Regions respectively purchased seed from a formal source between 1992 and 1994.

A seed rate of 22.5kg/ha was used to estimate the area under certified maize seed

removed by crops². One can attribute the slow growth in fertilizer use to macro-economic policy in Ghana.

Marketing and distribution

MOFA was the sole importer of fertilizer in Ghana until 1988 when it distributed its fertilizer through its sales outlets dotted throughout Ghana. The system of marketing and distribution created many problems. In particular, delays in Government funding, untimely delivery of fertilizers to farmers, and ineffective physical distribution at the district and sub-district levels became common. Other problems include the dual and conflicting role MOFA played in marketing fertilizer and carrying out extension activities.

In 1988, Ghana Government privatised the fertilizer trade apparently to mitigate some of the problems mentioned earlier. The marketing and distribution of fertilizer have since been privatised.

Trends in fertilizer imports

In Ghana, fertilizers that are recommended for maize cultivation are ammonium sulphate, urea and compound fertilizer of nitrogen-phosphorus-potassium (NPK) combination. Since these are the recommended ones, analysis of the study is based on them.

² Bumb B.L., J.F. Teboh, J.K. Atta and W.K. Asenso-Okyere (1994). " Ghana Policy Environment and Fertilizer Development." IFDC. 1994. P.25

The bulk of fertilizer consumed in Ghana is in the Guinea Savannah and the transition zones because of poor soils, as well as intensive and continuous cropping.

Imports of fertilizers in Ghana since 1970 are presented in Table 4.4.

Table 4.4: Fertilizer Imports to Ghana since 1970 (in mt)

Year	Ammonium sulphate	Urea	15-15-15 (NPK)	20-20-0 (NPK)	Total
1970	3140	3	3671	1087	7901
1971	1943	3	4923	544	7413
1972	3852	33	5787	2085	11757
1973	8100	8	14278	3418	25804
1974	4150	10	6000	1000	11160
1975	2258	3	16075	1475	19811
1976	2557	0	36626	4218	43401
1977	2900	0	4200	4000	11100
1978	13739	0	15896	6180	35815
1979	19000	0	39650	0	58650
1980	17980	0	39600	0	57580
1981	-	0	0	0	0
1982	14000	0	20000	8000	42000
1983	0	0	0	0	0
1984	13600	200	24550	0	38350
1985	5437	0	21362	3200	29999
1986	8500	0	0	9600	18100
1987	14650	0	4800	17620	37070
1988	20550	0	9400	3300	33250
1989	25711	6015	8000	15500	55226
1990	2000	20100	8500	34850	44950
1991	0	0	0	0	0
1992	11538	0	9575	4100	25213
1993	7600	0	10000	0	17600
1994	0	0	9040	0	9040
1995	8800	0	13040	0	21840

Source: Compiled by the author from MOFA records and Bumb et al, 1993, pp38-40.

Fertilizer imports are somewhat indicator of fertilizer consumption in Ghana. The increase in fertilizer imports and consequently use in the 1970s were the results of the rice boom in Northern Ghana and irrigated lands that were developed at that time. This was

due to the Ghana Government's " Operation Feed Yourself" (OFY) and "Operation Feed Your Industry" (OFYI) policies which placed more emphasis on food and industrial crops production. Another contributing factor was that fertilizers were heavily subsidised.

Trends in fertilizer prices

The pricing policies in Ghana in the seventies were to keep fertilizer prices low and constant over some time (1970 to 1976) so that farmers could plan ahead and use them. For example, the level of subsidy on fertilizer was 80% in 1979 as in Table 4.5.

Table 4.5: Nominal Fertilizer Prices and Subsidy Rates in Ghana

Year	Price (cedis/50kg bag)		Subsidy rate (%)
	Ammonium sulphate	15-15-15NPK	
1970	2.0	2.8	Not available (n.a.)
1971	2.0	2.8	n.a.
1972	2.0	2.8	n.a.
1973	2.0	2.8	n.a.
1974	2.0	2.8	n.a.
1975	2.0	2.8	n.a.
1976	2.0	2.8	n.a.
1977	5.0	6.5	n.a.
1978	6.0	7.5	n.a.
1979	8.5	10.0	80
1980	12.0	15.0	65
1981	25.0	30.0	45
1982	25.0	30.0	45
1983	45.0	58.0	45
1984	295.0	440.0	45
1985	295.0	440.0	59
1986	490.0	780.0	36
1987	820.0	1380.0	42
1988	1600.0	2300.0	30
1989	2350.0	3350.0	15
1990	3100.0	4200.0	0
1991	3500.0	6000.0	0
1992	6000.0	8500.0	0
1993	7500.0	10000.00	0

Source: MOFA, Accra., Bumb *et al* 1993. p.40.

The price of fertilizer remained constant from 1970 to 1976 after which several drastic adjustments in prices were made.

Several factors have accounted for these instabilities. One of them was a change in pricing policy that gradually removed subsidies on fertilizer from 80% in 1979 to zero percent in 1990. Consequently, fertilizer prices rose sharply. Furthermore, the exchange rate policy adversely affected fertilizer prices. As part of the Ghana Government's Economic Recovery Programme (ERP), the value of the Ghanaian Cedi was allowed to be market-determined. Thus the value of the cedi changed from 2.75 cedis/US\$1 in 1980 to 350 cedis/US\$1 in 1990. In 1996, it rose to 1700 cedis/US\$1. This led to increased import costs that were subsequently passed on to farmers.

Fertilizer and maize prices

In order that the real cost of fertilizer to the farmer is understood, it is necessary to compare maize and fertilizer prices. This is because fertilizer and maize prices have both changed over time.

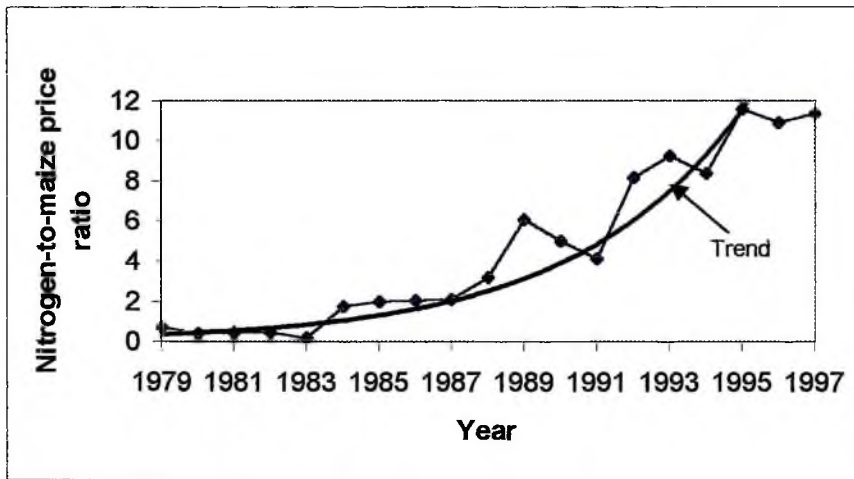
The economic reform and privatization programme in 1983 led to the removal of subsidies on agricultural inputs. For example, subsidies on fertilizer were reduced from 80% in 1979 to zero in 1990. This policy induced increases in fertilizer prices (Table 4.6). The nitrogen-maize price ratio has risen from 0.6 in 1979 to 11 in 1997 (Figure 4.2). This policy has made fertilizer more expensive.

Table 4.6: Fertilizer Prices and Subsidies in Ghana

Year	% subsidy	Cost for recommended rates of compound and ammonium sulphate fertilizers (cedis/ha)	
		With subsidy	Without subsidy
1979	80	46	83
1980	65	68	112
1981	45	138	200
1982	45	138	200
1983	45	258	374
1984	45	1838	2665
1985	59	1838	2922
1986	36	3175	4318
1987	42	5500	7810
1988	30	9750	12675
1989	15	14250	16388
1990	0	18250	18250

Source: Compiled by the author from MOFA records, Accra.

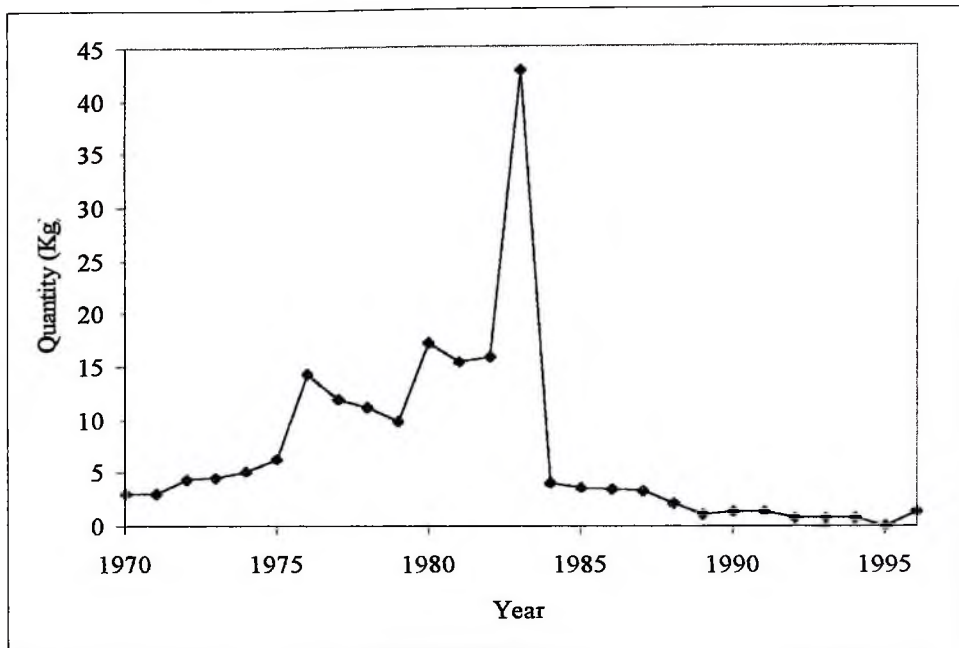
Figure 4.2: Nitrogen-to-Maize Price Ratio, Ghana (1979-1997)



Source: Updated MOFA data by the author.

The real cost of fertilizer has changed considerably since 1970. The quantity of fertilizer that 1kg of maize can buy in the period, 1970 to 1996 are shown in Figure 4.3.

Figure 4.3: Kilograms of Ammonium Sulphate Fertilizer that 1kg of Maize can buy in Ghana (1970-1996)



Source: Estimated by the author from MOFA data.

The quantity of fertilizer that a kilogram of maize could buy increased between 1970 and 1976. It further fluctuated but with increasing trend between 1977 and 1983. Since 1984, the amount of sulphate of ammonia that maize can buy has continuously decreased. This means that a farmer can now buy less of fertilizer for the same amount of maize. It again shows that the real cost of fertilizer has increased since 1984 and farmer's capacity to buy fertilizer has decreased. For example, farmers could buy about 3kg of ammonium sulphate in 1970, 17kg in 1980, but 0.7kg of sulphate of ammonia in 1993 for the same 1kg of maize. This increase in real cost of fertilizer means a reduced profitability in relative terms. This trend of affairs has worked against farmers.

Chapter Summary

The chapter has described the production environment such as the ecological zones, rainfall and input supply for maize production in Ghana. Maize can be produced in all the four ecological zones. Rainfall is an important factor in the production of maize in Ghana but it has played an unbiased role for maize production prior to the establishment of the GGDP and with the existence of the GGDP. Inputs such as improved seeds and fertilizer have been made available to facilitate the adoption of the improved maize technologies.

CHAPTER 5

RESEARCH METHODOLOGY

Data collection activities

A national survey of farmers was conducted from November 1997 through March 1998 by CRI in collaboration with CIMMYT, CIDA and Overseas Development Institute (ODI) to assess the adoption and impact of GGDP-generated maize technologies. The author participated in this survey. Unlike some maize adoption studies carried out in Ghana in 1987¹ and 1991² which focused on selected districts which were not necessarily representative of the whole country, this study sought to carefully sample the entire maize-producing population to generate information at the national level.

The survey sample was drawn using a three-stage randomised selection procedure. Firstly, 20 agricultural districts were selected at random from among all the agricultural districts in Ghana using random numbers from a statistical table³. Since adoption rates are measured in terms of area under production in the assessment of economic impact of agricultural research, this production parameter is used as the main criterion for selecting the districts⁴. The probability of the selection of each district was proportional to the area planted to maize in the district. This self-weighting procedure led

¹ GGDP. "A Study of Maize Technology in Ghana." Mexico, D.F, GGDP. 1991. pp 3-4.

² Tripp R., K. Marfo, A.A. Dankyi and M. Read. "Changing Maize Production practices of Small-scale Farmers in the Brong-Ahafo Region, Ghana." Ghana Grains Development Project. Kumasi. 1987. pp5-7.

³ Clarke G.M. and D. Cooke. "A Basic Course in Statistics" 2nd ed. Edward Arnold (publishers) Ltd. 1983. pp 404 -405.

⁴ This production parameter is based on data from the "Annual Sample Survey of Agriculture, Ghana, 1996," of the Policy Planning Monitoring and Evaluation Division of the Ministry of Food and Agriculture (MOFA), Accra. 1996. Various pages.

to the selection of districts located in nine of the ten regions of Ghana and across all ecological zones (See Tables 5.1, 5.2 and Figure 5.1)

Secondly, because maize production activities are carried out largely in rural and semi-urban areas, within each selected district, three enumeration areas (EAs) were chosen randomly from among all the EAs classified as rural or semi-urban.⁵ The advantage of using EAs instead of villages is that EAs contain roughly the same number of inhabitants, which removes the need to adjust for differences in village size. Thirdly, in each of the 60 selected EAs, seven farmers were picked at random from a sampling frame consisting of a list of all maize farmers in the EA. This procedure produced a total sample size of 420 maize farmers. The sampling procedure for the maize survey is summarised in Table 5. 1.

Table 5.1: Sampling Procedure for Maize Technology Survey in Ghana

Sampling stage	Sampling unit	Selection criterion	Number at this unit	Cumulative number
1	District	Randomly selected. The probability of selection is proportional to the area under maize production in the district	20	20
2	Enumeration area	Randomly chosen from among enumeration areas classified as rural or semi-urban	3	60
3	Farmer	Randomly selected from among all maize farmers in the enumeration area	7	420

Source: Compiled by the author

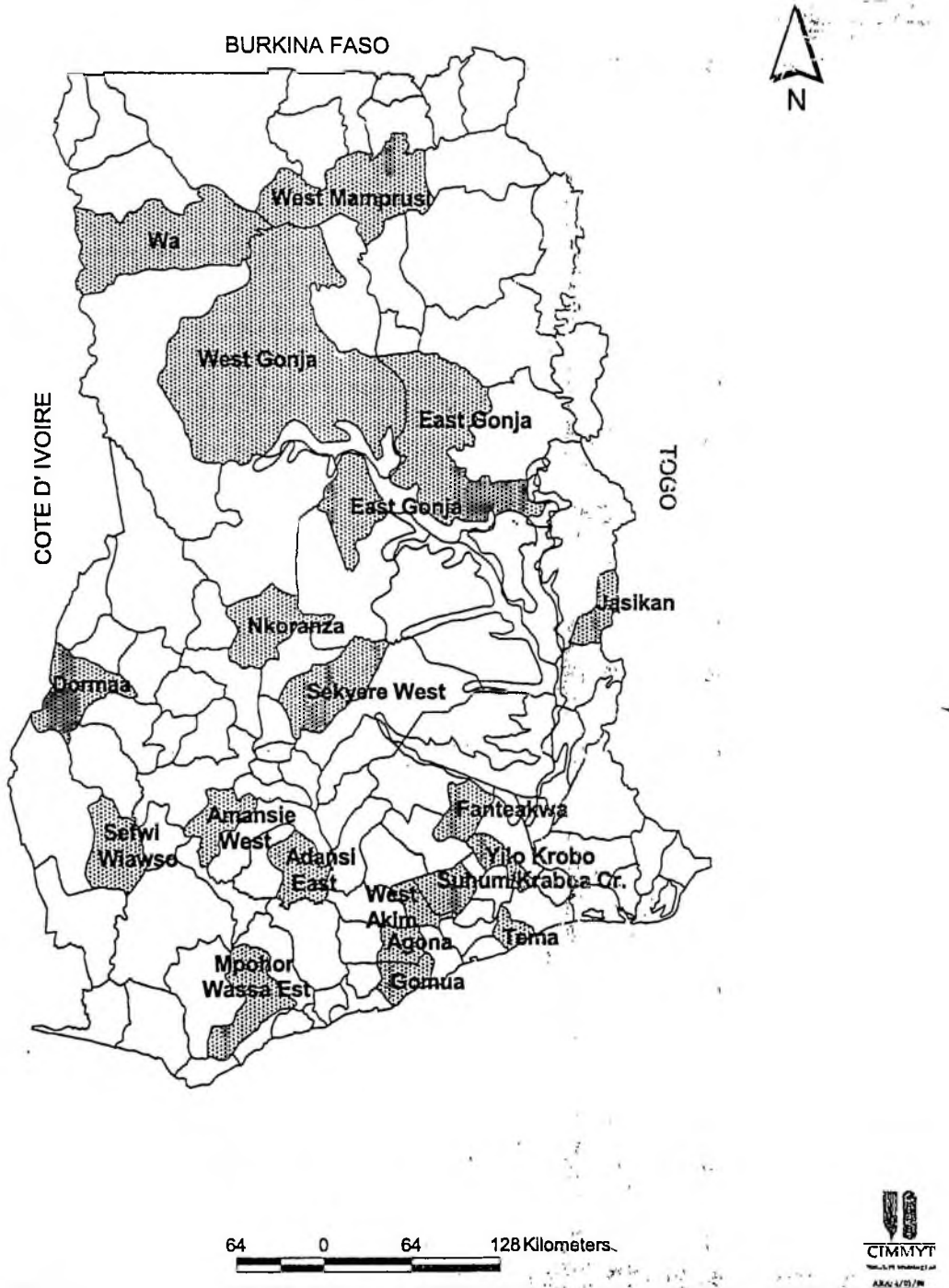
⁵ The Ghana Statistical Service classifies enumeration areas into rural, semi-urban and urban.

Table 5.2: Location of Survey Districts for Maize Adoption Study in Ghana, 1997

District	Ecological zone	Region
Wa	Guinea savannah	Upper West
Salaga	Guinea savannah	Northern
Damango	Guinea savannah	
Walewale	Guinea savannah	
Nkoranza	Transition	Brong Ahafo
Dorma-Ahenkro	Forest	
Amansie West	Forest	Ashanti
Adansi East	Forest	
Sekyere West	Transition	
Adidome	Coastal savannah	Volta
Jasikan	Forest	
Tema	Coastal savannah	Greater Accra
Yilo Krobo	Transition	Eastern
Suhum Kraboa	Forest	
Fanteakwa	Forest	
West Akim	Forest	
Agona	Coastal savannah	Central
Gomua-Assin-Ajumako	Coastal savannah	
Mpohor Wassa	Forest	Western
Sefwi Wiawso	Forest	

Source: Compiled by the author.

Figure 5.1: Location of Survey Districts, Ghana Maize Technology Adoption Study, 1997



The survey instrument

The questionnaire deals with farmer's household characteristics, maize variety use and production practices and maize utilisation patterns. Other sections deal with maize variety preferences, maize seed acquisition and management, impacts of modern variety adoption, and information about the respondent. The questionnaire administered to farmers is presented as Appendix 1.

Economics of maize production

Crop production recommendations should be updated regularly because of the changing economic environment. The results from such assessment can be used to plan further research, modify recommendations to farmers and provide information to policy-makers regarding current policy on input supply.

Results from the GGDP on-farm experiments are updated with current input prices using a partial budget technique. The marginal rate of return is then estimated. The analyses are done on the individual elements from the technological package such as fertilizer and improved variety and on the whole package of improved maize, fertilizer and row planting.

Since farmers usually take risks into consideration when adopting technologies, the results are subjected to risk analysis. The sensitivity of the results to changes in risk factors (yields and prices) is tested.

Determinants of adoption of improved maize

In determining the main factors affecting the adoption of improved maize technology in Ghana, the Logistic regression model and the TOBIT model are used. While the Logistic regression measures the probability of adoption, the TOBIT model not

only measures the probability but also the intensity of use. TOBIT model further gives better results if the dependent variable is continuous. In this study, the dependent variable in the TOBIT model is continuous and the dependent variable in the Logistic regression is dichotomous. Further details of these models are given in Appendix 5.

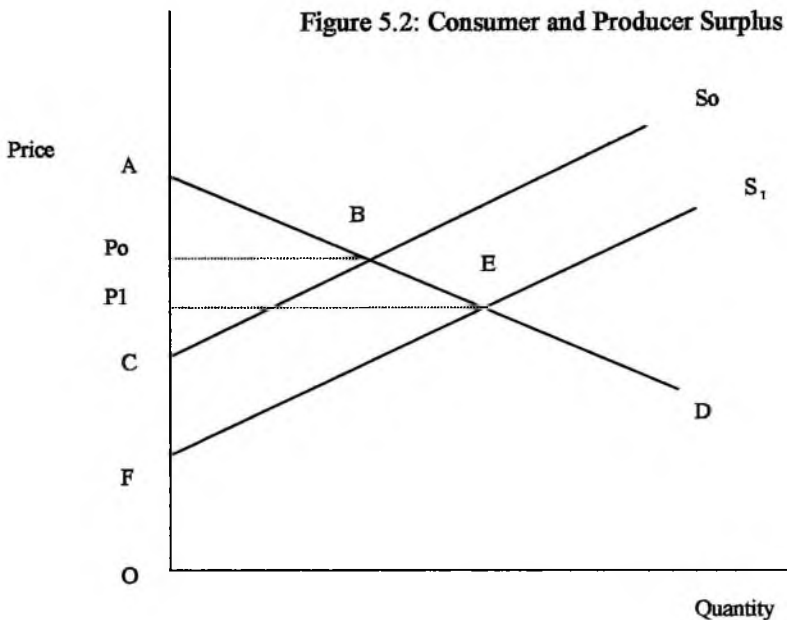
Returns to investment

Returns to investment in agricultural research can be calculated using an economic surplus approach whereby research costs are related to the benefits (measured in terms of changes in producer and consumer welfare) that result from technological innovations generated by the research program. The basic theoretical model is described in Alston et al⁶.

Applying the economic surplus approach to a commodity research program, research-induced technological innovations are hypothesized to increase production per unit of input (reduce per unit production costs), resulting in an outward shift in the aggregate supply curve (cost curve) for the commodity. Assuming linear supply and demand curves, the outward shift of the supply curve leads to a reduction in the market-clearing equilibrium prices and generates gains in producer and/or consumer welfare, with the distribution of these gains determined by the slopes of the supply and demand curves. In other words, producers benefit from research through reduced production costs. Consumers, on the other hand, benefit from research by being able to consume more at a lower price.

The benefits generated by a commodity research program can be depicted graphically as shown in Figure 5.2. As farmers use improved technologies generated by

the research program, the aggregate supply curve shifts outward (downward) from S_0 to S_1 . Any increase in economic surplus is a measure of social gains attributable to the new technology. The change in total surplus caused by the shift of the supply curve is area AEF minus area ABC, which is equal to area FEBC. Thus area FEBC represents the social gains derived from maize research. It is these gains that must be measured.



In order to utilize this model, it is necessary to obtain empirical estimates for three key parameters:

- The J-parameter (which represents the productivity increase attributable to research-induced technological change),
- The K-parameter (which represents the net reduction in production cost attributable to the new technology), and
- The I-parameter (which shows the increase in per unit input production costs).

⁶

Alston M. Julian, George W. Norton and Philip G. Pardey. "Science Under Scarcity." Published by Cornell

Calculation of these three key parameters is described in detail in Appendix 2.

In addition to calculating the three key parameters, it is also necessary to estimate the change in output attributable to research (dQ). In the case of commodity research programs, this is simply calculated as the product of the yield increase attributable to the adoption of improved technology (dY) multiplied by the area over which adoption takes place (dA), while holding input levels constant.

In Ghana as elsewhere, observed market supply and demand curves do not reflect all of the costs and benefits associated with maize production. Government policies (producer price supports, fertilizer subsidies, exchange rate controls) give rise to externalities and transfers that are not reflected in market prices. For this reason, it is advisable to calculate both financial and economic rates of return. In the financial analysis, production inputs and outputs are valued using actual market prices (domestic prices). This is because financial analysis takes the viewpoint of the individual participant of the project. In the economic analysis, production inputs and outputs are valued using economic prices that reflect their true scarcity value (social prices). Economic analysis thus takes the whole society's point of view into consideration. Prices are thus adjusted to reflect the type of analysis used.

In the economic returns, the world market prices adjusted to farm-gate price is used. Since fertilizer subsidies can be considered as transfer payments and are costs to the society, the subsidies have been removed to reflect the true cost to society. The effects of other costs such as seed and labour are small relative to fertilizer costs. The distortions in their prices will have very little effect on the gains from research and therefore, they have not been adjusted.



A real exchange rate is used for the maize price and other foreign component costs of research in the economic rate of return estimation. The real exchange rate (RER) is estimated from the formula: $RER = eP^*/P$

where,

RER = real exchange rate

e = nominal exchange rate

P* = foreign price (proxied by the consumer price index for the United States)

P = domestic price (proxied by the consumer price index for Ghana)

The US dollar is used as a proxy because of the role it plays as an international currency and as a result of the stable national economy of the US. The base period is taken to be 1997 and the estimated real exchange rates are shown in Table 5.3.

Table 5.3: Exchange Rates, 1979 to 1997

Year	Consumer price index ,Ghana (1997=100)	Consumer price index ,United States (1997=100)	Nominal exchange rate (e)	Real exchange rate ,RER, (1997=100)
1979	0.31	45.24	2.75	401.32
1980	0.46	51.34	2.75	306.92
1981	1.01	56.63	2.75	154.19
1982	1.22	60.13	2.75	135.54
1983	2.72	62.00	8.83	201.27
1984	3.81	64.69	35.99	611.07
1985	4.19	67.05	54.37	870.05
1986	5.23	68.27	89.20	1164.38
1987	7.31	70.79	162.37	1572.39
1988	9.61	73.64	202.35	1550.58
1989	12.03	77.22	270.00	1733.12
1990	16.50	81.37	326.33	1609.30
1991	19.49	84.92	367.78	1602.46
1992	21.44	87.39	437.09	1781.59
1993	26.79	89.99	649.06	2180.25
1994	33.46	92.27	956.71	2638.24
1995	58.34	94.87	1200.4	1952.04
1996	78.19	97.64	1637.2	2044.46
1997	100	100	2050.2	2050.20

Source: International Financial Statistics, 1998 pp.438-441; 892-893 and estimates by the author.

In the financial rate of return, domestic maize price and official exchange rates are used for cost estimation. Subsidies on fertilizers are also included.

The world market price for maize is used for the economic rate of return. Since this is to reflect the price the society is paying, 30% transport and 20% marketing costs have been added to the Freight-On-Board (F.O.B) maize price. The farm-gate price for the world price is estimated as 70% of the landed price and this is used as the economic maize price to the farmer (see Appendix 3 for details).

Key assumptions and critical parameters

Key assumptions made in estimating the theoretical model are briefly described in the scenarios presented below. More detailed explanations of how values were calculated for critical parameters appear in Appendix 3. In Appendix 4, the details of the derivation of the various formulae used to estimate the returns to investment are presented.

Baseline scenario (Scenario 1)

Research phase: Maize research under the GGDP was initiated in 1979. The first improved maize variety by the GGDP was released in 1984, together with fertilizer application rates and row planting recommendations. The research phase thus lasted from 1979 to 1983, a period of five years.

Adoption phase: Adoption of the GGDP-generated technologies began in 1984. The diffusion path was estimated based on the results of various adoption studies carried out during the course of the project. The diffusion path was modelled as a smooth logistic growth curve beginning in 1984. Based on historical adoption data, it is projected that complete adoption will be achieved after 30 years.

Research costs: Maize research costs consisted mainly of GGDP costs. The rate of returns calculations also took into account modest research investments made by the Savannah Agricultural Research Institute (SARI), the National Agricultural Research Project (NARP), as well as direct project management costs incurred by CIMMYT. Under the baseline scenario, 90% of GGDP costs were assigned to maize research in accordance with the initial budget allocation of the GGDP.

Extension costs: Extension cost for maize was borne mainly by MOFA. MOFA extension works on several crops in Ghana but the Policy Planning Monitoring and Evaluation Division (PPMED) of MOFA keeps production records of about 6-8 crops. Therefore using the area under production for these crops, extension activities were assumed to be proportional to it. This assumption put maize extension cost between 20% and 27%. Thus, under the baseline scenario, 30% of MOFA costs were assigned to extension activities on maize. In addition, the rate of return calculations took into account extension costs incurred by the Sasakawa Global 2000 Project.

Productivity gains: Productivity gains attributable to research were estimated from experimental data showing the yield gains associated with adoption of the three GGDP-generated maize technologies (improved varieties, fertilizer, row-planting). In on-farm trials managed by farmers, yields obtained through the use of improved technologies were compared to yields obtained through the use of farmers' own practices. The difference between the two (expressed in percentage terms) was attributed to the adoption of improved technologies.

Financial prices: Financial price for outputs (maize grain) and key inputs such as fertilizer were collected through surveys and also taken from several official government publications.⁷ (See also Appendix 3)

Economic prices: Economic prices were calculated when these were considered to cause economic profitability to diverge significantly from financial profitability. In particular, economic prices were calculated for maize grain and for fertilizer. Since the cost of other inputs such as seed used in maize production are small relative to the cost of fertilizer, policy-induced distortions in the prices of these other inputs had very little influence on profitability and therefore were ignored (see Appendix 7).

Exchange rate: In the financial analysis, international prices were converted to domestic prices using the official exchange rate. In the economic analysis, international prices were converted to domestic prices using the real exchange rate (see Appendix 8).

Alternative scenarios

Sensitivity analysis was carried out to test whether the rates of return are sensitive to changes in the values of key parameters such as research and extension costs, and yield gains. Four additional scenarios were modelled.

Scenario 2 (higher research costs)

Since the GGDP supported work on crops other than maize, in calculating returns to investment in maize research it is necessary to decide what proportion of GGDP costs should be assigned to maize and what proportion to other crops. The decision is not entirely straightforward, because many GGDP expenditures cannot be linked to specific crops. Under Scenario 2, 100% of the GGDP research costs were assigned to maize.

⁷ Policy Planning Monitoring and Evaluation Division, PPMED, (Statistics Division), MOFA, Accra. Various Issues of Market Price Surveys. 1996

These assumptions are very conservative, because clearly some portions of the GGDP funds were used to support work on cowpeas and soybeans.

Scenario 3 (higher extension costs)

Few MOFA extension agents work exclusively with maize; most work with maize along with a range of other crops. For this reason, just as it is necessary to decide how to assign research costs among crops, it is also necessary to decide what proportion of MOFA extension costs should be assigned to maize and what proportion to other crops. Under the baseline scenario, 30% of MOFA extension costs were assigned to maize. Under Scenario 3, this proportion was increased to 50% to reflect the fact that many MOFA extension agents in fact dedicate significantly a little more time to maize than to other crops.

Scenario 4 (higher research costs and higher extension costs)

To be even more conservative, 100% of the GGDP research costs and 50% of MOFA extension costs were assigned to maize. These represent extreme cases of research and extension expenditures on maize. This scenario assumes that all GGDP research costs were assigned to maize and that half of all MOFA extension costs were on maize.

Scenario 5 (lower projected research benefits)

In the baseline scenario, the productivity gains attributed to the adoption of improved technologies were set equal to the yield gains achieved in on-farm yield trials through use of improved varieties, fertilizer, and row planting. These productivity gains were relative to the yields achieved with local varieties and using farmers' management practices. Since all of the farmers who adopt the improved technologies are unlikely to achieve the same yields as those who participated in the on-farm trials, under Scenario 5

the projected yield increases attributable to adoption of the improved technologies were reduced by 40%⁸. The details of the scenarios are presented in Table 5.4.

Table 5.4: Research and Extension Costs Scenarios for Ghana, 1997

Scenario	Research and extension costs
Scenario 1	GGDP cost (actual) = 90%, MOFA cost (actual) = 30%
Scenario 2	GGDP cost = 100%, MOFA cost = 30%.
Scenario 3	GGDP cost (actual) = 90%, MOFA cost = 50%.
Scenario 4	GGDP cost = 100%, MOFA cost = 50%.
Scenario 5	Same as scenario 1 except that yield gain is reduced by 40%.

Source: Compiled by the author.

Chapter Summary

A formal survey with prepared questionnaire is used to obtain information from randomly selected farmers for the adoption rates of improved maize technologies. Furthermore, the economics of maize production technologies are analyzed. The information obtained is used for planning research and modifying maize recommendations. The determinants of adoption of improved maize are estimated with the Logistic regression and the TOBIT models. The returns to investments in research and extension activities are estimated with the economic surplus method.

⁸ CIMMYT, 1988. Op. Cit. pp.23-25. (CIMMYT recommends 5% to 30% yield adjustment to compensate for the difference between experimental yield and the yield farmers could expect from the same treatment).

CHAPTER 6

THE ADOPTION OF MAIZE TECHNOLOGIES IN GHANA

Demographic characteristics of the farmers

The demographic information about the farmers interviewed is presented in Table 6.1. The data are broken down into ecological zones to highlight possible geographic and demographic indicators that might affect farmers' acceptance of improved maize technologies.

Table 6.1: Demographic Characteristics of Maize Farmers, Ghana.

Ecological zone	Years of schooling (years)	Average age (years)	Average household size	Gender of respondents		Residence status		(N)
				Male (%)	Female (%)	Native (%)	Settler (%)	
Forest	6.7	44	8.0	70	30	55	45	189
Transition	6.5	45	9.8	65	35	90	10	63
Coastal Savannah	6.3	47	9.7	71	29	73	27	84
Guinea Savannah	2.3	41	15.4	98	2	74	26	84
All zones	5.7	44	10.1	75	25	68	32	420

Source: Author's computations based on the 1998 CRJ/CIMMYT survey.

On the average, farmers interviewed have less than seven years of formal education. Farmers in the Guinea Savannah Zone have the least number of years in formal education. The mean age of the farmers is forty-four years and this is within the age group of Ghana's labour force. Another important note is that female farmers form a quarter (25%) of the survey respondents. However, there is a considerable variability in the proportion of female farmers between ecological zones. These range from as low as 2% in the Guinea Savannah zone to 35% in the transition zone. Restrictions on women's access to land are common in the Guinea Savannah Zone, where inheritance is patrilineal and this

could be one of the explanations for low representation of females in the sample from the Guinea Savannah.

In Table 6.2, information on farmers' access to infrastructure such as education, good drinking water and health services are presented. The data on infrastructure is important because infrastructure may affect the flow of information, goods and services that in turn may influence the adoption of improved technologies. The data in Table 6.2 shows that the Guinea Savannah Zone has the least of the infrastructure particularly electricity and health services. Farmers in the transition zone have better access to infrastructure. In general, however, the coastal savannah has the best of the infrastructure.

Table 6.2: Access to Infrastructure by Survey Household

Zone	Percent of farmers who live in a village with:						
	Elementary school	Electricity	Health post	Pipe-borne water	Tarred road	Easy transportation	Market
Forest	100	19	30	41	15	41	33
Transition	100	22	44	44	44	56	22
Coastal Savannah	100	50	33	67	58	92	46
Guinea Savannah	83	0	8	50	17	33	46
All zones	97	22	28	48	28	52	34

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Adoption of maize technologies

Three main recommendations whose adoption rates were measured are improved varieties, fertilizer and row planting. The recommendations have been widely accepted. Farmers in the ecological zones who are using one or more of the maize technologies on part of their farm in 1997 crop season are presented in Table 6.3

Fifty-four percent of all farmers plant improved varieties and a similar proportion (54%) plant at least part of their maize fields in rows. The rate of fertilizer use is however low. Less than a quarter (21%) of the farmers use fertilizers. As explained earlier, the economic reform policy of the Ghana government made fertilizer more expensive and this made some farmers cease utilizing fertilizer. Furthermore, male farmers have adopted the improved technologies more than their female counterparts in all the ecological zones.

Table 6.3: Adoption of Maize Technologies in Ghana, 1997

Zone	Percent of farmers using technologies								
	Improved variety			Row planting (a)			Fertilizer		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Coastal savannah	42	27	69	31	22	53	24	5	29
Forest	23	15	38	23	16	39	8	1	9
Transition	41	27	68	35	24	59	24	5	29
Guinea savannah	40	26	66	43	28	73	30	6	36
All zones			54			54			21

(a) Row planting excludes ridge planting.

Source: Author's computations based on the 1998 CRI/CIMMYT survey

In Table 6.4, the percentage of farmers who have stopped using fertilizer (31%) is far more than farmers who have stopped using improved varieties (9%) and row planting (13%).

Table 6.4: Disadoption of Maize Technologies in Ghana

	Improved variety	Fertilizer	Row planting
Number of farmers ever used recommendation	250	128	239
Number of farmers using in 1997	227	88	208
Difference	23	40	31
Percentage of those stopping technology use	9.2%	31.3%	13%

Source: Author's computations based on the 1998 CRI/CIMMYT survey

The adoption rates of maize technologies (in terms of number of farmers using the technology) vary among the ecological zones. Generally, the adoption rates of all the three technologies are lowest in the forest zone.

The adoption of technologies can also be measured based on the area under the technologies. In Table 6.5 the percent of maize land area planted with improved varieties, row planted and fertilized in both the major and minor seasons are shown. In general, the adoption is high in the coastal savannah, transition and the Guinea Savannah Zones; and low in the forest zone. It is interesting to note that the proportion of the area planted to the improved varieties is identical to maize farmers who have adopted the improved technologies (54%).

Table 6.5: Proportion of Area under Maize Technology Adoption in Ghana, 1997

Zone	Improved variety	Row planting	Fertilizer
	(%)	(%)	(%)
Coastal Savannah	74	59	38
Forest	33	44	9
Transition	68	66	42
Guinea Savannah	60	68	32
All zones	54	55	26

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Among the improved varieties released by the GGDP, the most popular is Obatanpa. In 1997, Obatanpa accounted for 16% of Ghana's total maize area. In Table 6.6, the area planted to specific maize varieties in 1997 is presented. A significant proportion of the area is planted with improved varieties (18.5%) whose identities are not known and are simply called "Agric" by the farmers. The area under these specific varieties in the ecological zones is further presented in Appendix 17.

Table 6.6: Area Planted to Specific Maize Varieties in Ghana

Variety	Year released	Major season (ha)	Minor season (ha)	Total (ha)	Total (%)
Improved varieties:					
"Agric"	Unknown	103.0	16.6	119.6	18.5
Obatanpa	1992	80.1	22.5	102.6	15.9
Dobidi	1984	33.6	7.8	41.1	6.4
Aburotia	1984	17.6	5.4	23.0	3.6
Abelechi	1990	13.0	7.8	20.8	3.2
La Posta	Pre-1980	19.6	0.4	20.0	3.1
Okomasa	1988	16.6	2.4	19.0	2.9
Golden Crystal	1984	0.8	0.8	1.6	0.2
Dorke SR	1990	0.2	0	0.2	0
All Improved varieties		284.4	63.4	347.8	53.8
Local varieties					
		246.9	51.0	297.9	46.1
Total		531.4	114.4	645.8	100

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Farmers are generally known to adopt technologies in a step-wise manner and are selective of the available technologies depending on the farmers' circumstances. The interactions in maize technologies among maize farmers are presented in Table 6.7.

Table 6.7: Interaction among Maize Technologies in Ghana, 1997

Practice	Percent of farmers who:			
	Planted improved variety		Planted local variety	
	Applied fertilizer	No fertilizer	Applied fertilizer	No fertilizer
Row planting	12%	23%	5%	11%
Random planting	1%	10%	0.5%	38%

Note: n = 392 (excludes ridge planting)

Source: Author's computations based on 1998 CRI/CIMMYT survey

Only 12% of the farmers adopted the three technologies at a time. The common combination of practices among these farmers is the use of improved varieties and row planting. One of the explanations for the low adoption of all three technologies (improved variety, fertilizer and row planting) might be the cost involved especially with the use of

fertilizer. The reason for adopting improved variety and row planting together by these farmers might be the way improved maize technologies were introduced to farmers in the past through technological packages. Another reason could be the relative low cost involved with improved maize-row planting combination while at the same time ensuring good plant density.

Although maize recommendations by the GGDP are made on the basis of ecological zones, Ghana's agricultural activities are based on political boundaries rather than on ecological zones. Frequently, policy makers want to know the adoption rates within the regions of Ghana. For this reason, the adoption of the improved technologies in Ghana¹ is presented according to regions as in Tables 6.8 (and Figure 6.1), 6.9 (and Figure 6.2), and 6.10 (and Figure 6.3).

Table 6.8: Adoption of Improved Varieties in the Political Regions of Ghana

Region	% of sample within region	% of sample within total
Western	26.8	2.6
Eastern	48.8	9.8
Volta	47.6	4.8
Ashanti	59.7	8.8
Brong Ahafo	54.8	5.5
Central	52.4	5.3
Greater Accra	85.7	4.3
Northern	58.7	8.8
Upper West	85.7	4.3
(Total)	54.2	54.2

Source: Author's computations based on the 1998 CRI/CIMMYT survey

In Table 6.8, the percent of farmers who have adopted the improved technologies are presented. This is also shown in Figure 6.1. In Tables 6.9 and 6.10, the adoption rates

¹ None of the districts in the Upper East fell into the sample apparently because not much maize is grown there.

for row planting and fertilizer are respectively presented. These are also depicted in Figures 6.2 and 6.3 respectively.

The Western Region has the least adoption rates of improved varieties, row planting and fertilizer use (see Tables 6.8, 6.9, and 6.10). This is not surprising since the region is basically a forest zone where tree crops are predominant. The Ashanti, Volta, Eastern and Brong Ahafo Regions are of more than one ecological zone of transition and forest zones. The adoption of improved varieties in these regions is between 48% and 55%. The Greater Accra region is a coastal savannah while the Northern and Upper West Regions fall basically in the Guinea Savannah Zone.

The adoption rates in these regions are fairly high compared to other regions. These are similar to the results of the analysis based on ecological zones for coastal savannah and Guinea Savannah. The Upper West Region and the Greater Accra Region have the highest adoption rates (85.7%) for improved varieties in Ghana.

With row planting technology, the Northern and Upper West Regions have more adoption than the other regions (Table 6.9 and Figure 6.2). Three-quarters of sample farmers in these regions plant maize in rows. Within the country as a whole, however, the Northern Region farmers have adopted more of the row planting technology than the other regions. About a fifth of all sample farmers in Ghana who have adopted row planting technology come from the Northern Region sub-sample (10.2% out of 54.1%).

Figure 6.1: Regional and District Boundaries of Ghana Showing the Adoption Rate of Improved Varieties in the Regions (%)

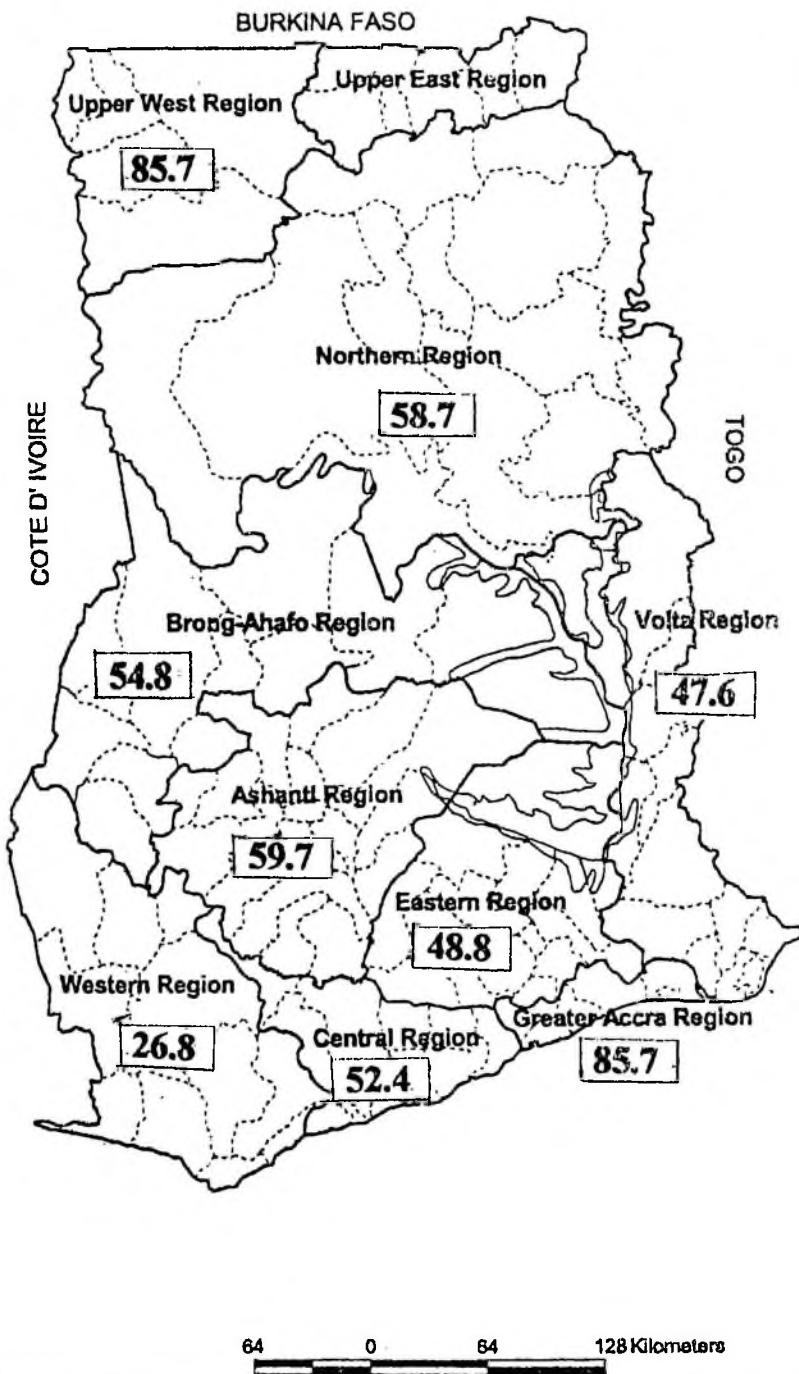


Table 6.9: Adoption of Row Planting in the Political Regions of Ghana

Region	% of sample within region	% of sample within total
Western	31.0	3.2
Central	50.0	5.2
Eastern	42.9	8.9
Greater Accra	66.7	3.5
Volta	66.7	6.9
Ashanti	41.9	6.5
Brong-Ahafo	66.7	6.5
Northern	75.9	10.2
Upper West	76.5	3.2
(Total)	54.1	54.1

Source: Author's computations based on the 1998 CRI/CIMMYT survey

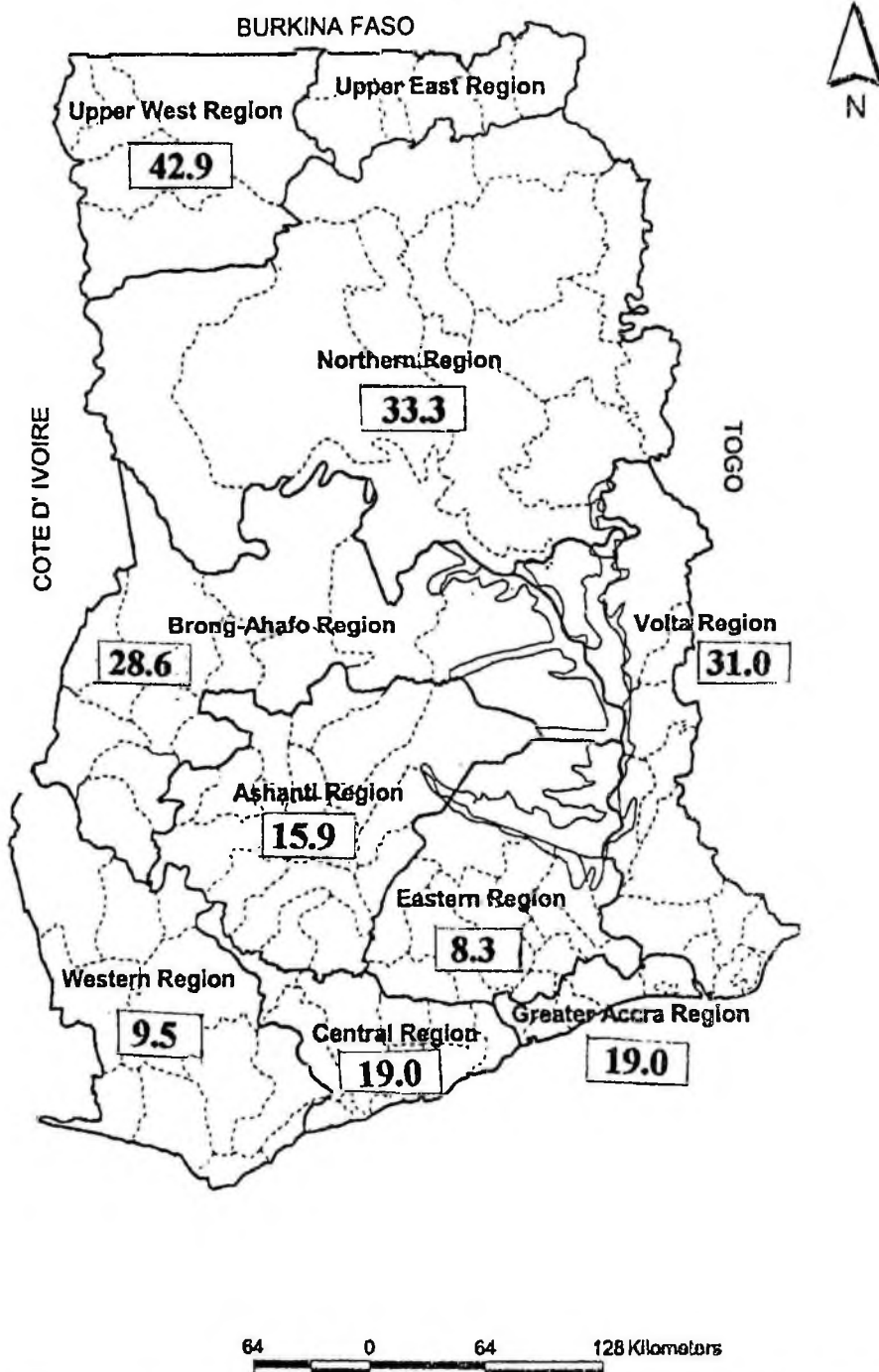
For fertilizer technology, the adoption rates for all the regions are generally low (Table 6.10 and Figure 6.3). This could be due to the high price of fertilizer. The adoption rates are between about 9% and 43%. The Eastern Region has the least adoption rates while the Upper West Region has the highest adoption rate of 42.9%. These results are not surprising since Eastern Region has basically more forest ecology that might be fertile while the Upper West is savannah that usually might require additional fertility.

Table 6.10: Adoption of Fertilizer in the Political Regions of Ghana

Region	% of sample within region	% of sample within total
Western	9.5	1.0
Eastern	8.3	1.9
Volta	31.0	3.1
Ashanti	15.9	2.4
Brong Ahafo	28.6	2.9
Central	19.0	1.9
Greater Accra	19.0	1.0
Northern	33.3	5.0
Upper West	42.9	2.1
(Total)	21.0	21.0

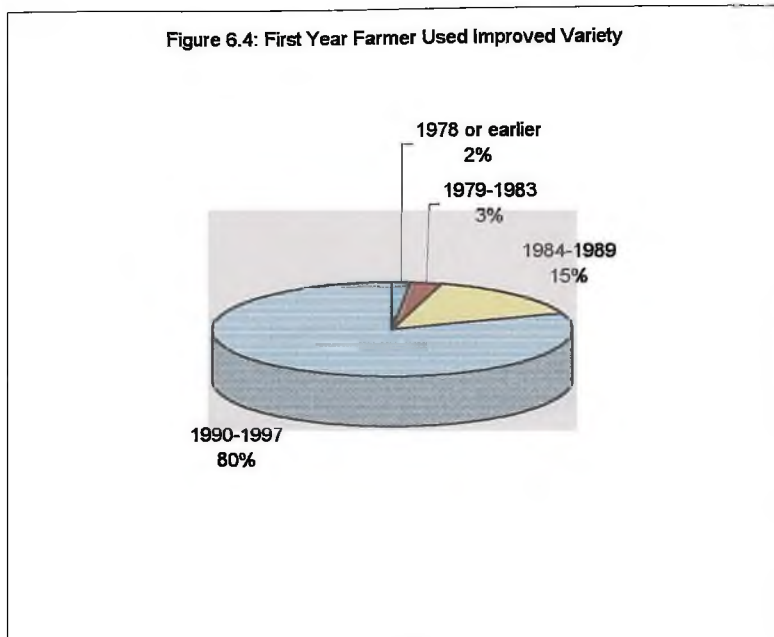
Source: Author's computations based on the 1998 CRI/CIMMYT survey

Figure 6.3: Regional and District Boundaries of Ghana Showing the Adoption Rate of Fertilizer in the Regions (%)

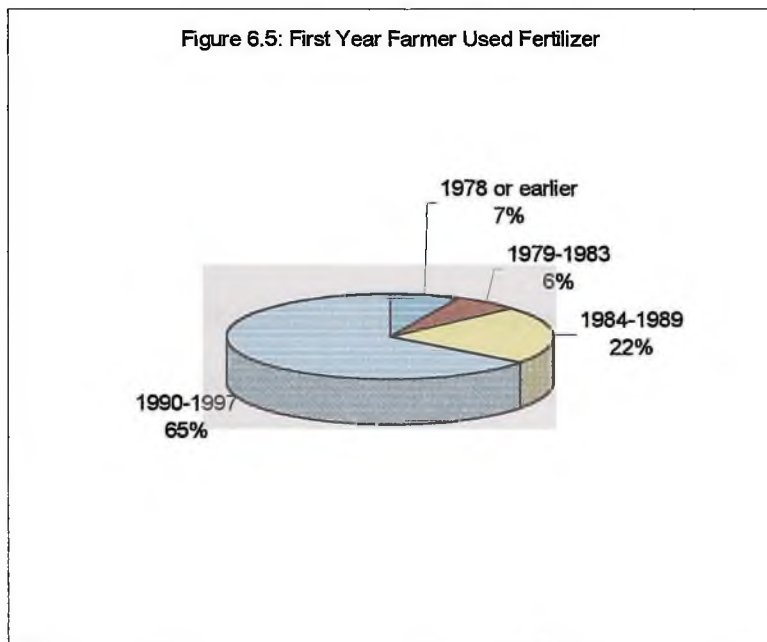


Thus, the adoption of the improved maize technologies seems to be related more to ecological zones than political regions. Maize technology recommendations based on political regions will be difficult to make since the recommendation domains are different even within regions. Thus, recommendations on ecological zones are more appropriate.

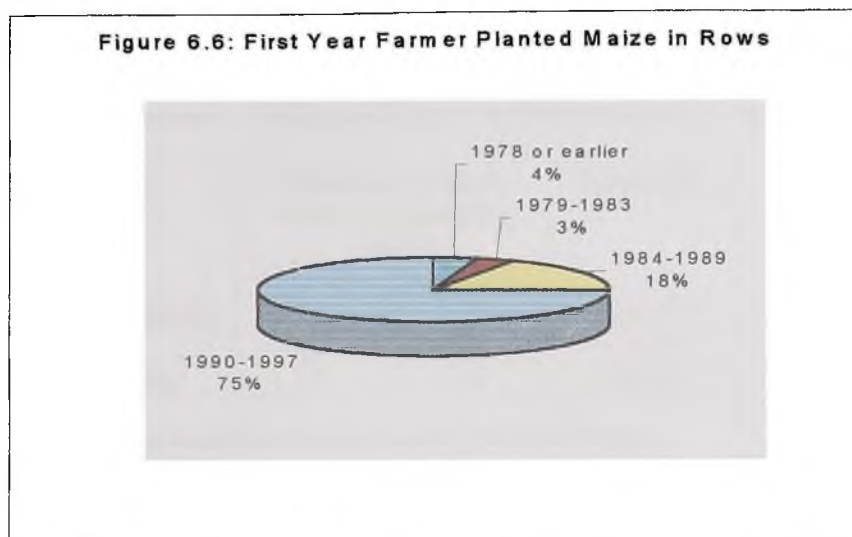
In making any inference as to whether maize research and extension have indeed helped farmers in the adoption of improved maize technologies, it is important to trace the history of the use of the technologies. The history of the adoption of maize technologies in Ghana is presented in Figures 6.4, 6.5, and 6.6. Most farmers began to use maize technologies in the late eighties and nineties. In all, 95% of the farmers first adopted improved maize varieties from 1984 to 1997 with an incremental rate of 65.2% (Figure 6.4). The period was the active research and extension period of the GGDP. Similarly, 86.8% of the farmers used fertilizer in the same period as shown in Figure 6.5, giving an incremental rate of 42.8%. With row planting, 92.7% of the farmers adopted it between the 1984 to 1997 period as in Figure 6.6 resulting in an incremental adoption rate of 57.3%. the 1984 to 1997 period as in Figure 6.6 resulting in an incremental adoption rate of 57.3%.



Source: Author's computations based on the 1998 CRI/CIMMYT survey



Source: Author's computations based on the 1998 CRI/CIMMYT survey



Source: Author's computations based on the 1998 CRI/CIMMYT survey

Explaining adoption:

Extension and the farmers: Although the adoption rate of the maize recommendations are fairly high, there are still about 37.5% of farmers who do not use any of the technologies. One way of explaining this situation is to examine farmers' contact with extension.

Access to information on technology is an important ingredient influencing technology adoption. From CRI/CIMMYT survey it was found that farmers who adopted any of the improved maize technologies had more contacts with extension agents. They have two to three times in a growing season extension officer visits to talk about maize technologies. These results are presented in Table 6.11. These significant differences of the number of the extension contacts suggest that if extension agents visited farmers many

more times, they could demonstrate the benefits to be derived from the adoption of improved maize technologies and thereby convince farmers to use improved inputs.

Table 6.11: Extension Contacts of Adopters and Non-Adopters of Maize Technologies

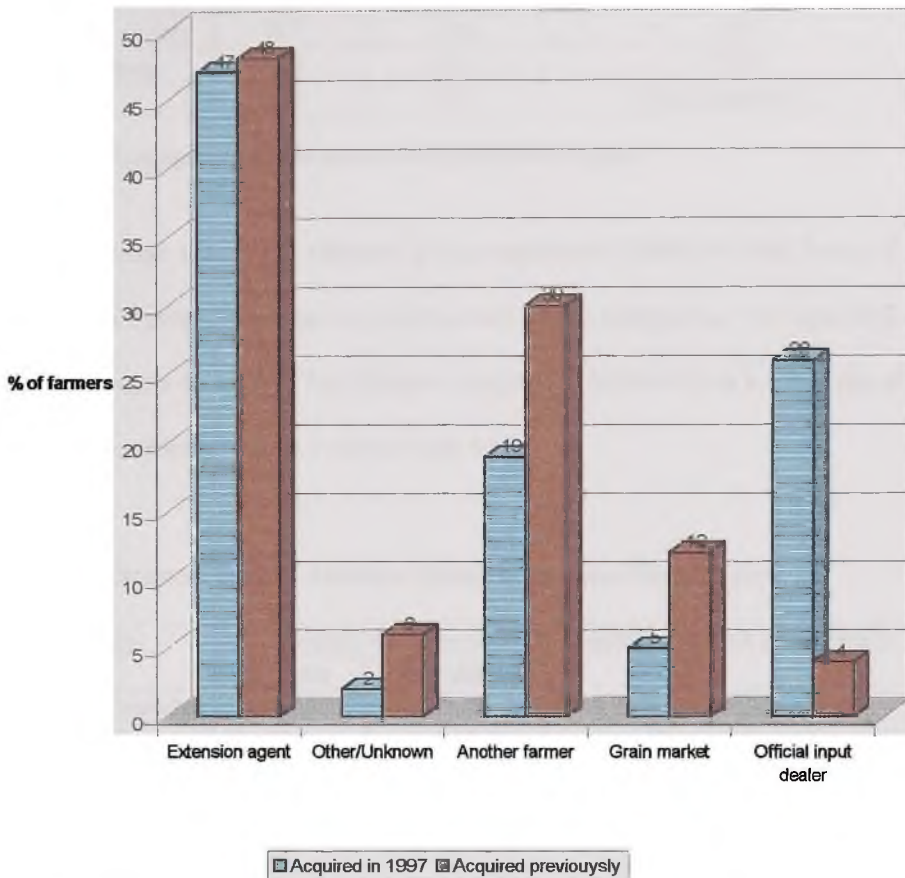
Technology	Number of extension contacts per growing season		Significance
	Adopter	Non-adopter	
Improved variety	3.3	1.1	<.001*
Fertilizer	4.0	1.9	<.001*
Row planting	3.3	1.2	<.001*

* t-test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

There is no doubt that extension has played an important role in introducing new technologies to maize growers in Ghana. Indeed, extension has assisted in the distribution of improved seeds to farmers. Data on the sources of improved seed provide evidence on this. Almost 47% of the survey respondents who grew improved maize in 1997 reported that the seed was originally obtained from an extension agent as in Figure 6.7. In previous years, this proportion was even higher (48%). Only 6% of the farmers acquired seeds from a recognized input dealer in earlier years, but in 1997, this number increased to 26%. This suggests that farmers are at least, becoming aware of where to obtain improved seeds. It could also be due to the privatization of the seed sector. Furthermore, only 5% of farmers now purchase seeds from the open grain market as against 12% in the previous years. In addition, fewer farmers currently obtain seeds from their neighbours than before suggesting that farmers are now getting aware of the correct source of improved seeds.

Figure 6.7: Source of Improved Seed in 1997 and in Previous Years



Source: Author's computations based on the 1998 CRI/CIMMYT survey

Characteristics of the farmers

Another way of explaining adoption is to recognize that the characteristics of the farmers themselves may influence their acceptance to the efforts of extension. Improved technology adopters have more formal education than non-adopters except in the use of fertilizer as shown in Table 6.12.

Table 6.12: Level of Education of Farmer and Adoption of Improved Maize Technologies

Technology	Years in school		Significance level of difference
	Adopter	Non-adopter	
Improved variety	6.3	5.0	<.01*
Row planting	6.3	5.3	<.05*
Fertilizer	5.7	5.7	Not significant*

* t-test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

The mean age of the adopters is not significantly different from those of non-adopters. For example, the mean age of improved variety adopters is 45.1 years while that of non-adopters is 43.3 years. Furthermore, adopters of fertilizer have a mean age of 42.4 years and non-adopters are 44.7 years (Table 6.13).

Table 6.13: Farmers' Age and Adoption of Improved Maize Technologies

Technology	Farmers Age (years)		Significance level of difference
	Adopter	Non-adopter	
Improved variety	45.1	43.3	Not significant*
Row planting	44.5	44.3	Not significant*
Fertilizer	42.4	44.7	Not significant*

* t-test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Other factors associated with the use of improved maize technologies

Improved variety: Some of the factors that are associated with the use of improved varieties are presented in Table 6.14. Farmers who plant improved varieties own more land than those who do not plant improved varieties. In a similar manner, improved maize adopters significantly put more acreage under maize production than their non-adopter counterparts.

Although farmers who plant improved varieties sell more maize (that is, 7.6 maxi-bags) than those who do not plant improved varieties (that is, 6.8 maxi-bags), the

difference is not significant. This result fails to support the notion that when farmers are market-oriented, they are more likely to invest in improved varieties and productivity improvement technologies.

Table 6.14: Factors Associated with the Adoption of Improved Maize Varieties in Ghana

Factor	Improved variety		Significance level of difference
	Adopter	Non-adopter	
Total land owned	2.3 hectares	1.4 hectares	<.001*
Maize area (major season)	1.4 hectares	1.0 hectares	<.001*
Maize sales	7.6 maxibags	6.8 maxibags	Not significant*

* t-test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Row planting: Row planting is closely linked with the use of improved varieties. Row planting allows for better management of maize fields such as weeding, fertilizer application and harvesting. Farmers who adopt row planting own more land and plant larger area to improved maize than those who do not adopt row planting as shown in Table 6.15.

Table 6.15: Factors Associated with Adoption of Row Planting in Ghana

Factor	Row planting		Significance level of difference
	Adopter	Non-adopter	
Resources:			
Total land owned	2.1 hectares	1.4 hectares	<.001*
Major season maize area	1.4 hectares	1.0 hectares	<.001*
Cropping period:			
Average period cropped	2.7 years	1.2 years	<.001*
Land preparation method:			<.001**
Animal or tractor	81% of farmers	19% of farmers	
Manual	44% of farmers	56% of farmers	
Maize sales	8.4 maxibags	6.6 maxibags	Not significant*

* t-test

** chi-square test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

The kind of land preparation method employed seems to be associated with the **management** of plant population. For example, more farmers (81%) who prepare their fields with tractors or animal power plant in rows. This is not surprising since the use of tractors gives an indication that the fields have fewer stumps and more open to facilitate row planting. Complementing this finding is the fact that fields that have been row planted have been continuously cropped for 2.7 years than those not row planted (1.2 years). Furthermore, farmers who plant in rows sell a little more maize than those who randomly plant maize but the difference is not significant.

Fertilizer: Fertilizer management is one of the maize recommendations difficult to adopt, because soil fertility is site specific. However, to make fertilizer recommendations for each maize field will be complex or almost impossible. Therefore, a more general fertilizer recommendation has to be made across ecological zones and cropping history. In this study, a farmer is said to adopt fertilizer if he or she uses some fertilizer at least in a portion of his or her field. Some of the factors that seem to be associated with the use of fertilizers are presented in Table 6.16.

Farmers who apply fertilizers own more land and also cultivate more maize than those who do not apply fertilizer and these differences are significant. Furthermore, fertilizer adopters have, on the average, cropped their fields continuously for more years than their non-adopter counterparts. This finding is logical since continuous cropping generally may deplete the soil of its nutrients if it is not replenished.

Cropping history makes a big difference in a farmer's decision to use fertilizer. A farmer is more likely to use fertilizer on an older field than one that has been newly cleared (or virgin land). It is also interesting to note that fertilizer use seems to be related to land tenure. Farmers with ownership of land tend to apply fertilizer than farmers with other

land arrangements such as sharecropping and renting of land. This is probably so because investments in fertilizer are expensive for farmers and therefore would wish to receive the full benefits from such investments. The low adoption of fertilizer among farmers who sharecrop is understandable since production must be shared with the land-owner but costs are borne solely by the sharecropper.

Table 6.16: Factors Associated with Fertilizer Adoption in Ghana

Factor	Fertilizer		Significance level of difference
	Adopter	Non-adopter	
Resources:			
Total land owned	2.6 hectares	1.7 hectares	<.001*
Major season maize area	1.5 hectares	1.2 hectares	<.01*
Cropping period:			
Average years cropped	4.1	1.7	<.001*
Cropping history:			
More than 5 years cropping	45%	55%	
1 – 5 years cropping	20%	80%	
0 – 5 years fallow	14%	86%	
More than 5 years fallow	9%	91%	
Land tenure:			
Own land	23%	77%	
Rent land	9%	91%	
Sharecrop land	4%	96%	
Marketing:			
Maize sales	8.8 maxibags	6.9 maxibags	Not significant*

* t-test

** chi-square test

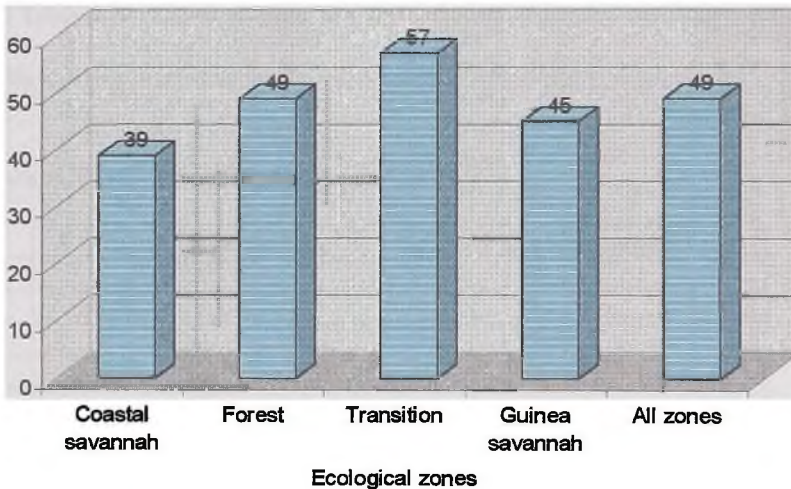
Source: Author's computations based on the 1998 CRI/CIMMYT survey

Commercial orientation seems to play a little role in the adoption of fertilizer. There is no significant difference between farmers who adopt fertilizer and those who do not in the sale of maize. This again negates the notion of market orientation as a factor for the adoption of improved maize technologies.

Maize utilization and storage

As pointed out earlier, maize is largely a commercial crop. It is the first or second most important source of income for 82% of the farmers in the survey. From the ecological zones, two-thirds of the farmers in the transition zone derive most of their cash income from maize production as compared with less than half of the farmers in the other ecological zones as shown in Figure 6.8 and Table 6.17. This seems to confirm the fact that maize is a commercial crop in the transition zone of Ghana. Fewer farmers in the coastal savannah and the Guinea Savannah consider maize as first source of income probably because in these two areas maize is very important in the household diet. If this is taken as an opportunity cost, then maize is also a commercial crop for farmers in the coastal and Guinea Savannah zones.

Figure 6.8: Percent of Farmers Indicating Maize as a First Source of Income



Source: Author's computations based on the 1998 CRI/CIMMYT survey.

Table 6.17: Household Source of Income from Maize

Zone	Household in which maize is:	
	First source of income	Second source of income
Coastal Savannah	39%	50%
Forest	49%	35%
Transition	67%	19%
Guinea Savannah	45%	21%
All zones	49%	33%

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Although farmers sell maize throughout the year, only 5.4% of them sell immediately after harvest, that is usually in August for the major maize season. This does not support the notion that most farmers sell their maize immediately after harvests. Most farmers at least store for over a month before selling probably to have a higher price. Two-thirds of the farmers sell their maize after 1 - 4 months of storage. Twenty-three percent of the farmers use actellic, a recommended storage insecticide, for storing their maize. The percent of farmers who sell some maize in the year and the sale price of maize are presented in Table 6.18. Prices of maize are higher between January and May with the peak period in May. About a third of the farmers sell their maize within this period.

Table 6.18: Principal Month for Selling Maize in Ghana, 1997

Month	Percent of farmers selling	Mean price (cedis/maxibag) (a)
January	6.6	51,824
February	4.6	64,375
March	7.1	56,324
April	6.0	51,516
May	4.8	66,640
June	3.1	49,875
July	2.7	38,071
August	5.4	37,214
September	11.0	37,771
October	14.3	40,472
November	21.2	44,964
December	19.1	45,859

(a) Maxibag = 110kg

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Gender

Gender issues are important in the generation and transfer of technologies. This is because females tend to be marginalised in the society but their household decisions directly affect children's welfare. Maize technologies developed by the GGDP are gender-neutral and all sexes are expected to adopt them equally. The percentages of male and female farmers who adopted the improved maize technologies is presented in Table 6.19. The adoption of improved varieties and row planting is significantly higher among male farmers than their female counterparts. These findings are contrary to earlier maize adoption studies in Ghana² that showed no difference between male and female farmers in the adoption of improved maize variety and row planting. There is no difference, however, in the use of fertilizer among the male and female farmers in the 1998 CRI/CIMMYT survey.

Table 6.19: Maize Technology Adoption among Male and Female Farmers in Ghana

Technology	Male adopters	Female adopters	Significance level of difference
	(%)	(%)	
Improved varieties	59	39	<.001
Row planting	59	38	<.001
Fertilizer	23	16	Not significant

Source: Authors computations based on the 1998 CRI/CIMMYT survey

Initially, there is no basis for these differences in the use of improved varieties and row planting among male and female farmers. Some of the reasons that might explain the differences in the adoption rates are presented in Table 6.20. Male farmers have better formal education than female farmers. Education is often an important factor in the

² Tripp R., K.A. Marfo, A.A. Dankyi and M.D. Read. "Changing Maize Production Practices of Small-scale Farmers in the Brong Ahafo Region, Ghana." GGDP. 1987. p 23.

adoption of improved technologies since more educated farmers have greater ability to understand and use complex technologies.

Male farmers who have adopted improved maize technology have significantly higher formal education, more extension exposure and attend more field days³ than their female farmers. These opportunities help to enhance the adoption of improved technologies and therefore appear to explain the observed differences in the adoption rates. Men farmers also have bigger maize farms. Large-scale farmers tend to have greater economic incentives to invest in learning and using new technologies than small-scale farmers and thus men have higher adoption rates. Female farmers, however, have more years' experience in growing maize than male farmers.

Table 6.20: Male and Female Adopters of Improved Maize Technology in Ghana

Circumstances	Male adopters	Female adopters	Significance level
Years in school	6.3	4.1	<.001*
Years growing maize	13.6	16.3	<.05*
Cultivated maize area (major season)	1.4 hectares	0.8 hectares	<.001*
Extension contacts (mean)	2.6	1.4	<.05*
Attendance in field days (number)	0.6	0.3	.01*
Access to land (own land)	77.6%	76.0%	Not significant

* t-test

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Decision-making in maize farming activities

The survey tried to find out who takes decisions with respect to maize farming activities. The results are presented in Table 6.21. The results show that as long as the farm belongs to the individual, irrespective of gender, he/she takes his/her own decisions

³ Field days are organized in farmers' fields by extension agents to demonstrate the use of maize technologies.

Table 6.21: Gender and Decision-Making on Maize Farming Activities

Decision / Field	Person responsible for decision				Significance (chi-square)
	Respondent (%)	Spouse (%)	Both (%)	Other (%)	
Selecting maize variety:					<.001
Male field	85.0	1.9	9.6	3.5	
Female field	68.6	11.4	18.1	1.9	
When to plant:					<.001
Male field	87.2	6.0	10.2	1.9	
Female field	69.5	13.3	17.1	0	
Obtaining fertilizer:					Not significant
Male field	85.7	1.6	7.9	4.8	
Female field	75.0	12.5	12.5	0	
Harvesting:					<.001
Male field	85.4	1.6	12.0	1.0	
Female field	71.4	11.4	17.1	0	
Sale of grain:					<.001
Male field	82.9	2.1	14.2	0.7	
Female field	70.7	14.1	15.2	0	
Use of cash					<.001
Male field	81.4	1.8	16.4	0.4	
Female field:	62.0	12.0	26.1	0	

Source: Author's computations based on the 1998 CRU/CIMMYT survey

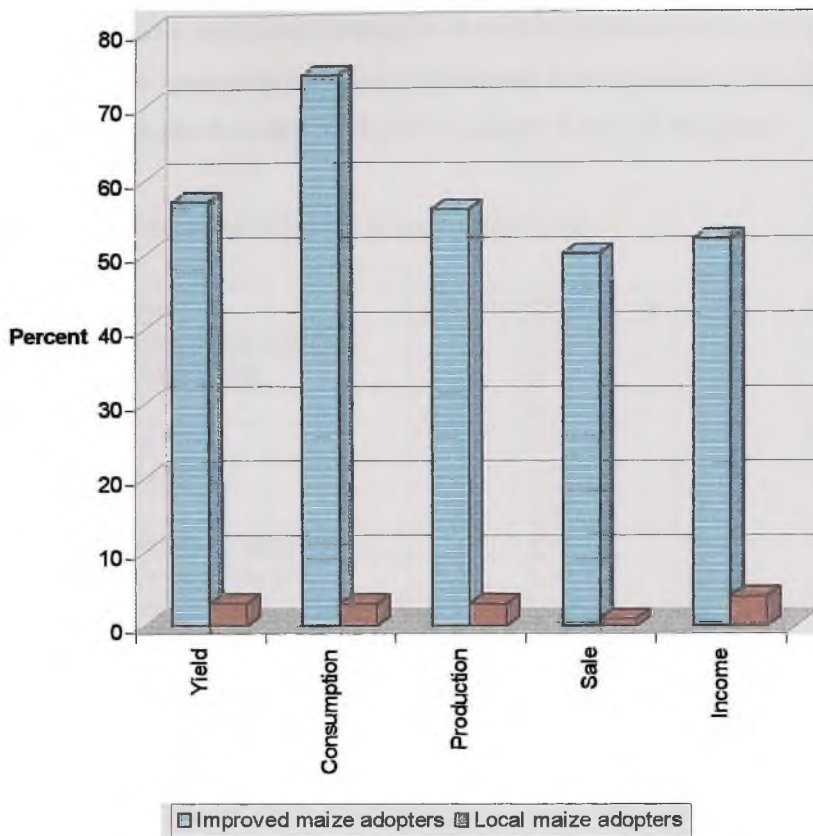
in most cases but when decisions are made by spouses, then female farmers significantly tend to rely more on their spouses' decisions than their male counterparts. In other words, when farming activity decisions are to be made by the farm family, female farmers tend to rely more on their male counterparts.

Impacts of improved maize technologies

Although a measure of the rate of return to investment in agricultural research gives some indications of the impact of the research, it can be supplemented with some descriptive or qualitative impacts such as farmer incomes, nutrition, productivity and gender effects. A more quantitative analysis of these impacts is not possible since the GGDP did not have baseline data at the onset of the project in 1979 and therefore makes it difficult for such an assessment.

Incomes of farmers

Income is an important welfare indicator because it is linked to the ability to acquire property such as clothing and shelter, and wealth. An increase in income can be translated either directly or indirectly into the betterment of the well being of the farmers. One of the goals of maize technology development is to increase the welfare of farmers. In the survey, farmers were asked whether over the past ten years they had noticed any changes in their production of maize, sales and income levels. Their qualitative assessment of impact of maize technology is presented in Figure 6.9. Improved maize adopters have benefited more in the production indicators than local maize adopters. These suggest that farmers who adopt improved maize technologies are likely to be better off than farmers who do not adopt the technologies. More than one-half of the adopters of improved maize technologies indicated that there were increases in production (56%), yields (57%), sales (50%), consumption (74%) and income (52%) from maize cultivation. These findings are important because increase in income is a measure of welfare gains. Thus these results suggest that maize research and extension have had some impact on household incomes and welfare of some of the maize farmers.

Figure 6.9: Percent of Farmers with Increases in Maize Indicators

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Farmers who obtain their income from maize sales were asked to indicate what they have done with the extra money from maize sales. The answers from improved maize technology adopters are presented in Table 6.22. Most of the farmers spend the extra money from maize on children's education. A third of the farmers take care of the whole family. A similar proportion has constructed houses from the income derived from maize sales. These are signals to improved welfare gains of the whole household.

Table 6.22: Farmers Use of Increased Income from Maize

Use of income	Percent of farmers (a)
Pay for children's fees/education	42.1
Take care of the family	34.2
Build house	28.3
Expand farm	15.8
Purchase livestock	5.3
Trade	4.6
Household furniture/equipment	1.9
Purchase vehicle or bicycle	1.3

(a) Total percentage is more than 100% because of multiple answers.

Source: Author's computations based on the 1998 CRI/CIMMYT survey

Nutrition

One of the objectives of the GGDP was to improve the nutritional status of farmers and consumers at large by making more maize available to the Ghanaian society through the development and subsequent adoption and production of improved maize. Maize consumption provides carbohydrate that is turned into energy in human beings. As discussed earlier (Figure 6.9), of about 77% of all the farmers who indicated increased consumption of maize, about 74% were adopters of improved maize technologies. Similarly, as maize is either consumed by farmers or eventually sold to the public, consumers also benefit from its consumption.

In addition to the importance of maize as a widely consumed food, it is used as a weaning food for infants in Ghana. In 1992, the GGDP released protein-quality maize,

Obatanpa. The fact that this variety is the most popular variety grown by farmers underscores the importance of Obatanpa. Although the actual impact of Obatanpa on Ghanaians is not documented, those on animals are documented by the GGDP. In the present survey, 51% of all farmers said they were aware of the nutritional enhancing ability of the Obatanpa. However, only 35.8% reported using Obatanpa or other improved maize varieties as weaning food. The reasons for this need further investigation but certainly, more education is needed on the nutritional prospects of Obatanpa.

Gender effects

As has been discussed earlier on, women are usually the disadvantaged in the society especially in decision making. The survey revealed that apart from the use of fertilizer in which men and women adopted equally, women have lower adoption rates for improved variety and row planting. From the survey, since women have grown some maize for a longer period than male farmers, there is need to ensure that they get equal access to the technologies.

Productivity

The importance of agriculture in rural Ghana cannot be overemphasized. This makes agricultural productivity a valid indicator of impacts of maize research and extension in Ghana. The fact that many Ghanaian farmers grow some maize, any technology that helps to increase productivity will bring about real income gains for producers and subsequently to consumers. This is because farmers can produce at a lower cost as productivity increases; thus, the cost of production will decrease. For consumers,

increases in productivity are translated into lower prices for maize. Thus, consumers can consume more at a lower price.

It has been shown earlier on that maize productivity (which is measured here as the yield per unit land area) has generally been increasing since 1985 (see Figure 1.1). Obtaining accurate historic yield gain data from farmers is difficult because most Ghanaian farmers do not keep quantitative records of their farming activities. Under this situation, the only way to obtain accurate information is to make crop yield cuts to measure the actual yields from farmers' fields but this will be equally expensive on a large scale.

In this study therefore, farmers were asked to estimate the number of bags they would expect to harvest from their largest maize field using each of the following combinations:

- Local variety without fertilizer
- Previous improved variety without fertilizer
- Current improved variety without fertilizer
- Local variety with fertilizer
- Previous improved variety with fertilizer
- Current improved variety with fertilizer

These are equivalent to experimental "treatments". Farmers were further asked to give estimates only for technology combinations that they have actually used. The results are therefore based on farmers' direct experience.

Farmers' estimates of maize harvests in bags under "with fertilizer" and "without fertilizer" scenarios are presented in Table 6.23. With fertilizer, the yield from the improved varieties doubles. The local varieties are less responsive to fertilizer and give about a quarter yield increase.

Table 6.23: Descriptive Statistics of Farmers' Estimates of Maize Harvests (in maxibags)

Treatment	Mean	Standard deviation	Sum (harvest)	(N)
Without fertilizer:				
Local variety	8.4	10.6	2461.2	(292)
Previous improved variety	10.8	9.2	520	(48)
Current improved variety	11.8	11.0	2546	(216)
With fertilizer:				
Local variety	12.3	16.5	1363.5	(111)
Previous improved variety	23.7	37.2	733.5	(31)
Current improved variety	21.8	28.3	2660.5	(112)

Source: author's computations based on the 1998 CRI/CIMMYT survey.

Table 6.24: Estimated Yield Increase Attributable to Improved Varieties and Fertilizer

Treatment	Percent yield increase	
	Without fertilizer	With fertilizer
Local variety to current improved variety	39.9	77.6
Previous improved variety to current improved variety	8.9	-7.8
Local variety to previous improved variety	28.5	92.7
Addition of fertilizer to local variety	45.7	
Addition of fertilizer to current improved variety	85	
Addition of fertilizer to previous improved variety	118.5	
Contribution of both fertilizer and current improved variety	158.7	
Contribution of both fertilizer and previous improved variety	180.7	

Source: Estimated by the author from the 1998 CRI/CIMMYT survey

In Table 6.24, the current improved variety alone increases yield by 39.9 percent. The yield difference between previous improved variety and current improved variety is 8.9%. This is not surprising since both are improved varieties. What is surprising is the fact that previous improved varieties respond more to fertilizer than the current improved variety. Newer improved varieties have some disease resistance incorporated in them than the earlier improved varieties and this is, however, expected to increase yields. Nevertheless, this assertion needs further experimental investigation.

Fertilizer response in improved varieties under farmer's estimate is about twice the response in local varieties. This is more than experimental results which put it about fifty

percent⁴. Farmers further recognize that interaction of fertilizer and improved variety gives higher yield increment.

These results give ample evidence that improved maize technologies have greatly increased productivity on farms where the adoption of maize technologies have taken place. Further evidence is given by the responses farmers gave to the question of whether they have seen any changes in their maize yields in the past ten years. Nearly 60% of those who responded indicated that their maize yields have increased.

Factors explaining the differences in adoption pattern between the ecological zones:

The GGDP maize recommendations are based on ecological zones and it is important to examine some of the factors that explain the adoption pattern between the ecological zones. It is believed that the GGDP played down research and extension of improved maize technologies in the forest zone because the forest zone is noted for growing tree crops. This explanation may not be wholly correct. The results of the maize survey show that farmers in the forest zone had a fair share of extension contacts on maize. The number of extension contacts by farmers in the forest zone is comparable with those of the coastal savannah and Guinea Savannah and is even more than the transition zone. For example, the number of extension contact in the forest zone is 2.1 and those of the Guinea Savannah and coastal savannah are 2.6 and 3.1 respectively. Farmers in the transition zone have 1.5 times extension contacts. In spite of comparable extension contacts, the adoption of maize technologies in the forest is low compared to the other zones.

⁴ GGDP Annual Report, 1980. p. 43

Furthermore, the years farmers have acquired experience in growing maize are about the same for farmers in the forest, transition and coastal savannah. For example, farmers have 15.2 years of experience in growing maize in the forest zone. It is 15 years in the transition, 16.2 years in the coastal savannah and 10 years in the Guinea Savannah. Therefore there seems to be other reasons for the differences in the adoption of maize technologies between the ecological zones other than those explained earlier.

The factors or reasons for such differences in adoption patterns include differences in farmer characteristics, resource ownership and access to technology. In addition, there are others that are frequently neglected in explaining adoption patterns. Based on the Boserup hypothesis⁵, factors such as intensification of agriculture, market orientation and land-labour endowments are other important factors influencing the adoption process.

Population density

There appears to be some relationship between years of schooling and household size. Generally, across the ecological zones, as the years in school are high the household size is low. In Table 6.25, while farmers in the forest zone have the highest number of years in school, their household size is the lowest compared to the Guinea savannah whose farmers have the lowest number of years in school but the highest household size.

⁵ Boserup, Ester. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. New York: Aldine Publishing. 1965.

Ester Boserup developed a theory to explain the interaction between population growth, land settlement and technological change. Boserup challenged the classical Malthusian theory of population increasing faster than food production and thereby leading to disaster. Boserup argued that as a result of increasing population pressure, a traditional agrarian society shifts from slash-and-burn fallow system to bush fallow, then to annual cropping, and finally to multiple cropping. Each sequence is an increasing intensification of the farming system. Technological change arises with increasing population pressure.

Table 6.25: Farmers' Formal Education Level and Household Size

Ecological zone	Years schooling (years)	Average household size
Forest	6.7	8.0
Transition	6.5	9.8
Coastal Savannah	6.3	9.7
Guinea Savannah	2.3	15.4
All zones	5.7	10.1

Source: 1998 CRI/CIMMYT survey

Technological change comes as a response to adversity, which results from increasing population pressure. The higher the household size, the more mouths the subsistence farmer is likely to feed and to have some in stock for the lean season. The farmer may therefore be forced to adopt strategies for increasing his or her food supply. This is probably one of the main reasons why the adoption rate of maize technologies is high in the Guinea Savannah, transition and coastal savannah zones than there is in the forest zone. Probably because the forest zone has a lower household size, it could afford extensive agriculture with traditional technologies.

Cropping intensity

Fertilizer use on maize is positively associated with high levels of cropping intensity. In general, maize fields that have received fertilizer have been continuously cropped for 4.1 years on the average compared to 1.7 years for fields that did not receive fertilizer.

As population density increases, there is over-exploitation of land and other natural resources of agriculture⁶. The land continuously becomes degraded because without fertilizer or other fertility enhancing measures, the land is unable to sustain crop growth

⁶ Broekhuyse, J.T. and A.M. Allen. "Farming Systems Research." *Human Organization* 47(4): 1988 pp.330-342.

once the fallow system breaks down. There will be, in the long run, yield decline and finally abandonment of land unless more intensive technologies are employed⁷.

In Table 6.26, there is more continuous cropping of maize in the Guinea Savannah, the transition and the coastal savannah zones than there is in the forest zone.

Table 6.26: Years of Continuous Maize Cropping of Major Maize Field

Ecological zone	Average years	t-ratio	Significance
Guinea savannah	4.7	8.753	.0000
Coastal savannah	3.2	4.322	.0000
Transition	1.9	2.876	.0060
Forest	0.6		

Source: 1998 CRI/CIMMYT survey

For example, while farmers in the Guinea Savannah crop maize continuously for 4.7 years, farmers in the forest zone crop maize for less than one year. These differences are significant compared to that of the forest zone. This seems to suggest that farmers in the forest zone plant maize on new fields every year. Maize fields in the forest zones might thus be more fertile than maize fields in the Guinea Savannah zone. It is not surprising therefore, that the adoption of fertilizer is relatively high in the Guinea Savannah, coastal savannah and the transition zones than the forest zone.

In a further explanation, Table 6.27 shows the average number of years that the major maize field was fallow. As expected, the fallow period for fields in the Guinea Savannah, coastal savannah and the transition zones are significantly shorter than the forest zone. For example, while the fallow period in the forest zone is 3.4 years, the fallow period in the Guinea Savannah is 0.6 years. This again provides evidence that there is less pressure on the land in the forest zone than the other ecological zones. Hence, the Guinea

⁷ Sanders John H., Barry I. Shapiro and Sunder Ramaswamy. *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa*. Johns Hopkins University Press. 1996 pp 145-177.

Savannah, the coastal savannah and the transition zones necessarily have to adopt some improved measures in order to get high yields.

Table 6.27: Average Fallow Periods in Ghana

Ecological zones	Average No. of years	t-ratio	Significance
Guinea Savannah	0.6	-10.825	.0000
Coastal Savannah	2.3	-3.004	.0040
Transition	2.3	-4.302	.0000
Forest	3.4		
All zones	2.6		

Source: 1998 CRI/CIMMYT survey

Extensive crop systems are the expected farmer behaviour in the forest zone because potential good land is available. Coupled with a low population density, extensive agriculture is economically and socially sustainable in the forest zone⁸. Furthermore, row planting of maize is positively associated with cropping intensity. Continuous cropping, no doubt, de-stumps the fields and makes planting in rows easier. Hence, the adoption rate of row planting is higher in the Guinea Savannah zone (73%) than the forest zone (39%), for example.

In addition, row planting is related to land preparation methods. Of the farmers who cultivate their fields by hand, about 56% plant their maize at random. On the other hand, about 81% of farmers who cultivate their fields with animals or tractors plant their maize in rows (1998 CRI/CIMMYT survey). In the transition, Guinea Savannah and coastal savannah, there is more tractor power or animal (in the Guinea Savannah) services than there are in the forest zone. These further explain the use of improved technologies in these areas than in the forest zone.

⁸ Pingali, P., Y. Bigot and H. Binswanger. "Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa." Baltimore: Johns Hopkins University Press. 1987 pp 5-15, 43-54.

Markets and commercial orientation

Given suitable soil conditions, areas with better access to markets may be more intensively cultivated. Access to urban centres is increased with reduced transport costs. Reduced transport cost is associated with good infrastructure. Access to infrastructure by the households in the present maize study has been presented in earlier section (see Table 6.2). Farmers in the coastal savannah have access to improved infrastructure. The intensity of maize technology adoption in the coastal savannah may partly be explained by the access to infrastructure such as tarred road network, easy transportation system and well organized markets. Similarly, farmers in the transition zone have reasonable access to transportation facilities and improved tarred roads but limited access to market. Farmers living in the coastal savannah have more electricity than other farmers in the other zones. Since maize is a major component of the diet of people in the coastal savannah, perhaps the use of electricity facilitates the processing of maize products that further induce marketing and subsequent adoption of improved technologies.

Economics of maize technology

One of the important determinants of adoption of a technology is the profitability of the technology. Whether farmers sell little or most of their farm produce, they are interested in the economic returns. Farmers weigh the benefits to be gained from the use of the technology against the costs incurred in the form of labour and cash given up. The farmers are simply assessing the returns to investment in the technology.

Of the three GGDP-generated maize technologies, the use of improved maize requires the least cash outlay per unit area. Farmers who decide to adopt improved varieties require few changes to their crop management practices. In Table 6.28, the

average values used in estimating the marginal rate of return are presented. The profitability of the adoption of improved maize in the ecological zones is analyzed in Table 6.29.

The marginal rate of return (MRR)⁹ to investment in improved maize in the forest zone is 3030% for Dobidi and that of Aburotia is 2250%. These are about twice as that of the transition zone (Dobidi: 1800% and Aburotia: 810%) or the savannah zones where the use of Dobidi gives a MRR of 1560% and that of Aburotia is 1290%. Thus, in the forest zone for example, for every one cedi invested in Dobidi, farmers can expect to recover the one cedi, and obtain additional 30.30 cedis. Although these returns are attractive in all the zones, the forest zone has the highest MRR.

Table 6.28: Economic indices for Estimating Marginal Rate of Return to Maize Technologies in Ghana, 1997

Item	Unit and Price
Option A	Improved maize; Row planting; 5 bags of NPK fertilizer, 5 bags of Sulphate of ammonia
Option B	Improved maize; Row planting; 2.5 bags of NPK fertilizer, 2.5 bags of Sulphate of ammonia
Option C	Farmer practices
Field price of maize grain	300 cedis/ kg
Improved maize seed	2,000 cedis/kg
Local seed	1,500 cedis/kg
Seed rate	20kg/ha
NPK fertilizer	30,000 cedis/bag of 50kg
Sulphate of Ammonia	36,800 cedis/bag of 50kg
Transport cost for fertilizer	1,000/bag
Labour for fertilizer application	35,000 cedis/ha
Row planting cost	35,000 cedis/ha

Source: Data is from personal interviews with MOFA staff, GLDB, farmers and various GGDP reports

⁹ *The Marginal Rate of Return (MRR) is obtained as the change in net benefits between farmer practice and the improved practice divided by the change in costs of the same practices, expressed as a percentage.*

Table 6.29: Marginal Return Analysis of Adoption of Improved Maize in the Ecological Zones of Ghana

Technical coefficients:

	Ecological zones		
	Forest	Transition	Savannah
Average grain yield (t/ha)			
Dobidi	2.89	2.78	1.79
Aburotia	2.63	2.45	1.7
Farmers' variety	1.88	2.18	1.27
Increase in grain yield of Dobidi relative to farmer variety	1.01	0.6	0.52
Increase in grain yield of Aburotia relative to farmer variety	0.75	0.27	0.43
Field price of maize grain (cedis/t)	300,000	300,000	300,000
Value of increase in grain yield of Dobidi relative to farmer variety (cedis/ha)	303000	180000	156000
Value of increase in grain yield of Aburotia relative to farmer variety (cedis/ha)	225000	81000	129000
<i>Marginal costs:</i>			
Seed rate (kg/ha):			
Dobidi	20	20	20
Aburotia	20	20	20
Farmer's variety	20	20	20
Seed price (cedis/kg):			
Dobidi	2000	2000	2000
Aburotia	2000	2000	2000
Farmer's variety	1500	1500	1500
Additional seed cost associated with:			
Dobidi	10,000	10,000	10,000
Aburotia	10,000	10,000	10,000
<i>Net benefits (cedis/ha)</i>			
Dobidi	293,000	170,000	146,000
Aburotia	215,000	71,000	119,000
<i>Marginal rate of return to additional investment (%):</i>			
Dobidi	3030	1800	1560
Aburotia	2250	810	1290
<i>Benefit/Cost ratio:</i>			
Dobidi	30.3	18	15.6
Aburotia	22.5	8.1	12.9

Source: Technical coefficients based on GGDP Annual Report 1985 (p. 135) and updated by the author using 1998 prices

To make farmer recommendations from a marginal analysis it is further necessary to estimate the **minimum** rate of return that will be acceptable to the farmers. Farmers commit inputs (purchased or owned) to their enterprises with the expectation of a return in a future period. The benefits given up by the farmer in tying up his capital for a period of time is the cost of capital. Using a lending rate of 35% for agriculture from the commercial banks in Ghana as opportunity cost of capital as the minimum acceptable rate of return for farmers, the MRR from the use of Dobidi and Aburotia are well above the minimum acceptable returns to farmers.

Risks: Farmers are generally risk averse and therefore take risks into consideration before adopting a technology. One of the objectives of on-farm research is to improve the productivity of farmers' resources by lowering cost of production or increasing the stability of production. Farmers' practices reflect attempts to reduce the risk of failure and thus may prefer stable returns to the highest possible returns with high risks. Two of such risks which farmers face are changes in yield because of the weather or diseases and output price changes. When the yield of maize (see Table 6.29) is reduced by 20%¹⁰, the MRR drops to 1296% from a baseline scenario of 3030% in the forest zone for a farmer who changes his variety to Dobidi, for example. The use of Dobidi in the forest zone gives the highest MRR among the zones and the varieties. In the transition zone, the planting of Aburotia gives negative returns. These results are given in Table 6.30.

Table 6.30: Effect of Yield Reduction in Improved maize on the Marginal Rate of Return (%)

Scenario	Option	Forest	Transition	Savannah
Baseline	Farmer variety to Dobidi	3030	1800	1560
	Farmer variety to Aburotia	2250	810	1290
20% yield reduction	Farmer variety to Dobidi	1296	132	486
	Farmer variety to Aburotia	672	-660	270

Source: Author's estimates based on data from Table 6.28.

If the field price for maize is reduced by 20%, there is a high MRR in all the ecological zones as shown in Table 6.31. Thus, the profitability of using improved maize is less affected by changes in maize grain price at 20% reduction. It is therefore profitable to invest in improved maize as a single technology in all the ecological zones with the Forest zone having the highest MRR among the ecological zones.

Table 6.31: Effect of Lower Maize Grain Price on the Marginal Rate of Return on Improved Maize (%)

Scenario	Option	Forest	Transition	Savannah
Baseline	Farmer variety to Dobidi	3030	1800	1560
	Farmer variety to Aburotia	2250	810	1290
20% yield reduction	Farmer variety to Dobidi	2424	1440	1248
	Farmer variety to Aburotia	1800	648	1032

Source: Estimated by the author from data in Tables 6.28 and 6.29.

In the adoption of fertilizer, the savannah zones have the highest MRR (129%) among the ecological zones as shown in Table 6.32. The transition zone has 103% and the forest zone has the lowest marginal rate of return of 85% among the zones. This trend is justifiable because soil fertility gradient decreases from the forest zone through the transition zone to the savannah zones. Nevertheless, with a minimum acceptable rate of return assumed at 35%, the use of fertilizer in all the ecological zones have an acceptable

¹⁰ CIMMYT recommends 5% to 30% downward yield adjustment to reflect the differences between experimental yield and the yield farmers could expect from the same treatment.

rate of return. It must be noted that field price of maize is used to estimate the MRR. Field price is the value of an extra unit of production in the field prior to harvest. Thus when field price is used, costs like harvesting, shelling, threshing, winnowing, bagging and transport to point of sale are excluded.

Table 6.32: Marginal Return Analysis to the Adoption of Fertilizer in Maize Production in the Ecological Zones in Ghana

(Farmer-managed fertilizer experiments, 1985)	Forest	Transition	Savannah
<i>Marginal benefits:</i>			
Grain yield with fertilizer (t/ha)	1.97	1.61	2.03
Grain yield without fertilizer	1.37	0.88	1.12
Increase in grain yield due to fertilizer (t/ha)	0.6	0.73	0.91
Field price of maize grain (cedis/t)	300,000	300,000	300,000
Value of increase in grain yield (cedis/ha)	180,000	219,000	273,000
<i>Marginal costs:</i>			
NPK fertilizer cost (cedis/ha)	75,000	75,000	75,000
Ammonium sulphate cost (cedis/ha)	92,000	92,000	92,000
Fertilizer transport cost Cedis/ha)	10,000	10,000	10,000
Labour for fertilizer application (cedis/ha)	35,000	35,000	35,000
Total variable costs (cedis/ha)	212,000	212,000	212,000
<i>Marginal rate of return to additional investment (%)</i>	85	103	129

Source: Technical coefficients based on GGDP Annual Report, 1985 and updated by the author using 1998 prices

The MRR for fertilizer is comparatively lower in the forest zone than either the transition zone or the savannah zones. This might be one of the reasons for the comparative low fertilizer adoption in the forest zone. Similarly, the higher adoption rate of fertilizer in the savannah zones may partly be attributed to higher profitability in these zones.

With risks, if the yield is reduced by 20%, the MRR for applying fertilizer drops from 129% to 71% in the savannah zones as in Table 6.33. In the transition zone, the decline of MRR is from a value of 103% to 58%. The savannah zones have the highest

MRR among the zones when fertilizer is applied. With a minimum acceptable rate of return for the farmer at 35%, applying fertilizer on maize in the transition and the savannah zones are the zones with profitable options.

Another risk that Ghanaian farmers face is rising fertilizer prices. Because of this, variable costs (see Table 6.32) for fertilizer application were assumed to be increased by 50% and 100% to test the sensitivity of MRR. The results are also shown in Table 6.33. It is interesting to note that even with 100% price increase in fertilizer, the MRR is between 42% and 64% in the three zones. These values are higher than the minimum acceptable rate of return of 35%. This means that applying fertilizer as a single technology has a reasonable MRR even with a 100% price increase.

Table 6.33: Effect of Yield Reduction and Increase in Fertilizer Price on the Marginal Rate of Return (%)

Scenario	Option	Forest	Transition	Savannah
Baseline	Without fertilizer to fertilizer	85	103	129
20% yield reduction	Without fertilizer to fertilizer	29	58	71
50% increase in fertilizer price	Without fertilizer to fertilizer	57	69	86
100% increase in fertilizer price	Without fertilizer to fertilizer	42	52	64

Source: Estimated by the author from data in Table 6.32.

Marginal Rate of Return to Maize Technology as a Package

Maize production in the past was very profitable because some input such as fertilizers were subsidized. With the removal of subsidies and other economic reform policies, it is important to revisit the profitability of the maize production by farmers in Ghana. It has been shown earlier that when improved maize varieties and fertilizer are

adopted separately, each is profitable (see Tables 6.31 and 6.32). The MRR of maize recommendation as a package needs also to be analyzed

The main components of the maize technology package by the GGDP are improved variety, fertilizer and row planting. Two technological options from this package were made based on the fertility level of the soil (see Table 3.15). In option A (high input use), fertilizer rate of 38:38:38 (NPK) per hectare was recommended for soils with very low fertility. In option B, half the rate of option A was recommended (that is, 19:19:19 NPK) per hectare with all other production conditions such as improved varieties and row planting remaining the same. These are compared with the farmer's practice (option C). The profitability of maize recommendation package is presented in Table 6.34.

The marginal rate of return (MRR) from the farmer's practice (option C) to the use of 19:19:19 NPK (option B) in the forest zone for example, is 65% and from option C to option A (38:38:38 NPK) is 39%. Similarly, the MRR of option C to option B in the transition zone is 68% and from option B to option A is 40%. The Guinea Savannah zone has the least of the MRR with 11% for option C to option B, and a negative return (-7%) from C to A. This means that using maize recommendation package in the Guinea Savannah is less profitable than the other ecological zones. If the minimum acceptable rate of return to farmers of 35% is imposed, maize production is profitable in all the ecological zones (because the MRR are above the minimum acceptable rate of return) except the Guinea Savannah zone.

For purposes of risk analysis, when yields are reduced by 10%, the MRR drops from the base value of 65% in the forest zone to 27% from option C to option B as shown in Table 6.35. Similarly, from the base value of 68% in the transition zone, the MRR decreases to 34%. With a 20% reduction in yield, there is a loss.

Table 6.34: Marginal Rate of Return to Adopting Improved Maize, Fertilizer and Row Planting as a Package

Mean yield (t/ha):	Forest	Transition	Coastal	Guinea
			Savannah	Savannah
Option A	3.81	3.49	3.84	2.67
Option B	3.21	2.91	3.14	2.27
Option C	1.8	1.47	1.81	1.32
Field price of maize grain (cedis/t)	300,000	300,000	300,000	300,000
<i>Gross benefits (cedis/ha)</i>				
Option A	1,143,000	1,047,000	1,152,000	801,000
Option B	963,000	873,000	942,000	681,000
Option C	540,000	441,000	543,000	396,000
<i>Variable costs (cedis/ha)</i>				
<i>Seed (cedis/ha):</i>				
Option A	40,000	40,000	40,000	40,000
Option B	40,000	40,000	40,000	40,000
Option C	30,000	30,000	30,000	30,000
<i>Fertilizer (cedis/ha):</i>				
Option A	334,000	334,000	334,000	334,000
Option B	167,000	167,000	167,000	167,000
Option C	0	0	0	0
<i>Fertilizer application (cedis/ha):</i>				
Option A	35,000	35,000	35,000	35,000
Option B	35,000	35,000	35,000	35,000
Option C	0	0	0	0
<i>Transport cost for fertilizers (cedis/ha)</i>				
Option A	20,000	20,000	20,000	20,000
Option B	10,000	10,000	10,000	10,000
Option C	0	0	0	0
<i>Row planting cost (cedis/ha)</i>				
Option A	35,000	35,000	35,000	35,000
Option B	35,000	35,000	35,000	35,000
Option C	0	0	0	0
<i>Total variable costs (cedis/ha)</i>				
Option A	464,000	464,000	464,000	464,000
Option B	287,000	287,000	287,000	287,000
Option C	30,000	30,000	30,000	30,000
<i>Net benefits (cedis/ha):</i>				
Option A	679,000	583,000	688,000	337,000
Option B	676,000	586,000	655,000	394,000
Option C	510,000	411,000	513,000	366,000
<i>Marginal rate of return (%)</i>				
C to B	65	68	55	11
C to A	39	40	40	-7

Source: Estimated by the author based on data from GGDP Annual Reports, 1982 (p.85), 1983 (p.93) and 1984 (p.93) and updated with 1998 prices. Mean yield is the average of yield data from demonstration plots from 1982-1984

This analysis means that maize recommendation package is sensitive to changes in yield. Thus if the expected yields from maize production package is to fall by 20%, maize production will be unprofitable and barely profitable at 10% yield reduction.

Table 6.35: Changes in Yields on Marginal Rate of Return to Improved Maize Technology (%)

Scenario	Option	Forest	Transition	Coastal Savannah	Guinea Savannah
Baseline	C to B	65	68	55	11
	C to A	39	40	40	-7
10% yield reduction	C to B	27	34	19	-16
	C to A	13	16	14	-25
20% yield reduction	C to B	-10	0	-18	-42
	C to A	-14	-9	-13	-44

Source: Estimated by the author from data in Table 6.34.

The possibility of many farmers receiving lower prices for their product exists particularly at harvest time. To test how sensitive maize recommendation are to changes to falling maize price, a 10% to 20% price reduction on field price of maize was imposed on the analysis. The outcome is presented in Table 6.36. When maize price is lowered by 10% and the minimum acceptable rate of return is set at 35%, only option C to B is profitable in the forest, transition, and the coastal savannah zones. At 20% maize price reduction, none of the options is profitable. This suggests that if farmers were to sell at lower price (more than 10% price reduction), they would make some losses.

Maize production could thus be profitable if yields of maize are stable and maize prices do not fluctuate much. In all the scenarios, the adoption of maize recommendation package is not profitable in the Guinea Savannah.

Table 6.36: Marginal Rate of Return to Changes in the price of Maize (%)

Scenario	Option	Forest	Transition	Coastal savannah	Guinea Savannah
Baseline	C to B	65	68	55	11
	C to A	39	40	40	-7
10% price reduction	C to B	48	51	40	0
	C to A	25	26	26	-16
20% price reduction	C to B	32	34	24	-11
	C to A	11	12	12	-25

Source: Estimated by the author from Table 6.34.

Determinants of Adoption of Improved Maize Technology with Logistic and TOBIT Models

The main factors affecting the adoption of improved maize technology in Ghana, are determined with the Logistic regression and the TOBIT models.

Logistic Regression Analysis

The Logistic regression model was used to determine the factors that affect the adoption of improved maize varieties in Ghana. It is similar to the ordinary least square regression model but it is suited to models where the dependent variable is dichotomous. The Logistic regression estimates directly the probability of an event occurring.

The empirical Logistic Model was developed using farm and farmer specific characteristics as explanatory variables. The dependent variable is the adoption of improved varieties (MVUSER). The other variables in the model are described in Table 6.37. The model takes the form:

$MVUSER = f(\text{EXTVISIT}, \text{HHSIZE}, \text{ZONECS}, \text{ZONETR}, \text{ZONEGS}, \text{GENDER}, \text{TENURE}, \text{MZAREA}) + e$, where the definitions of the relevant variables are detailed in Table 6.37.

Table 6.37: Definitions of Variables in the Logistic Model

Dependent variable:	
MVUSER	1 if improved maize is adopted, and 0 otherwise.
Independent variables:	
EXTVISIT	Number of contacts with extension agents. It is measured as a continuous variable.
HHSIZE	Total household size. Measured as a continuous variable
ZONECS	Coastal Savannah ecological zone. It is measured as a binary variable: 1, if maize is planted in Coastal Savannah zone, 0 if planted elsewhere.
ZONETR	Transition ecological zone: it is measured as a binary variable: 1, if maize is planted in the transition zone and 0 if planted elsewhere.
ZONEGS	Guinea Savannah ecological zone. It is a binary variable: 1, if maize is planted in the Guinea Savannah zone, 0 if planted elsewhere.
GENDER	Gender of farmer: it is a binary variable: male = 1 and female = 0
TENURE	Ownership of land under maize cultivation. It is a binary variable: 1, if farmer owns the land and 0 otherwise. 1, if land is owned, 0 if any other land arrangements
MZAREA	Total maize area for the farmer. This is measured as a continuous variable.
e	Error term

Source: Compiled by the author.

The classification table of the Logistic Regression is presented in Table 6.38. The classification table is describing how well the model fits and compares the predictions to the observed outcomes, at a predicted probability cut off point of 0.5 or greater. The overall percentage of variables predicted correctly is 67.5%.

Table 6.38: Classification Table for MVUSER

		Predicted		Percent Correct
		Did not grow MV (D)	Grew MV in 1997(G)	
Observed	Did not grow MV (D)	117	75	60.94%
	Grew MV in 1997 (G)	61	166	73.13%
Overall				67.54%

Source: Estimated by the author based on the 1998 CRI/CIMMYT survey.

The results from the logistic regression are shown in Table 6.39. The results of the coefficients (B), the WALD statistic¹¹ of the variables and the significance level (sig.) show that extension contacts, the coastal savannah zone, the transition zone, the Guinea Savannah zone, gender and total area under maize production are significantly and positively related to the adoption of improved maize varieties. This means that there is a high probability of adoption of improved varieties if farmers have more extension contacts (EXTVIST), or cultivate maize in the coastal savannah (ZONECS), the transition (ZONETR), and the Guinea Savannah (ZONEGS) zones, or are males (GENDER) or have larger area put to maize production (MZAREA).

Household size (HHSIZE), although has a positive relation with the adoption of improved varieties, the relationship is not significant. The sign of the logistic regression coefficient for land tenure (TENURE) is negative but insignificant.

The R-statistic in Table 6.39 above shows the partial correlation between the dependent variable, MVUSER, and each of the independent variables such as EXTVIST. There appears to be very low partial correlation among the variables in the model. The values are all positive indicating that as the value of the independent variables increase, so does the likelihood of the adoption of improved maize varieties.

¹¹ WALD statistic = (Logistic regression coefficient / Standard error)². It is used to test whether the regression coefficients are zero. A high WALD statistic leads to acceptance of the null hypothesis that the regression coefficient is zero and a low value (close to zero) means a rejection of the null hypothesis. For larger sample size, WALD statistic is better than the t-statistic.

Table 6.39: Indicator Variables for Factors of Adoption of Improved Maize Varieties in Ghana.

Variables in the Equation						
Variable	B	S.E	WALD	df	Sig	R
EXTVISIT	.1602	.0366	19.1498	1	.0000	.1723
HHSIZE	.0165	.0187	.7750	1	.3787	.0000
ZONECS	1.3201	.3053	18.6975	1	.0000	.1700
ZONETR	1.4332	.3273	19.1770	1	.0000	.1724
ZONEGS	.7542	.3210	5.5211	1	.0188	.0781
GENDER	.5987	.2677	5.0026	1	.0253	.0721
TENURE	-.0132	.0359	.1356	1	.7127	.0000
MZAREA	.1303	.0447	8.4866	1	.0036	.1059
Constant	-1.8253	.3278	31.0153	1	.0000	

where, B: regression coefficient; S.E.: Standard error; Wald: Wald statistic; df: Degrees of freedom; Sig: Significance level; R: R statistic.

Source: Estimated by the author from the 1998 CRI/CIMMYT survey.

The correlation matrix of the variables of the Logistic Model used is presented in

Table 6.40. This shows how the variables are correlated. The values of the correlation coefficients are generally low indicating that there are little relationships among the variables. This further suggests that the model is devoid of any serious multicollinearity problem and the variables selected for the analysis are appropriate.

Table 6.40: Correlation Matrix of Variables in the Logistic Model

	Constant	EXTVISIT	HHSIZE	ZONECS	ZONETR	ZONEGS	GENDER	TENURE	MZAREA
Constant	1.000	-.149	-.435	-.324	-.289	.054	-.568	-.097	-.351
EXTVISIT	-.149	1.000	-.026	.035	.109	.018	-.080	.009	.029
HHSIZE	-.435	-.026	1.000	-.095	-.090	-.385	.063	-.013	-.129
ZONECS	-.324	.035	-.095	1.000	.288	.284	.072	.041	.103
ZONETR	-.289	.109	-.090	.288	1.000	.269	.080	.020	.024
ZONEGS	.054	.018	-.385	.284	.269	1.000	-.204	.007	-.015
GENDER	-.568	-.080	.063	.072	.080	-.204	1.000	-.014	-.111
TENURE	-.097	.009	-.013	.041	.020	.007	-.014	1.000	.020
MZAREA	-.351	.029	-.129	.103	.024	-.015	-.111	.020	1.000

Source: Estimated by the author based on data from the 1998 CRI/CIMMYT survey

TOBIT analysis

A TOBIT model developed by James Tobin (1958) is used to determine the determinants of adoption of maize technology in Ghana. The TOBIT model measures not only the probability of adoption but also the intensity of adoption.

The empirical TOBIT model is based on the national data collected during the 1997 crop season through CRI/CIMMYT maize survey of Ghana. The estimated empirical model was developed using farm and farmer specific characteristics. The dependent variable is “area planted to improved maize varieties (MVAREA)”. The definitions of the other variables in the model are given in Table 6.41.

The model takes the following form:

$$MVAREA = f(\text{EXTVISIT}, \text{HHSIZE}, \text{ZONECS}, \text{ZONETR}, \text{ZONEGS}, \text{GENDER}, \text{TENURE}, \text{MZAREA}) + e$$

Table 6.41: Definitions of the Variables in the TOBIT Model

Dependent variable:	
MVAREA	Proportion of maize area under improved maize.
Independent variables:	
EXTVISIT	Number of contacts with extension agents: this is measured as a continuous variable.
HHSIZE	Total household size: measured as a continuous variable
ZONECS	Coastal Savannah ecological zone: this is measured as a binary variable: 1, if maize is planted in Coastal Savannah zone, 0, if planted elsewhere.
ZONETR	Transition ecological zone: this is measured as a binary variable: 1, if maize is planted in the transition zone and 0, if planted elsewhere.
ZONEGS	Guinea Savannah ecological zone: this is a binary variable: 1, if maize is planted in the Guinea Savannah zone, 0, if planted elsewhere.
GENDER	Sex of farmer. It is a binary variable: male = 1 and female = 0
TENURE	Ownership of land under maize cultivation. It is a binary variable: 1 if land is owned, 0 if any other land arrangements
MZAREA	Total maize area for the farmer and is measured as a continuous variable.
e	Error term

Source: Compiled by the author.

Results

Table 6.42: Estimated Results of the Factors Affecting the Proportion of Area under Improved Maize Varieties using Farmer, Farm Specific Variables and Ecological Zones in Ghana

Variable	Coefficient	Standard error	b/St. Er	P[z > z]	Mean of Variable
Constant	-4.88674	0.5985	-8.165	0.0000	
EXTVISIT	0.14602	0.36953E-01	3.952	0.0001	2.3000
HHSIZE	0.17974E-01	0.26549E-01	0.677	0.4984	10.1047
ZONECS	2.28518	0.45684	5.002	0.0000	0.2000
ZONETR	2.62006	0.49790	5.262	0.0000	0.1500
ZONEGS	1.42237	0.49998	2.845	0.0044	0.2000
GENDER	1.02497	0.43278	2.368	0.0179	0.7500
TENURE	0.88860	0.37861	2.347	0.0189	-1.6523
MZAREA	0.65899	0.51433E-01	12.813	0.0000	3.7049
Disturbance standard deviation					
Sigma ¹²	3.06781	0.15564	19.713	0.0000	

Log of likelihood function -694.7732

Source: Estimated by the author based on data from the 1998 CRI/CIMMYT survey.

The results in Table 6.42 show that extension contact, coastal savannah, Transition, Guinea Savannah zones, gender, land tenure and maize area are all significant at 5% level and are positively related to the proportion of area planted to improved varieties.

The significance level of extension contact is remarkable because it is through contacts with extension officers that many farmers become aware of improved varieties and consequently acquire them for use. This finding confirms the result that improved maize adopters had relatively more contacts with extension agents during a 12-month period of 1997 crop season. Thus, extension information plays an important role in the promotion of adoption of improved technologies.

¹² Sigma is the ancillary parameter

The ecological zones are important factors explaining adoption. All the three zones have significant positive coefficients. The value of the coefficient of the coastal savannah is 2.2852 and that of the transition zone is 2.6201 while it is 1.4224 in the Guinea Savannah zone. Household size is, however, not significant but it is positively related to the dependent variable.

The marginal analyses of the factors influencing the proportion of area planted with improved varieties are shown in Table 6.43. All the factors are significant except household size. The coefficients of the equation give indications of the marginal changes.

Table 6.43: TOBIT Marginal Effect for Factors of Maize Technology Adoption

Variable	Coefficient	Standard error	b/St. Er	P[z > z]	Mean of Variable
Constant	-1.53086	0.4486	-3.413	0.0006	
EXTVISIT	0.45744E-01	0.2013E-01	2.273	0.0230	2.3000
HHSIZE	0.56307E-02	0.86928E-02	0.648	0.5171	10.1047
ZONECS	0.71588	0.26716	2.680	0.0074	0.2000
ZONETR	0.82079	0.31942	2.570	0.0102	0.1500
ZONEGS	0.44558	0.22961	1.941	0.0523	0.2000
GENDER	0.32109	0.16454	1.951	0.0510	0.7500
TENURE	0.27837	0.30610E-01	9.094	0.0000	-1.6523
MZAREA	0.20644	0.72315E-01	2.855	0.0043	3.7049

Source: Estimated by the author based on data from the 1998 CRI/CIMMYT survey.

For example, one standard deviation change in extension contact leads to a change of 0.046 or 4.6% change of proportion of area planted to improved varieties. Similarly, one standard deviation change in maize area, changes the proportion of improved maize area by 0.2 or 20%. The coastal and the transition zone have the highest marginal effect among the variables in the model. The marginal effect of the transition zone is 82% while that of the coastal savannah is about 72%. This shows that ecological zones are important variables to consider in the introduction and adoption of improved maize technologies in Ghana.

The TOBIT analysis has examined the factors that affect proportion of area that is planted to improved maize varieties and the marginal effect of these factors. These are important factors that must be taken into consideration to guide future maize research and improve strategies for increased adoption of improved maize varieties.

The analysis has also included ecological zones as separate independent variables in order to show their significance than if they were bulked together as ecological zone. Future adoption studies could include ecological zones as some of the explanatory variables in adoption decision models.

Chapter Summary

The adoption of improved maize and row planting has been relatively high. However, fertilizer adoption is low. Over ninety percent of the farmers first adopted the improved maize technologies between 1984 and 1997 coinciding with the increased research and extension activities of the GGDP. Farmers who adopted improved maize technologies reported of increases in their maize production, yield, consumption and income. The marginal analysis of maize recommendation shows that when farmers adopt improved maize technologies in a piece-meal manner, the MRR are much higher than adopting the whole package of improved seed, fertilizer and row planting. The profitability of maize technology depends also on the ecological zones. The critical factors affecting the adoption of improved varieties are farmer contact with extension activities, being in the transition zone, Guinea Savannah zone and the coastal savannah zone. Gender and the size of the area cultivated to maize further affect the adoption of improved maize varieties.

CHAPTER 7

RETURNS TO INVESTMENT IN MAIZE RESEARCH AND EXTENSION

The key assumptions and scenarios used to estimate the internal rate of return to maize research and extension are given in Table 7.1. Five scenarios are described. These scenarios serve as sensitivity analysis. The results are summarized in Table 7.2, whereas in Table 7.3, the estimation of the financial rate of return for the baseline scenario is given. The details of the results from the scenarios are presented in Appendices 7 through to 16.

Table 7.1: Key Indicators Used in Estimating Internal Rate of Return

Parameter	<i>Scenarios</i>				
	1	2	3	4	5
Research lag (years)	5	5	5	5	5
Adoption lag (years)	30	30	30	30	30
Adoption level ceiling (%)	95	95	95	95	95
GGDP research cost included (%)	90	100	90	100	90
MOFA extension cost included (%)	30	30	50	50	30
Yield increase (%)	100	100	100	100	60

Source: Compiled by the author.

Scenario 1 in Table 7.1 (see also Appendices 7 and 8) is the baseline scenario where actual research and extension costs for maize are included. Because of lack of continuous data on adoption rates for each year and the fact that these had to be estimated in order to estimate the IRR, upon discussions with scientists and extension officers, the time to full adoption was assumed to be 30 years with adoption ceiling of 95%. These were used in the logistic function to estimate the adoption rates with the best fit. Scenarios 2 to 5 serve as sensitivity analysis where research costs, extension costs and yields are changed. In scenario 2 (Appendices 9 and 10), research costs are increased from 90% to

100%. Higher extension costs are included in scenario 3 (Appendices 11 and 12) from MOFA baseline budget of 30% to 50%. In scenario 4 (Appendix 13 and 14), both research and extension costs are increased. The yield advantage of the improved maize varieties over farmers' varieties is reduced by 40% in scenario 5 (Appendix 15 and 16).

Scenario 1 (Baseline):

Under the baseline scenario where the actual expenditures from research and extension were included, the financial rate of return to public investment in maize research and extension in Ghana during the period 1979-97 was 79% (Table 7.2).

Table 7.2: Financial and Economic Rate of Return to Maize Research in Ghana

Scenarios	Financial rate of return	Economic rate of return
1 Baseline	79%	33%
2 Higher Research Costs	73%	30%
3 Higher Extension Costs	71%	31%
4 Higher Research and Higher Extension Costs	68%	30%
5 Lower Projected Research Benefit	50%	25%

Source: Estimated by the author.

This internal rate of return is the discount or interest rate at which the Net Present Value is equal to zero. It thus represents the maximum interest rate that maize research and extension in Ghana could pay for all the resources employed from 1979 to 1997 after recovering its investment and operating cost. The financial rate of return is thus the return accruing to the maize farmers from maize research and extension. The IRR of 79% means that for every cedi invested in research and extension activities in Ghana during

the period of 1979 to 1997, seventy-nine pesewas was generated in return after recovering the cost. This result is similar to other studies in Ghana.¹

The economic rate of return was 33%. This is the contribution of maize research and extension to national income relative to the resources used. Similarly, an IRR of 33% means that the Ghanaian society gains thirty-three pesewas for every cedi spent on maize research and extension after paying the cost. In estimating the economic rate of return, since economic prices were used for the social costs of the inputs and maize price, the analysis represents the whole society's point of view. Hence, the economic rate of return is the benefit for the whole Ghanaian society.

The financial and economic rates of return are very attractive by normal investment standards and suggest that there may have been under-investment in maize research.

The difference in the financial and economic rates of return indicates that policy-induced distortions were relatively excessive. This suggests that markets for maize and inputs used in maize production are not competitive. In other words, the domestic prices of maize and inputs over the entire period of years were relatively lower than the world prices.

¹ Sanders John H., Taye Bezuney, Alan C. Schroeder. Op. Cit. pp. 1-28.

Table 7.3: Social Gains and Financial Rate of Return

Year	Proportional production Increase	Proportional cost increase	Net shift in supply	Change in quantity Caused by research
Parameter	$j = t \times (dY/Y_m)$	$i = I/P = (dC \times t)/(Y_m \times P)$	$k = (j / E) - i$	$dQ = (Q \times e \times E \times k)/(e + E)$
Unit				
1979	0	0	0	0
1980	0	0	0	0
1981	0	0	0	0
1982	0	0	0	0
1983	0	0	0	0
1984	0.0133	0.0019	0.0149	3,746
1985	0.0185	0.0035	0.0199	3,443
1986	0.0274	0.0047	0.0299	7,317
1987	0.041	0.0076	0.0443	11,598
1988	0.0547	0.0137	0.0555	14,577
1989	0.0684	0.0325	0.0541	16,906
1990	0.0889	0.0335	0.0791	19,119
1991	0.1163	0.0421	0.0151	42,843
1992	0.1505	0.0948	0.0957	30,589
1993	0.1915	0.1337	0.1087	45,724
1994	0.2325	0.1725	0.1218	50,107
1995	0.2804	0.2261	0.1288	58,296
1996	0.3283	0.2485	0.167	73,647
1997	0.3693	0.2895	0.178	77,881

Table 7.3 Continued

Social gains from research (In million cedis)	Research, Extension and CIMMYT real cost (million cedis)	Net gains (million cedis)	Internal Rate of Return (%)
$SG = (k \times P \times Q) - 1/2(k \times P \times dQ)$		$NG = SG - (R + Ext)$	
0	269	-269	
0	168	-168	
0	102	-102	
0	138	-138	
0	77	-77	
3,022	1292	1,730	
2,222	1995	227	
6,308	1794	4,514	
11,869	1579	10,290	
14,553	3222	11,331	
10,524	2819	7,705	
14,115	2340	11,775	
36,592	5209	31,383	
20,441	3699	16,742	
27,059	7587	19,472	
29,892	3583	26,309	
31,920	1978	29,942	
36,040	1314	34,726	
35,919	673	35,246	
			79%

Source: Estimated by the author.

Where,

- j = proportional production increase (incremental output)
 dY = yield increase due to the improved technology
 t = adoption rate (proportion of total area under improved technology)
 Y_m = farmers' yield (instead of national average yield because the yield gain is higher than the national average yield).
 i = proportional (per unit) input expenditure
 I = per unit input expenditure
 P = maize price
 dC = change in costs due to new technology
 k = net shift in supply
 E = elasticity of supply
 dQ = change in quantity caused by research
 SG = social gains.
 NG = net gains
 R = research cost
 Ex = extension cost

The difference between the financial and the economic rates of return seems to have resulted from the differences between the real exchange rates and the official exchange rates used to estimate them. These exchange rates had effect on the total costs and benefits from research and extension activities and hence the net social gains. There were initial higher negative values of the net social gains in the economic rate of return than in the financial rate of return (Table 7.4). In other words, the initial losses in the social gains in economic rate of return were higher than the financial rate of return. Since internal rate of return calculations are especially sensitive to net benefits accruing earlier in the period of analysis, the lower initial benefits had the effect of making the economic rate of return lower than the financial rate of return.

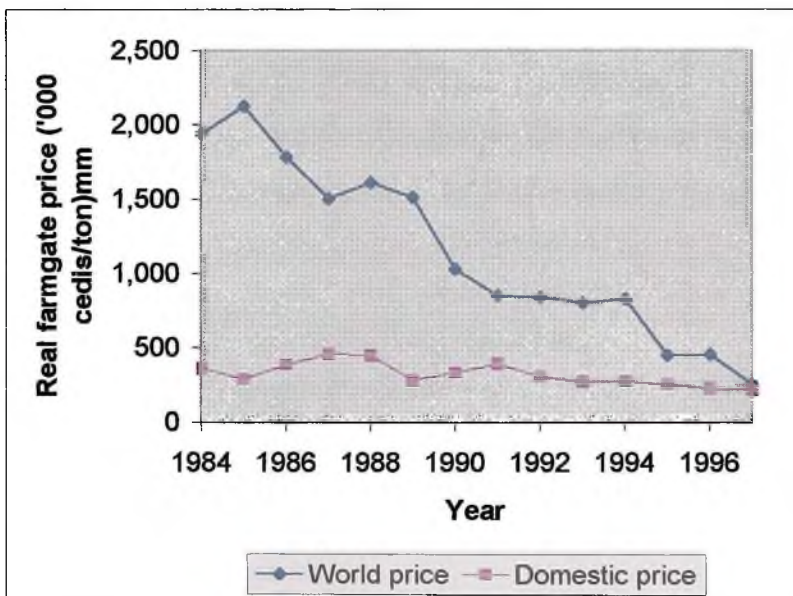
Table 7.4: Economic and Financial Net Social Gains

Year	Net social gains (million cedis)	
	Economic	Financial
1979	-24,898	-269
1980	-11,895	-168
1981	-3,551	-102
1982	-2,238	-138
1983	-1,143	-76
1984	11,515	1,730
1985	7,594	227
1986	29,406	4,514
1987	42,571	10,289
1988	50,468	11,331
1989	85,497	7,705
1990	56,886	11,775
1991	97,231	31,383
1992	100,027	16,742
1993	148,728	19,472
1994	194,312	26,309
1995	120,896	29,942
1996	133,228	34,726
1997	53,549	35,246

Source: Extracted from Appendices 7 and 8 by the author

As shown in Figure 7.1, both the real domestic and world maize price has been falling steadily. With the increase in national maize production and yield, the fall in maize price seems to suggest that the supply curve for maize has indeed shifted to the right. Consumers are able to consume more at a lower price. Thus, the consumer surplus has increased over the years. On the producer side, the increase in supply means a reduction in maize production cost. Thus, the producer surplus has increased and therefore, farmers have also gained by spending less per unit of output. These are indicators of the benefits of maize research to producers and consumers.

Figure 7.1: Real (Farmgate) Domestic and World Price of Maize



Source: Estimated by the author

As further shown in Figure 7.1, since the real domestic price of maize is lower than the real world price, (using the rural price index as a deflator), the export of maize

seems possible.

Transportation and marketing costs were estimated as 50% of the F.O.B. price and assumed constant. Given improved transportation system and infrastructure, transportation cost and marketing margin are expected to decrease over time. This invariably affects the import parity price estimated because parity price is the border price of the input or product at the border and adjusted for expenses between the border and the project boundary. The value of the parity price for maize for example, may in turn, affect the estimation of economic rate of return. There is thus a need for better estimates for transportation and marketing margin over time

Scenario 2 (Higher research costs):

As discussed earlier, in estimating parameters for the net social gains, because of lack of reliable data, several assumptions were made. These assumptions could in some cases, have underestimated the cost with inherent overestimation of the benefits leading to higher IRR. The reverse of this situation is also possible. To assess the effect of these assumptions, sensitivity analyses were made. Sensitivity analysis measures the effects of risks and uncertainty in project analysis. By changing some of the values of some key parameters of the project, it is possible to evaluate the robustness of the IRR. Not only does sensitivity analysis have important implications for decisions, it also has implications for project management.

In estimating the IRR for maize research and extension, total expenditures from research and extension could affect the results of the IRR. Since some of these costs are based on estimates, it is important that some sensitivity analysis is conducted on research

and extension costs to see how sensitive the results are to changes in their costs. If the proportion of GGDP research costs assigned to maize is increased from 90% to 100% and all other costs and assumptions remain the same, the financial rate of return goes down from 79% to 73% leading to a fall of 7.6%. The economic rate of return on the other hand, drops from 33% to 30% representing 9% drop.

Scenario 3 (Higher extension cost):

As pointed out earlier, obtaining the exact cost information for extension activities for maize was difficult. As such estimates were based on information from MOFA and in consultation with senior extension officers. Some costs may have been underestimated. In order to assess the sensitivity of the IRR to increased extension costs, the analysis was repeated with the proportion of MOFA extension costs assigned to maize increased from 30% to 50% while all other conditions remained the same. The financial rate of return decreased to 71% from the baseline value of 79% (see Table 7.2). This is a decrease of 10.1%. The economic rate of return is 31%.

Scenario 4 (higher projected research and extension costs):

The essence of this scenario is to test the IRR with further increased costs. Thus if the proportion of research costs is increased from 90% to 100% and that of MOFA extension costs also increased from 30% to 50%, the financial rate of return drops further to 68%, a decrease of 13.9%. The economic rate of return becomes 30%, falling by 9%. The result shows that as costs increase, the returns to investment also decline. Therefore, care should be taken not to over spend.

Scenario 5 (lower projected research benefits)

A sensitivity test of IRR to errors in estimated yield was conducted. A test to determine how sensitive the financial and economic rate of return are to lower yields not only provide useful information in deciding whether the project is worthwhile, but also emphasize the need for sufficient extension services if high yielding varieties are expected. If the projected yield gains attributable to the adoption of the research-generated technologies are reduced by 40%, the financial rate of return falls to 50% and the economic rate of return is 25%. The drop in the financial rate of return is 36.7% and that of economic rate of return becomes 24.2%. These are substantial reductions of the IRR and indicate that the IRR analysis is sensitive to 40% drop in yield gain. This has implications for future maize research because the drop in the values of the IRR show how much yield loss will cost the nation in lost opportunities to generate wealth. Hence, researchers will have to ensure high-yielding and stable varieties.

Chapter Summary

The estimated IRR for maize research and extension investment in Ghana ranged between 25% and 79%. Under the most conservative assumptions, the IRR was 25%. This means that for every cedi invested, the society as a whole received twenty-five pesewas in return. This is a clear demonstration that past public investments in maize research and extension activities in Ghana from 1979 to 1997 have had a pay-off.

CHAPTER 8

POLICY IMPLICATIONS AND CONCLUSIONS

Policy implications

During the past two decades, public investment in maize research and extension in Ghana clearly has been successful. The analysis shows that the resources invested by the Ghana government, foreign donor agencies, international agricultural research centers, and non-governmental organizations (NGOs) have generated attractive returns. The estimated internal rate of return to investments in maize research and extension activities ranged from 25% to 79%. This means that for every cedi invested in maize research and extension activities, 25 to 79 pesewas are obtained as a return after recovering cost. This clearly demonstrates that past public investments in maize research and extension support in Ghana have been profitable. The payoffs to maize research have been reflected in increased output, decreased production costs, and lower prices for consumers. These findings have a number of important policy implications.

Research policy issues:

Considering the role maize plays in the diet of most Ghanaians and in food security in general in Ghana, it is legitimate to focus on maize crop because it is such an important crop and thus a priority for research and extension. This is contrary to the notion that maize research and extension have had sufficient financial support and therefore do not need any more support. Indeed, some financial and material support is still needed to maintain and increase research and extension activities.

Continued funding is absolutely essential to maintain the successes that have been achieved over the past years. Since research is a long-term process requiring sustained financial support, it is necessary that maize research, and extension activities in particular, is financed to maintain the momentum of adoption of the improved maize technologies. Agricultural research and extension expenditures in one year potentially affect agricultural productivity for many years to come. The effect of inadequate funding of agricultural research and extension activities in one period will thus be very difficult to overcome later.

Germplasm improvement research has complemented crop management research. Adoption of fertilizer-responsive improved varieties is an important factor in enhancing the efficiency and thus the profitability of fertilizer use. Continued research on germplasm is therefore necessary to facilitate the increased maize adoption and subsequent production. With crop management activities, attention should be given to soil fertility issues particularly the use of leguminous plants in the cropping systems.

Technology adoption is usually related to profitability. Therefore, crop management recommendations should take the step-wise adoption behaviour of farmers and profitability into consideration. In developing maize recommendations, there is the need to identify the important technological components and options and their effect on production systems and the use of resources. Recommendations for maize production should have alternatives for farmers to select and adjust to their needs and circumstances.

The rate of return on recommended technological package of improved seeds, fertilizer, and row planting for maize is very sensitive to changes in yield. Even at 10% yield reduction, none of the technological options recommended for the ecological zones had acceptable **minimum** rate of return of 35%. Therefore, if farmers are to accept recommended maize technological package, then yields from varieties must be stable. Hence, breeders should develop stable varieties that can stand the test of weather and diseases.

Recycling of maize seed is a common practice among farmers. There is need to undertake research on maize seed recycling for loss assessment. Perhaps, this information when made available to farmers may change their attitude to purchasing improved seeds from seed dealers.

Maize technology recommendations were made based on past agronomic data. With changing economic and climatic conditions, some of the recommendations may have been outdated or inappropriate. Therefore, it is necessary to review and update the recommendations for growing maize in Ghana. This will also enable researchers to modify their research activities to produce competitive recommendations for farmers.

Impact assessment studies usually overlook many benefits generated by research projects because it is not easy assigning economic value to them. If all these were included, then the benefits would be much higher than expected. Therefore, even if such benefits cannot be measured, a descriptive assessment is a useful complement to these quantitative estimates.

In interpreting these findings, it is important to remember that this study has focused only on economic benefits of research. Other benefits have not been taken into account, even though these have undoubtedly been considerable. These include:

(a) Improved nutritional status: One of the objectives of the GGDP was to improve the nutritional status of rural households and maize consumers in general. This is because by increasing maize production, it is expected that there will be improved levels of food consumption and more so when maize is important in the diet of most Ghanaians and as a weaning food for children. The fact that protein-quality maize was released to farmers and that most farmers planted this variety emphasizes the importance farmers and researchers are paying to nutritional impact.

(b) Improved research efficiency: The GGDP was instrumental in introducing an integrated national strategy for technology generation, testing and diffusion that involved a large number of research and extension organizations. This approach has been adopted by other research and extension projects.

(c) Strengthened institutional capacity: The GGDP served as a model for collaboration between key players in maize technology development process, including national agricultural research and extension organizations (CRI, MOFA, GLDB), international agricultural research centres (CIMMYT, IITA) and donor agencies (CIDA). Therefore, the GGDP has had the experience to manage other new projects when available.

(d) Better-trained human capital: During the life of the GGDP, hundreds of Ghanaian researchers and extension officers received various forms of training. The effects of this training will long outlive the Project. Crops Research Institute, MOFA and the

national agricultural extension service will continue to benefit from having better-trained personnel and continue to have impact on Ghanaian agriculture.

(e) Gender issues: The GGDP was one of the first agricultural research and extension project that incorporated gender issues in its research programmes. All CRI research projects and programmes have had spill-over effects of this and are following suit.

(f) Increased employment: The GGDP also generated employment for those employed in the inputs distribution industries, such as seed growers, seed distributors, fertilizer importers and distributors.

(g) Improved policy information: The GGDP generated a substantial amount of information that can and is still put to good use by policy makers, extension officials, research managers, CRI scientists, input distributors, grain traders and others in their day-to-day activities.

One of the problems of impact assessment is with data particularly on national production figures and yield gain from the new technology. Since these can affect the estimation of internal rate of return, it is important that more attention and resources are given to them for quality data. For crop technology, it is imperative that a clear scenario of “with-and-without” technologies are continuously included in on-farm trials and should be farmer- managed as much as possible. This will provide a better assessment of yield gains.

An evidence of the advantages of collaborating with international research centres is that the GGDP took advantage of CIMMYT and IITA germplasm and avoided a substantial portion of possible expenses in the development of improved varieties. This spill-over from international centres is necessary and collaboration of national research

systems and the international centres should be encouraged. This collaborative effort has resulted in the **high** rates of return for maize research in a relatively short time. This experience goes to emphasize that if research methods or outcomes can be borrowed from other institutions at no or very little cost and are adaptive and user friendly, it will be better to do so. This will not only save time, resources and money but will provide rapid returns to investment. Furthermore, the high rate of return to maize research underscores the role of international cooperation in making National Research Systems (NARS) cost-effective.

Extension policy issues:

Information about improved technologies ought to reach more farmers. Improved seed has had a fairly extensive adoption in much of the maize-growing areas in Ghana, whereas fertilizer technology has been rather less successful. There is need for extra effort to speed up dissemination of fertilizer technologies to farmers for ultimate adoption.

Women farmers are not being reached as effectively as men farmers. Since women are usually the disadvantaged in the society, this calls for some review on the technology transfer strategy.

About 36% of farmers actually use quality protein maize or other improved varieties as weaning food but because of its nutritional value, additional efforts are needed to publicize benefits of quality protein maize.

With maize recommendations on planting practices, the adoption of maize practices as a package seems to be less profitable unless yields and fertilizer prices are stable. In particular, the adoption of all the three components of the package (improved

variety, fertilizer and row planting) together is not profitable in the Guinea savannah zone. However, a piecemeal adoption of variety or fertilizer is profitable among all the ecological zones. This approach is consistent with small-scale farmers' stepwise adoption behaviour. Thus, farmers should be encouraged to select and adopt portions of the recommended package for growing maize appropriate to their conditions and circumstances.

The adoption of improved maize technology is generally low in the forest zone but this zone has more agricultural districts than the other ecological zones. In addition, the forest zone has a reasonably good climate for growing maize. If adoption of improved maize is to be expanded, then the forest zone should receive equal attention as others. The marginal rate of return to investing in improved maize in the forest zone is high ranging from 672% to 3030%. Therefore, extension activities for the adoption of improved maize varieties in the forest zone should be given a priority.

Input policy issues:

Efficient supply of inputs is probably one of the key elements of policy environment necessary to facilitate technology transfer. When farmers begin to use purchased inputs, the public and private sectors have a role in promoting the use of the inputs by supplying them on timely basis. Support such as credit from the public sector in particular is necessary to enhance the adoption for purchased inputs such as fertilizer. Furthermore, most input stores are located in bigger towns farther away from the producing areas. It is necessary to improve the input delivery system by siting input shops

closer to the producing areas for easy access to these inputs. In addition, the role of farmer organizations should be strengthened to improve access to input.

Although the seed delivery system for improved varieties have shown significant improvements, there is room for further strengthening. A critical requirement for more widespread adoption of maize varieties is an effective improved seed delivery system. Although there is usually a farmer-to-farmer seed distribution, this facility is inadequate. A well-developed seed production and distribution system is important for smooth adoption of improved technologies. Additionally, formation of farmer organizations for acquisition of inputs and other agricultural services should be encouraged.

The maize adoption study revealed that fertilizer adoption is generally low in all the ecological zones. Considering the fact that yields are still low by international standards, more continuous cropping will persist and fertilizer prices might continue to rise, there is the need to explore ways to reduce the cost of chemical fertilizer or new and profitable fertility improvement technologies. With continuing attention to fertilization, yields can be increased further.

Concluding remarks

Some conclusions emerge from the study. First, the adoption of improved maize varieties has maintained its momentum in Ghana. Second, GGDP-generated varieties and other recommendations continue to be used extensively and third, investment in maize research and extension has continued to provide high rate of return.

The results of this study raise some issues that must be addressed by CRI. The fact that the improved varieties have been adopted widely places special responsibility on CRI

breeders to maintain and widen the genetic diversity of improved maize. With more varieties being released from different crosses, diversity such as disease resistance increases. Efforts to promote greater diversity will require complete awareness by breeders and stronger extension support. Furthermore, improved seed systems are needed to promote a much faster replacements of varieties over time.

Another issue is whether these gains can be maintained in the future. There are opportunities for the expansion of the area under improved varieties and accompanying recommendations in all the ecological zones particularly the forest zone. However, the expansion and adoption of improved technologies in the marginal areas will be slow and the impacts modest. More attention should be given to fertility issues in the Guinea Savannah zone, transition zone and coastal savannah zone. In more favorable areas, a major source of growth will be genetic yield gains in areas already sown to improved maize. Yields are still low by international standards and can still be increased. The gains in developing resistant varieties, increased yield potential and grain quality will make important contributions to yield stability and the overall food security for most Ghanaians.

In Ghana, public investments in maize research and extension have generated attractive rates of return. Investment in agriculture may just be as profitable as investing in other sectors of the Ghanaian economy.

Finally, this study has contributed to the growing body of literature on research impact assessment and evaluation.

BIBLIOGRAPHY

- Adesina Akinwumi A. and Moses M. Zinnah. "Technology Characteristics, Farmers' Perceptions and Adoption Decisions: A TOBIT Model Application in Sierra Leone." *Agricultural Economics* 9(1993).
- Adesina, A. A. and Baidu-Forson, J. "Farmers' Perception and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa." *Agricultural Economics* 13(1995).
- Akino Masakatsu and Yujiro Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development" *American Journal of Agricultural Economics* Vol.57. (1975).
- Alderman Harold and Gerald Shively. "Economic Reform and Food Prices: Evidence from Markets in Ghana." *World Development*. 24(1996).
- Alderman Harold and Paul Higgins. "Food and Nutritional Adequacy in Ghana." Cornell Food and Nutrition Policy Program. Working paper 27. 1992.
- Alston Julian M., George W. Norton and Philip G. Pardey. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Cornell University Press. 1995.
- Alston Julian M., Geoff W. Edwards, and John W. Freebairn. "Market Distortions and Benefits from Research." *American Journal of Agricultural Economics*. 9(1988).
- Anandajayasekeram, P., D. R. Martella and M Rukuni. *A Training Manual for Biological Scientists on Impact Assessment of Investments in Agricultural and Natural Resources Research*. Southern African Center for Cooperation in Agricultural and Natural Resources and Training (SACCAR). 1996.
- Anandajayasekeram, P., D.R. Martella, Rukumi M. *A Training Manual on Research and Development Evaluation and Impact Assessments of Investments in Agricultural and Natural Resources Research*. SACCAR. 1996.
- Anandajayasekeram P., D.R. Martella and M. Rukuni. *A Training Manual on R and D Evaluation and Impact Assessment of Investments in Agricultural and Natural Resources Research*. SACCAR. 1996.
- Anderson, J.R., and R.W Herdt. "Reflection on Impact Assessment." Proceedings of the ISNAR/Rutgers Agricultural Technology Management Workshop, 6-8 July, 1988. Rutgers University, New Jersey. Vol.2. Assessing the Impact of Agricultural Research, ISNAR. The Hague. The Netherlands. 1990.
- Asenso Okyere, W., F.A Asante, L. Oware Gyekye. "Case Studies on Rural Poverty Alleviation in the Commonwealth. Ghana." Food and Rural Development Division, Commonwealth Secretariat, London. (1992).

Asiedu-Saforo Kwame. "Economic Reform Programmes and Agricultural Development: Macro Policy Sequencing in Ghana, 1983-88." *Food Policy*. 14 (1989).

Boateng, E.O., K. Ewusi, R. Kanbur, A. McKay. "A Poverty Profile for Ghana, 1987-1988. Social Dimensions of Adjustment in Sub-Sahara Africa". Working Paper No.5. The World Bank, Washington D. C. (1990).

Boserup, Ester. "The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure. New York: Aldine Publishing. 1965.

Bumb B.L., J.F. Teboh, J.K. Atta and W.K. Asenso-Okyere (1994). " *Ghana Policy Environment and Fertilizer Development.*" IFDC. 1994.

Byerlee, D., and P. Moya. *Impacts of International Wheat Breeding Research in the Developing World, 1966-90.* Mexico D.F.:CIMMYT. 1993.

Byerlee, D., with P. Anandajayasekeram, A. Diallo, Bantanyu Gelaw, P. W. Heisey, M. Lopez Pereira, W. Mwangi, M. Smale, R. Tripp, and S. Waddington. *Maize Research in Sub-Saharan Africa: An Overview of Past Impacts and Future Prospects.* CIMMYT Economics Working Paper. 94-03. Mexico, D.F.: CIMMYT. 1994.

CIMMYT Economics Program. *The Adoption of Agricultural Technology: A Guide for Survey Design.* Mexico, D.F.: CIMMYT. 1993.

Clarke G.M. and D. Cooke. *A Basic Course in Statistics.* 2nd ed. Edward Arnold (publishers) Ltd. London. 1983.

CSIR and ISNAR,. "Review of the Ghana Agricultural System". Vol 1: Report. The Hague: ISNAR. 1991.

Dankyi A.A. and A.O.Apau. "Maize Marketing Channel Study" GGDP. 1990.

Dankyi, A.A., H.A. Dakurah and J.N. Asafo-Agyei. "Cowpea Technology Adoption in Ghana" Paper presented at the OAU/SAFGRAD Workshop, Abidjan, Ivory Coast. 1993.

Dankyi, A.A., V.M. Anchirinah and A.O. Apau "The Adoption of the Improved Rice Technologies in the Wetlands of the Ashanti Region of Ghana." Unpublished Paper. West Africa Rice Development Association (WARDA). Bouake, Ivory Coast, 1996.

Dankyi, A.A., V.M. Anchirinah, A.O. Apau.. " Profitability and Impact of Extension Test Plot on Maize Production in Ghana". GGDP/SG2000/DAES Collaboration. GGDP Memio. (1995).

Edmeades, G., A.A.Dankyi, K. Marfo and R. Tripp. "On-Farm Maize Research in the Transition zone of Ghana." *In Planned Change in Farming Systems.* Edited by R. Tripp. 1991. Wiley-Sayce Co-Publication.

Ekpere J. A. "Towards a New Orientation to the Challenge of Technology Transfer Systems and Food Production in the 21st Century Africa." Paper presented at the Regional Workshop. Technology Options and Transfer Systems. Abidjan, Cote D'Ivoire. April 26-28, 1995. pp, 1-26.

Evenson R.E. "*Economic Impact Studies of Agricultural Research and Extension*. Yale University. 1999.

GGDP Annual Report. Various Issues

GGDP. *A Study of Maize Technology in Ghana*. Mexico, D.F, GGDP. 1991.

GGDP. *Maize and Legumes Production Guide*. 1996.

Ghana Grains Development Project. Fourth Annual Report. Research Results. 1982.

Ghana Living Standards Survey 3. 1995.

Ghana Statistical Service. "Rural Communities in Ghana." Report of the National Rural Community Survey. Ghana Living Standards Survey. 1993.

_____ Quaterly Digest of Statistics. June 1995

Gittinger Price J. *Economic Analysis of Agricultural Projects*. Johns Hopkins University Press. 2nd Ed. 1982.

Greene William, H. *Econometric Analysis*. MacMillan Publishers. 1995.

Griliches Zvi "Research Expenditures, Education and Aggregate Agricultural Production." *The American Economic Review*. Vol, LIV (1964).

Griliches Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica*. 25 (1957).

Griliches, Zvi. "Research Costs and Social Returns: Hybrid Corn and Related Innovations." *Journal of Political Economy*. Vol. 66. No.5. October, 1958.

Gujarati Damodar, N., *Basic Econometrics*. 3rd ed. McGraw-hill, Inc. 1995.

Howard Julie, A., with George M. Chitalu, and Sylvester M. Kalenge. *The Impact of Investment in Maize Research and Dissemination in Zambia*. MSU International Development Working Paper. No. 39/1. 1993

International Monetary Fund. *International Financial Statistics Yearbook*. Washington DC. 1993.

International Financial Statistics, 1998.

Kivlin, J.E. and F.C. Fliegel. "Differentiated Perceptions of Innovations and Rate of Adoption." *Rural Sociology* 32 (1967).

- La-Anyane, S. "Research in Agriculture in Relation to National Economic Development". CSIR/Universities/U.S. Academy of Sciences Workshop, January 18. 1971.
- Laker-Ojok Rita. "The Rate of Return to Agricultural Research in Uganda: The Case of Oilseeds and Maize." MSU International Development Working Paper. No.42. 1994.
- Masters W.A., Touba Bedingar and James F. Oehmke. "The Impact of Agricultural Research in Africa: Aggregate and Case Study Evidence". Paper presented at the 23rd International Conference of Agricultural Economists. August 10-16, 1997, Sacramento, California. (1997).
- Masters W.A., Bakari Coulibaly, Diakalia Sanago, Mamadou Sidibe, Anne Williams, John H. Sanders and Jess Lowenberg-DeBoer. *The Economic Impact of Agricultural Research: A Practical Guide*. Department of Agricultural Economics. Purdue University. 1996.
- Mazzucato Valentia and Samba Ly. "An Economic Analysis of Resource and Technology Transfer of Millet, Sorghum and Cowpeas in Niger." MSU International Development Working Paper. No, 40.1994.
- Melinda Smale and Paul W. Heisey. "Maize of the Ancestors and Modern Varieties: The Microeconomics of High-Yielding Variety Adoption in Malawi." *Economic Development and Cultural Change*. 1995.
- Morris, M.L., H.J. Dubin and T. Pokhred. "Returns to Wheat Research in Nepal". CIMMYT Economics Working Paper 92-04. Mexico, D.F.: CIMMYT. (1992).
- Moshi A., P. Anandajayasekeram, A. Kaliba, D. Martella, W. Mwangi, and F. Shao. *Economic Impact of Maize Research in Tanzania*. Southern African Center for Cooperation in Agricultural and Natural Resources (SACCAR). 1997.
- Mudhara, M., P. Anandajayasekeram, D. Martella E. Mazhangara and M. Murata. *Impact Assessment of Soybean Research and Enabling Environment in Zimbabwe: 1965-2000*. Department of research and Specialist Services, Ministry of Agriculture, Zimbabwe. SACCAR. 1997.
- Nichola Tennassie and John H. Sanders. "A Probit Analysis of the Determinants of Adoption when Inputs are Rationed: The Gezira Experience with Hybrid Sorghum." *Science, Technology and Development*. Vol,14.no.3, 1996. pp.107-119.
- Nkonya, E., P. Xavery, H. Akonaay, W. Mwangi, P. Anandajayasekeram, H. Verkuijijl, D. Martella, and A. Moshi. *Adoption of Maize Production Technologies in Northern Tanzania*. Mexico D.F.: CIMMYT, The United Republic of Tanzania and the Southern African Center for Cooperation in Agricultural Research. 1998.
- Norton G. W. and Jeffrey S. Davis. "Evaluating Returns to Agricultural Research: A Review." *American Journal of Agricultural Economics* 63(4) 1981.

Oehmke James F. and Eric W, Crawford. "The impact of Agricultural Technology in Sub-Saharan Africa: A Synthesis of Symposium Findings." Michigan State University International Development Papers. No.14, 1993.

Oehmke, J., L. Daniels, J. Howard, M. Maredia, R. Bernsten, 1992. "The Impact of Agricultural Research: A Review of the Ex-post Assessment Literature with Implications for Africa. Staff Paper No. 92-38. Department of Agricultural Economics. Michigan State University.

Oehmke, James F., and Eric Crawford.. "The Impact of Agricultural Technology in Sub-Saharan Africa: A Synthesis of Symposium Findings". MSU International Paper No. 14. East Lansing: Department of Agricultural Economics, Michigan State University. (1993).

Rahm Michael, R. and Wallace E. Huffman. " The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables." *Australian Journal of Agricultural Economics*. 66(1984).

Rogers, E.M. *Diffusion of Innovations*. Free Press. Glencoe. Illinois. 1962

Sanders John H., Taye Bezuneh, and Alan C. Schroeder. (1994). " Impact Assessment of the SAFGRAD Commodity Networks." USAID/AFR/OAU/STRC-SAFGRAD.1994 pp 1-28.

Schuh Edward G. and Hellio Tollini. "Costs and Benefits of Agricultural Research." World Bank Staff Working Papers. The World Bank. no.360. 1979.

Schwartz, L.A., Sterns.J. A., and Oehmke, J.F. "Economic Returns to Cowpea Research, Extension, and Input Distribution in Senegal." *Agricultural Economics*. 8 (1993).

Shively Gerald E. "Consumption Risk, Farm Characteristics and Soil Conservation Adoption among Low-income Farmers in the Philipines." *Agricultural Economics*. 17(1997).

Sterns James, A., and Richard H. Bernsten. "Assessing the Impact of Cowpea and Sorghum Research and Extension in Northern Cameroun." MSU International Development Working Paper. No.43. (1994).

Stryker Dirck, J. with assistance of E. Dumeau, Jennifer Wohl, P. Haymond, Andrew Cook, and Katherine Coon. " *Trade, Exchange Rate, and Agricultural Pricing Policies in Ghana*." The World Bank. Washington D.C. 1990.

Tennassie Nichola. "The adoption of Hybrid Sorghum at the Farm and Regional Levels in the Gezira Irrigated Scheme of Sudan". Unpublished PhD Thesis. Department of Agricultural Economics, Purdue University. West Lafayette, USA.

Timothy J. Dalton. "Soil Degradation and Technical Change in Southern Mali." Unpublished PhD Thesis. Department of Agricultural Economics, Purdue University, West Lafayette, USA.

Tripp Robert. "Maize Seed Management Study in the Brong-Ahafo and Volta Regions of Ghana." GGDP. 1996.

Tripp, R., K. Marfo, A.A. Dankyi, and M. Read. *Changing Maize Production Practices of Small-scale Farmers in the Brong-Ahafo Region, Ghana*. Kumasi: Ghana Grains Development Project. 1987.

Twumasi-Afriyie S. "Achievements of the Crops Research Institute." CRI Ghana. 1995.

Voon Jan P., and Geoff W. Edwards. "The Calculation of Research Benefits with Linear and Nonlinear Specifications of Demand and Supply Functions." *American Journal of Agricultural Economics*. 73 (1991).

West Africa Rice Development Association (WARDA). "An Introduction to Impact Assessment Research." RETWA Methodology Series. 1997.

White Fred, C. and Joseph Havlicek, Jr. "Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding." *American Journal of Agricultural Economics*. 64 (1982).

APPENDIX 1
MAIZE SURVEY QUESTIONNAIRE

Adoption and impacts of improved maize technologies in Ghana

Collaborating institutions:

Crops Research Institute (CRI)
International Maize and Wheat Improvement Center (CIMMYT)
Canadian International Development Agency (CIDA)
Overseas Development Institute (ODI)

Survey questionnaire

Enumerator #1

Enumerator #2

Interview date

Questionnaire ID (1)

Region (2)

District (3)

Enumeration Area (4)

Village

Ecological zone (5)

(1 = forest, 2 = transition, 3 = coastal savannah, 4 = Guinea savannah)

Respondent's name

A. Farmer's household characteristics

A.1 Household membership

1. Size of household (6)

includes:

Adult males (7)

Adult females (8)

Children under 16 (9)

A.2 Farmer's resource ownership

2. Land farmed (all crops) in 1997(ac):

- owned (ac) (10)
 - sharecropped (ac) (11)
 - rented (ac) (12)
 - other (ac) (13)

Bicycles (14)
 Motorcycles (15)
 Vehicles (16)
 Tractors (17)

Cattle (18)
 Pigs (19)
 Sheep/goats (20)

3. Does your house have electricity? (1 = yes, 2 = no) (21)

A.3 Farmer's sources of income

4. Of the crops that you grow, please list those that provide the most cash income (list in order of importance)

Source 1 (22)

Source 2 (23)

Source 3 (24)

1 = maize, 2 = rice, 3 = sorghum, 4 = millet, 5 = cassava, 6 = yam, 7 = cocoyam, 8 = plantain, 9 = cowpea, 10 = soybean, 11 = groundnuts, 12 = cocoa, 13 = coffee, 14 = tobacco, 15 = cotton, 16 = vegetables, 17 = oil palm, 18 = citrus, 19 = other, 88 = N/A

5. Please list your most important sources of non-agricultural income (list in order of importance)

Source 1 (25)

Source 2 (26)

1 = wage labor in agriculture, 2 = wage labor elsewhere, 3 = remittances from relatives, 4 = sales of animals, 5 = trading, 6 = transport, 7 = tailoring, 8 = carpentry, 9 = other, 88 = N/A

6. What is your most important source of income? (check one)

Agriculture (27)

Non-agriculture (28)

A.3 Use of agricultural credit

7. Please indicate your use of agricultural credit during 1997:

Crop	Source of credit	Type	Use of credit	
(29)	(30)	(31)	(32)	(33)
(34)	(35)	(36)	(37)	(38)
(39)	(40)	(41)	(42)	(43)
(44)	(45)	(46)	(47)	(48)
(49)	(50)	(51)	(52)	(53)

Crops: 1 = maize, 2 = rice, 3 = sorghum, 4 = millet, 5 = cassava, 6 = yam, 7 = cocoyam, 8 = plantain, 9 = cowpea, 10 = soybean, 11 = groundnuts, 12 = cocoa, 13 = coffee, 14 = tobacco, 15 = cotton, 16 = vegetables, 17 = oil palm, 18 = citrus, 19 = other, 88 = N/A

Sources of credit: 1 = government program, 2 = private bank, 3 = family member, 4 = neighbor, 5 = money lender, 6 = credit society, 7 = other, 88 = N/A

Types of credit: 1 = cash, 2 = kind, 88 = N/A

Uses of credit: 1 = purchase seed, 2 = purchase fertilizer, 3 = purchase herbicide, 4 = purchase pesticide, 5 = hire labor, 6 = hire tractor, 7 = other, 88 = N/A

A.4 Contact with extension services and technical assistance organizations

- | | Maize | Other |
|---|---------------------------|---------------------------|
| 8. Number of times in the last three years that you discussed your farming activities with an extension officer | <input type="text"/> (54) | <input type="text"/> (55) |
| 9. Number of field days attended in the last three years | <input type="text"/> (56) | <input type="text"/> (57) |
| 10. Ever gave land for a maize demonstration plot? (1 = yes, 2 = no) | <input type="text"/> (58) | |

B. Maize varietal use and production practices**B1 Maize cropping activities**

11. How many years have you been growing maize? (59)

12. How many maize fields did you plant in 1997?

Major season: Number of fields (60) Total area (ac) (61)

Minor season: Number of fields (62) Total area (ac) (63)

B.2 Management of maize fields (1997 cropping season)

13. Please provide the following information about your 1997 maize production practices.

Maize field (largest fields)	Major season (up to three fields)			Minor season
	Field 1	Field 2	Field 3	Field 4
Size of field (ac)	(64)	(82)	(100)	(118)
Before 1997, how many years continuously cropped?	(65)	(83)	(101)	(119)
Before 1997, how many years fallow?	(66)	(84)	(102)	(120)
Land tenure (1 = own field, 2 = share crop, 3 = rent for cash, 4 = other)	(67)	(85)	(103)	(121)
First maize variety (1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other)	(68)	(86)	(104)	(122)
Year in which this variety first planted	(69)	(87)	(105)	(123)
Second maize variety (1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 88 = N/A)	(70)	(88)	(106)	(124)
Year in which this variety first planted	(71)	(89)	(107)	(125)
Main intercrop (0 = none, 1 = cassava, 2 = sorghum, 3 = millet, 4 = plantain, 5 = cocoyam, 6 = rice, 7 = cowpea, 8 = groundnuts, 9 = other)	(72)	(90)	(108)	(126)
Land preparation practice (1 = manual, 2 = animal, 3 = tractor, 4 = other)	(73)	(91)	(109)	(127)
Planting date (fortnight/month)	(74)	(92)	(110)	(128)
Planting pattern (1 = lines, 2 = ridge, 3 = random)	(75)	(93)	(111)	(129)
First type of fertilizer used (0 = none used, 1 = urea, 2 = ammonium sulphate, 3 = compound, 4 = manure)	(76)	(94)	(112)	(130)
Second type of fertilizer used (0 = none used, 1 = urea, 2 = ammonium sulphate, 3 = compound, 4 = manure)	(77)	(95)	(113)	(131)
Herbicide used? (1 = yes, 2 = no)	(78)	(96)	(114)	(132)
Pesticide used on maize in field? (1 = yes, 2 = no)	(79)	(97)	(115)	(133)
Pesticide used on maize in storage? (1 = none, 2 = actellic, 3 = other)	(80)	(98)	(116)	(134)
Number of maxi bags harvested	(81)	(99)	(117)	(135)

Local varieties: Field 1: _____ (136) Field 2: _____ (137)
 Field 3: _____ (138) Field 4: _____ (139)

B.3 Decision making responsibility for largest maize field (1997 cropping season)

14. Please provide the following information about your 1997 maize fields.

	Who took decision?	Who performed task?		Hired labor cost (c/day)
• obtaining land	(140)			
• selecting maize variety	(141)			
• obtaining seed	(142)	(143)	(144)	
• obtaining fertilizer	(145)	(146)	(147)	
• preparing land	(148)	(149)	(150)	(151)
• planting	(152)	(153)	(154)	(155)
• applying fertilizer	(156)	(157)	(158)	(159)
• weeding	(160)	(161)	(162)	(163)
• harvesting	(164)	(165)	(166)	(167)
• selling grain	(168)	(169)	(170)	(171)
• use of cash from maize sales	(172)			

Person responsible for decision: 1 = respondent, 2 = respondent's spouse, 3 = both, 4 = other, 88 = N/A

Task performed by: 1 = respondent, 2 = respondent's spouse, 3 = respondent and spouse,
4 = other family members, 5 = hired labor, 6 = exchange labor, 7 = other, 88 = N/A

B.4 Fertilizer use on maize

15. What was the most recent year in which you used fertilizer on maize? (173)
(Never = 00)

16. For the most recent year in which you used fertilizer on maize, please indicate:

Size of field (ac) (174) Years continuously cropped (before that year) (175)

17. Please describe your fertilizer practices in that year:

Fertilizer type	Days after planting	Rate (bags/acre)	Method
(176)	(177)	(178)	(179)
(180)	(181)	(182)	(183)
(184)	(185)	(186)	(187)

Fertilizer type: 1 = urea, 2 = ammonium sulphate, 3 = compound, 4 = manure, 5 = other, 88 = N/A

Fertilizer application method: 1 = applied on surface, 2 = buried

18. What was the first year in which you used fertilizer on maize?

 (188)

(Never = 00)

- In that year, how many acres of maize did you plant? (189)
- Of those acres, how many received fertilizer? (190)
- If you formerly used fertilizer but no longer use it, why did you stop? (191)

1 = don't need (land fertile), 2 = too expensive, 3 = can't get, 4 = credit not available, 5 = other

- If you have never used fertilizer on maize, why not?

19. What was the first year in which you row planted maize?

 (192)

(Never = 00)

- In that year, how many acres of maize did you plant? (193)
- Of those acres, how many were row planted? (194)
- If you have never row planted maize, why not?

20. What was the first year in which you planted improved maize?

 (195)

(Never = 00)

- In that year, how many acres of maize did you plant? (196)
- Of those acres, how many were planted to the improved variety? (197)
- What was the name of the improved variety? (198)

1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 88 = N/A

- If you have never planted an improved maize variety, why not?

C. Maize utilization patterns

C.1 Maize grain marketed in 1997

21. Please provide information about sales of the maize grain you harvested in 1997.

	Code	How many bags harvested?	How many bags sold?	Proportion sold (%)
Variety 1:	(199)	(200)	(201)	(202)
Variety 2:	(203)	(204)	(205)	(206)
Variety 3:	(207)	(208)	(209)	(210)
Variety 4:	(211)	(212)	(213)	(214)

1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 77 = all varieties combined, 88 = N/A

C.2 Household maize grain sales in 1997

22. Please provide information about your 1997 maize grain sales.

	Quantity sold (bags)	Average price (cedis/bag)	Buyer	Distance transported (km)
January	(215)	(227)	(239)	(251)
February	(216)	(228)	(240)	(252)
March	(217)	(229)	(241)	(253)
April	(218)	(230)	(242)	(254)
May	(219)	(231)	(243)	(255)
June	(220)	(232)	(244)	(256)
July	(221)	(233)	(245)	(257)
August	(222)	(234)	(246)	(258)
September	(223)	(235)	(247)	(259)
October	(224)	(236)	(248)	(260)
November	(225)	(237)	(249)	(261)
December	(226)	(238)	(250)	(262)

Buyer: 1 = neighbor, 2 = trader in your village, 3 = trader in other place, 4 = other

23. In 1997, did you feed maize to poultry? (263) No. of maxi bags (264)
(1 = yes, 2 = no)

24. In 1997, did you feed maize to pigs? (265) No. of maxi bags (266)
(1 = yes, 2 = no)

D. Maize varietal preferences

D.1 Farmer's rating of the importance of varietal attributes (in general)

25. If you are thinking about planting a new maize variety, how important are the following characteristics?

Yield	(267)
Early maturity	(268)
Drought tolerance	(269)
Insect resistance	(270)
Lodging tolerance	(271)
Grain size	(272)
Grain texture	(273)

Milling quality	(274)
Taste	(275)
Chafiness	(276)
Nutritional value	(277)
Storage quality	(278)
Market price	(279)

Importance of characteristics: 1 = very important, 2 = somewhat important, 3 = not important

D.2 Farmer's rating of specific varieties

26. Please rate the performance of the varieties you currently are growing or used to grow with regard to the varietal characteristics.

Variety name	Improved varieties			Local varieties	
	Now growing (1)	Now growing (2)	Used to grow	Now growing (1)	Used to grow
Variety code	(280)	(294)	(308)	(322)	(336)
Yield	(281)	(295)	(309)	(323)	(337)
Early maturity	(282)	(296)	(310)	(324)	(338)
Drought tolerance	(283)	(297)	(311)	(325)	(339)
Insect resistance	(284)	(298)	(312)	(326)	(340)
Lodging tolerance	(285)	(299)	(313)	(327)	(341)
Grain size	(286)	(300)	(314)	(328)	(342)
Grain texture	(287)	(301)	(315)	(329)	(343)
Milling quality	(288)	(302)	(316)	(330)	(344)
Taste	(289)	(303)	(317)	(331)	(345)
Chafiness	(290)	(304)	(318)	(332)	(346)
Nutritional value	(291)	(305)	(319)	(333)	(347)
Storage quality	(292)	(306)	(320)	(334)	(348)
Market price	(293)	(307)	(321)	(335)	(349)

Varieties: 1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie,
7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa
13 = other, 88 = N/A

Performance ratings: 1 = superior, 2 = acceptable, 3 = poor

E. Maize seed acquisition and management practices**E.1 Maize seed acquisition practices**

27. The following table refers to seed planted in 1997 (fields described in section B.1):

Note 1: If two varieties were grown in the same field, enter in separate columns.

Note 2: If the same variety was planted in two seasons, enter in separate columns (if seed used in 1997 minor season was saved from 1997 major season, fill in only first three lines).

	Variety 1	Variety 2	Variety 3	Variety 4
Variety (1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Dobidi, 6 = Abeleehi, 7 = Safita, 8 = Golden Crystal, 9 = Dorke, 10 = Kawanzie, 11 = Obatarpa, 12 = Okomasa, 13 = other, 88 = N/A)	(350)	(365)	(380)	(395)
Season planted (1 = major, 2 = minor, 3 = other)	(351)	(366)	(381)	(396)
Source of seed used in 1997 (1 = farm saved, 2 = another farmer, 3 = extension, 4 = SG2000, 5 = inputs shop, 6 = grain market, 7 = other)	(352)	(367)	(382)	(397)

IF FARM SAVED:

Maize seed selection practice (1 = in field before harvest, 2 = after harvest before storage, 3 = at home after storage)	(353)	(368)	(383)	(398)
Selected by whom (1 = man, 2 = woman, 3 = both)	(354)	(369)	(384)	(399)
Original source of seed (2 = another farmer, 3 = research or extension, 4 = SG2000, 5 = seed dealer, 6 = grain market, 7 = other, 8 = unknown)	(355)	(370)	(385)	(400)
Year acquired this seed (not variety)	(356)	(371)	(386)	(401)

FOR ALL SEED:

Quantity seed (kg) originally acquired (Note: 1 bowl = 2.5 kg)	(357)	(372)	(387)	(402)
How originally acquired? (1 = purchase, 2 = gift, 3 = loan)	(358)	(373)	(388)	(403)
If purchased, price (cedis/kg)	(359)	(374)	(389)	(404)
Why did you acquire new seed? (1 = to try new variety, 2 = had planted variety previously [old seed available but needed fresh seed], 3 = no other seed available, 4 = participated in extension activity, 5 = other)	(360)	(375)	(390)	(405)
Distance from seed source (in km)	(361)	(376)	(391)	(406)
Was seed in a sealed bag? (1 = yes, 2 = no)	(362)	(377)	(392)	(407)
Did you ask for this variety by name? (1 = yes, 2 = no)	(363)	(378)	(393)	(408)
How did you first learn about variety? (2 = from another farmer, 3 = from research or extension, 4 = from trader, 5 = from radio, 6 = other)	(364)	(379)	(394)	(409)

E.2 Past use of improved maize seed

28. Have you ever wished to obtain improved maize seed from a dealer and discovered that none was available?

 (410)

(1 = yes, 2 = no)

- If yes, most recent year (411)
- If farmer answers 1996, most recent year prior to 1996 (412)
- How many dealers did you visit in your search for seed? (413)
- Which variety were you looking for? (414)

1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 88 = N/A

- Were you able to get seed anyway from another source? (415)
(1 = yes, 2 = no, 88 = N/A)
- If no, which variety did you end up planting? (416)

1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal, 8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 88 = N/A

29. If you buy maize seed from a dealer, what do you do to try to ensure good quality?

Buy seed from known dealer (417) (1 = always, 2 = sometimes, 3 = never, 88 = N/A)

Buy seed from known seed producer (418) (1 = always, 2 = sometimes, 3 = never, 88 = N/A)

Look for certification label (419) (1 = always, 2 = sometimes, 3 = never, 88 = N/A)

F. Impacts of MV adoption

F.1 Incremental production attributable to modern varieties

(Refer to the respondent's main maize field. Fill in the box on the first line based on the answers given in Section B.2. Then ask farmer to estimate amounts in the other two boxes.)

30. Without fertilizer:

In a normal year, how many bags does _____ yield without fertilizer? (421)
(farmer's current improved variety) (420)

In a normal year, how many bags did _____ yield without fertilizer? (423)
(farmer's previous improved variety) (422)

In a normal year, how many bags would _____ yield without fertilizer? (425)
(farmer's current or previous local variety) (424)

31. With fertilizer:

In a normal year, how many bags does _____ yield with fertilizer? (427)
(farmer's current improved variety) (426)

In a normal year, how many bags did _____ yield with fertilizer? (429)
(farmer's previous improved variety) (428)

In a normal year, how many bags would _____ yield with fertilizer? (431)
(farmer's current or previous local variety) (430)

F.2 Nutritional awareness

32. Are any maize varieties particularly good for young children, to help them grow? (432)
(1 = yes, 2 = no)

IF YES:

Name of variety that is particularly good for young children (433)

Name of variety that is particularly good for young children (434)

1 = local, 2 = agric, 3 = La Posta, 4 = Aburotia, 5 = Safita, 6 = Kawanzie, 7 = Golden Crystal,
8 = Okomasa, 9 = Dobidi, 10 = Abeleehi, 11 = Dorke, 12 = Obatanpa, 13 = other, 88 = N/A

How did you learn that these varieties are particularly good for young children? (435)

Source of nutrition information: 1 = own experience, 2 = other farmer, 3 = research or extension worker,
4 = health worker, 5 = radio, 6 = newspaper, 7 = other

Do you use these varieties to prepare weaning foods? (436)
(1 = yes, 2 = no)



33. In the past ten years, have you noticed changes in any of the following:

- Maize yields in your fields (437)
- Area you plant to maize (438)
- Quantity of maize you produce (439)
- Quantity of maize consumed in your household (440)
- Quantity of maize you have sold (441)
- Income from maize sales (442)

1 = increased, 2 = same, 3 = decreased, 4 = don't know, 5 = other, 88 = N/A

34. If your income from maize sales has increased, what have you done with the extra money?

G. Information about respondent

35. Gender (1 = male, 2 = female) (443)
36. Age (444)
37. Years of schooling (445)
38. Marital status (1 = single, 2 = married, 3 = widowed, 4 = divorced) (446)
39. Residence status (1 = native, 2 = settler) (447)

H. Information about village

40. Please indicate if your village has the following infrastructure (1 = yes, 2 = no):

Electricity	<input type="text"/>	(448)
Tarred road	<input type="text"/>	(449)
Good feeder road	<input type="text"/>	(450)
Easy transportation	<input type="text"/>	(451)

Pipeborne water	<input type="text"/>	(452)
Market	<input type="text"/>	(453)
Health post	<input type="text"/>	(454)
Elementary school	<input type="text"/>	(455)

Appendix 2

Theoretical Model for Measuring Net Social Gains

APPENDIX 2

MODEL FOR MEASURING NET SOCIAL GAINS.

Key parameters that must be estimated in order to run the model for estimating the net social gains include the J-parameter (which measures the production increases or the incremental output from the technology). The K-parameter (which measures the net reduction in production cost from the new technology), and the I-parameter (which measures the increase in per-unit input cost). Other parameters that must be estimated include the change in quantity caused by research (dQ in equation 4), social gains and the net gains from research¹.

The J-parameter, which measures the total increase in production attributable to adoption of the new technology (holding prices and costs constant), is estimated from the formula:

$$j = (dY \times t) / Y_m \quad (A2.1)$$

Where:

j = proportional production increase (incremental output)

dY = yield increase due to the improved technology

t = adoption rate (proportion of total area under improved technology)

Y_m = farmers' yield (instead of national average yield because the yield gain is higher than the national average yield).

¹ Masters William A., Bakari Coulibaly, Diakalia Sanogo, Mamadou Sidibe, Anne Williams, John H. Sanders and Jess Lowenberg De-Boer. "The Economic Impact of Agricultural Research: A Practical Guide. 1996. pp 6-29.

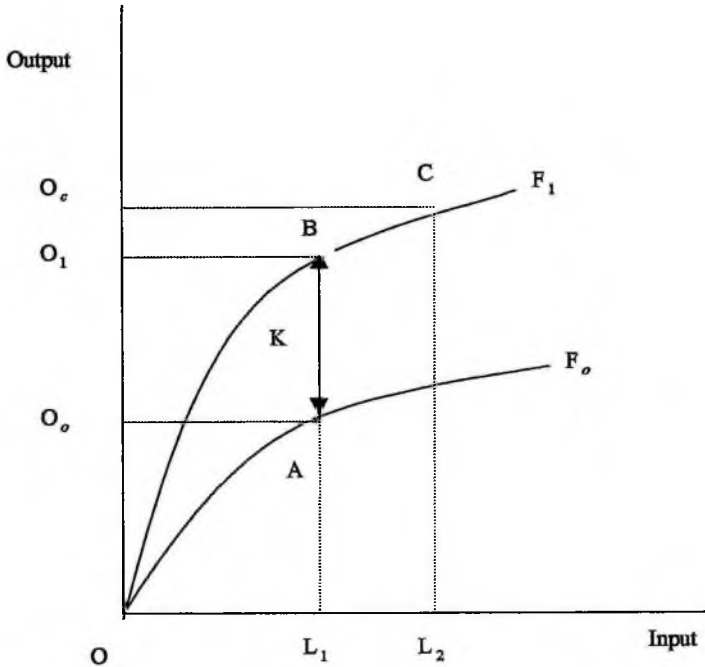
The I-parameter measures the increase in per-unit input costs associated with the reduction in production cost attributable to adoption of the improved technology (k). In practice, input levels often increase with the adoption of new technologies. This per unit cost can be referred to as "input expenditure" (I-parameter) instead of adoption cost.²

A distinction must be made between costs associated with a shift in the production function and those associated with movement along a production function. This is shown in Figure A2.1. Let F_o be the production function of an old technology (say, cutlass) and let F_1 be the production function for a new technology (say, chainsaw). At an input level of L_1 , production can be increased from A to B with a new technology. This is a complete shift between production functions but at the same input level. This shift is equivalent to the K-parameter or the net shift in production cost. It is per unit input cost associated with this shift that are to be estimated in impact assessment.

Position C is a point on the same production function, F_1 as position B. This point can only be produced at a new input level of L_2 . This is movement along the same production function, F_1 and not a change in the production function. Costs associated with this movement from B to C are not the same as those associated with the change from A to B. Increase in output (O_1O_o) is related to the shift of inputs (L_1L_2). Moving from A to C involves not only the shift but also change in input use. In assessing per unit input expenditure, we are interested in per unit input costs associated with the shift in the production function or the net reduction of production costs.

² Masters William A et al .Op. Cit.,p.16

Figure A2.1: Shift and Movement in Production Functions



In estimating per unit input cost (which Masters et al. call adoption costs, or the I-parameter,), I-parameter is defined as "the increase in per unit costs required to obtain a given production increase (J)." This definition dwells on production increase on the same production function curve instead of the actual shift of production function curves due to a shift from old to new technologies with fixed inputs.

A clear distinction must therefore be made between production increase due to a shift of supply curve and one due to movement on the same supply function. The I-

parameter, which will be called the "per unit input expenditure" is that cost associated with the shift from one supply curve to another given the same input. Alternatively, it is per unit of input cost associated with the net reduction of production cost (K-parameter) as illustrated Figure A2.2.

The I-parameter may therefore be defined as the increase in per unit input expenditure associated with the reduction in production cost (K-parameter). It is not associated with the production increase (J-parameter).

As shown in Figure A2.2, shifting from A to G involves changes in quantity from Q_o to Q' (which is similar to changes in input use in production function as in Figure A2.1). Instead of keeping quantity constant and observing the costs associated with the actual shift of the curve, we rather observe changes in quantity. As in Figure A2.2, the input expenditure (EF) is the cost associated with the shift from A to E at the same quantity, Q_o . Input expenditure should therefore be associated with the shift in supply curve and not with the production increase.

The input expenditure (per unit) is estimated from the equation:

$$i = I/P = (dC \times t) / (Y_m \times P) \quad (A2.2)$$

Where

i = proportional (per unit) input expenditure

I = per unit input expenditure

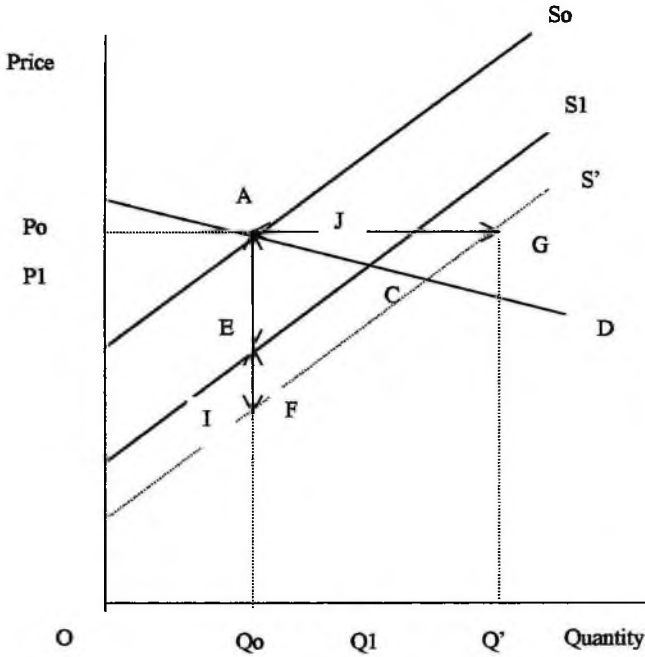
P = maize price

dC = change in costs due to new technology

t = adoption rate

Y_m = farmer's yield (Y_f)

Figure A2.2: Production Increases, Supply Shift and Input Expenditure



The net supply shift (K-parameter) is obtained from the formula:

$$k = (j/E) - i \tag{A2.3}$$

Where

- k = net shift in supply
- j = proportional production increase
- E = elasticity of supply
- i = proportional input expenditure

The change in quantity caused by research, dQ is estimated with the formula:

$$dQ = (Q \times e \times E \times k) / (e + E) \tag{A2.4}$$

Where

dQ = change in quantity caused by research

e = elasticity of demand

E = elasticity of supply

k = net shift in supply

Q = quantity supplied

The social gain is estimated from:

$$SG = (k \times P \times Q) - \frac{1}{2} (k \times P \times dQ) \quad (A2.5)$$

Where

SG = social gains.

Parameter k , P , Q , and dQ are as defined earlier on.

The net social gain is obtained from:

$$NG = SG - (R + Ex) \quad (A2.6)$$

Where

NG = net gains

R = research cost

Ex = extension cost

The estimated empirical model is derived from equation (A2.1) in which the J -parameter is estimated, equation (A2.2) in which estimates of the proportional increase in costs are made. In equation (A2.3), the proportional supply shift is estimated. Equation (A2.4) is used to estimate the change in quantity caused by maize research and extension.

The social gains are estimated using equation (A2.5) and the net gains are finally calculated with equation (A2.6). The IRR is then estimated from the streams of costs and benefits (net gains).

APPENDIX 3

EMPIRICAL PARAMETER ESTIMATES

The methods for estimating key parameters used in the internal rate of returns calculations are summarized below.

- Adoption rate:

The logistic growth function adopted from Griliches¹ is used to estimate the adoption rates for 1984 to 1996. The adoption rate for 1997 is obtained from the CRI/CIMMYT survey conducted in 1998.

In general, the logistic function is used to portray the diffusion curve. The curve shows the cumulative proportion of adoption of a technology. The diffusion curve follows an S-shaped curve in which there is a small initial growth in the use of the new technology, followed by a more rapid increase and then a decline as the cumulative proportion of adoption reaches its maximum. The curve can be described mathematically as:

$$Y_t = K / (1 + e^{-a-bt}) \quad (A3.1)$$

Where,

Y_t = cumulative percent area adopted by time t

K = upper bound of adoption (ceiling adoption level)

b = rate at which adoption occurs.

a = constant term

t = year (1, 2, ... N)

¹ Griliches, Z. "Hybrid Corn: An Exploration of the Economics of Technological Change." *Econometrica*. 1957 Vol. 25: 201-522.

This function may be simplified as:

$$-\ln \left(\left(\frac{K}{Y_t} \right) - 1 \right) = a + bt \quad (\text{A3.2})$$

- Yield gains attributable to adoption of improved technology:

Productivity gains associated with the adoption of improved maize technologies were estimated based on experimental data generated through GGDP on-farm trials. Since experimental data are available for two years only (1984 and 1985), the average percentage yield increases reported in these two years were used for subsequent years and were assumed to remain constant between 1986 and 1997.

Prior to 1991, the mean yields registered in GGDP trials for farmer-managed treatments were higher than national mean yields. This indicates either that official statistical data are flawed or that the GGDP trials were carried out in more favorable locations. The productivity gains used to calculate the research benefits were estimated by applying the proportional yield gain observed in the GGDP trials to the farmers' yields instead of the national mean yields figure for reasons given above. For consistency, this method was used for the entire period, 1984-97.

- Proportional production increase (j-parameter):

This was obtained by multiplying production increase, dY/Y_m by the adoption rate, t .

- Fertilizer prices:

The average fertilizer recommendation for maize calls for the application of compound fertilizer and sulphate of ammonium at a rate of 2.5 bags each per hectare.

This is equivalent to applying 30 kg/ha of nitrogen, 30 kg/ha phosphorus, and 45 kg/ha of potassium. Fertilizer price data were obtained from MOFA records.

The financial analysis was conducted using the subsidized fertilizer prices actually paid by farmers. These subsidies were removed for the economic analysis because subsidies are simply transfer payments.

- Fertilizer application cost:

Based on GGDP trial data², it was determined that five person days per hectare are needed to apply fertilizer. In 1997, agricultural wage rates averaged 2,925 cedis per day, so the cost of the labor required for applying fertilizer amounted to approximately 11% of the cost of fertilizer itself. Based on these data, fertilizer application costs for all years were assumed to be 12% of total fertilizer cost.

- Row planting cost:

Based on GGDP trial data, it was determined that 10 person days per hectare are required for row planting (GGDP 1984). In 1997, agricultural wage rates averaged 2,925 cedis per day, so the cost of the labor required for row planting one hectare of maize amounted to approximately 22% of fertilizer cost. Based on these data, row planting cost for all years were assumed to be 30% of total fertilizer cost.

² GGDP Annual Report. 1984. P.94.

- **Maize prices:**

Import parity prices for maize were calculated based on the standard international reference price for maize, No.2 yellow, F.O.B. US Gulf ports.³ This price was adjusted by adding international transport and handling costs to arrive at the important parity price in Accra. Domestic transport and handling costs were then subtracted to arrive at the import parity price valued at the farm gate.

Domestic maize prices were obtained from the Policy Planning Monitoring Evaluation Division of MOFA. In the absence of farm-gate prices, it was necessary to begin with wholesale prices in regional markets; these wholesale prices were then adjusted downwards by 30% (representing domestic transport and handling charges) to arrive at estimated farm gate prices. The 30% figure was based on the results of a maize marketing study conducted in 1991⁴.

- **Exchange rate (cedis: 1 US \$):**

Official exchange rates were used for the estimation of the financial rate of return for 1984-97. In the economic rate of return estimation, real exchange rates were used. Data were obtained from the IMF International Financial Statistics Yearbook (various issues).

³ Obtained from United States Department of Agriculture (USDA) and FAO Food Outlook on the Website, May/June, 1998.

⁴ Dankyi A.A. and A.O.Apau. "Maize Marketing Channel Study." GGDP Annual Report. 1990 pp.112-126.

- **Price index:**

The rural price index from the Ghana Statistical Service is used as a deflator. In estimating the real prices, 1997 is taken as the reference year.

- **Supply and demand elasticity:**

The value for elasticity of Supply for maize was obtained from Stryker⁵ and the elasticity of demand from Alderman and Higgins⁶. The elasticity of demand for maize was assumed to be 0.981, and the elasticity of supply was assumed to be 0.79.

- **Ghana Grains Development Project (GGDP) research costs:**

Cost data for the GGDP were compiled from GGDP Annual Report (various issues). GGDP local costs include salaries and benefits, travel costs, direct research costs, vehicle costs, general administration charges, capital development costs, financial charges, and counterpart funds.

In GGDP project documentation, the research costs from 1979-81 are combined. To obtain yearly cost figures for 1979, 1980, and 1981, the three-year total was broken down as follows: 30% for 1979, 30% for 1980, and 40% for 1981.

In 1997, GGDP was funded from the National Agricultural Project (NARP). Therefore, GGDP cost data for 1997 were obtained from NARP documents.

⁵ Stryker Dirck, J., Emmanuel Dumeau, Jennifer Wohl, Peter Haymond, Andrew Cook and Katherine Coon. "Trade, Exchange Rate and Agricultural Pricing Policies in Ghana." The World Bank, Washington D.C. 1990. pp 164-167.

⁶ Alderman Harold and Paul Higgins. "Food and Nutritional Adequacy in Ghana." Cornell Food and Nutrition Policy Program. Working paper 27. 1992. P 48.

- Proportion of GGDP cost assigned to maize:

Since the GGDP works on three main crops (maize, cowpea, soybean), it was necessary to decide the proportion of the total GGDP research budget that was allocated to maize research. The GGDP costs were assigned among these three crops in the following proportions:

1979-83: Maize 90%, cowpea 10%

1984 - 96: Maize 55%, cowpea 30%, soybean 15%

- GGDP foreign costs:

The Canadian International Development Agency (CIDA) paid for certain costs associated with the GGDP, including vehicles, equipment and supplies, professional services, management and administrative costs, consultants and visiting scientists, technical training, and miscellaneous local costs.

The CIDA contribution was estimated using assumptions similar to those used in estimating GGDP costs. Thus, it was estimated that maize research consumed 90% of all expenditures from 1979 to 1983, and 55% from 1984 to 1996.

Long-term postgraduate training expenses supported by CIDA were not included because training is assumed to be a long-term investment whose returns are unlikely to be fully captured in the period under study.

- NARP-CRI cost:

The National Agricultural Research Project (NARP) finances 7 projects of Crops Research Institute. The data from NARP is a bulk sum. Maize cost is therefore, assumed

to be one-seventh (15%) of the total NARP-CRI costs. The data is compiled from the NARP secretariat.

- SARI cost:

Savannah Agricultural Research Institute (SARI) is the second research institute working on maize. It used to be part of Crops Research Institute until 1994 when it became autonomous. Its research costs from 1979 to 1993 are inclusive of the GGDP costs. Available data (NARP/CSIR, 1997), show that scientific time for maize research in Ghana is 8%. This has been used to apportion research costs to SARI from 1994-97. The estimates are obtained from the Ministry of Finance and Economic Planning, Ghana.

- MOFA extension cost estimates:

The Ministry of Food and Agriculture (MOFA) budget estimates is used. Data available shows that usually 60-70% of the estimates is released. In this calculation, 80% of the estimates is assumed released. The data is compiled from records of the PPMED of MOFA, Ghana.

- MOFA extension cost on maize:

MOFA extension works on several crops in Ghana but the Policy Planning Monitoring and Evaluation Division (PPMED) of MOFA keeps production records of about 6-8 crops. Therefore using the area under production for these crops, extension activities are assumed to be proportional to it. This assumption puts maize extension cost

between 20% and 27%. In this analysis, maize extension cost is taken to be 30% of all MOFA costs.

- Global 2000 costs

The Sasakawa Global 2000 is an NGO providing additional extension for maize. It was established in 1988 to help disseminate maize and cowpea technologies in Ghana. Eighty percent of its budget was spent on maize extension. The data is from SG 2000 records.

Data on extension cost was only available for 1995-97. The costs for the other years have been calculated as 15% drop from the preceding years budget.

- CIMMYT costs

These are estimated costs by CIMMYT management staff. The cost does not include basic research on maize. This "spill-over benefits" generated by CIMMYT global breeding research is assumed free. CIMMYT costs are obtained from CIMMYT, Mexico.

APPENDIX 4
DERIVATION OF KEY FORMULAE FOR NET SOCIAL GAINS AND
INTERNAL RATE OF RETURN

APPENDIX 4**DERIVATION OF KEY FORMULAE FOR NET SOCIAL GAINS AND
INTERNAL RATE OF RETURN****I. PRODUCTION INCREASES, J-PARAMETER**

The J-parameter is the total increase in production as a result of the adoption of the technology if prices or costs remain constant.

$$J = dY \times t \times A \quad (\text{A4.1})$$

Where

dY = Yield increase in adopting the technology

t = Adoption rate (proportion of area under new technology)

A = Total area under maize production

To simplify calculation, J can be expressed in proportional terms as j .

This is the increase in quantity produced over the total quantity produced in the country.

$$j = J/Q \quad (\text{A4.2})$$

where Q = total quantity of maize produced

or,

$$j = (dY \times t \times A)/Q \quad (\text{A4.3})$$

But Q can be expressed as $Y_m \times A$ (A4.4)

where Y_m = overall national average production (yield) level

Therefore,

$$j = (dY \times t \times A) / (Y_m \times A) \quad (A4.5)$$

$$= (dY \times t) / Y_m \quad (A4.6)$$

II. INPUT EXPENDITURE, I-PARAMETER

The I-parameter is the increase in production costs (per unit costs) required to obtain the given

Production increase (J) It can be calculated as:

$$I = (dC \times t) / Y_m \quad (A4.7)$$

Where

dC = adoption costs (change in costs by switching to new technology)

t = adoption rate

Y_m = National average production level

To avoid using different units in the calculation, I, can be expressed in a proportional terms, i

, as a :

$$\text{Proportional cost increase, } i = I / P \quad (\text{A4.8})$$

where

P = product price

But, $I = (dC \times t) / Y_m$ (from equation A4.7)

Therefore,

$$i = ((dC \times t) / Y_m) / P \quad (\text{A4.9})$$

$$= (dC \times t) / Y_m \times P \quad (\text{A4.10})$$

III. THE NET SHIFT IN SUPPLY CURVE, K-PARAMETER

K-parameter is the vertical shift in the supply curve given the production increase, J, and the per unit input cost, I. It is the net reduction in production costs because of the new technology.

K-parameter can be calculated from the slope (b) of the supply curve and combining the effects of

Production increases (J) and the adoption costs (I). Thus :

$$K = (J \times b) - I \quad (\text{A4.11})$$

Because the slopes of the supply curve are associated with specific measurement units, the supply

Elasticity (E) is used instead. This is devoid of units of measurement.

Generally,

$$E = \%dQ / \%dP \quad (A4.12)$$

Where

dQ = change in quantity

dP = change in price

And,

$$\%dQ = dQ / Q \quad (A4.13)$$

$$\%dP = dP / P \quad (A4.14)$$

Therefore,

$$E = (dQ / Q) / (dP / P) \quad (A4.15)$$

$$= (dQ / Q) \times (P / dP) \quad (A4.16)$$

$$= (dQ / dP) \times (P / Q) \quad (A4.17)$$

But dQ / dP is the inverse of the slope (b) ie. $1/b$

Substituting dQ / dP with $1/b$ in equation (A4.17),

$$E = (1/b) \times (P/Q) \quad (A4.18)$$

$$\text{Therefore, the slope, } b = E \times (Q / P) \quad (A4.19)$$

But from equation (A4.11), $K = (J \times b) - I$

$$\begin{aligned} &\text{Hence substituting for } b, \\ K &= J / (EQ/P) - I \end{aligned} \quad (A4.20)$$

$$= [(J \times P) / (E \times Q)] - I \quad (A4.21)$$

Expressing K in proportional terms (k) to the price of the product,

$$k = K / P \quad (\text{A4.22})$$

Substituting for K using equation (A4.21),

$$k = [((J \times P) / (E \times P)) - I] / P \quad (\text{A4.23})$$

$$= [(J \times P / E \times Q \times P)] - (I / P) \quad (\text{A4.24})$$

Canceling out the Ps

$$k = (j / E) - I \quad (\text{A4.25})$$

IV. THE CHANGE IN QUANTITY CAUSED BY RESEARCH, dQ

Generally, it is given by:

$$dQ = (Q \times e \times E \times k) / (e + E) \quad (\text{A4.26})$$

Where,

dQ = change in equilibrium quantity

e = elasticity of demand

and E = elasticity of supply

Q = quantity supplied

k = proportional supply shift

The change in quantity actually caused by research, dQ, depends on the shift of the supply

Curve and the responsiveness of supply and demand. **Without research**, the equilibrium is:

$$Q_s = Q_d \quad (\text{A4.27})$$

Expressed linearly,

$$a_s + b_s P = a_d + b_d P \quad (\text{A4.28})$$

Or

$$a_s - a_d = b_d P - b_s P \quad (\text{A4.29})$$

Or

$$a_s - a_d = P(b_d - b_s) \quad (\text{A4.30})$$

Or

$$P = a_s - a_d / b_d - b_s \quad (\text{A4.31})$$

With research, the equilibrium is the new supply curve that is shifted in the direction of the price increase(as in Figure A2.2):

$$Q'_s = Q_d \quad (\text{A4.32})$$

$$a_s + b_s P' + b_s K = a_d + b_d P' \quad (\text{A4.33})$$

$$P' = (a_s - a_d + b_s K) / (b_d - b_s) \quad (\text{A4.34})$$

$$\text{The resulting change in price, } dP = P - P' \quad (\text{A4.35})$$

$$dP = P - P' = [(a_s - a_d) / (b_d - b_s)] - [(a_s - a_d + b_s K) / (b_d - b_s)] \quad (\text{A4.36})$$

$$= -b_s K / (b_d - b_s) \quad (\text{A4.37})$$

$$\text{Multiplying through by a minus sign, } = b_s K / (b_d + b_s) \quad (\text{A4.38})$$

Hence the change in quantity, dQ , is the slope of demand multiplied by the change in price.

$$\text{That is, } dQ = b_d dP \quad (\text{A4.39})$$

$$\text{But from equation (A4.38), } dP = b_s K / (b_d + b_s)$$

Therefore,

$$dQ = b_d b_s K / (b_d + b_s) \quad (\text{A4.40})$$

Since it is easier to work with elasticity than slopes (because slopes have specific units), the Slopes in the equation are converted to elasticity that has absolute values.

$$\text{And elasticity of demand, } e, = \%dQ / \%dP = (dQ / Q) / (dP / P) \quad (\text{A4.41})$$

$$\text{Or, } e = (dQ/dP) \times (P/Q) \quad (\text{A4.42})$$

But $dQ/dP = b_d$, the slope of the demand curve

Hence,

$$e = b_d \times (P/Q) \quad (\text{A4.43})$$

Therefore,

$$b_d = eQ / P \quad (\text{A4.44})$$

$$\text{By similar token, } b_s = EQ/P \text{ (where E = elasticity of supply)} \quad (\text{A4.45})$$

But it is known from equation (A4.40) that: $dQ = b_d b_s K / (b_d + b_s)$

Substituting the values of b_d and b_s from equations (A4.44) and (A4.45) in the equation below:

$$dQ = b_d b_s K / (b_d + b_s) \quad (\text{A4.46})$$

$$= [(eQ/P) (EQ/P)K] / [(eQ/P) + (EQ/P)] \quad (\text{A4.47})$$

$$= [(eEQK / PP)] / [(eQ + EQ) / P] \quad (\text{A4.48})$$

$$= [(eEQK / PP) / [(Q(e + E) / P)]] \quad (\text{A4.49})$$

Multiplying and canceling out,

$$dQ = eEQK / (e + E) \quad (A4.50)$$

Hence,

$$dQ = (Q \times e \times E \times K) / (e + E) \quad (A4.51)$$

Where Q is the quantity supplied to the market.

V. THE SOCIAL GAINS, SG

This is calculated as the area of the parallelogram between the supply curves, area ABCD minus Area of triangle BCE. The sign is minus because this is an ex-post analysis.

Thus generally,

$$SG = KQ - 1/2(KdQ) \quad (A4.52)$$

Where, KQ = area of the parallelogram, ABCD and $1/2(KdQ)$ = area of the triangle, BCE

But from previous equation (A4.22), $K = kP$

Substituting,

$$SG = [k \times P \times Q] - 1/2[k \times P \times dQ] \quad (A4.53)$$

VI. NET SOCIAL GAINS, NG

$$NG = SG - (R + Ex) \quad (A4.54)$$

Where R and Ex are the research and extension costs respectively.

The Internal Rate of Return (IRR) is then estimated from the streams of benefits and costs (the net gains). The IRR measures the discount rate (or interest rate) at which the Net Present Worth (or value) is zero.¹

That is:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad (A4.55)$$

$$\text{Or, } \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t} - C_o = 0 \quad (A4.56)$$

Where:

B_t = Benefit in each year

C_t = Cost in each year

C_o = Initial investment

$t = 1, 2, \dots, n$

n = number of years

i = discount (interest) rate.

Internal Rate of Return is thus a measure of the maximum interest rate that a project could pay for resources used if the project is to recover its investment and operating cost

¹ Gittinger Price, J. "Economic Analysis of Agricultural Projects." The World Bank. Johns Hopkins University Press. 1982. pp. 332-343.

and still break even. The selection criterion for IRR is to accept all independent projects having an IRR equal to or greater than the opportunity cost of capital.

APPENDIX 5

THE LOGISTIC REGRESSION AND THE TOBIT MODEL

APPENDIX 5

THE LOGISTIC REGRESSION

The logistic regression model is suited for models in which the dependent variable is dichotomous. The probability of an event occurring can be estimated directly with the logistic regression.

For a single independent variable, the logistic regression model can be written as :

$$\text{Probability of adoption} = \frac{e^{b_0 + b_1 X}}{1 + e^{b_0 + b_1 X}} \quad (\text{A5.1})$$

or

$$\text{Probability of adoption} = \frac{1}{1 + e^{-(b_0 + b_1 X)}} \quad (\text{A5.2})$$

where b_0 and b_1 are coefficients from the data, X is the independent variable, and e is the natural logarithm of value of approximately 2.718.

For more than one independent variable, the model can be written as:

$$\text{Probability of adoption} = \frac{e^Z}{1 + e^Z} \quad (\text{A5.3})$$

or

$$\text{Probability of adoption} = \frac{1}{1 + e^{-Z}} \quad (\text{A5.4})$$

where Z is a linear combination of explanatory variables,

$$\text{and } Z = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_k X_k \quad (\text{A5.5})$$

The probability of the event not occurring is estimated as:

$$\text{Prob(no event)} = 1 - \text{Prob(event)} \quad (\text{A5.6})$$

The probability estimated is between 0 and 1. In logistic regression, the parameters of the regression are estimated using the maximum likelihood method. Thus, the coefficients that make the observed results most “likely” are selected.

THE TOBIT MODEL

A TOBIT model is used to determine the factors of adoption of improved maize in Ghana. Mathematically, the TOBIT model¹ can be expressed as:

$$Y_i = \beta_1 + \beta_2 X_{2i} + \mu_{2i}, \text{ if Right Hand Side} > 0 \quad (\text{A5.7})$$

= 0, otherwise

where

Y_i = Limited dependent variable

X_i = Explanatory variable

μ_i = Disturbance term

β_1 = Intercept

β_{2i} = Coefficient to be estimated

The TOBIT model measures not only the probability of adoption but also the intensity of adoption. Rahm and Huffman² developed a general model where farmers are assumed to make adoption decisions based on utility maximization.

Define t_1 = New technology

t_2 = Farmer technology

The underlying utility function ranking the preference of the i^{th} farmer is given by:

$$U(H_H, N_H).$$

¹ Gujarati Damodar, N., Basic Econometrics. 3rd ed. McGraw-hill, Inc. 1995. pp.570-575.

² Rahm, Michael R. and Wallace E. Huffman, “The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables.” Australian Journal of Agricultural Economics, 1984. 66:pp.405-413.

This means that utility is a function of H_n a vector of farm specific attributes such as farm size, and N_n which are technology-specific characteristics such as taste.

$$U_{it} = \alpha_t F_i(H_n, N_n) + e_{it} \quad (\text{A5.8})$$

where $t = 1, 2; i = 1, \dots, N$

The utilities are random and the i^{th} farmer adopts the new technology ($t = 1$) if $U_{1i} > U_{2i}$ or if the non-observable random variable $y^* = U_{1i} - U_{2i} > 0$.

The probability that $y^* > 0$, (i.e. that the farmer adopts the new technology) can be written as a function of the independent variables:

$$P_i = \Pr(y_i > 0) = \Pr(U_{1i} > U_{2i}) \quad (\text{A5.9})$$

$$= \Pr[\alpha_1 F_i(H_n, N_n) + e_{1i} > \alpha_2 F_i(H_n, N_n) + e_{2i}] \quad (\text{A5.10})$$

$$= \Pr[e_{1i} - e_{2i} > F_i(H_n, N_n)(\alpha_2 - \alpha_1)] \quad (\text{A5.11})$$

$$= \Pr(\mu_i > F_i(H_n, N_n)\beta) = F_i(X_i\beta) \quad (\text{A5.12})$$

where

P_i = Probability function

$\mu_i = e_{1i} - e_{2i}$ is a random disturbance term

$\beta = \alpha_2 - \alpha_1$ is a vector of parameters to be determined.

$X = (n \times k)$ is vector of explanatory variables.

$F(X_i\beta)$ = cumulative distribution function for the disturbance term, μ_i , evaluated at

$X_i\beta$.

The dependent variable (Y_i) is the proportion of maize area under improved varieties. The dependent variable is censored because information on the regressand is available only for some observations. TOBIT model can therefore be used.

APPENDIX 6
LOGISTIC GROWTH CURVE

APPENDIX 6

LOGISTIC GROWTH CURVE EXPERIMENT

GHANA MAIZE STUDY – LOGISTIC GROWTH CURVE EXPERIMENT

LOGISTIC GROWTH CURVE FORMULA (ADOPTED FROM GRILICHES, 1957):

$$- \ln\left[\frac{K}{Y_t} - 1\right] = A + Bt$$

WHERE: Y_t = CUMULATIVE PERCENTAGE OF ADOPTERS BY TIME t
 K = UPPER BOUND ON PERCENTAGE ADOPTION
 b = RATE AT WHICH ADOPTION OCCURS
 a = CONSTANT TERM

EXAMPLE 1: $K = 95$
 30 YEARS TO TOTAL ADOPTION

$K = 95$
 $a = -3.923$
 $b = 0.3028$

t	$Y(t)$	t	$-\ln\left[\frac{K}{Y_t} - 1\right]$
3	5	3	-2.89
9	20	9	-1.322
14	54	14	0.2754
23	90	23	2.8904
25	93	25	3.8395

APPENDIX 6 continued

YEAR	% ADOPTION (Predicted)
1	2
2	3
3	4
4	6
5	8
6	10
7	13
8	17
9	22
10	28
11	34
12	41
13	48
14	55
15	62
16	68
17	73
18	78
19	82
20	85
21	87
22	89
23	91
24	92
25	93
26	93
27	94
28	94
29	94
30	94

APPENDIX 6 Continued

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.99854355
R Square	0.99708921
Adjusted R Square	0.99611895
Standard Error	0.1754122
Observations	5

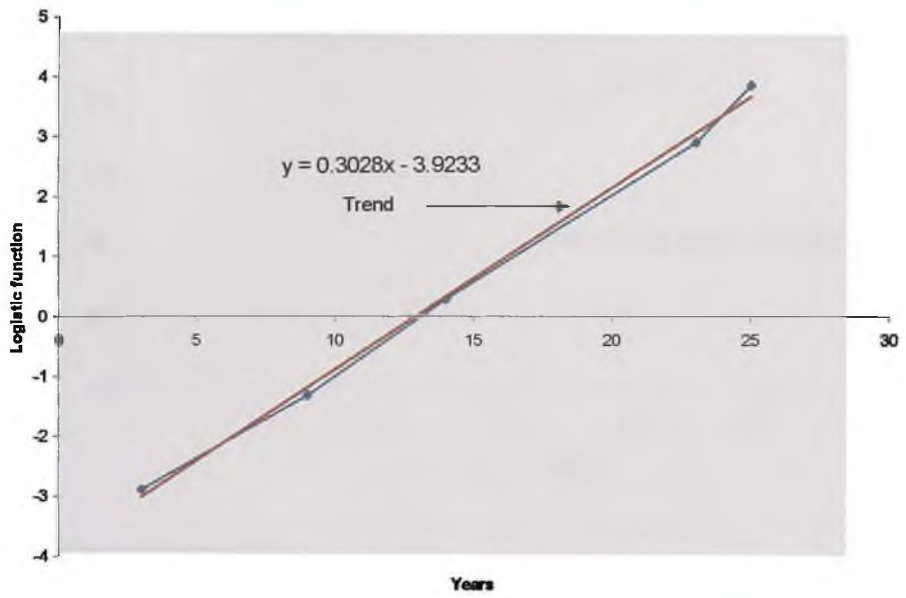
ANOVA

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	31.62018283	31.62018	1027.649	6.6709E-05
Residual	3	0.092308321	0.030769		
Total	4	31.71249115			

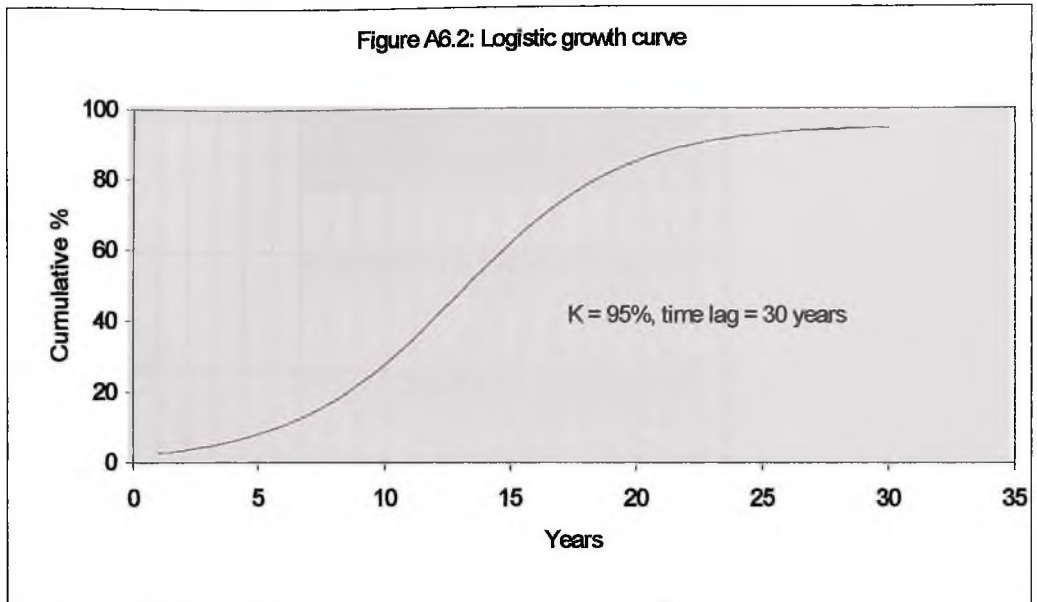
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	-3.92325883	0.160314356	-24.4723	0.00015	-4.433451142	-3.413066527
X Variable 1	0.30282977	0.009446614	32.05696	6.67E-05	0.272766395	0.332893135

<i>Lower 95.0%</i>	<i>Upper 95.0%</i>	<i>Upper 95.0%</i>
-4.43345	-3.413066527	-3.636447359
0.272766	0.332893135	0.325277624

Source: Estimated by the author

Figure A6.1: Logistic regression

Source: Estimated by the author.



Source: Estimated by the author

Table A7: Financial Rate of Return (Baseline scenario)

Year	Total quantity produced (mt)	Total area planted (ha)	National average production (mt/ha)	Adoption rate (at K = 95%, Lag = 30 years)	Yield of improved technology (mt/ha)	Yield of farmer technology (mt/ha)	Change in yield (mt/ha)	Proportional increase
Parameter	Q	A	Ym	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf
1979	308600	313900	0.98	0				
1980	354000	319900	1.11	0				
1981	334200	315500	1.06	0				
1982	264300	276300	0.96	0				
1983	140800	279800	0.50	0				
1984	574000	723600	0.79	0.02	2.88	1.73	1.15	0.6647
1985	395000	405000	0.98	0.03	2.75	1.7	1.05	0.6176
1986	559100	472100	1.18	0.04	2.93	1.74	1.19	0.6839
1987	597700	548336	1.09	0.06	2.93	1.74	1.19	0.6839
1988	600000	500000	1.20	0.08	2.93	1.74	1.19	0.6839
1989	714614	595800	1.20	0.1	2.93	1.74	1.19	0.6839
1990	552549	464784	1.19	0.13	2.93	1.74	1.19	0.6839
1991	931478	610445	1.53	0.17	2.93	1.74	1.19	0.6839
1992	730617	606783	1.20	0.22	2.93	1.74	1.19	0.6839
1993	960920	636670	1.51	0.28	2.93	1.74	1.19	0.6839
1994	939908	629401	1.49	0.34	2.93	1.74	1.19	0.6839
1995	1034170	668600	1.55	0.41	2.93	1.74	1.19	0.6839
1996	1007610	664950	1.52	0.48	2.93	1.74	1.19	0.6839
1997	1000000	650000	1.54	0.54	2.93	1.74	1.19	0.6839

Table A/ continued

	Proportional	Fertilizer prices	Change in	Change in	Improved	Farmers
	production increase	(comp. + S. Ammonia)	fertilizer cost	row planting	seed	seed
Year		(cedis/ha)	including application	cost	(cedis/ha)	(cedis/ha)
	$i = t \times (dY/Yf)$		(cedis/ha)	(cedis/ha)		
1979						
1980						
1981						
1982						
1983						
1984	0.0133	1,838	2,059	551	400	300
1985	0.0185	1,838	2,059	551	1,000	750
1986	0.0274	3,175	3,556	953	1,000	750
1987	0.0410	5,500	6,160	1,650	2,000	1,500
1988	0.0547	9,750	10,920	2,925	2,000	1,500
1989	0.0684	14,250	15,960	4,275	3,000	2,250
1990	0.0889	18,250	20,440	5,475	3,000	2,250
1991	0.1163	23,750	26,600	7,125	5,000	3,750
1992	0.1505	36,250	40,600	10,875	5,000	3,750
1993	0.1915	43,750	49,000	13,125	9,000	6,750
1994	0.2325	58,750	65,800	17,625	9,000	6,750
1995	0.2804	92,500	103,600	27,750	12,000	9,000
1996	0.3283	107,500	120,400	32,250	20,000	15,000
1997	0.3693	132,500	148,400	39,750	30,000	22,250

Table A/ continued

Year	Change in	Change in total	Maize price:		Rural price index (1977 = 100)	Real price (C/t) (1997 = 1)
	seed cost (cedis/ha)	cost of technology (cedis/ha)	Average wholesale price (cedis/mt)	Farmgate price (70% of wholesale) (cedis/mt)		
	dC					
1979					279	
1980					448	
1981					938	
1982					1,150	
1983			0	0	2,640	0
1984	100	2,710	23,380	16,366	3,652	354,204
1985	250	2,860	20,380	14,266	3,974	283,737
1986	250	4,759	33,110	23,177	4,824	379,744
1987	500	8,310	53,870	37,709	6,591	452,205
1988	500	14,345	68,590	48,013	8,581	442,244
1989	750	20,985	53,000	37,100	10,637	275,674
1990	750	26,665	85,030	59,521	14,310	328,755
1991	1,250	34,975	116,050	81,235	16,784	382,551
1992	1,250	52,725	100,480	70,336	18,613	298,678
1993	2,250	64,375	110,720	77,504	23,092	265,280
1994	2,250	85,675	138,630	97,041	28,598	268,201
1995	3,000	134,350	200,000	140,000	44,880	246,557
1996	5,000	157,650	250,000	175,000	62,230	222,269
1997	7,750	195,900	300,000	210,000	79,039	210,000

Table A7 continued

Year	Real change in cost,	Proportional cost increase				Change in quantity caused by
Unit	(cedis/ha)		Supply elasticity (E = 0.79)	Net shift in supply	Demand elasticity (e = - 0.981)	research, d Q
Parameter	dC	$i = I/P = (dC \cdot t)/(Yf \cdot P)$		$k = (j / E) - i$		$dQ = (Q \times e \times E \times k) / (e + E)$
1979			0.79		0.981	
1980			0.79		0.981	
1981			0.79		0.981	
1982			0.79		0.981	
1983		0.0000	0.79		0.981	0
1984	58,651	0.0019	0.79	0.0149	0.981	3,746
1985	56,882	0.0035	0.79	0.0199	0.981	3,443
1986	77,966	0.0047	0.79	0.0299	0.981	7,317
1987	99,653	0.0076	0.79	0.0443	0.981	11,598
1988	132,131	0.0137	0.79	0.0555	0.981	14,577
1989	155,931	0.0325	0.79	0.0541	0.981	16,906
1990	147,280	0.0335	0.79	0.0791	0.981	19,119
1991	164,704	0.0421	0.79	0.1051	0.981	42,843
1992	223,894	0.0948	0.79	0.0957	0.981	30,589
1993	220,342	0.1337	0.79	0.1087	0.981	45,724
1994	236,788	0.1725	0.79	0.1218	0.981	50,107
1995	236,606	0.2261	0.79	0.1288	0.981	58,296
1996	200,233	0.2485	0.79	0.1670	0.981	73,647
1997	195,900	0.2895	0.79	0.1780	0.981	77,881

Table A7 continued

Year	Social gains from research	GGDP (all local costs),	Proportional GGDP	GGDP (foreign costs),	Exchange rate
		cedis	maize cost (cedis)	Canadian \$	(CN\$:1US\$)
	SG = (k . P . Q) - 1/2 (k . P . dQ)		(90% for 1979-83, 55% for 1984-96)		
1979	0	389,380	350,442	228,346	1.1714
1980	0	389,380	350,442	228,346	1.1692
1981	0	519,173	467,256	304,462	1.1989
1982	0	1,402,036	1,261,832	319,903	1.2337
1983	0	1,030,870	927,783	197,800	1.2324
1984	3,022,432,946	9,918,988	5,455,443	998,300	1.2951
1985	2,222,511,149	36,387,694	20,013,232	1,430,482	1.3655
1986	6,308,461,916	65,949,829	36,272,406	319,101	1.3895
1987	11,868,961,201	80,393,569	44,216,463	175,183	1.326
1988	14,553,035,743	98,738,058	54,305,932	2,023,483	1.2307
1989	10,524,457,658	187,897,196	103,343,458	365,767	1.184
1990	14,115,007,059	201,386,259	110,762,442	501,532	1.1668
1991	36,591,818,286	278,083,542	152,945,948	2,484,702	1.1457
1992	20,441,327,147	427,815,898	235,298,744	1,160,624	1.2087
1993	27,059,117,346	450,923,659	248,008,012	4,821,245	1.2901
1994	29,891,504,647	699,105,294	384,507,912	679,765	1.3656
1995	31,920,145,086	192,709,160	105,990,038	212,020	1.3724
1996	36,040,383,882	815,007,795	448,254,287	55,996	1.3635
1997	35,919,159,696			0	

Table A7 continued

	Exchange rate, cedis:1US\$	Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis) (90% for 1979-83, 55% for 1984-96)	Total GGDP maize cost (cedis)	NARP-CRI Cost (cedis)	NARP-CRI Maize (cedis) (15% of NARP-CRI)
1979	2.75	2.35	536,069	482,462	832,904	0	0
1980	2.75	2.35	537,078	483,370	833,812	0	0
1981	2.75	2.29	698,366	628,529	1,095,785	0	0
1982	2.75	2.23	713,085	641,777	1,903,609	0	0
1983	8.83	7.16	1,417,214	1,275,492	2,203,275	0	0
1984	35.99	27.79	27,742,118	15,258,165	20,713,608	0	0
1985	54.37	39.82	56,957,383	31,326,561	51,339,792	0	0
1986	89.2	64.20	20,484,929	11,266,711	47,539,117	0	0
1987	153.73	115.94	20,309,866	11,170,426	55,386,889	0	0
1988	202.35	164.42	332,698,290	182,984,059	237,289,991	0	0
1989	270	228.04	83,409,704	45,875,337	149,218,795	0	0
1990	326.33	279.68	140,268,202	77,147,511	187,909,953	0	0
1991	367.83	321.05	797,720,116	438,746,064	591,692,012	0	0
1992	437.09	361.62	419,704,761	230,837,618	466,136,362	0	0
1993	649.06	503.11	2,425,608,309	1,334,084,570	1,582,092,583	0	0
1994	956.71	700.58	476,228,744	261,925,809	646,433,721	0	0
1995	1200.43	874.69	185,452,615	101,998,938	207,988,976	1,361,979,250	204,296,888
1996	1637.23	1,200.76	67,237,500	36,980,625	485,234,912	1,535,228,229	230,284,234
1997			0			1,927,478,424	289,121,764

Table A7 continued

Year	SARI cost (cedis)	SARI maize (8%)	GGDP, SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)	Actual releases (80% of estimates)	MOFA Extension cost for maize at 30% (cedis)
1979	0	0	832,904	0	0	0
1980	0	0	833,812	0	0	0
1981	0	0	1,095,785	0	0	0
1982	0	0	1,903,609	0	0	0
1983	0	0	2,203,275	0	0	0
1984	0	0	20,713,608	156,631,040	125,304,832	37,591,450
1985	0	0	51,339,792	195,788,800	156,631,040	46,989,312
1986	0	0	47,539,117	244,736,000	195,788,800	58,736,640
1987	0	0	55,386,889	305,920,000	244,736,000	73,420,800
1988	0	0	237,289,991	382,400,000	305,920,000	91,776,000
1989	0	0	149,218,795	853,829,000	683,063,200	204,918,960
1990	0	0	187,909,953	857,208,000	685,766,400	205,729,920
1991	0	0	591,692,012	1,997,101,000	1,597,680,800	479,304,240
1992	0	0	466,136,362	1,516,825,000	1,213,460,000	364,038,000
1993	0	0	1,582,092,583	2,435,152,000	1,948,121,600	584,436,480
1994	535,742,408	42,859,393	689,293,114	2,272,267,000	1,817,813,600	545,344,080
1995	597,144,000	47,771,520	460,057,384	2,455,425,000	1,964,340,000	589,302,000
1996	1,171,434,025	93,714,722	809,233,869	533,000,000	426,400,000	127,920,000
1997	1,353,509,000	108,280,720	397,402,484	829,000,000	663,200,000	198,960,000

Table A7 continued

Year	SG 2000	80% of SG2000	Total extension (cedis)	Extension + Research	Extension + Research (Real cost in cedis)	CIMMYT Costs (CN\$)
1979	0	0	0	832,904	235,956,716	50,000
1980	0	0	0	833,812	147,106,421	50,000
1981	0	0	0	1,095,785	92,334,466	50,000
1982	0	0	0	1,903,609	130,834,226	50,000
1983	0	0	0	2,203,275	65,963,890	50,000
1984	0	0	37,591,450	58,305,058	1,261,876,635	50,000
1985	0	0	46,989,312	98,329,104	1,955,670,376	50,000
1986	0	0	58,736,640	106,275,757	1,741,278,930	50,000
1987	0	0	73,420,800	128,807,689	1,544,656,495	25,000
1988	20,789,424	16,631,539	108,407,539	345,697,531	3,184,196,145	25,000
1989	24,458,146	19,566,517	224,485,477	373,704,272	2,776,836,698	25,000
1990	28,774,290	23,019,432	228,749,352	416,659,305	2,301,351,139	25,000
1991	33,852,105	27,081,684	506,385,924	1,098,077,936	5,171,054,694	25,000
1992	39,826,006	31,860,805	395,898,805	862,035,167	3,660,581,184	25,000
1993	46,854,125	37,483,300	621,919,780	2,204,012,363	7,543,865,110	25,000
1994	55,122,500	44,098,000	589,442,080	1,278,735,194	3,534,161,514	25,000
1995	64,850,000	51,880,000	641,182,000	1,101,239,384	1,939,413,094	25,000
1996	84,305,000	67,444,000	195,364,000	1,004,597,869	1,275,950,682	25,000
1997	96,000,000	76,800,000	275,760,000	673,162,484	673,162,484	0

Table A8: Economic Rate of Return (Baseline scenario)

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of improved technology (mt/ha)	Yield of farmer technology (mt/ha)	Change in yield (mt/ha)	Proportional increase
Unit	(mt)	(ha)	(mt/ha)	t	Y _n	Y _f = Y _m	dY = Y _n - Y _f	dY/Y _f
Parameter	Q	A	Y _m	t	Y _n	Y _f = Y _m	dY = Y _n - Y _f	dY/Y _f
1979	308,600	313,900	0.98	0				
1980	354,000	319,900	1.11	0				
1981	334,200	315,500	1.06	0				
1982	264,300	276,300	0.96	0				
1983	140,800	279,800	0.50	0				
1984	574,000	723,600	0.79	0.02	2.88	1.73	1.15	0.6647
1985	395,000	405,000	0.98	0.03	2.75	1.7	1.05	0.6176
1986	559,100	472,100	1.18	0.04	2.93	1.74	1.19	0.6839
1987	597,700	548,336	1.09	0.06	2.93	1.74	1.19	0.6839
1988	600,000	500,000	1.20	0.08	2.93	1.74	1.19	0.6839
1989	714,614	595,800	1.20	0.1	2.93	1.74	1.19	0.6839
1990	552,549	464,784	1.19	0.13	2.93	1.74	1.19	0.6839
1991	931,478	610,445	1.53	0.17	2.93	1.74	1.19	0.6839
1992	730,617	606,783	1.20	0.22	2.93	1.74	1.19	0.6839
1993	960,920	636,670	1.51	0.28	2.93	1.74	1.19	0.6839
1994	939,908	629,401	1.49	0.34	2.93	1.74	1.19	0.6839
1995	1,034,170	668,600	1.55	0.41	2.93	1.74	1.19	0.6839
1996	1,007,610	664,950	1.52	0.48	2.93	1.74	1.19	0.6839
1997	1,000,000	650,000	1.54	0.54	2.93	1.74	1.19	0.6839

Table A8 continued.

	Proportional						
	production increase	Fertilizer prices					
	(i-parameter)	(comp. + S.A, cedis/ha)	Change in fertilizer costs including application	Change in row planting	Improved seed	Farmers seed	Change in seed cost
Year		(Without subsidy)	(cedis/ha)	cost	(cedis/ha)	(cedis/ha)	(cedis/ha)
	$j = t \times (dY/Yf)$			(cedis/ha)			
1979	0.0000						
1980	0.0000						
1981	0.0000						
1982	0.0000						
1983	0.0000						
1984	0.0133	2,665	2,985	800	400	300	100
1985	0.0185	2,922	3,273	877	1,000	750	250
1986	0.0274	4,318	4,836	1,295	1,000	750	250
1987	0.0410	7,810	8,747	2,343	2,000	1,500	500
1988	0.0547	12,675	14,196	3,803	2,000	1,500	500
1989	0.0684	16,388	18,355	4,916	3,000	2,250	750
1990	0.0889	18,250	20,440	5,475	3,000	2,250	750
1991	0.1163	23,750	26,600	7,125	5,000	3,750	1,250
1992	0.1505	36,250	40,600	10,875	5,000	3,750	1,250
1993	0.1915	43,750	49,000	13,125	9,000	6,750	2,250
1994	0.2325	58,750	65,800	17,625	9,000	6,750	2,250
1995	0.2804	92,500	103,600	27,750	12,000	9,000	3,000
1996	0.3283	107,500	120,400	32,250	20,000	15,000	5,000
1997	0.3693	132,500	148,400	39,750	30,000	22,250	7,750

Table A8 continued.

Year	Change in total cost of technology (cedis/ha) dC	Export price (F.O.B) U.S. Gulf (\$/ton)	Freight and	Value of maize	Real	Value of maize
			marketing cost (\$/ton) No.2 yellow maize (30% + 20% = 50% of export price)	(\$/ton) (ie. 100% + 50%)	Exchange rate (cedis:1 US\$)	(Cedis/ton)
1979						
1980						
1981						
1982						
1983		0	0			
1984	3,884	139.1	69.55	208.65	611.07	127,500
1985	4,399	116.8	58.4	175.2	870.05	152,433
1986	6,382	88.7	44.35	133.05	1164.38	154,921
1987	11,590	75.6	37.8	113.4	1572.39	178,309
1988	18,499	107	53.5	160.5	1550.58	248,868
1989	24,021	111.3	55.65	166.95	1733.12	289,344
1990	26,665	109.7	54.85	164.55	1609.3	264,810
1991	34,975	107	53.5	160.5	1602.46	257,195
1992	52,725	105.1	52.55	157.65	1781.59	280,868
1993	64,375	101.9	50.95	152.85	2180.25	333,251
1994	85,675	107.5	53.75	161.25	2638.24	425,416
1995	134,350	123.7	61.85	185.55	1952.04	362,201
1996	157,650	165.1	82.55	247.65	2044.46	506,311
1997	195,900	117.1	58.55	175.65	2050.2	360,118

Table A8 continued.

Year	Real price (C/t)		Real change in cost, (cedis/mt)	Proportional cost increase	Supply elasticity (E = 0.79)	Net shift in supply
Unit	Rural price index (1977 = 100)	(Farmgate) (1997 = 1)	dC	$i = I/P = (dC \cdot t)/(Yf \cdot P)$		$k = (j / E) - i$
1979	279				0.79	
1980	448				0.79	
1981	938				0.79	
1982	1,150				0.79	
1983	2,640				0.79	
1984	3,652	1,931,604	84,067	0.0000	0.79	0.0168
1985	3,974	2,122,218	87,497	0.0000	0.79	0.0234
1986	4,824	1,776,813	104,559	0.0001	0.79	0.0345
1987	6,591	1,496,792	138,989	0.0003	0.79	0.0517
1988	8,581	1,604,615	170,388	0.0005	0.79	0.0687
1989	10,637	1,504,996	178,489	0.0009	0.79	0.0857
1990	14,310	1,023,846	147,280	0.0019	0.79	0.1106
1991	16,784	847,825	164,704	0.0040	0.79	0.1431
1992	18,613	834,882	223,894	0.0080	0.79	0.1825
1993	23,092	798,454	220,342	0.0130	0.79	0.2294
1994	28,598	823,034	236,788	0.0203	0.79	0.2740
1995	44,880	446,515	236,606	0.0709	0.79	0.2840
1996	62,230	450,149	200,233	0.0966	0.79	0.3189
1997	79,039	252,082	195,900	0.2412	0.79	0.2263

Table A8 continued.

		Change in quantity caused by research, dQ	Social gains from research	Research cost	Proportional GGDP
		$dQ = (Q \times e \times E \times k) / (e + E)$	$SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$	GGDP (all local costs), cedis	maize cost (cedis) (90% for 1979-83, 55% for 1984-96)
Year	Demand elasticity (e = - 0.981)	dQ			
1979	0.981			389,380	350,442
1980	0.981			389,380	350,442
1981	0.981			519,173	467,256
1982	0.981			1,402,036	1,261,832
1983	0.981			1,030,870	927,783
1984	0.981	4,221.3	18,564,547,348	9,918,988	5,455,443
1985	0.981	4,047.9	19,530,468,891	36,387,694	20,013,232
1986	0.981	8,452.0	34,058,854,442	65,949,829	36,272,406
1987	0.981	13,515.9	45,707,766,058	80,393,569	44,216,463
1988	0.981	18,044.8	65,172,721,789	98,738,058	54,305,932
1989	0.981	26,785.1	90,393,025,287	187,897,196	103,343,458
1990	0.981	26,741.6	61,052,934,824	201,386,259	110,762,442
1991	0.981	58,345.9	109,501,384,670	278,083,542	152,945,948
1992	0.981	58,339.2	106,859,423,256	427,815,898	235,298,744
1993	0.981	96,472.4	167,189,237,112	450,923,659	248,008,012
1994	0.981	112,697.1	199,252,301,157	699,105,294	384,507,912
1995	0.981	128,543.7	123,010,986,604	192,709,160	105,990,038
1996	0.981	140,624.8	134,563,115,856	815,007,795	448,254,287
1997	0.981	99,030.7	54,222,550,318		

Table A8 continued.

			Real	Real		
	GGDP (foreign costs),	Exchange rate	Exchange rate,	Exchange rate	All costs	Proportional foreign
	Canadian \$	(CN\$:1US\$)	cedis:1US\$	(Cedis:CN\$)	(CN\$ to cedis)	cost (cedis)
Year						(90% for 1979-83, 55% for 1984-96)
1979	228,346	1.1714	401.32	342.60	78,231,020	70,407,918
1980	228,346	1.1692	306.92	262.50	59,941,802	53,947,621
1981	304,462	1.1989	154.19	128.61	39,156,723	35,241,051
1982	319,903	1.2337	135.54	109.86	35,146,026	31,631,424
1983	197,800	1.2324	201.27	163.32	32,303,802	29,073,422
1984	998,300	1.2951	611.07	471.83	471,030,176	259,066,597
1985	1,430,482	1.3655	870.05	637.17	911,454,313	501,299,872
1986	319,101	1.3895	1164.38	837.98	267,401,815	147,070,998
1987	175,183	1.326	1572.39	1,185.81	207,734,538	114,253,996
1988	2,023,483	1.2307	1550.58	1,259.92	2,549,420,874	1,402,181,481
1989	365,767	1.184	1733.12	1,463.78	535,403,803	294,472,092
1990	501,532	1.1668	1609.3	1,379.24	691,734,185	380,453,802
1991	2,484,702	1.1457	1602.46	1,398.67	3,475,286,346	1,911,407,490
1992	1,160,624	1.2087	1781.59	1,473.97	1,710,727,320	940,900,026
1993	4,821,245	1.2901	2180.25	1,689.99	8,147,833,045	4,481,308,175
1994	679,765	1.3656	2638.24	1,931.93	1,313,256,600	722,291,130
1995	212,020	1.3724	1952.04	1,422.35	301,567,707	165,862,239
1996	55,996	1.3635	2044.46	1,499.42	83,961,556	46,178,856
1997	0		2050.2		0	

Table A8 continued.

	Total GGDP	NARP-CRI Cost	NARP-CRI Maize	SARI cost	SARI maize (8%)	GGDP ,SARI and	MOFA Extension
Year	maize cost (cedis)	(in cedis)	(15% of NARP-CRI)	(cedis)	(cedis)	NARP-CRI (cedis)	estimates (cedis)
			(in cedis)				
1979	70,758,360	0	0	0	0	70,758,360	0
1980	54,298,063	0	0	0	0	54,298,063	0
1981	35,708,307	0	0	0	0	35,708,307	0
1982	32,893,256	0	0	0	0	32,893,256	0
1983	30,001,205	0	0	0	0	30,001,205	0
1984	264,522,040	0	0	0	0	264,522,040	156,631,040
1985	521,313,104	0	0	0	0	521,313,104	195,788,800
1986	183,343,404	0	0	0	0	183,343,404	244,736,000
1987	158,470,459	0	0	0	0	158,470,459	305,920,000
1988	1,456,487,413	0	0	0	0	1,456,487,413	382,400,000
1989	397,815,550	0	0	0	0	397,815,550	853,829,000
1990	491,216,244	0	0	0	0	491,216,244	857,208,000
1991	2,064,353,439	0	0	0	0	2,064,353,439	1,997,101,000
1992	1,176,198,770	0	0	0	0	1,176,198,770	1,516,825,000
1993	4,729,316,187	0	0	0	0	4,729,316,187	2,435,152,000
1994	1,106,799,042	0	0	535,742,408	42,859,393	1,149,658,435	2,272,267,000
1995	271,852,277	1,361,979,250	204,296,888	597,144,000	47,771,520	523,920,684	2,455,425,000
1996	494,433,143	1,535,228,229	230,284,234	1,171,434,025	93,714,722	818,432,100	533,000,000
1997		1,927,478,424	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000

Table A8 continued.

Year	Actual releases (80% of estimates) (cedis)	MOFA Extension cost for maize at 30% (cedis)	SG 2000 (cedis)	80% of SG2000 (cedis)	Total extension (in cedis)	Extension + Research Cost (in cedis)
1979	0	0	0	0	0	70,758,360
1980	0	0	0	0	0	54,298,063
1981	0	0	0	0	0	35,708,307
1982	0	0	0	0	0	32,893,256
1983	0	0	0	0	0	30,001,205
1984	125,304,832	37,591,450	0	0	37,591,450	302,113,490
1985	156,631,040	46,989,312	0	0	46,989,312	568,302,416
1986	195,788,800	58,736,640	0	0	58,736,640	242,080,044
1987	244,736,000	73,420,800	0	0	73,420,800	231,891,259
1988	305,920,000	91,776,000	20,789,424	16,631,539	108,407,539	1,564,894,952
1989	683,063,200	204,918,960	24,458,146	19,566,517	224,485,477	622,301,026
1990	685,766,400	205,729,920	28,774,290	23,019,432	228,749,352	719,965,596
1991	1,597,680,800	479,304,240	33,852,105	27,081,684	506,385,924	2,570,739,363
1992	1,213,460,000	364,038,000	39,826,006	31,860,805	395,898,805	1,572,097,575
1993	1,948,121,600	584,436,480	46,854,125	37,483,300	621,919,780	5,351,235,967
1994	1,817,813,600	545,344,080	55,122,500	44,098,000	589,442,080	1,739,100,515
1995	1,964,340,000	589,302,000	64,850,000	51,880,000	641,182,000	1,165,102,684
1996	426,400,000	127,920,000	84,305,000	67,444,000	195,364,000	1,013,796,100
1997	663,200,000	198,960,000	96,000,000	76,800,000	275,760,000	673,162,484

Table A8 continued.

Year	Extension + Research (Real cost in cedis)	CIMMYT Costs (CN\$)	CIMMYT Costs (in cedis)	CIMMYT Real cost (1997 = 1) (cedis)	Extension , Research and CIMMYT real costs (in cedis)	NET SOCIAL GAINS NG = SG - (R + E) (cedis)
1979	20,045,412,220	50,000	17,129,930	4,852,804,793	24,898,217,013	-24,898,217,013
1980	9,579,608,548	50,000	13,125,214	2,315,633,427	11,895,241,975	-11,895,241,975
1981	3,008,900,708	50,000	6,430,478	541,853,460	3,550,754,168	-3,550,754,168
1982	2,260,739,187	50,000	5,493,232	377,547,429	2,638,286,616	-2,638,286,616
1983	898,206,534	50,000	8,165,774	244,475,234	1,142,681,769	-1,142,681,769
1984	6,538,540,012	50,000	23,591,615	510,585,329	7,049,125,341	11,515,422,007
1985	11,302,983,049	50,000	31,858,294	633,630,517	11,936,613,566	7,593,855,325
1986	3,966,369,118	50,000	41,899,244	686,499,663	4,652,868,781	29,405,985,661
1987	2,780,830,406	25,000	29,645,362	355,505,958	3,136,336,364	42,571,429,694
1988	14,414,139,625	25,000	31,497,928	290,125,246	14,704,264,871	50,468,456,919
1989	4,624,052,912	25,000	36,594,595	271,918,789	4,895,971,702	85,497,053,585
1990	3,976,615,007	25,000	34,481,059	190,450,625	4,167,065,632	56,885,869,192
1991	12,106,093,214	25,000	34,966,833	164,665,364	12,270,758,578	97,230,626,092
1992	6,675,819,064	25,000	36,849,301	156,478,370	6,832,297,434	100,027,125,822
1993	18,316,141,504	25,000	42,249,632	144,611,495	18,460,752,999	148,728,484,113
1994	4,806,516,735	25,000	48,298,184	133,486,263	4,940,002,998	194,312,298,160
1995	2,051,883,936	25,000	35,558,875	62,623,394	2,114,507,330	120,896,479,274
1996	1,287,633,455	25,000	37,485,515	47,610,761	1,335,244,216	133,227,871,640
1997	673,162,484	0	0	0	673,162,484	53,549,387,834
						IRR =
						33%

Source: Estimated by the author.

Table A9 continued.

	Fertilizer prices (comp. + S.Ammonia) (cedis/ha)	Change in fertilizer costs including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)
Year							dC
1979							
1980							
1981							
1982							
1983							
1984	1,838	2,059	551	400	300	100	2,710
1985	1,838	2,059	551	1,000	750	250	2,860
1986	3,175	3,556	953	1,000	750	250	4,759
1987	5,500	6,160	1,650	2,000	1,500	500	8,310
1988	9,750	10,920	2,925	2,000	1,500	500	14,345
1989	14,250	15,960	4,275	3,000	2,250	750	20,985
1990	18,250	20,440	5,475	3,000	2,250	750	26,665
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900

Table A9 continued.

	Maize price:						
	Average wholesale	Farmgate price	Rural price index	Real price	Real change	Proportional cost increase	
Year	price	(70% of wholesale)	(1977 = 100)	(1997 = 1)	in cost		Supply elasticity
	(cedis/t)	(cedis/t)		(cedis/t)	(cedis/ha)		(E = 0.79)
					dC	$i = I/P = (dC \cdot t)/(Y_f \cdot P)$	
1979			279				0.79
1980			448				0.79
1981			938				0.79
1982			1,150				0.79
1983	0	0	2,640	0		0.0000	0.79
1984	23,380	16,366	3,652	354,204	58,651	0.0019	0.79
1985	20,380	14,266	3,974	283,737	56,882	0.0035	0.79
1986	33,110	23,177	4,824	379,744	77,966	0.0047	0.79
1987	53,870	37,709	6,591	452,205	99,653	0.0076	0.79
1988	68,590	48,013	8,581	442,244	132,131	0.0137	0.79
1989	53,000	37,100	10,637	275,674	155,931	0.0325	0.79
1990	85,030	59,521	14,310	328,755	147,280	0.0335	0.79
1991	116,050	81,235	16,784	382,551	164,704	0.0421	0.79
1992	100,480	70,336	18,613	298,678	223,894	0.0948	0.79
1993	110,720	77,504	23,092	265,280	220,342	0.1337	0.79
1994	138,630	97,041	28,598	268,201	236,788	0.1725	0.79
1995	200,000	140,000	44,880	246,557	236,606	0.2261	0.79
1996	250,000	175,000	62,230	222,269	200,233	0.2485	0.79
1997	300,000	210,000	79,039	210,000	195,900	0.2895	0.79

Table A9 continued.

Year	Net shift in supply	Demand elasticity ($e = -0.981$)	Change in quantity caused by research, dQ $dQ = (Q \times e \times E \times k) / (e + E)$	Social gains from research	GGDP (all local cedis)	Proportional GGDP maize cost (cedis) (100% for 1979-96)
				$SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$		
1979		0.981		0	389,380	389,380
1980		0.981		0	389,380	389,380
1981		0.981		0	519,173	519,173
1982		0.981		0	1,402,036	1,402,036
1983		0.981	0	0	1,030,870	1,030,870
1984	0.0149	0.981	3,746	3,022,432,946	9,918,988	9,918,988
1985	0.0199	0.981	3,443	2,222,511,149	36,387,694	36,387,694
1986	0.0299	0.981	7,317	6,308,461,916	65,949,829	65,949,829
1987	0.0443	0.981	11,598	11,868,961,201	80,393,569	80,393,569
1988	0.0555	0.981	14,577	14,553,035,743	98,738,058	98,738,058
1989	0.0541	0.981	16,906	10,524,457,658	187,897,196	187,897,196
1990	0.0791	0.981	19,119	14,115,007,059	201,386,259	201,386,259
1991	0.1051	0.981	42,843	36,591,818,286	278,083,542	278,083,542
1992	0.0957	0.981	30,589	20,441,327,147	427,815,898	427,815,898
1993	0.1087	0.981	45,724	27,059,117,346	450,923,659	450,923,659
1994	0.1218	0.981	50,107	29,891,504,647	699,105,294	699,105,294
1995	0.1288	0.981	58,296	31,920,145,086	192,709,160	192,709,160
1996	0.1670	0.981	73,647	36,040,383,882	815,007,795	815,007,795
1997	0.1780	0.981	77,881	35,919,159,696		

Table A9 continued.

Year	GGDP (foreign costs), (Canadian \$)	Exchange rate (CN\$:1US\$)	Exchange rate, cedis:1US\$	Exchange rate Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis) (100% for 1979-96)	Total GGDP maize cost (cedis)	NARP-CRI Cost cedis
1979	228,346	1.1714	2.75	2.35	536,069	536,069	925,449	0
1980	228,346	1.1692	2.75	2.35	537,078	537,078	926,458	0
1981	304,462	1.1989	2.75	2.29	698,366	698,366	1,217,539	0
1982	319,903	1.2337	2.75	2.23	713,085	713,085	2,115,121	0
1983	197,800	1.2324	8.83	7.16	1,417,214	1,417,214	2,448,084	0
1984	998,300	1.2951	35.99	27.79	27,742,118	27,742,118	37,661,106	0
1985	1,430,482	1.3655	54.37	39.82	56,957,383	56,957,383	93,345,077	0
1986	319,101	1.3895	89.2	64.20	20,484,929	20,484,929	86,434,758	0
1987	175,183	1.326	153.73	115.94	20,309,866	20,309,866	100,703,435	0
1988	2,023,483	1.2307	202.35	164.42	332,698,290	332,698,290	431,436,348	0
1989	365,767	1.184	270	228.04	83,409,704	83,409,704	271,306,900	0
1990	501,532	1.1668	326.33	279.68	140,268,202	140,268,202	341,654,461	0
1991	2,484,702	1.1457	367.83	321.05	797,720,116	797,720,116	1,075,803,658	0
1992	1,160,624	1.2087	437.09	361.62	419,704,761	419,704,761	847,520,659	0
1993	4,821,245	1.2901	649.06	503.11	2,425,608,309	2,425,608,309	2,876,531,968	0
1994	679,765	1.3656	956.71	700.58	476,228,744	476,228,744	1,175,334,038	0
1995	212,020	1.3724	1200.43	874.69	185,452,615	185,452,615	378,161,775	1,361,979,250
1996	55,996	1.3635	1637.23	1,200.76	67,237,500	67,237,500	882,245,295	1,535,228,229
1997	0				0			1,927,478,424

Table A9 continued.

Year	NARP-CRI Maize (15% of NARP-CRI) (cedis)	SARI cost (cedis)	SARI maize (8%) (cedis)	GGDP ,SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)	Actual releases (80% of estimates)	MOFA Extension cost for maize at 30% (cedis)
1979	0	0	0	925,449	0	0	0
1980	0	0	0	926,458	0	0	0
1981	0	0	0	1,217,539	0	0	0
1982	0	0	0	2,115,121	0	0	0
1983	0	0	0	2,448,084	0	0	0
1984	0	0	0	37,661,106	156,631,040	125,304,832	37,591,450
1985	0	0	0	93,345,077	195,788,800	156,631,040	46,989,312
1986	0	0	0	86,434,758	244,736,000	195,788,800	58,736,640
1987	0	0	0	100,703,435	305,920,000	244,736,000	73,420,800
1988	0	0	0	431,436,348	382,400,000	305,920,000	91,776,000
1989	0	0	0	271,306,900	853,829,000	683,063,200	204,918,960
1990	0	0	0	341,654,461	857,208,000	685,766,400	205,729,920
1991	0	0	0	1,075,803,658	1,997,101,000	1,597,680,800	479,304,240
1992	0	0	0	847,520,659	1,516,825,000	1,213,460,000	364,038,000
1993	0	0	0	2,876,531,968	2,435,152,000	1,948,121,600	584,436,480
1994	0	535,742,408	42,859,393	1,218,193,431	2,272,267,000	1,817,813,600	545,344,080
1995	204,296,888	597,144,000	47,771,520	630,230,182	2,455,425,000	1,964,340,000	589,302,000
1996	230,284,234	1,171,434,025	93,714,722	1,206,244,251	533,000,000	426,400,000	127,920,000
1997	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000	663,200,000	198,960,000

Table A9 continued.

	SG 2000	80% of SG 2000	Total extension	Extension + Research	Extension + Research	CIMMYT Costs	CIMMYT Costs
Year	(cedis)	(cedis)	(cedis)	cost (cedis)	(Real cost in cedis)	(CN\$)	(cedis)
1979	0	0	0	925,449	262,174,129	50,000	117,381
1980	0	0	0	926,458	163,451,579	50,000	117,602
1981	0	0	0	1,217,539	102,593,851	50,000	114,688
1982	0	0	0	2,115,121	145,371,363	50,000	111,453
1983	0	0	0	2,448,084	73,293,211	50,000	358,244
1984	0	0	37,591,450	75,252,556	1,628,665,592	50,000	1,389,468
1985	0	0	46,989,312	140,334,389	2,791,114,686	50,000	1,990,846
1986	0	0	58,736,840	145,171,398	2,378,565,951	50,000	3,209,788
1987	0	0	73,420,800	174,124,235	2,088,090,643	25,000	2,898,379
1988	20,789,424	16,631,539	108,407,539	539,843,887	4,972,464,862	25,000	4,110,466
1989	24,458,146	19,566,517	224,485,477	495,792,377	3,684,021,219	25,000	5,701,014
1990	28,774,290	23,019,432	228,749,352	570,403,812	3,150,534,375	25,000	6,991,987
1991	33,852,105	27,081,684	506,385,924	1,582,189,582	7,450,827,120	25,000	8,026,316
1992	39,826,006	31,860,805	395,898,805	1,243,419,464	5,280,106,967	25,000	9,040,498
1993	46,854,125	37,483,300	621,919,780	3,498,451,748	11,974,455,557	25,000	12,577,707
1994	55,122,500	44,098,000	589,442,080	1,807,635,511	4,995,933,392	25,000	17,514,463
1995	64,850,000	51,880,000	641,182,000	1,271,412,182	2,239,107,564	25,000	21,867,349
1996	84,305,000	67,444,000	195,364,000	1,401,608,251	1,780,197,888	25,000	30,018,885
1997	96,000,000	76,800,000	275,760,000	673,162,484	673,162,484	0	0

Table A9 continued.

	CIMMYT Real Costs	Research, extension	Net social gains
	(1997 = 1)	and CIMMYT real costs	NG = SG - (R + E)
	(cedis)	(cedis)	
Year			
1979	33,253,297	295,427,426	-295,427,426
1980	20,748,051	184,199,630	-184,199,630
1981	9,664,031	112,257,882	-112,257,882
1982	7,660,140	153,031,503	-153,031,503
1983	10,725,475	84,018,686	-84,018,686
1984	30,071,786	1,658,737,377	1,363,695,569
1985	39,595,990	2,830,710,676	-608,199,527
1986	52,590,881	2,431,156,832	3,877,305,085
1987	34,757,236	2,122,847,879	9,746,113,322
1988	37,861,215	5,010,326,078	9,542,709,665
1989	42,361,794	3,726,383,013	6,798,074,645
1990	38,619,122	3,189,153,497	10,925,853,563
1991	37,797,425	7,488,624,544	29,103,193,742
1992	38,389,939	5,318,496,906	15,122,830,241
1993	43,050,814	12,017,506,371	15,041,610,974
1994	48,406,378	5,044,339,770	24,847,164,877
1995	38,510,994	2,277,618,558	29,642,526,528
1996	38,127,313	1,818,325,201	34,222,058,681
1997	0	673,162,484	35,245,997,213
			IRR =
			73%

Source: Estimated by the author.

Table A10: Economic Rate of Return with Higher Research Cost

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of Improved technology (mt/ha)	Yield of Farmer technology (mt/ha)	Change in yield (mt/ha)	Proportional increase	Proportional production increase (j-parameter)
Unit	(mt)	(ha)	(mt/ha)	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf	j = t x (dY/Yf)
Parameter	Q	A	Y						
1979	308,600	313,900	0.98	0					0.0000
1980	354,000	319,900	1.11	0					0.0000
1981	334,200	315,500	1.06	0					0.0000
1982	264,300	276,300	0.96	0					0.0000
1983	140,800	279,800	0.50	0					0.0000
1984	574,000	723,600	0.79	0.02	2.88	1.73	1.15	0.6647	0.0133
1985	395,000	405,000	0.98	0.03	2.75	1.7	1.05	0.6176	0.0185
1986	559,100	472,100	1.18	0.04	2.93	1.74	1.19	0.6839	0.0274
1987	597,700	548,336	1.09	0.06	2.93	1.74	1.19	0.6839	0.0410
1988	600,000	500,000	1.20	0.08	2.93	1.74	1.19	0.6839	0.0547
1989	714,614	595,800	1.20	0.1	2.93	1.74	1.19	0.6839	0.0684
1990	552,549	464,784	1.19	0.13	2.93	1.74	1.19	0.6839	0.0889
1991	931,478	610,445	1.53	0.17	2.93	1.74	1.19	0.6839	0.1163
1992	730,617	606,783	1.20	0.22	2.93	1.74	1.19	0.6839	0.1505
1993	960,920	636,670	1.51	0.28	2.93	1.74	1.19	0.6839	0.1915
1994	939,908	629,401	1.49	0.34	2.93	1.74	1.19	0.6839	0.2325
1995	1,034,170	668,600	1.55	0.41	2.93	1.74	1.19	0.6839	0.2804
1996	1,007,610	664,950	1.52	0.48	2.93	1.74	1.19	0.6839	0.3283
1997	1,000,000	650,000	1.54	0.54	2.93	1.74	1.19	0.6839	0.3693

Table A10 continued.

Year	Fertilizer prices (comp. + S.A, cedis/ha) (Without subsidy)	Change in fertilizer costs including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)	Product price: Export price (F.O.B) U.S. Gulf (\$/ton)
1979								
1980								
1981								
1982								
1983								0
1984	2,665	2,985	800	400	300	100	3,884	139.1
1985	2,922	3,273	877	1,000	750	250	4,399	116.8
1986	4,318	4,836	1,295	1,000	750	250	6,382	88.7
1987	7,810	8,747	2,343	2,000	1,500	500	11,590	75.6
1988	12,675	14,196	3,803	2,000	1,500	500	18,499	107
1989	16,388	18,355	4,916	3,000	2,250	750	24,021	111.3
1990	18,250	20,440	5,475	3,000	2,250	750	26,665	109.7
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975	107
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725	105.1
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375	101.9
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675	107.5
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350	123.7
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650	165.1
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900	117.1

Table A10 continued.

	Freight and marketing cost			Value of maize (Cedis/ton)				
	No.2 yellow maize (30% + 20% = 50% of export price)	Value of maize (\$/ton)	Real exchange rate (cedis:1 US\$)		Rural price index (1997 = 100)	Real price (Farmgate) (1997 = 1) (cedis/ton)	Real change in cost (cedis/t)	Proportional cost increase $i = I/P = (dC \cdot t)/(Yf \cdot P)$
Year	(\$/ton)	(\$/ton)			(1997 = 100)	(cedis/ton)	(cedis/t)	dC
1979					279			
1980					448			
1981					938			
1982					1,150			
1983	0				2,640			
1984	69.55	208.65	611.07	127,500	3,652	1,931,604	84,067	0.0000
1985	58.4	175.2	870.05	152,433	3,974	2,122,218	87,497	0.0000
1986	44.35	133.05	1164.38	154,921	4,824	1,776,813	104,559	0.0001
1987	37.8	113.4	1572.39	178,309	6,591	1,496,792	138,989	0.0003
1988	53.5	160.5	1550.58	248,868	8,581	1,604,615	170,388	0.0005
1989	55.65	166.95	1733.12	289,344	10,637	1,504,996	178,489	0.0009
1990	54.85	164.55	1609.3	264,810	14,310	1,023,846	147,280	0.0019
1991	53.5	160.5	1602.46	257,195	16,784	847,825	164,704	0.0040
1992	52.55	157.65	1781.59	280,868	18,613	834,882	223,894	0.0080
1993	50.95	152.85	2180.25	333,251	23,092	798,454	220,342	0.0130
1994	53.75	161.25	2638.24	425,416	28,598	823,034	236,788	0.0203
1995	61.85	185.55	1952.04	362,201	44,880	446,515	236,606	0.0709
1996	82.55	247.65	2044.46	506,311	62,230	450,149	200,233	0.0966
1997	58.55	175.65	2050.2	360,118	79,039	252,082	195,900	0.2412

Table A10 continued.

	Net shift in supply		Change in quantity caused by research		Social gains from research	Research cost: GGDP (all local cost) (cedis)
Year	Supply elasticity (E = 0.79)	$k = (j / E) - i$	Demand elasticity (e = - 0.981)	$dQ = (Q \times e \times E \times k) / (e + E)$ dQ	$SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$	
1979	0.79		0.981			389,380
1980	0.79		0.981			389,380
1981	0.79		0.981			519,173
1982	0.79		0.981			1,402,036
1983	0.79		0.981			1,030,870
1984	0.79	0.0168	0.981	4,221.3	18,564,547,348	9,918,988
1985	0.79	0.0234	0.981	4,047.9	19,530,468,891	36,387,694
1986	0.79	0.0345	0.981	8,452.0	34,058,854,442	65,949,829
1987	0.79	0.0517	0.981	13,515.9	45,707,766,058	80,393,569
1988	0.79	0.0687	0.981	18,044.8	65,172,721,789	98,738,058
1989	0.79	0.0857	0.981	26,785.1	90,393,025,287	187,897,196
1990	0.79	0.1106	0.981	26,741.6	61,052,934,824	201,386,259
1991	0.79	0.1431	0.981	58,345.9	109,501,384,670	278,083,542
1992	0.79	0.1825	0.981	58,339.2	106,859,423,256	427,815,898
1993	0.79	0.2294	0.981	96,472.4	167,189,237,112	450,923,659
1994	0.79	0.2740	0.981	112,697.1	199,252,301,157	699,105,294
1995	0.79	0.2840	0.981	128,543.7	123,010,986,604	192,709,160
1996	0.79	0.3189	0.981	140,624.8	134,563,115,856	815,007,795
1997	0.79	0.2263	0.981	99,030.7	54,222,550,318	

Table A10 continued.

				Real			
	Proportional GGDP	GGDP (foreign costs),	Exchange rate	Exchange rate,	Cedis:CN\$	All costs	Proportional foreign
	maize cost (cedis)	Canadian \$	(CN\$:1US\$)	cedis:1US\$		(CN\$ to cedis)	cost (cedis)
Year	(90% for 1979-83, 55% for 1984-96)						(100% for 1979-96)
1979	389,380	228,346	1.1714	401.32	342.60	78,231,020	78,231,020
1980	389,380	228,346	1.1692	306.92	262.50	59,941,802	59,941,802
1981	519,173	304,462	1.1989	154.19	128.61	39,156,723	39,156,723
1982	1,402,036	319,903	1.2337	135.54	109.86	35,146,026	35,146,026
1983	1,030,870	197,800	1.2324	201.27	163.32	32,303,802	32,303,802
1984	9,918,988	998,300	1.2951	611.07	471.83	471,030,176	471,030,176
1985	36,387,694	1,430,482	1.3655	870.05	637.17	911,454,313	911,454,313
1986	65,949,829	319,101	1.3895	1164.38	837.98	267,401,815	267,401,815
1987	80,393,569	175,183	1.326	1572.39	1,185.81	207,734,538	207,734,538
1988	98,738,058	2,023,483	1.2307	1550.58	1,259.92	2,549,420,874	2,549,420,874
1989	187,897,196	365,767	1.184	1733.12	1,463.78	535,403,803	535,403,803
1990	201,386,259	501,532	1.1668	1609.3	1,379.24	691,734,185	691,734,185
1991	278,083,542	2,484,702	1.1457	1602.46	1,398.67	3,475,286,346	3,475,286,346
1992	427,815,898	1,160,624	1.2087	1781.59	1,473.97	1,710,727,320	1,710,727,320
1993	450,923,659	4,821,245	1.2901	2180.25	1,689.99	8,147,833,045	8,147,833,045
1994	699,105,294	679,765	1.3656	2638.24	1,931.93	1,313,256,600	1,313,256,600
1995	192,709,160	212,020	1.3724	1952.04	1,422.35	301,567,707	301,567,707
1996	815,007,795	55,996	1.3635	2044.46	1,499.42	83,961,556	83,961,556
1997		0		2050.2		0	

Table A10 continued.

	Actual releases (80% of estimates)	MOFA Extension cost for maize at 30%	SG 2000 (cedis)	80% of SG 2000 (cedis)	Total extension (cedis)	Extension + Research (cedis)	Extension + Research (Real cost)
Year	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)
1979	0	0	0	0	0	78,620,400	22,272,680,245
1980	0	0	0	0	0	60,331,182	10,644,009,498
1981	0	0	0	0	0	39,675,896	3,343,223,008
1982	0	0	0	0	0	36,548,062	2,511,932,430
1983	0	0	0	0	0	33,334,672	998,007,260
1984	125,304,832	37,591,450	0	0	37,591,450	518,540,614	11,222,599,004
1985	156,631,040	46,989,312	0	0	46,989,312	994,831,319	19,786,228,637
1986	195,788,800	58,736,640	0	0	58,736,640	392,088,284	6,424,184,474
1987	244,736,000	73,420,800	0	0	73,420,800	361,548,907	4,335,679,572
1988	305,920,000	91,776,000	20,789,424	16,631,539	108,407,539	2,756,566,472	25,390,543,918
1989	683,063,200	204,918,960	24,458,146	19,566,517	224,485,477	947,786,476	7,042,596,154
1990	685,766,400	205,729,920	28,774,290	23,019,432	228,749,352	1,121,869,796	6,196,468,680
1991	1,597,680,800	479,304,240	33,852,105	27,081,684	506,385,924	4,259,755,813	20,059,988,064
1992	1,213,460,000	364,038,000	39,826,006	31,860,805	395,898,805	2,534,442,023	10,762,357,658
1993	1,948,121,600	584,436,480	46,854,125	37,483,300	621,919,780	9,220,676,484	31,560,412,637
1994	1,817,813,600	545,344,080	55,122,500	44,098,000	589,442,080	2,644,663,367	7,309,306,520
1995	1,964,340,000	589,302,000	64,850,000	51,880,000	641,182,000	1,387,527,274	2,443,600,005
1996	426,400,000	127,920,000	84,305,000	67,444,000	195,364,000	1,418,332,308	1,801,439,294
1997	663,200,000	198,960,000	96,000,000	76,800,000	275,760,000	673,162,484	673,162,484

Table A10 continued.

	CIMMYT cost	CIMMYT Cost	CIMMYT Real Costs	Extension , Research	NET SOCIAL GAINS
			(1997 = 1)	and CIMMYT real cost	NG = SG - (R + E)
Year	(CN\$)	(cedis)	(cedis)	(cedis)	
1979	50,000	17,129,930	4,852,804,793	27,125,485,037	-27,125,485,037
1980	50,000	13,125,214	2,315,633,427	12,959,642,925	-12,959,642,925
1981	50,000	6,430,478	541,853,460	3,885,076,469	-3,885,076,469
1982	50,000	5,493,232	377,547,429	2,889,479,859	-2,889,479,859
1983	50,000	8,165,774	244,475,234	1,242,482,495	-1,242,482,495
1984	50,000	23,591,615	510,585,329	11,733,184,333	6,831,363,015
1985	50,000	31,858,294	633,630,517	20,419,859,154	-889,390,263
1986	50,000	41,899,244	686,499,663	7,110,684,137	26,948,170,305
1987	25,000	29,645,362	355,505,958	4,691,185,530	41,016,580,528
1988	25,000	31,497,928	290,125,246	25,680,669,164	39,492,052,626
1989	25,000	36,594,595	271,918,789	7,314,514,943	83,078,510,344
1990	25,000	34,481,059	190,450,625	6,386,919,305	54,666,015,519
1991	25,000	34,966,833	164,665,364	20,224,653,428	89,276,731,242
1992	25,000	36,849,301	156,478,370	10,918,836,028	95,940,587,228
1993	25,000	42,249,632	144,611,495	31,705,024,132	135,484,212,980
1994	25,000	48,298,184	133,486,263	7,442,792,784	191,809,508,374
1995	25,000	35,558,875	62,623,394	2,506,223,399	120,504,763,205
1996	25,000	37,485,515	47,610,761	1,849,050,055	132,714,065,801
1997	0	0	0	673,162,484	53,549,387,834
					IRR =
					30%

Source: Estimated by the author.

Table A11: Financial Rate of Return with Higher Extension Cost.

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of improved technology	Yield of farmer technology	Change in yield	Proportional increase
Unit	(mt)	(ha)	(mt/ha)	t	(mt/ha)	(mt/ha)	(mt/ha)	
Parameter	Q	A	Ym	t	Yn	Yf	dY=Yn-Yf	dY/Yf
1979	308,600	313,900	0.98	0				
1980	354,000	319,900	1.11	0				
1981	334,200	315,500	1.06	0				
1982	264,300	276,300	0.96	0				
1983	140,800	279,800	0.50	0				
1984	574,000	723,600	0.79	0.02	2.88	1.73	1.15	0.6647
1985	395,000	405,000	0.98	0.03	2.75	1.7	1.05	0.6176
1986	559,100	472,100	1.18	0.04	2.93	1.74	1.19	0.6839
1987	597,700	548,336	1.09	0.06	2.93	1.74	1.19	0.6839
1988	600,000	500,000	1.20	0.08	2.93	1.74	1.19	0.6839
1989	714,614	595,800	1.20	0.1	2.93	1.74	1.19	0.6839
1990	552,549	464,784	1.19	0.13	2.93	1.74	1.19	0.6839
1991	931,478	610,445	1.53	0.17	2.93	1.74	1.19	0.6839
1992	730,617	606,783	1.20	0.22	2.93	1.74	1.19	0.6839
1993	960,920	636,670	1.51	0.28	2.93	1.74	1.19	0.6839
1994	939,908	629,401	1.49	0.34	2.93	1.74	1.19	0.6839
1995	1,034,170	668,600	1.55	0.41	2.93	1.74	1.19	0.6839
1996	1,007,610	664,950	1.52	0.48	2.93	1.74	1.19	0.6839
1997	1,000,000	650,000	1.54	0.54	2.93	1.74	1.19	0.6839

Table A11 continued.

Year	Proportional production increase (i-parameter) $j = t \times (dY/Yf)$	Fertilizer prices (comp. + S.A, cedis/ha)	Change in fertilizer costs including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)
1979								
1980								
1981								
1982								
1983								
1984	0.0133	1,838	2,059	551	400	300	100	2,710
1985	0.0185	1,838	2,059	551	1,000	750	250	2,860
1986	0.0274	3,175	3,556	953	1,000	750	250	4,759
1987	0.0410	5,500	6,160	1,650	2,000	1,500	500	8,310
1988	0.0547	9,750	10,920	2,925	2,000	1,500	500	14,345
1989	0.0684	14,250	15,960	4,275	3,000	2,250	750	20,985
1990	0.0889	18,250	20,440	5,475	3,000	2,250	750	26,665
1991	0.1163	23,750	26,600	7,125	5,000	3,750	1,250	34,975
1992	0.1505	36,250	40,600	10,875	5,000	3,750	1,250	52,725
1993	0.1915	43,750	49,000	13,125	9,000	6,750	2,250	64,375
1994	0.2325	58,750	65,800	17,625	9,000	6,750	2,250	85,675
1995	0.2804	92,500	103,600	27,750	12,000	9,000	3,000	134,350
1996	0.3283	107,500	120,400	32,250	20,000	15,000	5,000	157,650
1997	0.3693	132,500	148,400	39,750	30,000	22,250	7,750	195,900

Table A11 continued.

Year	Product price:		Rural price index (1977 = 100)	Real price (cedis/t) (1997 = 1)	Real change in cost (cedis/t) dC	Proportional cost increase $i = (dC \cdot T)/Yf$ $i = I/P = (dC \cdot t)/(Yf \cdot P)$
	Average wholesale price (cedis/t)	Farmgate price (70% of wholesale) (cedis/t)				
1979			279			
1980			448			
1981			938			
1982			1,150			
1983			2,640	0		0.0000
1984	23,380	16,366	3,652	354,204	58,651	0.0019
1985	20,380	14,266	3,974	283,737	56,882	0.0035
1986	33,110	23,177	4,824	379,744	77,966	0.0047
1987	53,870	37,709	6,591	452,205	99,653	0.0076
1988	68,590	48,013	8,581	442,244	132,131	0.0137
1989	53,000	37,100	10,637	275,674	155,931	0.0325
1990	85,030	59,521	14,310	328,755	147,280	0.0335
1991	116,050	81,235	16,784	382,551	164,704	0.0421
1992	100,480	70,336	18,613	298,678	223,894	0.0948
1993	110,720	77,504	23,092	265,280	220,342	0.1337
1994	138,630	97,041	28,598	268,201	236,788	0.1725
1995	200,000	140,000	44,880	246,557	236,606	0.2261
1996	250,000	175,000	62,230	222,269	200,233	0.2485
1997	300,000	210,000	79,039	210,000	195,900	0.2895

Table A11 continued.

Year	Net shift in supply		Demand elasticity (e = - 0.981)	Change in quantity caused by research, dQ = (Q x e x E x k) / (e + E) dQ	Social gains from research SG = (k . P . Q) - 1/2 (k . P . dQ)	Research costs:
	Supply elasticity (E = 0.79)	k = (j / E) - c				GGDP (all local costs) (cedis)
1979	0.79		0.981		0	389,380
1980	0.79		0.981		0	389,380
1981	0.79		0.981		0	519,173
1982	0.79		0.981		0	1,402,036
1983	0.79		0.981	0	0	1,030,870
1984	0.79	0.0149	0.981	3,746	3,022,432,946	9,918,988
1985	0.79	0.0199	0.981	3,443	2,222,511,149	36,387,694
1986	0.79	0.0299	0.981	7,317	6,308,461,916	65,949,829
1987	0.79	0.0443	0.981	11,598	11,868,961,201	80,393,569
1988	0.79	0.0555	0.981	14,577	14,553,035,743	98,738,058
1989	0.79	0.0541	0.981	16,906	10,524,457,658	187,897,196
1990	0.79	0.0791	0.981	19,119	14,115,007,059	201,386,259
1991	0.79	0.1051	0.981	42,843	36,591,818,286	278,083,542
1992	0.79	0.0957	0.981	30,589	20,441,327,147	427,815,898
1993	0.79	0.1087	0.981	45,724	27,059,117,346	450,923,659
1994	0.79	0.1218	0.981	50,107	29,891,504,647	699,105,294
1995	0.79	0.1288	0.981	58,296	31,920,145,086	192,709,160
1996	0.79	0.1670	0.981	73,647	36,040,383,882	815,007,795
1997	0.79	0.1780	0.981	77,881	35,919,159,696	

Table A11 continued.

Year	Proportional GGDP maize cost (cedis) (90% of total)	GGDP (foreign costs), Canadian \$	Exchange rate (CN\$:1US\$)	Exchange rate, cedis:1US\$	Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis) (90% of total)
1979	350,442	228,346	1.1714	2.75	2.3476	536,069	482,462
1980	350,442	228,346	1.1692	2.75	2.3520	537,078	483,370
1981	467,256	304,462	1.1989	2.75	2.2938	698,366	628,529
1982	1,261,832	319,903	1.2337	2.75	2.2291	713,085	641,777
1983	927,783	197,800	1.2324	8.83	7.1649	1,417,214	1,275,492
1984	8,927,089	998,300	1.2951	35.99	27.7894	27,742,118	24,967,906
1985	32,748,925	1,430,482	1.3655	54.37	39.8169	56,957,383	51,261,645
1986	59,354,846	319,101	1.3895	89.20	64.1958	20,484,929	18,436,436
1987	72,354,212	175,183	1.3260	153.73	115.9351	20,309,866	18,278,880
1988	88,864,252	2,023,483	1.2307	202.35	164.4186	332,698,290	299,428,461
1989	169,107,476	365,767	1.1840	270.00	228.0405	83,409,704	75,068,734
1990	181,247,633	501,532	1.1668	326.33	279.6795	140,268,202	126,241,381
1991	250,275,188	2,484,702	1.1457	367.83	321.0526	797,720,116	717,948,104
1992	385,034,308	1,160,624	1.2087	437.09	361.6199	419,704,761	377,734,285
1993	405,831,293	4,821,245	1.2901	649.06	503.1083	2,425,608,309	2,183,047,478
1994	629,194,765	679,765	1.3656	956.71	700.5785	476,228,744	428,605,870
1995	173,438,244	212,020	1.3724	1,200.43	874.6940	185,452,615	166,907,353
1996	733,507,016	55,996	1.3635	1,637.23	1,200.7554	67,237,500	60,513,750
1997		0				0	

Table A11 continued.

Year	Total GGDP maize cost (cedis)	NARP-CRI Cost (cedis)	NARP-CRI Maize (15% of NARP-CRI) (cedis)	SARI cost (cedis)	SARI maize (8%)	GGDP, SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)
1979	832,904	0	0	0	0	832,904	0
1980	833,812	0	0	0	0	833,812	0
1981	1,095,785	0	0	0	0	1,095,785	0
1982	1,903,609	0	0	0	0	1,903,609	0
1983	2,203,275	0	0	0	0	2,203,275	0
1984	33,894,995	0	0	0	0	33,894,995	156,631,040
1985	84,010,569	0	0	0	0	84,010,569	195,788,800
1986	77,791,282	0	0	0	0	77,791,282	244,736,000
1987	90,633,092	0	0	0	0	90,633,092	305,920,000
1988	388,292,713	0	0	0	0	388,292,713	382,400,000
1989	244,176,210	0	0	0	0	244,176,210	853,829,000
1990	307,489,014	0	0	0	0	307,489,014	857,208,000
1991	968,223,292	0	0	0	0	968,223,292	1,997,101,000
1992	762,768,593	0	0	0	0	762,768,593	1,516,825,000
1993	2,588,878,771	0	0	0	0	2,588,878,771	2,435,152,000
1994	1,057,800,634	0	0	535,742,408	42,859,393	1,100,660,027	2,272,267,000
1995	340,345,597	1,361,979,250	204,296,888	597,144,000	47,771,520	592,414,005	2,455,425,000
1996	794,020,765	1,535,228,229	230,284,234	1,171,434,025	93,714,722	1,118,019,722	533,000,000
1997		1,927,478,424	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000

Table A11 continued.

Year	Actual releases (80% of estimates) (cedis)	MOFA Extension cost for maize at 50% (cedis)	SG 2000 (cedis)	80% of SG 2000 (cedis)	Total extension (cedis)	Extension + Research	Extension + Research (Real cost in cedis)
1979	0	0	0	0	0	832,904	235,956,716
1980	0	0	0	0	0	833,812	147,106,421
1981	0	0	0	0	0	1,095,785	92,334,466
1982	0	0	0	0	0	1,903,609	130,834,226
1983	0	0	0	0	0	2,203,275	65,963,890
1984	125,304,832	62,652,416	0	0	62,652,416	96,547,411	2,089,542,949
1985	156,631,040	78,315,520	0	0	78,315,520	162,326,089	3,228,508,245
1986	195,788,800	97,894,400	0	0	97,894,400	175,685,682	2,878,528,328
1987	244,736,000	122,368,000	0	0	122,368,000	213,001,092	2,554,300,301
1988	305,920,000	152,960,000	20,789,424	16,631,539	169,591,539	557,884,252	5,138,633,424
1989	683,063,200	341,531,600	24,458,146	19,566,517	361,098,117	605,274,327	4,497,534,789
1990	685,766,400	342,883,200	28,774,290	23,019,432	365,902,632	673,391,646	3,719,371,231
1991	1,597,680,800	798,840,400	33,852,105	27,081,684	825,922,084	1,794,145,376	8,448,966,658
1992	1,213,460,000	606,730,000	39,826,006	31,860,805	638,590,805	1,401,359,398	5,950,789,526
1993	1,948,121,600	974,060,800	46,854,125	37,483,300	1,011,544,100	3,600,422,871	12,323,481,003
1994	1,817,813,600	908,906,800	55,122,500	44,098,000	953,004,800	2,053,664,827	5,675,907,905
1995	1,964,340,000	982,170,000	64,850,000	51,880,000	1,034,050,000	1,626,464,005	2,864,395,911
1996	426,400,000	213,200,000	84,305,000	67,444,000	280,644,000	1,398,663,722	1,776,458,009
1997	663,200,000	331,600,000	96,000,000	76,800,000	408,400,000	805,802,484	805,802,484

Table A11 continued.

Year	CIMMYT Costs (CN\$)	CIMMYT Costs (cedis)	CIMMYT Real Costs (cedis, 1997 = 1)	Research, extension and CIMMYT real cost (cedis)	Net social gains NG = SG - (R + E)	
1979	50,000	117,381	33,253,297	269,210,013	-269,210,013	
1980	50,000	117,602	20,748,051	167,854,472	-167,854,472	
1981	50,000	114,688	9,664,031	101,998,497	-101,998,497	
1982	50,000	111,453	7,660,140	138,494,367	-138,494,367	
1983	50,000	358,244	10,725,475	76,689,365	-76,689,365	
1984	50,000	1,389,468	30,071,786	2,119,614,734	902,818,212	
1985	50,000	1,990,846	39,595,990	3,268,104,235	-1,045,593,085	
1986	50,000	3,209,788	52,590,881	2,931,119,209	3,377,342,708	
1987	25,000	2,898,379	34,757,236	2,589,057,538	9,279,903,663	
1988	25,000	4,110,466	37,861,215	5,176,494,639	9,376,541,103	
1989	25,000	5,701,014	42,361,794	4,539,896,583	5,984,561,075	
1990	25,000	6,991,987	38,619,122	3,757,990,353	10,357,016,707	
1991	25,000	8,026,316	37,797,425	8,486,764,083	28,105,054,203	
1992	25,000	9,040,498	38,389,939	5,989,179,464	14,452,147,683	
1993	25,000	12,577,707	43,050,814	12,366,531,817	14,692,585,528	
1994	25,000	17,514,463	48,406,378	5,724,314,283	24,167,190,364	
1995	25,000	21,867,349	38,510,994	2,902,906,905	29,017,238,182	
1996	25,000	30,018,885	38,127,313	1,814,585,322	34,225,798,560	
1997	0	0	0	805,802,484	35,113,357,213	
					IRR =	71%

Source: Estimated by the author.

Table A12: Economic Rate of Return with Higher Extension Cost

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of Improved technology (mt/ha)	Yield of Farmer technology (mt/ha)	Change in yield (mt/ha)	Proportional increase	Proportional production increase (j-parameter)
Unit	(mt)	(ha)	(mt/ha)	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf	j = t x (dY/Yf)
Parameter	Q	A	Ym						
1979	308,600	313,900	0.98	0					0.0000
1980	354,000	319,900	1.11	0					0.0000
1981	334,200	315,500	1.06	0					0.0000
1982	264,300	276,300	0.96	0					0.0000
1983	140,800	279,800	0.50	0					0.0000
1984	574,000	723,600	0.79	0.02	2.88	1.73	1.15	0.6647	0.0133
1985	395,000	405,000	0.98	0.03	2.75	1.7	1.05	0.6176	0.0185
1986	559,100	472,100	1.18	0.04	2.93	1.74	1.19	0.6839	0.0274
1987	597,700	548,336	1.09	0.06	2.93	1.74	1.19	0.6839	0.0410
1988	600,000	500,000	1.20	0.08	2.93	1.74	1.19	0.6839	0.0547
1989	714,614	595,800	1.20	0.1	2.93	1.74	1.19	0.6839	0.0684
1990	552,549	464,784	1.19	0.13	2.93	1.74	1.19	0.6839	0.0889
1991	931,478	610,445	1.53	0.17	2.93	1.74	1.19	0.6839	0.1163
1992	730,617	606,783	1.20	0.22	2.93	1.74	1.19	0.6839	0.1505
1993	960,920	636,670	1.51	0.28	2.93	1.74	1.19	0.6839	0.1915
1994	939,908	629,401	1.49	0.34	2.93	1.74	1.19	0.6839	0.2325
1995	1,034,170	668,600	1.55	0.41	2.93	1.74	1.19	0.6839	0.2804
1996	1,007,610	664,950	1.52	0.48	2.93	1.74	1.19	0.6839	0.3283
1997	1,000,000	650,000	1.54	0.54	2.93	1.74	1.19	0.6839	0.3693

Table A12 continued.

	Fertilizer prices (comp. + S.A, cedis/ha)	Change in fertilizer costs including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)	Product price: Export price (F.O.B) U.S. Gulf (\$/ton)
							dC	
1979								
1980								
1981								
1982								
1983								0
1984	2,665	2,985	800	400	300	100	3,884	139.1
1985	2,922	3,273	877	1,000	750	250	4,399	116.8
1986	4,318	4,836	1,295	1,000	750	250	6,382	88.7
1987	7,810	8,747	2,343	2,000	1,500	500	11,590	75.6
1988	12,675	14,196	3,803	2,000	1,500	500	18,499	107
1989	16,388	18,355	4,916	3,000	2,250	750	24,021	111.3
1990	18,250	20,440	5,475	3,000	2,250	750	26,665	109.7
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975	107
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725	105.1
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375	101.9
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675	107.5
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350	123.7
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650	165.1
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900	117.1

Table A12 continued.

Year	Freight and	Value of maize (\$/ton)	Real		Rural price index (1997 = 100)	Real price (Cedis/ton) (1997 = 1)	Real change in cost, dC (cedis/mt)
	marketing cost (\$/ton)		Exchange rate	Value of maize (Cedis/ton)			
	No.2 yellow maize (30% + 20% = 50% of export price)		(cedis:1 US\$)				
1979					279		
1980					448		
1981					938		
1982					1,150		
1983	0				2,640		
1984	69.55	208.65	611.07	127,500	3,652	1,931,604	84,067
1985	58.4	175.2	870.05	152,433	3,974	2,122,218	87,497
1986	44.35	133.05	1164.38	154,921	4,824	1,776,813	104,559
1987	37.8	113.4	1572.39	178,309	6,591	1,496,792	138,989
1988	53.5	160.5	1550.58	248,868	8,581	1,604,615	170,388
1989	55.65	166.95	1733.12	289,344	10,637	1,504,996	178,489
1990	54.85	164.55	1609.3	264,810	14,310	1,023,846	147,280
1991	53.5	160.5	1602.46	257,195	16,784	847,825	164,704
1992	52.55	157.65	1781.59	280,868	18,613	834,882	223,894
1993	50.95	152.85	2180.25	333,251	23,092	798,454	220,342
1994	53.75	161.25	2638.24	425,416	28,598	823,034	236,788
1995	61.85	185.55	1952.04	362,201	44,880	446,515	236,606
1996	82.55	247.65	2044.46	506,311	62,230	450,149	200,233
1997	58.55	175.65	2050.2	360,118	79,039	252,082	195,900

Table A12 continued.

Year	Proportional cost increase $i = (dC \cdot t)/Yf$	Supply elasticity ($E = 0.79$)	Net shift in supply $k = (j/E) - i$	Demand elasticity ($e = -0.981$)	Change in quantity caused by research, dQ . $dQ = (Q \cdot e \cdot x \cdot E \cdot k) / (e + E)$
Parameter	$i = I/P = (dC \cdot t)/(Yf \cdot P)$	Supply elasticity ($E = 0.79$)	$k = (j/E) - i$	Demand elasticity ($e = -0.981$)	dQ
1979		0.79		0.981	
1980		0.79		0.981	
1981		0.79		0.981	
1982		0.79		0.981	
1983		0.79		0.981	
1984	0.0000	0.79	0.0168	0.981	4,221.28
1985	0.0000	0.79	0.0234	0.981	4,047.91
1986	0.0001	0.79	0.0345	0.981	8,452.03
1987	0.0003	0.79	0.0517	0.981	13,515.88
1988	0.0005	0.79	0.0687	0.981	18,044.83
1989	0.0009	0.79	0.0857	0.981	26,785.11
1990	0.0019	0.79	0.1106	0.981	26,741.63
1991	0.0040	0.79	0.1431	0.981	58,345.87
1992	0.0080	0.79	0.1825	0.981	58,339.16
1993	0.0130	0.79	0.2294	0.981	96,472.40
1994	0.0203	0.79	0.2740	0.981	112,697.06
1995	0.0709	0.79	0.2840	0.981	128,543.75
1996	0.0986	0.79	0.3189	0.981	140,624.80
1997	0.2412	0.79	0.2263	0.981	99,030.72

Table A12 continued.

		Research cost				Real
	Social gains from research	GGDP (all local costs), cedis	Proportional GGDP maize cost (cedis)	GGDP (foreign costs), (in Canadian \$)	Exchange rate (CN\$:1US\$)	exchange rate, Cedis:1US\$
	SG = (k . P . Q) - 1/2 (k . P . dQ)		(90% of total)			
Year						
1979	0	389,380	350,442	228,346	1.1714	401.32
1980	0	389,380	350,442	228,346	1.1692	306.92
1981	0	519,173	467,256	304,462	1.1989	154.19
1982	0	1,402,036	1,261,832	319,903	1.2337	135.54
1983	0	1,030,870	927,783	197,800	1.2324	201.27
1984	18,564,547,348	9,918,988	8,927,089	998,300	1.2951	611.07
1985	19,530,468,891	36,387,694	32,748,925	1,430,482	1.3655	870.05
1986	34,058,854,442	65,949,829	59,354,846	319,101	1.3895	1164.38
1987	45,707,766,058	80,393,569	72,354,212	175,183	1.326	1572.39
1988	65,172,721,789	98,738,058	88,864,252	2,023,483	1.2307	1550.58
1989	90,393,025,287	187,897,196	169,107,476	365,767	1.184	1733.12
1990	61,052,934,824	201,386,259	181,247,633	501,532	1.1668	1609.3
1991	109,501,384,670	278,083,542	250,275,188	2,484,702	1.1457	1602.46
1992	106,859,423,256	427,815,898	385,034,308	1,160,624	1.2087	1781.59
1993	167,189,237,112	450,923,659	405,831,293	4,821,245	1.2901	2180.25
1994	199,252,301,157	699,105,294	629,194,765	679,765	1.3656	2638.24
1995	123,010,986,604	192,709,160	173,438,244	212,020	1.3724	1952.04
1996	134,563,115,856	815,007,795	733,507,016	55,996	1.3635	2044.46
1997	54,222,550,318			0		2050.2

Table A12 continued.

	Real exchange						
	rate	All costs	Proportional foreign	Total GGDP	NARP-CRI Cost	NARP-CRI Maize	SARI cost
	Cedis:CN\$	(CN\$ to cedis)	cost (90% of total)	maize cost (cedis)	(cedis)	(15% of NARP-CRI)	(cedis)
Year			(in cedis)			(cedis)	
1979	342.60	78,231,020	70,407,918	70,758,360		0	0
1980	262.50	59,941,802	53,947,621	54,298,063		0	0
1981	128.61	39,156,723	35,241,051	35,708,307		0	0
1982	109.86	35,146,026	31,631,424	32,893,256		0	0
1983	163.32	32,303,802	29,073,422	30,001,205		0	0
1984	471.83	471,030,176	423,927,158	432,854,248		0	0
1985	637.17	911,454,313	820,308,882	853,057,806		0	0
1986	837.98	267,401,815	240,661,634	300,016,480		0	0
1987	1,185.81	207,734,538	186,961,084	259,315,296		0	0
1988	1,259.92	2,549,420,874	2,294,478,787	2,383,343,039		0	0
1989	1,463.78	535,403,803	481,863,423	650,970,899		0	0
1990	1,379.24	691,734,185	622,560,767	803,808,400		0	0
1991	1,398.67	3,475,286,346	3,127,757,712	3,378,032,899		0	0
1992	1,473.97	1,710,727,320	1,539,654,588	1,924,688,897		0	0
1993	1,689.99	8,147,833,045	7,333,049,740	7,738,881,034		0	0
1994	1,931.93	1,313,256,600	1,181,930,940	1,811,125,705		0	535,742,408
1995	1,422.35	301,567,707	271,410,936	444,849,180	1,361,979,250	204,296,888	597,144,000
1996	1,499.42	83,961,556	75,565,401	809,072,416	1,535,228,229	230,284,234	1,171,434,025
1997		0			1,927,478,424	289,121,764	1,353,509,000

Table A12 continued.

Year	SARI maize (8%)	GGDP ,SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)	Actual releases (80% of estimates)	MOFA Extension cost for maize at 50% (in cedis)	SG 2000	80% of SG2000
1979	0	70,758,360	0	0	0	0	0
1980	0	54,298,063	0	0	0	0	0
1981	0	35,708,307	0	0	0	0	0
1982	0	32,893,256	0	0	0	0	0
1983	0	30,001,205	0	0	0	0	0
1984	0	432,854,248	156,631,040	125,304,832	62,652,416	0	0
1985	0	853,057,806	195,788,800	156,631,040	78,315,520	0	0
1986	0	300,016,480	244,736,000	195,788,800	97,894,400	0	0
1987	0	259,315,296	305,920,000	244,736,000	122,368,000	0	0
1988	0	2,383,343,039	382,400,000	305,920,000	152,960,000	20,789,424	16,631,539
1989	0	650,970,899	853,829,000	683,063,200	341,531,600	24,458,146	19,566,517
1990	0	803,808,400	857,208,000	685,766,400	342,883,200	28,774,290	23,019,432
1991	0	3,378,032,899	1,997,101,000	1,597,680,800	798,840,400	33,852,105	27,081,684
1992	0	1,924,688,897	1,516,825,000	1,213,460,000	606,730,000	39,826,006	31,860,805
1993	0	7,738,881,034	2,435,152,000	1,948,121,600	974,060,800	46,854,125	37,483,300
1994	42,859,393	1,853,985,098	2,272,267,000	1,817,813,600	908,906,800	55,122,500	44,098,000
1995	47,771,520	696,917,588	2,455,425,000	1,964,340,000	982,170,000	64,850,000	51,880,000
1996	93,714,722	1,133,071,373	533,000,000	426,400,000	213,200,000	84,305,000	67,444,000
1997	108,280,720	397,402,484	829,000,000	663,200,000	331,600,000	96,000,000	76,800,000

Table A12 continued.

			Extension + Research	CIMMYT Costs	CIMMYT Costs	CIMMYT Real Costs
	Total extension	Extension + Research	(Real cost in cedis)	(CN\$)	(cedis)	(1997 = 1)
Year	(in cedis)	cost				(in cedis)
1979	0	70,758,360	20,045,412,220	50,000	17,129,930	4,852,804,793
1980	0	54,298,063	9,579,608,548	50,000	13,125,214	2,315,633,427
1981	0	35,708,307	3,008,900,708	50,000	6,430,478	541,853,460
1982	0	32,893,256	2,260,739,187	50,000	5,493,232	377,547,429
1983	0	30,001,205	898,206,534	50,000	8,165,774	244,475,234
1984	62,652,416	495,506,664	10,724,083,020	50,000	23,591,615	510,585,329
1985	78,315,520	931,373,326	18,524,110,801	50,000	31,858,294	633,630,517
1986	97,894,400	397,910,880	6,519,584,999	50,000	41,899,244	686,499,663
1987	122,368,000	381,683,296	4,577,130,338	25,000	29,645,362	355,505,958
1988	169,591,539	2,552,934,579	23,514,904,574	25,000	31,497,928	290,125,246
1989	361,098,117	1,012,069,016	7,520,252,230	25,000	36,594,595	271,918,789
1990	365,902,632	1,169,711,032	6,460,712,105	25,000	34,481,059	190,450,625
1991	825,922,084	4,203,954,984	19,797,211,508	25,000	34,966,833	164,665,364
1992	638,590,805	2,563,279,702	10,884,815,147	25,000	36,849,301	156,478,370
1993	1,011,544,100	8,750,425,134	29,950,842,375	25,000	42,249,632	144,611,495
1994	953,004,800	2,806,989,898	7,757,943,721	25,000	48,298,184	133,486,263
1995	1,034,050,000	1,730,967,588	3,048,439,108	25,000	35,558,875	62,623,394
1996	280,644,000	1,413,715,373	1,795,575,275	25,000	37,485,515	47,610,761
1997	408,400,000	805,802,484	805,802,484	0	0	0

Table A12 continued.

	Extension , Research and CIMMYT real costs (in cedis)	Net social gains NG = SG - (R + E)	
Year			
1979	24,898,217,013	-24,898,217,013	
1980	11,895,241,975	-11,895,241,975	
1981	3,550,754,168	-3,550,754,168	
1982	2,638,286,616	-2,638,286,616	
1983	1,142,681,769	-1,142,681,769	
1984	11,234,668,349	7,329,878,999	
1985	19,157,741,317	372,727,574	
1986	7,206,084,662	26,852,769,780	
1987	4,932,636,295	40,775,129,763	
1988	23,805,029,820	41,367,691,970	
1989	7,792,171,019	82,600,854,267	
1990	6,651,162,731	54,401,772,094	
1991	19,961,876,873	89,539,507,797	
1992	11,041,293,517	95,818,129,739	
1993	30,095,453,871	137,093,783,241	
1994	7,891,429,984	191,360,871,173	
1995	3,111,062,502	119,899,924,102	
1996	1,843,186,035	132,719,929,821	
1997	805,802,484	53,416,747,834	
		IRR =	31%

Source: Estimated by the author

1. The following are the names of the members of the committee:

- (a) Mr. A. K. A. A.
- (b) Mr. B. K. B. B.
- (c) Mr. C. K. C. C.
- (d) Mr. D. K. D. D.
- (e) Mr. E. K. E. E.

2. The following are the names of the members of the committee:

- (a) Mr. F. K. F. F.
- (b) Mr. G. K. G. G.
- (c) Mr. H. K. H. H.
- (d) Mr. I. K. I. I.
- (e) Mr. J. K. J. J.

3. The following are the names of the members of the committee:

- (a) Mr. K. K. K. K.
- (b) Mr. L. K. L. L.
- (c) Mr. M. K. M. M.
- (d) Mr. N. K. N. N.
- (e) Mr. O. K. O. O.

4. The following are the names of the members of the committee:

- (a) Mr. P. K. P. P.
- (b) Mr. Q. K. Q. Q.
- (c) Mr. R. K. R. R.
- (d) Mr. S. K. S. S.
- (e) Mr. T. K. T. T.

5. The following are the names of the members of the committee:

- (a) Mr. U. K. U. U.
- (b) Mr. V. K. V. V.
- (c) Mr. W. K. W. W.
- (d) Mr. X. K. X. X.
- (e) Mr. Y. K. Y. Y.

6. The following are the names of the members of the committee:

- (a) Mr. Z. K. Z. Z.
- (b) Mr. A. K. A. A.
- (c) Mr. B. K. B. B.
- (d) Mr. C. K. C. C.
- (e) Mr. D. K. D. D.

7. The following are the names of the members of the committee:

- (a) Mr. E. K. E. E.
- (b) Mr. F. K. F. F.
- (c) Mr. G. K. G. G.
- (d) Mr. H. K. H. H.
- (e) Mr. I. K. I. I.

8. The following are the names of the members of the committee:

- (a) Mr. J. K. J. J.
- (b) Mr. K. K. K. K.
- (c) Mr. L. K. L. L.
- (d) Mr. M. K. M. M.
- (e) Mr. N. K. N. N.

9. The following are the names of the members of the committee:

- (a) Mr. O. K. O. O.
- (b) Mr. P. K. P. P.
- (c) Mr. Q. K. Q. Q.
- (d) Mr. R. K. R. R.
- (e) Mr. S. K. S. S.

10. The following are the names of the members of the committee:

Table A13: Financial Rate of Return with Higher Research and Higher Extension Cost

	Total quantity	Total area	National average	Adoption rate	Yield of	Yield of	Change in	Proportional	
Year	produced	planted	production	(at K = 95%, Lag = 30 years)	improved technology	farmer technology	yield	increase	Proportional
Unit	(mt)	(ha)	(mt/ha)		(mt/ha)	(mt/ha)	(mt/ha)		production increase
Parameter	Q	A	Y	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf	j = t x (dY/Yf)
1979	308600	313900	0.98	0					
1980	354000	319900	1.11	0					
1981	334200	315500	1.06	0					
1982	264300	276300	0.96	0					
1983	140800	279800	0.50	0					
1984	574000	723600	0.79	0.02	2.88	1.73	1.15	0.6647	0.0133
1985	395000	405000	0.98	0.03	2.75	1.7	1.05	0.6176	0.0185
1986	559100	472100	1.18	0.04	2.93	1.74	1.19	0.6839	0.0274
1987	597700	548336	1.09	0.06	2.93	1.74	1.19	0.6839	0.0410
1988	600000	500000	1.20	0.08	2.93	1.74	1.19	0.6839	0.0547
1989	714614	595800	1.20	0.1	2.93	1.74	1.19	0.6839	0.0684
1990	552549	464784	1.19	0.13	2.93	1.74	1.19	0.6839	0.0889
1991	931478	610445	1.53	0.17	2.93	1.74	1.19	0.6839	0.1163
1992	730617	606783	1.20	0.22	2.93	1.74	1.19	0.6839	0.1505
1993	960920	636670	1.51	0.28	2.93	1.74	1.19	0.6839	0.1915
1994	939908	629401	1.49	0.34	2.93	1.74	1.19	0.6839	0.2325
1995	1034170	668600	1.55	0.41	2.93	1.74	1.19	0.6839	0.2804
1996	1007610	664950	1.52	0.48	2.93	1.74	1.19	0.6839	0.3283
1997	1000000	650000	1.54	0.54	2.93	1.74	1.19	0.6839	0.3693

Table A13 continued.

Year	Fertilizer prices (comp. + S.Ammonia) (cedis/ha)	Change in fertilizer cost including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)	Maize price: Average wholesale price (cedis/t)
							dC	
1979								
1980								
1981								
1982								
1983								0
1984	1,838	2,059	551	400	300	100	2,710	23,380
1985	1,838	2,059	551	1,000	750	250	2,860	20,380
1986	3,175	3,556	953	1,000	750	250	4,759	33,110
1987	5,500	6,160	1,650	2,000	1,500	500	8,310	53,870
1988	9,750	10,920	2,925	2,000	1,500	500	14,345	68,590
1989	14,250	15,960	4,275	3,000	2,250	750	20,985	53,000
1990	18,250	20,440	5,475	3,000	2,250	750	26,665	85,030
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975	116,050
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725	100,480
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375	110,720
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675	138,630
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350	200,000
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650	250,000
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900	300,000

Table A13 continued.

Year	Farmgate price (70% of wholesale) (cedis/t)	Rural price index (1977 = 100)	Real price (1997 = 1) (cedis/t)	Real change in cost, (cedis/ha) dC	Proportional cost increase $i = I/P = (dC \cdot t)/(Y_f \cdot P)$	Supply elasticity (E = 0.79)
1979		279				0.79
1980		448				0.79
1981		938				0.79
1982		1,150				0.79
1983	0	2,640	0		0.0000	0.79
1984	16,366	3,652	354,204	58,651	0.0019	0.79
1985	14,266	3,974	283,737	56,882	0.0035	0.79
1986	23,177	4,824	379,744	77,966	0.0047	0.79
1987	37,709	6,591	452,205	99,653	0.0076	0.79
1988	48,013	8,581	442,244	132,131	0.0137	0.79
1989	37,100	10,637	275,674	155,931	0.0325	0.79
1990	59,521	14,310	328,755	147,280	0.0335	0.79
1991	81,235	16,784	382,551	164,704	0.0421	0.79
1992	70,336	18,613	298,678	223,894	0.0948	0.79
1993	77,504	23,092	265,280	220,342	0.1337	0.79
1994	97,041	28,598	268,201	236,788	0.1725	0.79
1995	140,000	44,880	246,557	236,606	0.2261	0.79
1996	175,000	62,230	222,269	200,233	0.2485	0.79
1997	210,000	79,039	210,000	195,900	0.2895	0.79

Table A13 continued.

Year	Net shift in supply $k = (j/E) - i$	Demand elasticity ($e = -0.981$)	Change in quantity caused by research, $dQ = (Q \times e \times E \times k) / (e + E)$	Social gains from research $SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$	GGDP (all local costs), (cedis)
1979		0.981		0	389,380
1980		0.981		0	389,380
1981		0.981		0	519,173
1982		0.981		0	1,402,036
1983		0.981	0	0	1,030,870
1984	0.0149	0.981	3,746	3,022,432,946	9,918,988
1985	0.0199	0.981	3,443	2,222,511,149	36,387,694
1986	0.0299	0.981	7,317	6,308,461,916	65,949,829
1987	0.0443	0.981	11,598	11,868,961,201	80,393,569
1988	0.0555	0.981	14,577	14,553,035,743	98,738,058
1989	0.0541	0.981	16,906	10,524,457,658	187,897,196
1990	0.0791	0.981	19,119	14,115,007,059	201,386,259
1991	0.1051	0.981	42,843	36,591,818,286	278,083,542
1992	0.0957	0.981	30,589	20,441,327,147	427,815,898
1993	0.1087	0.981	45,724	27,059,117,346	450,923,659
1994	0.1218	0.981	50,107	29,891,504,647	699,105,294
1995	0.1288	0.981	58,296	31,920,145,086	192,709,160
1996	0.1670	0.981	73,647	36,040,383,882	815,007,795
1997	0.1780	0.981	77,881	35,919,159,696	

Table A13 continued.

Year	Proportional GGDP maize cost (cedis) (100% for 1979-96)	GGDP (foreign cost) Canadian \$	Exchange rate (CN\$:1US\$)	Exchange rate, cedis:1US\$	Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis) (100% for 1979-96)
1979	389,380	228,346	1.1714	2.75	2.35	536,069	536,069
1980	389,380	228,346	1.1692	2.75	2.35	537,078	537,078
1981	519,173	304,462	1.1989	2.75	2.29	698,366	698,366
1982	1,402,036	319,903	1.2337	2.75	2.23	713,085	713,085
1983	1,030,870	197,800	1.2324	8.83	7.16	1,417,214	1,417,214
1984	9,918,988	998,300	1.2951	35.99	27.79	27,742,118	27,742,118
1985	36,387,694	1,430,482	1.3655	54.37	39.82	56,957,383	56,957,383
1986	65,949,829	319,101	1.3895	89.2	64.20	20,484,929	20,484,929
1987	80,393,569	175,183	1.326	153.73	115.94	20,309,866	20,309,866
1988	98,738,058	2,023,483	1.2307	202.35	164.42	332,698,290	332,698,290
1989	187,897,196	365,767	1.184	270	228.04	83,409,704	83,409,704
1990	201,386,259	501,532	1.1668	326.33	279.68	140,268,202	140,268,202
1991	278,083,542	2,484,702	1.1457	367.83	321.05	797,720,116	797,720,116
1992	427,815,898	1,160,624	1.2087	437.09	361.62	419,704,761	419,704,761
1993	450,923,659	4,821,245	1.2901	649.06	503.11	2,425,608,309	2,425,608,309
1994	699,105,294	679,765	1.3656	956.71	700.58	476,228,744	476,228,744
1995	192,709,160	212,020	1.3724	1200.43	874.69	185,452,615	185,452,615
1996	815,007,795	55,996	1.3635	1637.23	1,200.76	67,237,500	67,237,500
1997		0				0	

Table A13 continued.

	Total GGDP	NARP-CRI Cost	NARP-CRI Maize	SARI cost	SARI maize (8%)	GGDP, SARI and	MOFA Extension
Year	maize cost		(15% of NARP-CRI)			NARP-CRI	estimates
	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)
1979	925,449	0	0	0	0	925,449	0
1980	926,458	0	0	0	0	926,458	0
1981	1,217,539	0	0	0	0	1,217,539	0
1982	2,115,121	0	0	0	0	2,115,121	0
1983	2,448,084	0	0	0	0	2,448,084	0
1984	37,661,106	0	0	0	0	37,661,106	156,631,040
1985	93,345,077	0	0	0	0	93,345,077	195,788,800
1986	86,434,758	0	0	0	0	86,434,758	244,736,000
1987	100,703,435	0	0	0	0	100,703,435	305,920,000
1988	431,436,348	0	0	0	0	431,436,348	382,400,000
1989	271,306,900	0	0	0	0	271,306,900	853,829,000
1990	341,654,461	0	0	0	0	341,654,461	857,208,000
1991	1,075,803,658	0	0	0	0	1,075,803,658	1,997,101,000
1992	847,520,659	0	0	0	0	847,520,659	1,516,825,000
1993	2,876,531,968	0	0	0	0	2,876,531,968	2,435,152,000
1994	1,175,334,038	0	0	535,742,408	42,859,393	1,218,193,431	2,272,267,000
1995	378,161,775	1,361,979,250	204,296,888	597,144,000	47,771,520	630,230,182	2,455,425,000
1996	882,245,295	1,535,228,229	230,284,234	1,171,434,025	93,714,722	1,206,244,251	533,000,000
1997		1,927,478,424	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000

Table A13 continued.

	Actual releases	MOFA Extension cost	SG 2000	80% of SG 2000	Total extension	Extension + Research	Extension + Research
Year	(80% of estimates)	for maize at 50%				cost	(Real cost)
	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)	(cedis)
1979	0	0	0	0	0	925,449	262,174,129
1980	0	0	0	0	0	926,458	163,451,579
1981	0	0	0	0	0	1,217,539	102,593,851
1982	0	0	0	0	0	2,115,121	145,371,363
1983	0	0	0	0	0	2,448,084	73,293,211
1984	125,304,832	62,652,416	0	0	62,652,416	100,313,522	2,171,051,606
1985	156,631,040	78,315,520	0	0	78,315,520	171,660,597	3,414,162,536
1986	195,788,800	97,894,400	0	0	97,894,400	184,329,158	3,020,147,666
1987	244,736,000	122,368,000	0	0	122,368,000	223,071,435	2,675,063,445
1988	305,920,000	152,960,000	20,789,424	16,631,539	169,591,539	601,027,887	5,536,026,472
1989	683,063,200	341,531,600	24,458,146	19,566,517	361,098,117	632,405,017	4,699,131,349
1990	685,766,400	342,883,200	28,774,290	23,019,432	365,902,632	707,557,092	3,908,078,617
1991	1,597,680,800	798,840,400	33,852,105	27,081,684	825,922,084	1,901,725,742	8,955,582,753
1992	1,213,460,000	606,730,000	39,826,006	31,860,805	638,590,805	1,486,111,464	6,310,684,144
1993	1,948,121,600	974,060,800	46,854,125	37,483,300	1,011,544,100	3,888,076,068	13,308,056,658
1994	1,817,813,600	908,906,800	55,122,500	44,098,000	953,004,800	2,171,198,231	6,000,746,100
1995	1,964,340,000	982,170,000	64,850,000	51,880,000	1,034,050,000	1,664,280,182	2,930,994,682
1996	426,400,000	213,200,000	84,305,000	67,444,000	280,644,000	1,486,888,251	1,888,512,944
1997	663,200,000	331,600,000	96,000,000	76,800,000	408,400,000	805,802,484	805,802,484

Table A13 continued.

	CIMMYT Costs (CN\$)	CIMMYT Costs	CIMMYT Real Costs	Research, extension	Net social gains
			(1997 = 1)	and CIMMYT real cost	NG = SG - (R + E)
	(CN\$)	(cedis)	(cedis)	(cedis)	
Year					
1979	50,000	117,381	33,253,297	295,427,426	-295,427,426
1980	50,000	117,602	20,748,051	184,199,630	-184,199,630
1981	50,000	114,688	9,664,031	112,257,882	-112,257,882
1982	50,000	111,453	7,660,140	153,031,503	-153,031,503
1983	50,000	358,244	10,725,475	84,018,686	-84,018,686
1984	50,000	1,389,468	30,071,786	2,201,123,391	821,309,555
1985	50,000	1,990,846	39,595,990	3,453,758,526	-1,231,247,377
1986	50,000	3,209,788	52,590,881	3,072,738,547	3,235,723,370
1987	25,000	2,898,379	34,757,236	2,709,820,682	9,159,140,519
1988	25,000	4,110,466	37,861,215	5,573,887,688	8,979,148,055
1989	25,000	5,701,014	42,361,794	4,741,493,143	5,782,964,515
1990	25,000	6,991,987	38,619,122	3,946,697,739	10,168,309,321
1991	25,000	8,026,316	37,797,425	8,993,380,177	27,598,438,108
1992	25,000	9,040,498	38,389,939	6,349,074,083	14,092,253,064
1993	25,000	12,577,707	43,050,814	13,351,107,472	13,708,009,873
1994	25,000	17,514,463	48,406,378	6,049,152,478	23,842,352,169
1995	25,000	21,867,349	38,510,994	2,969,505,676	28,950,639,410
1996	25,000	30,018,885	38,127,313	1,926,640,256	34,113,743,625
1997	0	0	0	805,802,484	35,113,357,213
					IRR =
					68%

Source: Estimated by the author

Table A.14: Economic Rate of Return with Higher Research and Higher Extension Cost

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of Improved technology (mt/ha)	Yield of Farmer technology (mt/ha)	Change in yield (mt/ha)	Proportional increase	Proportional production increase (j-parameter)
Unit	(mt)	(ha)	(mt/ha)	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf	j = t x (dY/Yf)
Parameter	Q	A	Ym						
1979	308,600	313,900	0.9831	0					0.0000
1980	354,000	319,900	1.1066	0					0.0000
1981	334,200	315,500	1.0593	0					0.0000
1982	264,300	276,300	0.9566	0					0.0000
1983	140,800	279,800	0.5032	0					0.0000
1984	574,000	723,600	0.7933	0.02	2.88	1.73	1.15	0.6647	0.0133
1985	395,000	405,000	0.9753	0.03	2.75	1.7	1.05	0.6176	0.0185
1986	559,100	472,100	1.1843	0.04	2.93	1.74	1.19	0.6839	0.0274
1987	597,700	548,336	1.0900	0.06	2.93	1.74	1.19	0.6839	0.0410
1988	600,000	500,000	1.2000	0.08	2.93	1.74	1.19	0.6839	0.0547
1989	714,614	595,800	1.1994	0.1	2.93	1.74	1.19	0.6839	0.0684
1990	552,549	464,784	1.1888	0.13	2.93	1.74	1.19	0.6839	0.0889
1991	931,478	610,445	1.5259	0.17	2.93	1.74	1.19	0.6839	0.1163
1992	730,617	606,783	1.2041	0.22	2.93	1.74	1.19	0.6839	0.1505
1993	960,920	636,670	1.5093	0.28	2.93	1.74	1.19	0.6839	0.1915
1994	939,908	629,401	1.4933	0.34	2.93	1.74	1.19	0.6839	0.2325
1995	1,034,170	668,600	1.5468	0.41	2.93	1.74	1.19	0.6839	0.2804
1996	1,007,610	664,950	1.5153	0.48	2.93	1.74	1.19	0.6839	0.3283
1997	1,000,000	650,000	1.5385	0.54	2.93	1.74	1.19	0.6839	0.3693

Table A14 continued

	Fertilizer prices (comp. + S.A, (Without subsidy) cedis/ha)	Change in fertilizer costs including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha)	Product price: Export price (F.O.B) U.S. Gulf (\$/ton) (\$/ton)
Year								
							dC	
1979								
1980								
1981								
1982								
1983								0
1984	2,665	2,985	800	400	300	100	3,884	139.1
1985	2,922	3,273	877	1,000	750	250	4,399	116.8
1986	4,318	4,836	1,295	1,000	750	250	6,382	88.7
1987	7,810	8,747	2,343	2,000	1,500	500	11,590	75.6
1988	12,675	14,196	3,803	2,000	1,500	500	18,499	107
1989	16,388	18,355	4,916	3,000	2,250	750	24,021	111.3
1990	18,250	20,440	5,475	3,000	2,250	750	26,665	109.7
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975	107
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725	105.1
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375	101.9
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675	107.5
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350	123.7
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650	165.1
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900	117.1

Table A14 continued

	Freight and marketing cost							
	No.2 yellow maize		Real					
	(30% + 20% = 50%	Value of maize	exchange rate	Value of maize	Rural price index	Real price		Proportional cost increase
Year	of export price)				(1997 = 100)	(Farmgate)	Real change	
	(\$/ton)	(\$/ton)	(cedis:1 US\$)	(cedis/ton)		(1997 = 1)	in cost	$i = I/P = (dC \cdot t)/(Yf \cdot P)$
						(cedis/ton)	(cedis/ton)	
							dC	
1979					279			
1980					448			
1981					938			
1982					1,150			
1983	0				2,640			
1984	69.55	208.65	611.07	127,500	3,652	1,931,604	84,067	0.0000
1985	58.4	175.2	870.05	152,433	3,974	2,122,218	87,497	0.0000
1986	44.35	133.05	1164.38	154,921	4,824	1,776,813	104,559	0.0001
1987	37.8	113.4	1572.39	178,309	6,591	1,496,792	138,989	0.0003
1988	53.5	160.5	1550.58	248,868	8,581	1,604,615	170,388	0.0005
1989	55.65	166.95	1733.12	289,344	10,637	1,504,996	178,489	0.0009
1990	54.85	164.55	1609.3	264,810	14,310	1,023,846	147,280	0.0019
1991	53.5	160.5	1602.46	257,195	16,784	847,825	164,704	0.0040
1992	52.55	157.65	1781.59	280,868	18,613	834,882	223,894	0.0080
1993	50.95	152.85	2180.25	333,251	23,092	798,454	220,342	0.0130
1994	53.75	161.25	2638.24	425,416	28,598	823,034	236,788	0.0203
1995	61.85	185.55	1952.04	362,201	44,880	446,515	236,606	0.0709
1996	82.55	247.65	2044.46	506,311	62,230	450,149	200,233	0.0966
1997	58.55	175.65	2050.2	360,118	79,039	252,082	195,900	0.2412

Table A14 continued

Year	Supply elasticity ($E = 0.79$)	Net shift in supply $k = (j/E) - i$	Demand elasticity ($e = -0.981$)	Change in quantity caused by research. $dQ = (Q \times e \times E \times k) / (e + E)$ dQ	Social gains from research $SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$	Research cost: GGDP (all local cost) (in cedis)
1979	0.79		0.981			389,380
1980	0.79		0.981			389,380
1981	0.79		0.981			519,173
1982	0.79		0.981			1,402,036
1983	0.79		0.981			1,030,870
1984	0.79	0.0168	0.981	4,221.3	18,564,547,348	9,918,988
1985	0.79	0.0234	0.981	4,047.9	19,530,468,891	36,387,694
1986	0.79	0.0345	0.981	8,452.0	34,058,854,442	65,949,829
1987	0.79	0.0517	0.981	13,515.9	45,707,766,058	80,393,569
1988	0.79	0.0687	0.981	18,044.8	65,172,721,789	98,738,058
1989	0.79	0.0857	0.981	26,785.1	90,393,025,287	187,897,196
1990	0.79	0.1106	0.981	26,741.6	61,052,934,824	201,386,259
1991	0.79	0.1431	0.981	58,345.9	109,501,384,670	278,083,542
1992	0.79	0.1825	0.981	58,339.2	106,859,423,256	427,815,898
1993	0.79	0.2294	0.981	96,472.4	167,189,237,112	450,923,659
1994	0.79	0.2740	0.981	112,697.1	199,252,301,157	699,105,294
1995	0.79	0.2840	0.981	128,543.7	123,010,986,604	192,709,160
1996	0.79	0.3189	0.981	140,624.8	134,563,115,856	815,007,795
1997	0.79	0.2263	0.981	99,030.7	54,222,550,318	

Table A14 continued

				Real	Real		
	Proportional GGDP	GGDP (foreign costs),	Exchange rate	Exchange rate,	Exchange rate	All costs	Proportional foreign
	maize cost (cedis)	(Canadian \$)	(CN\$:1US\$)	Cedis:1US\$	Cedis:CN\$	(CN\$ to cedis)	cost (cedis)
Year	(90% for 1979-83, 55% for 1984-96)						(100% for 1979-96)
1979	389,380	228,346	1.1714	401.32	342.60	78,231,020	78,231,020
1980	389,380	228,346	1.1692	306.92	262.50	59,941,802	59,941,802
1981	519,173	304,462	1.1989	154.19	128.61	39,156,723	39,156,723
1982	1,402,036	319,903	1.2337	135.54	109.86	35,146,026	35,146,026
1983	1,030,870	197,800	1.2324	201.27	163.32	32,303,802	32,303,802
1984	9,918,988	998,300	1.2951	611.07	471.83	471,030,176	471,030,176
1985	36,387,694	1,430,482	1.3655	870.05	637.17	911,454,313	911,454,313
1986	65,949,829	319,101	1.3895	1164.38	837.98	267,401,815	267,401,815
1987	80,393,569	175,183	1.326	1572.39	1,185.81	207,734,538	207,734,538
1988	98,738,058	2,023,483	1.2307	1550.58	1,259.92	2,549,420,874	2,549,420,874
1989	187,897,196	365,767	1.184	1733.12	1,463.78	535,403,803	535,403,803
1990	201,386,259	501,532	1.1668	1609.3	1,379.24	691,734,185	691,734,185
1991	278,083,542	2,484,702	1.1457	1602.46	1,398.67	3,475,286,346	3,475,286,346
1992	427,815,898	1,160,624	1.2087	1781.59	1,473.97	1,710,727,320	1,710,727,320
1993	450,923,659	4,821,245	1.2901	2180.25	1,689.99	8,147,833,045	8,147,833,045
1994	699,105,294	679,765	1.3656	2638.24	1,931.93	1,313,256,600	1,313,256,600
1995	192,709,160	212,020	1.3724	1952.04	1,422.35	301,567,707	301,567,707
1996	815,007,795	55,996	1.3635	2044.46	1,499.42	83,961,556	83,961,556
1997		0		2050.2		0	

Table A14 continued

	Total GGDP maize cost (cedis)	NARP-CRI Cost (cedis)	NARP-CRI Maize (15% of NARP-CRI) (cedis)	SARI cost (cedis)	SARI maize (8%) (cedis)	GGDP, SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)
Year							
1979	78,620,400	0	0	0	0	78,620,400	0
1980	60,331,182	0	0	0	0	60,331,182	0
1981	39,675,896	0	0	0	0	39,675,896	0
1982	36,548,062	0	0	0	0	36,548,062	0
1983	33,334,672	0	0	0	0	33,334,672	0
1984	480,949,164	0	0	0	0	480,949,164	156,631,040
1985	947,842,007	0	0	0	0	947,842,007	195,788,800
1986	333,351,644	0	0	0	0	333,351,644	244,736,000
1987	288,128,107	0	0	0	0	288,128,107	305,920,000
1988	2,648,158,932	0	0	0	0	2,648,158,932	382,400,000
1989	723,300,999	0	0	0	0	723,300,999	853,829,000
1990	893,120,444	0	0	0	0	893,120,444	857,208,000
1991	3,753,369,888	0	0	0	0	3,753,369,888	1,997,101,000
1992	2,138,543,218	0	0	0	0	2,138,543,218	1,516,825,000
1993	8,598,756,704	0	0	0	0	8,598,756,704	2,435,152,000
1994	2,012,361,894	0	0	535,742,408	42,859,393	2,055,221,287	2,272,267,000
1995	494,276,867	1,361,979,250	204,296,888	597,144,000	47,771,520	746,345,274	2,455,425,000
1996	898,969,351	1,535,228,229	230,284,234	1,171,434,025	93,714,722	1,222,968,308	533,000,000
1997		1,927,478,424	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000

Table A14 continued

	Actual releases (80% of estimates) (cedis)	MOFA Extension cost for maize at 50% (cedis)	SG 2000 (cedis)	80% of SG2000 (cedis)	Total extension (cedis)	Extension + Research	Extension + Research (Real cost) (cedis)
Year							
1979	0	0	0	0	0	78,620,400	22,272,680,245
1980	0	0	0	0	0	60,331,182	10,644,009,498
1981	0	0	0	0	0	39,675,896	3,343,223,008
1982	0	0	0	0	0	36,548,062	2,511,932,430
1983	0	0	0	0	0	33,334,672	998,007,260
1984	125,304,832	62,652,416	0	0	62,652,416	543,601,580	11,764,985,018
1985	156,631,040	78,315,520	0	0	78,315,520	1,026,157,527	20,409,276,487
1986	195,788,800	97,894,400	0	0	97,894,400	431,246,044	7,065,766,189
1987	244,736,000	122,368,000	0	0	122,368,000	410,496,107	4,922,652,374
1988	305,920,000	152,960,000	20,789,424	16,631,539	169,591,539	2,817,750,472	25,954,105,528
1989	683,063,200	341,531,600	24,458,146	19,566,517	361,098,117	1,084,399,116	8,057,706,284
1990	685,766,400	342,883,200	28,774,290	23,019,432	365,902,632	1,259,023,076	6,954,012,922
1991	1,597,680,800	798,840,400	33,852,105	27,081,684	825,922,084	4,579,291,973	21,564,743,697
1992	1,213,460,000	606,730,000	39,826,006	31,860,805	638,590,805	2,777,134,023	11,792,934,835
1993	1,948,121,600	974,060,800	46,854,125	37,483,300	1,011,544,100	9,610,300,804	32,894,013,738
1994	1,817,813,600	908,906,800	55,122,500	44,098,000	953,004,800	3,008,226,087	8,314,119,229
1995	1,964,340,000	982,170,000	64,850,000	51,880,000	1,034,050,000	1,780,395,274	3,135,487,123
1996	426,400,000	213,200,000	84,305,000	67,444,000	280,644,000	1,503,612,308	1,909,754,350
1997	663,200,000	331,600,000	96,000,000	76,800,000	408,400,000	805,802,484	805,802,484

Table A14 continued

				Extension , Research and CIMMYT real costs	NET SOCIAL GAIN
	CIMMYT Costs	CIMMYT Costs	CIMMYT Real Costs	(in cedis)	NG = SG - (R + E)
	(CN\$)	(cedis)	1997 = 1) (cedis)		
Year					
1979	50,000	17,129,930	4,852,804,793	27,125,485,037	-27,125,485,037
1980	50,000	13,125,214	2,315,633,427	12,959,642,925	-12,959,642,925
1981	50,000	6,430,478	541,853,460	3,885,076,469	-3,885,076,469
1982	50,000	5,493,232	377,547,429	2,889,479,859	-2,889,479,859
1983	50,000	8,165,774	244,475,234	1,242,482,495	-1,242,482,495
1984	50,000	23,591,615	510,585,329	12,275,570,347	6,288,977,001
1985	50,000	31,858,294	633,630,517	21,042,907,004	-1,512,438,112
1986	50,000	41,899,244	686,499,663	7,752,265,852	26,306,588,590
1987	25,000	29,645,362	355,505,958	5,278,158,332	40,429,607,726
1988	25,000	31,497,928	290,125,246	26,244,230,774	38,928,491,016
1989	25,000	36,594,595	271,918,789	8,329,625,073	82,063,400,214
1990	25,000	34,481,059	190,450,625	7,144,463,547	53,908,471,278
1991	25,000	34,966,833	164,665,364	21,729,409,062	87,771,975,608
1992	25,000	36,849,301	156,478,370	11,949,413,204	94,910,010,052
1993	25,000	42,249,632	144,611,495	33,038,625,233	134,150,611,878
1994	25,000	48,298,184	133,486,263	8,447,605,492	190,804,695,665
1995	25,000	35,558,875	62,623,394	3,198,110,517	119,812,876,087
1996	25,000	37,485,515	47,610,761	1,957,365,111	132,605,750,745
1997	0	0	0	805,802,484	53,416,747,834
					IRR =
					30%

Source: Estimated by the author.

Table A15: Financial Rate of Return with Lower Projected Research Benefit

	Total quantity produ	Total area planted	National average	Adoption rate	Yield of	Yield of	Change in	Proportional
Year	(mt)	(ha)	production	(at K = 95%, Lag = 30 years)	improved	farmer	yield	increase
Unit	(mt)	(ha)	(t/ha)		(t/ha)	(t/ha)	(reduced by 40%)	
Parameter	Q	A	Ym	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf
1979	308600	313900	0.98	0				
1980	354000	319900	1.11	0				
1981	334200	315500	1.06	0				
1982	264300	276300	0.96	0				
1983	140800	279800	0.50	0				
1984	574000	723600	0.79	0.02	2.88	1.73	0.69	0.3988
1985	395000	405000	0.98	0.03	2.75	1.7	0.63	0.3706
1986	559100	472100	1.18	0.04	2.93	1.74	0.714	0.4103
1987	597700	548336	1.09	0.06	2.93	1.74	0.714	0.4103
1988	600000	500000	1.20	0.08	2.93	1.74	0.714	0.4103
1989	714614	595800	1.20	0.1	2.93	1.74	0.714	0.4103
1990	552549	464784	1.19	0.13	2.93	1.74	0.714	0.4103
1991	931478	610445	1.53	0.17	2.93	1.74	0.714	0.4103
1992	730617	606783	1.20	0.22	2.93	1.74	0.714	0.4103
1993	960920	636670	1.51	0.28	2.93	1.74	0.714	0.4103
1994	939908	629401	1.49	0.34	2.93	1.74	0.714	0.4103
1995	1034170	668600	1.55	0.41	2.93	1.74	0.714	0.4103
1996	1007610	664950	1.52	0.48	2.93	1.74	0.714	0.4103
1997	1000000	650000	1.54	0.54	2.93	1.74	0.714	0.4103

Table A15 continued.

	Proportional production increase j = t x (dY/Yf)	Fertilizer prices (comp. + S.Ammonia) (cedis/ha)	Change in fertilizer cost including application (cedis/ha)	Change in row planting cost (cedis/ha)	Improved seed (cedis/ha)	Farmers seed (cedis/ha)	Change in seed cost (cedis/ha)	Change in total cost of technology (cedis/ha) dC
1979								
1980								
1981								
1982								
1983								
1984	0.0080	1,838	2,059	551	400	300	100	2,710
1985	0.0111	1,838	2,059	551	1,000	750	250	2,860
1986	0.0164	3,175	3,556	953	1,000	750	250	4,759
1987	0.0246	5,500	6,160	1,650	2,000	1,500	500	8,310
1988	0.0328	9,750	10,920	2,925	2,000	1,500	500	14,345
1989	0.0410	14,250	15,960	4,275	3,000	2,250	750	20,985
1990	0.0533	18,250	20,440	5,475	3,000	2,250	750	26,665
1991	0.0698	23,750	26,600	7,125	5,000	3,750	1,250	34,975
1992	0.0903	36,250	40,600	10,875	5,000	3,750	1,250	52,725
1993	0.1149	43,750	49,000	13,125	9,000	6,750	2,250	64,375
1994	0.1395	58,750	65,800	17,625	9,000	6,750	2,250	85,675
1995	0.1682	92,500	103,600	27,750	12,000	9,000	3,000	134,350
1996	0.1970	107,500	120,400	32,250	20,000	15,000	5,000	157,650
1997	0.2216	132,500	148,400	39,750	30,000	22,250	7,750	195,900

Table A15 continued.

Year	Maize price:		Rural price index (1977 = 100)	Real price (1997 = 1) (cedis)	Real change in cost (cedis/ha) dC	Proportional cost increase $i = I/P = (dC \cdot t)/(Yf \cdot P)$	Supply elasticity (E = 0.79)
	Average wholesale price (cedis/mt)	Farmgate price (70% of wholesale) (cedis/mt)					
1979			279				0.79
1980			448				0.79
1981			938				0.79
1982			1,150				0.79
1983	0	0	2,640	0		0.0000	0.79
1984	23,380	16,366	3,652	278,876	46,178	0.0019	0.79
1985	20,380	14,266	3,974	223,395	44,785	0.0035	0.79
1986	33,110	23,177	4,824	298,985	61,385	0.0047	0.79
1987	53,870	37,709	6,591	356,036	78,460	0.0076	0.79
1988	68,590	48,013	8,581	348,194	104,031	0.0137	0.79
1989	53,000	37,100	10,637	217,047	122,769	0.0325	0.79
1990	85,030	59,521	14,310	258,839	115,958	0.0335	0.79
1991	116,050	81,235	16,784	301,195	129,677	0.0421	0.79
1992	100,480	70,336	18,613	235,159	176,279	0.0948	0.79
1993	110,720	77,504	23,092	208,863	173,482	0.1337	0.79
1994	138,630	97,041	28,598	211,164	186,431	0.1725	0.79
1995	200,000	140,000	44,880	194,122	186,288	0.2261	0.79
1996	250,000	175,000	62,230	175,000	157,650	0.2485	0.79
1997	300,000	210,000	79,039	165,340	154,239	0.2895	0.79

Table A15 continued.

Year	Net shift in supply $k = (j/E) - i$	Demand elasticity ($e = -0.981$)	Change in quantity caused by research, dQ	Social gains from research $SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$	GGDP (all local cost) (cedis)	Proportional GGDP maize cost (cedis) (90% for 1979-83, 55% for 1984-96)
1979		0.981		0	389,380	350,442
1980		0.981		0	389,380	350,442
1981		0.981		0	519,173	467,256
1982		0.981		0	1,402,036	1,261,832
1983		0.981	0	0	1,030,870	927,783
1984	0.0082	0.981	2,055	1,307,554,723	9,918,988	5,455,443
1985	0.0105	0.981	1,821	927,495,195	36,387,694	20,013,232
1986	0.0161	0.981	3,929	2,674,725,832	65,949,829	36,272,406
1987	0.0236	0.981	6,164	4,989,130,832	80,393,569	44,216,463
1988	0.0278	0.981	7,304	5,776,092,252	98,738,058	54,305,932
1989	0.0194	0.981	6,078	3,001,605,119	187,897,196	103,343,458
1990	0.0341	0.981	8,234	4,834,211,445	201,386,259	110,762,442
1991	0.0462	0.981	18,847	12,841,042,255	278,083,542	152,945,948
1992	0.0195	0.981	6,233	3,335,029,962	427,815,898	235,298,744
1993	0.0118	0.981	4,953	2,357,871,674	450,923,659	248,008,012
1994	0.0041	0.981	1,682	810,726,281	699,105,294	384,507,912
1995	-0.0132	0.981	-5,955	-2,649,338,607	192,709,160	105,990,038
1996	0.0008	0.981	358	143,001,579	815,007,795	448,254,287
1997	-0.0090	0.981	-3,947	-1,494,063,460		

Table A15 continued.

Year	GGDP (foreign costs), Canadian \$	Exchange rate (CN\$:1US\$)	Exchange rate, cedis:1US\$	Exchange rate Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis) (90% for 1979-83, 55% for 1984-96)	Total GGDP maize cost (cedis)
1979	228,346	1.1714	2.75	2.35	536,069	482,462	832,904
1980	228,346	1.1692	2.75	2.35	537,078	483,370	833,812
1981	304,462	1.1989	2.75	2.29	698,366	628,529	1,095,785
1982	319,903	1.2337	2.75	2.23	713,085	641,777	1,903,609
1983	197,800	1.2324	8.83	7.16	1,417,214	1,275,492	2,203,275
1984	998,300	1.2951	35.99	27.79	27,742,118	15,258,165	20,713,608
1985	1,430,482	1.3655	54.37	39.82	56,957,383	31,326,561	51,339,792
1986	319,101	1.3895	89.2	64.20	20,484,929	11,266,711	47,539,117
1987	175,183	1.326	153.73	115.94	20,309,866	11,170,426	55,386,889
1988	2,023,483	1.2307	202.35	164.42	332,698,290	182,984,059	237,289,991
1989	365,767	1.184	270	228.04	83,409,704	45,875,337	149,218,795
1990	501,532	1.1668	326.33	279.68	140,268,202	77,147,511	187,909,953
1991	2,484,702	1.1457	367.83	321.05	797,720,116	438,746,064	591,692,012
1992	1,160,624	1.2087	437.09	361.62	419,704,761	230,837,618	466,136,362
1993	4,821,245	1.2901	649.06	503.11	2,425,608,309	1,334,084,570	1,582,092,583
1994	679,765	1.3656	956.71	700.58	476,228,744	261,925,809	646,433,721
1995	212,020	1.3724	1200.43	874.69	185,452,615	101,998,938	207,988,976
1996	55,996	1.3635	1637.23	1,200.76	67,237,500	36,980,625	485,234,912
1997	0				0		

Table A15 continued.

Year	NARP-CRI Cost (cedis)	NARP-CRI Maize (15% of NARP-CRI) (cedis)	SARI cost (cedis)	SARI maize (8%)	GGDP, SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)	Actual releases (80% of estimates) (cedis)
1979	0	0	0	0	832,904	0	0
1980	0	0	0	0	833,812	0	0
1981	0	0	0	0	1,095,785	0	0
1982	0	0	0	0	1,903,609	0	0
1983	0	0	0	0	2,203,275	0	0
1984	0	0	0	0	20,713,608	156,631,040	125,304,832
1985	0	0	0	0	51,339,792	195,788,800	156,631,040
1986	0	0	0	0	47,539,117	244,736,000	195,788,800
1987	0	0	0	0	55,386,889	305,920,000	244,736,000
1988	0	0	0	0	237,289,991	382,400,000	305,920,000
1989	0	0	0	0	149,218,795	853,829,000	683,063,200
1990	0	0	0	0	187,909,953	857,208,000	685,766,400
1991	0	0	0	0	591,692,012	1,997,101,000	1,597,680,800
1992	0	0	0	0	466,136,362	1,516,825,000	1,213,460,000
1993	0	0	0	0	1,582,092,583	2,435,152,000	1,948,121,600
1994	0	0	535,742,408	42,859,393	689,293,114	2,272,267,000	1,817,813,600
1995	1,361,979,250	204,296,888	597,144,000	47,771,520	460,057,384	2,455,425,000	1,964,340,000
1996	1,535,228,229	230,284,234	1,171,434,025	93,714,722	809,233,869	533,000,000	426,400,000
1997	1,927,478,424	289,121,764	1,353,509,000	108,280,720	397,402,484	829,000,000	663,200,000

Table A15 continued.

Year	MOFA Extension cost for maize at 30% (cedis)	SG 2000 (cedis)	80% of SG2000 (cedis)	Total extension (cedis)	Extension + Research (cedis)	Extension + Research (Real cost) (cedis)
1979	0	0	0	0	832,904	185,776,470
1980	0	0	0	0	833,812	115,821,715
1981	0	0	0	0	1,095,785	72,697,957
1982	0	0	0	0	1,903,609	103,010,082
1983	0	0	0	0	2,203,275	51,935,536
1984	37,591,450	0	0	37,591,450	58,305,058	993,516,909
1985	46,989,312	0	0	46,989,312	98,329,104	1,539,763,503
1986	58,736,640	0	0	58,736,640	106,275,757	1,370,966,078
1987	73,420,800	0	0	73,420,800	128,807,689	1,216,158,779
1988	91,776,000	20,789,424	16,631,539	108,407,539	345,697,531	2,507,022,180
1989	204,918,960	24,458,146	19,566,517	224,485,477	373,704,272	2,186,294,712
1990	205,729,920	28,774,290	23,019,432	228,749,352	416,659,305	1,811,929,318
1991	479,304,240	33,852,105	27,081,684	506,385,924	1,098,077,936	4,071,341,156
1992	364,038,000	39,826,006	31,860,805	395,898,805	862,035,167	2,882,095,764
1993	584,436,480	46,854,125	37,483,300	621,919,780	2,204,012,363	5,939,532,709
1994	545,344,080	55,122,500	44,098,000	589,442,080	1,278,735,194	2,782,561,406
1995	589,302,000	64,850,000	51,880,000	641,182,000	1,101,239,384	1,526,963,611
1996	127,920,000	84,305,000	67,444,000	195,364,000	1,004,597,869	1,004,597,869
1997	198,960,000	96,000,000	76,800,000	275,760,000	673,162,484	530,002,927

Table A16: Economic Rate of Return with Lower Projected Research Benefit

Year	Total quantity produced	Total area planted	National average production	Adoption rate (at K = 95%, Lag = 30 years)	Yield of Improved technology (t/ha)	Yield of Farmer technology (t/ha)	Change in yield (and 40% reduction) (t/ha)	Proportional increase	Proportional production increase
Unit	(t)	(ha)	(t/ha)	t	Yn	Yf = Ym	dY=Yn-Yf	dY/Yf	j = t x (dY/Yf)
Parameter	Q	A	Ym						
1979	308,600	313,900	0.98	0					0.0000
1980	354,000	319,900	1.11	0					0.0000
1981	334,200	315,500	1.06	0					0.0000
1982	264,300	276,300	0.96	0					0.0000
1983	140,800	279,800	0.50	0					0.0000
1984	574,000	723,600	0.79	0.02	2.88	1.73	0.69	0.3988	0.0080
1985	395,000	405,000	0.98	0.03	2.75	1.7	0.63	0.3706	0.0111
1986	559,100	472,100	1.18	0.04	2.93	1.74	0.714	0.4103	0.0164
1987	597,700	548,336	1.09	0.06	2.93	1.74	0.714	0.4103	0.0246
1988	600,000	500,000	1.20	0.08	2.93	1.74	0.714	0.4103	0.0328
1989	714,614	595,800	1.20	0.1	2.93	1.74	0.714	0.4103	0.0410
1990	552,549	464,784	1.19	0.13	2.93	1.74	0.714	0.4103	0.0533
1991	931,478	610,445	1.53	0.17	2.93	1.74	0.714	0.4103	0.0698
1992	730,617	606,783	1.20	0.22	2.93	1.74	0.714	0.4103	0.0903
1993	960,920	636,670	1.51	0.28	2.93	1.74	0.714	0.4103	0.1149
1994	939,908	629,401	1.49	0.34	2.93	1.74	0.714	0.4103	0.1395
1995	1,034,170	668,600	1.55	0.41	2.93	1.74	0.714	0.4103	0.1682
1996	1,007,610	664,950	1.52	0.48	2.93	1.74	0.714	0.4103	0.1970
1997	1,000,000	650,000	1.54	0.54	2.93	1.74	0.714	0.4103	0.2216

Table A16 continued.

		Change in fertilizer costs	Change in	Improved	Farmers	Change in	Change in total cost of
	Fertilizer prices	including application	row planting	seed	seed	seed cost	technology
	(comp. + S.A,	(cedis/ha)	cost	(cedis/ha)	(cedis/ha)	(cedis/ha)	(cedis/ha)
Year	cedis/ha)		(cedis/ha)				
	(Without subsidy)						dC
1979							
1980							
1981							
1982							
1983							
1984	2,665	2,985	800	400	300	100	3,884
1985	2,922	3,273	877	1,000	750	250	4,399
1986	4,318	4,836	1,295	1,000	750	250	6,382
1987	7,810	8,747	2,343	2,000	1,500	500	11,590
1988	12,675	14,196	3,803	2,000	1,500	500	18,499
1989	16,388	18,355	4,916	3,000	2,250	750	24,021
1990	18,250	20,440	5,475	3,000	2,250	750	26,665
1991	23,750	26,600	7,125	5,000	3,750	1,250	34,975
1992	36,250	40,600	10,875	5,000	3,750	1,250	52,725
1993	43,750	49,000	13,125	9,000	6,750	2,250	64,375
1994	58,750	65,800	17,625	9,000	6,750	2,250	85,675
1995	92,500	103,600	27,750	12,000	9,000	3,000	134,350
1996	107,500	120,400	32,250	20,000	15,000	5,000	157,650
1997	132,500	148,400	39,750	30,000	22,250	7,750	195,900

Table A16 continued.

	Product price:	Freight and marketing cost		Real			
Year	Export price (F.O.B) U.S. Gulf (\$/ton)	No.2 yellow maize (30% + 20% = 50% of export price) (\$/ton)	Value of maize (\$/ton)	Exchange rate (cedis:1 US\$)	Value of maize (cedis/ton)	Rural price index (1997 = 100)	Real price (Farmgate) (1997 = 1) cedis/ton
1979						279	
1980						448	
1981						938	
1982						1,150	
1983						2,640	
1984	139.1	69.55	208.65	611.07	127,500	3,652	1,931,604
1985	116.8	58.4	175.2	870.05	152,433	3,974	2,122,218
1986	88.7	44.35	133.05	1164.38	154,921	4,824	1,776,813
1987	75.6	37.8	113.4	1572.39	178,309	6,591	1,496,792
1988	107	53.5	160.5	1550.58	248,868	8,581	1,604,615
1989	111.3	55.65	166.95	1733.12	289,344	10,637	1,504,996
1990	109.7	54.85	164.55	1609.3	264,810	14,310	1,023,846
1991	107	53.5	160.5	1602.46	257,195	16,784	847,825
1992	105.1	52.55	157.65	1781.59	280,868	18,613	834,882
1993	101.9	50.95	152.85	2180.25	333,251	23,092	798,454
1994	107.5	53.75	161.25	2638.24	425,416	28,598	823,034
1995	123.7	61.85	185.55	1952.04	362,201	44,880	446,515
1996	165.1	82.55	247.65	2044.46	506,311	62,230	450,149
1997	117.1	58.55	175.65	2050.2	360,118	79,039	252,082

Table A16 continued.

Year	Real change in cost dC (cedis/mt)	Proportional cost increase		Net shift in supply		
Parameter		$i = I/P = (dC \cdot t)/(Yf \cdot P)$	Supply elasticity ($E = 0.79$)	$k = (j/E) - i$	Demand elasticity ($e = -0.981$)	Change in quantity caused by research $dQ = (Q \times e \times E \times k) / (e + E)$
1979			0.79		0.981	
1980			0.79		0.981	
1981			0.79		0.981	
1982			0.79		0.981	
1983			0.79		0.981	
1984	84,067	0.0000	0.79	0.0101	0.981	2,530.43
1985	87,497	0.0000	0.79	0.0140	0.981	2,426.22
1986	104,559	0.0001	0.79	0.0207	0.981	5,063.14
1987	138,989	0.0003	0.79	0.0309	0.981	8,081.59
1988	170,388	0.0005	0.79	0.0410	0.981	10,771.23
1989	178,489	0.0009	0.79	0.0510	0.981	15,956.33
1990	147,280	0.0019	0.79	0.0656	0.981	15,856.78
1991	164,704	0.0040	0.79	0.0843	0.981	34,350.38
1992	223,894	0.0080	0.79	0.1063	0.981	33,982.34
1993	220,342	0.0130	0.79	0.1325	0.981	55,701.21
1994	236,788	0.0203	0.79	0.1563	0.981	64,271.75
1995	236,606	0.0709	0.79	0.1421	0.981	64,292.15
1996	200,233	0.0966	0.79	0.1527	0.981	67,335.28
1997	195,900	0.2412	0.79	0.0393	0.981	17,202.73

Table A16 continued.

		Research costs:	Proportional GGDP	GGDP (foreign cost:	Exchange rate	Real
	Social gain from research	GGDP (all local costs),	maize cost (cedis)	Canadian \$	(CN\$:1US\$)	Exchange rate,
Year		cedis	(90% for 1979-83,			cedis:1US\$
	$SG = (k \cdot P \cdot Q) - 1/2 (k \cdot P \cdot dQ)$		55% for 1984-96)			
1979		389,380	350,442	228,346	1.1714	401.32
1980		389,380	350,442	228,346	1.1692	306.92
1981		519,173	467,256	304,462	1.1989	154.19
1982		1,402,036	1,261,832	319,903	1.2337	135.54
1983		1,030,870	927,783	197,800	1.2324	201.27
1984	11,144,907,262	9,918,988	5,455,443	998,300	1.2951	611.07
1985	11,730,231,816	36,387,694	20,013,232	1,430,482	1.3655	870.05
1986	20,465,056,973	65,949,829	36,272,406	319,101	1.3895	1164.38
1987	27,455,852,643	80,393,569	44,216,463	175,183	1.326	1572.39
1988	39,141,982,605	98,738,058	54,305,932	2,023,483	1.2307	1550.58
1989	54,264,381,552	187,897,196	103,343,458	365,767	1.184	1733.12
1990	36,567,519,046	201,386,259	110,762,442	501,532	1.1668	1609.3
1991	65,324,735,077	278,083,542	152,945,948	2,484,702	1.1457	1602.46
1992	63,325,898,817	427,815,898	235,298,744	1,160,624	1.2087	1781.59
1993	98,687,794,274	450,923,659	248,008,012	4,821,245	1.2901	2180.25
1994	116,748,672,838	699,105,294	384,507,912	679,765	1.3656	2638.24
1995	63,562,775,074	192,709,160	105,990,038	212,020	1.3724	1952.04
1996	66,951,845,061	815,007,795	448,254,287	55,996	1.3635	2044.46
1997	9,824,501,845			0		2050.2

Table A16 continued.

	Real							
Year	Exchange rate Cedis:CN\$	All costs (CN\$ to cedis)	Proportional foreign cost (cedis)	Total GGDP maize cost (cedis)	NARP-CRI Cost (cedis)	NARP-CRI Maize (15% of NARP-CRI) (cedis)	SARI cost (cedis)	SARI maize (8%)
			(90% for 1979-83, 55% for 1984-96)					
1979	342.60	78,231,020	70,407,918	70,758,360	0	0	0	0
1980	262.50	59,941,802	53,947,621	54,298,063	0	0	0	0
1981	128.61	39,156,723	35,241,051	35,708,307	0	0	0	0
1982	109.86	35,146,026	31,631,424	32,893,256	0	0	0	0
1983	163.32	32,303,802	29,073,422	30,001,205	0	0	0	0
1984	471.83	471,030,176	259,066,597	264,522,040	0	0	0	0
1985	637.17	911,454,313	501,299,872	521,313,104	0	0	0	0
1986	837.98	267,401,815	147,070,998	183,343,404	0	0	0	0
1987	1,185.81	207,734,538	114,253,996	158,470,459	0	0	0	0
1988	1,259.92	2,549,420,874	1,402,181,481	1,456,487,413	0	0	0	0
1989	1,463.78	535,403,803	294,472,092	397,815,550	0	0	0	0
1990	1,379.24	691,734,185	380,453,802	491,216,244	0	0	0	0
1991	1,398.67	3,475,286,346	1,911,407,490	2,064,353,439	0	0	0	0
1992	1,473.97	1,710,727,320	940,900,026	1,176,198,770	0	0	0	0
1993	1,689.99	8,147,833,045	4,481,308,175	4,729,316,187	0	0	0	0
1994	1,931.93	1,313,256,600	722,291,130	1,106,799,042	0	0	535,742,408	42,859,393
1995	1,422.35	301,567,707	165,862,239	271,852,277	1,361,979,250	204,296,888	597,144,000	47,771,520
1996	1,499.42	83,961,556	46,178,856	494,433,143	1,535,228,229	230,284,234	1,171,434,025	98,714,722
1997		0			1,927,478,424	289,121,764	1,353,509,000	108,280,720

Table A16 continued.

Year	GGDP ,SARI and NARP-CRI (cedis)	MOFA Extension estimates (cedis)	Actual releases (80% of estimates)	MOFA Extesion cost for maize at 30% (cedis)	SG 2000	80% of SG2000	Total extension (cedis)
1979	70,758,360	0	0	0	0	0	0
1980	54,298,063	0	0	0	0	0	0
1981	35,708,307	0	0	0	0	0	0
1982	32,893,256	0	0	0	0	0	0
1983	30,001,205	0	0	0	0	0	0
1984	264,522,040	156,631,040	125,304,832	37,591,450	0	0	37,591,450
1985	521,313,104	195,788,800	156,631,040	46,989,312	0	0	46,989,312
1986	183,343,404	244,736,000	195,788,800	58,736,640	0	0	58,736,640
1987	158,470,459	305,920,000	244,736,000	73,420,800	0	0	73,420,800
1988	1,456,487,413	382,400,000	305,920,000	91,776,000	20,789,424	16,631,539	108,407,539
1989	397,815,550	853,829,000	683,063,200	204,918,960	24,458,146	19,566,517	224,485,477
1990	491,216,244	857,208,000	685,766,400	205,729,920	28,774,290	23,019,432	228,749,352
1991	2,064,353,439	1,997,101,000	1,597,680,800	479,304,240	33,852,105	27,081,684	506,385,924
1992	1,176,198,770	1,516,825,000	1,213,460,000	364,038,000	39,826,006	31,860,805	395,898,805
1993	4,729,316,187	2,435,152,000	1,948,121,600	584,436,480	46,854,125	37,483,300	621,919,780
1994	1,149,658,435	2,272,267,000	1,817,813,600	545,344,080	55,122,500	44,098,000	589,442,080
1995	523,920,684	2,455,425,000	1,964,340,000	589,302,000	64,850,000	51,880,000	641,182,000
1996	818,432,100	533,000,000	426,400,000	127,920,000	84,305,000	67,444,000	195,364,000
1997	397,402,484	829,000,000	663,200,000	198,960,000	96,000,000	76,800,000	275,760,000

Table A16 continued.

	Extension + Research	Extension + Research (Real cost in cedis)	CIMMYT Costs (CN\$)	CIMMYT Costs (cedis)	CIMMYT Real Costs (cedis, 1997 = 1)	Extension , Research and CIMMYT real costs (in cedis)
Year						
1979	70,758,360	20,045,412,220	50,000	17,129,930	4,852,804,793	24,898,217,013
1980	54,298,063	9,579,608,548	50,000	13,125,214	2,315,633,427	11,895,241,975
1981	35,708,307	3,008,900,708	50,000	6,430,478	541,853,460	3,550,754,168
1982	32,893,256	2,260,739,187	50,000	5,493,232	377,547,429	2,638,286,616
1983	30,001,205	898,206,534	50,000	8,165,774	244,475,234	1,142,681,769
1984	302,113,490	6,538,540,012	50,000	23,591,615	510,585,329	7,049,125,341
1985	568,302,416	11,302,983,049	50,000	31,858,294	633,630,517	11,936,613,566
1986	242,080,044	3,966,369,118	50,000	41,899,244	686,499,663	4,652,868,781
1987	231,891,259	2,780,830,406	25,000	29,645,362	355,505,958	3,136,336,364
1988	1,564,894,952	14,414,139,625	25,000	31,497,928	290,125,246	14,704,264,871
1989	622,301,026	4,624,052,912	25,000	36,594,595	271,918,789	4,895,971,702
1990	719,965,596	3,976,615,007	25,000	34,481,059	190,450,625	4,167,065,632
1991	2,570,739,363	12,106,093,214	25,000	34,966,833	164,665,364	12,270,758,578
1992	1,572,097,575	6,675,819,064	25,000	36,849,301	156,478,370	6,832,297,434
1993	5,351,235,967	18,316,141,504	25,000	42,249,632	144,611,495	18,460,752,999
1994	1,739,100,515	4,806,516,735	25,000	48,298,184	133,486,263	4,940,002,998
1995	1,165,102,684	2,051,883,936	25,000	35,558,875	62,623,394	2,114,507,330
1996	1,013,796,100	1,287,633,455	25,000	37,485,515	47,610,761	1,335,244,216
1997	673,162,484	673,162,484	0	0	0	673,162,484

APPENDIX 17

Table A.17: Area Planted to Specific Improved Maize Varieties in the Ecological Zones of Ghana

Variety	Area (hectares)				
	Forest	Transition	Coastal Savanna	Guinea Savannah	Total
“Agric”	16.9	34.6	37.7	30.4	119.6
Obatanpa	14.5	29.7	32.3	26.2	102.6
Dobidi	5.8	11.9	13.1	10.3	41.1
Aburotia	3.2	6.6	7.2	6.0	23.0
Abelechi	2.9	6.0	6.6	5.3	20.8
La Posta	2.8	5.8	6.3	5.1	20.0
Okomasa	2.7	5.5	6.0	4.8	19
Golden Crystal	0.2	0.5	0.5	0.4	1.6
Dorke SR	0	0.1	0.1	0	0.2
All improved	49.0	100.5	109.6	88.7	347.8

Source: Author's computations based on the CRI/CIMMYT survey

APPENDIX 18

Table A18: Principal Month for Selling Maize in the Ecological Zones of Ghana

Month	Percent of farmers selling maize			
	Coastal Savannah	Forest	Transition	Guinea Savannah
January	6.0	7.5	9.5	9.5
February	3.6	6.9	4.8	7.1
March	8.3	11.6	6.3	4.8
April	3.6	10.1	0	10.7
May	8.3	7.4	4.8	1.2
June	1.2	3.7	9.5	2.4
July	2.4	4.8	4.8	0
August	7.1	6.3	11.1	2.4
September	10.7	16.0	23.8	2.4
October	14.3	19.8	30.2	4.8
November	15.5	31.2	47.6	10.7
December	16.7	30.2	34.9	9.5

Source: Author's computations based on the CRI/CIMMYT survey