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Ex Post Assessment of Investments in Cameroon's Cowpea and Sorghum Research-Extension Systems

presented by

James Arthur Sterns

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EX POST ASSESSMENT OF INVESTMENTS IN CAMEROON'S COWPEA AND SORGHUM RESEARCH-EXTENSION SYSTEMS

By

James Arthur Sterns

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ABSTRACT

EX POST ASSESSMENT OF INVESTMENTS IN CAMEROON'S COWPEA AND SORGHUM RESEARCH-EXTENSION SYSTEMS

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Throughout Africa, per capita food production has been declining since the early 1960s. Cameroon has sought to counter this trend by increasing agricultural productivity through research and extension. In order to establish future investment priorities, policy makers need to know if past agricultural research investments have earned sufficient returns to justify continued funding. To address this issue, data were collected in Cameroon and analyzed in order to estimate the benefits and costs of investments in sorghum and cowpea research and extension in northern Cameroon. Focusing on the period 1979 to 1987, the analysis addressed three questions: what were the returns to past investments, what factors explained the estimated returns, and how were the benefits distributed. Results include estimated internal rates of return of 15% for cowpea research and extension, and 1% for sorghum research and extension. The analysis also highlights the impact of institutions on the returns to investments and why similar investments in parallel research programs within the same research-extension system had different returns.

This thesis is dedicated to my parents, John and Harriett Sterns,

whose love I treasure.

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First in a long queue of friends and colleagues who deserve recognition for their support, care, and nurturing are Noah, Colin and Carol Evans with whom I have shared much random kindness and many senseless acts of beauty.

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And thanks to Jen, because she deserves it.

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KEY TO ACRONYMS

ARR	Average Rate of Return
CRSP	Collaborative Research Support Project
CCCE	*Caisse Centrale de Coopération Economique*
CFDT	*la Campagne Française pour le Développement des Fibres Textiles*
DEAPA	*Division des Enquêtes Agroéconomiques et de la Planification Agricole*
EEC	European Economic Community
FAC	*Fonds d'Aide et Coopération*
FAO	Food and Agricultural Organization, United Nations
fcfa	*franc de la Communauté Financière Africaine*
FONADER	*Fonds National de Développement Rural*
GDP	Gross Domestic Product
IARC	International Agricultural Research Center
ICRISAT	International Center for Research in Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IRA	*l'Institut de Recherches Agronomiques*
IRAT	*l'Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières*
IRCT	*l'Institut de Recherche sur le Coton et Fibres Textiles*
IRR	Internal Rate of Return
IMF	International Monetary Fund
MESIRES	*Ministère de l'Enseignement Supérieur, de l'Informatique et de la Recherche Scientifique*
MIDEVIV	*Mission de Développement des Cultures Vivrières, Maraîchères et Fruitiers*
MINAGRI	Ministry of Agriculture, Government of Cameroon
MRR	Marginal Rate of Return
NAETP	National Agriculture Extension and Training Project
NCRE	National Cereals Research and Extension Project
NCSM	North Cameroon Seed Multiplication Project
NEB	*Projet Nord-Est Benoue*
NGO	Non-Government Organization
ONAREST	*Office National de la Recherche Scientifique et Technique*
PCN	*Projet Centre-Nord*
PI	Principal Investigator
ROR	Rate of Return
SAFGRAD	Semi-Arid Food Grain Research and Development project
SEMRY	*le Société d'Expansion et de Modernisation de la Riziculture à Yagoua*
SODECOTON	*Société de Développement du Coton*
TLU	Testing-Liaison Unit
USAID	United States Agency for International Development

CHAPTER 1 INTRODUCTION

1.1 Problem Statement

Since the early 1960s, developing countries, assisted by foreign donors, have invested resources to strengthen their agricultural research systems. Agricultural economists have supported this strategy, arguing that technological innovations in agricultural production drive the development of the agricultural sector, which in turn contributes to the development of the general economy (Mellor, 1966; Eicher and Staatz, 1984). While several studies report a high rate of return to agricultural research in the US, Europe, Asia and Latin America, there is considerable debate as to whether these investments have netted positive returns in Sub-Saharan Africa (Oehmke, et al., 1991).

This quandary suggests that research is needed to address two critical issues. First, in today's world of limited resources and tight budgets, there is a need to determine if past investments in technology-generating agricultural research in Sub-Saharan Africa have generated sufficient returns to justify continued investments. Second, there exists a need to examine national experiences in implementing agricultural research in order to identify factors that explain the variability in the impact of these investments.

1.2 Objectives

Cameroon, like many other countries, has sought to increase agricultural productivity through research and extension of locally developed and/or screened technologies. The general objective of this study is to assess the impact of the development and extension of improved cowpea and sorghum technologies in northern Cameroon, and to describe factors that contributed to the observed impact.

The specific objectives of this study are to:

a. Describe the evolution of the research and extension system since its inception in order to provide a detailed background for the analysis;

b. Estimate the economic rates of return to sorghum and cowpea research and extension in northern Cameroon, using a benefit-cost approach;

c. Review the institutional factors, linkages, and characteristics associated with the research-extension system in order to determine how each interacted to complement and/or impede the performance of the cowpea and sorghum subsectors;

d. Discuss lessons learned from this study, focusing on how and why the returns to research and extension differed between commodities;

e. Provide project managers and researchers with guidelines as to data needed to more accurately monitor the impact of future agricultural research and extension projects.

1.3 Hypotheses

This study tests the hypothesis that investments in agricultural research and extension systems have positive returns. Specifically, it will determine if the internal rate of return (IRR) of investments in cowpea and sorghum research and extension in Cameroon is greater than zero.

Qualitative analysis complements the quantitative analysis by identifying the role of institutions and their influence on the productivity of agricultural research investments. The hypothesis to be tested is that the necessary institutions and inter-institutional linkages existed in northern Cameroon and that these institutions contributed to a positive IRR.

1.4 Organization of Thesis

The thesis is divided into six chapters. Chapter 2 outlines the analytical framework of the study, including general descriptions of Cameroon's economy, and the roles of its agricultural sector and agricultural research system. Chapter 3 briefly reviews the rate of return literature, and presents the research design and methodology. Chapter 4 reports results of the rate of return analysis. Chapter 5 identifies the institutional factors that have contributed to the rate of return. Chapter 6 summarizes the findings of the study and draws policy implications for institutionalizing impact assessment.

CHAPTER 2 THE PROBLEM SETTING

2.1 Overview of Cameroon

2.1.1 Social-Political Evolution

Cameroon is a west-central African country bordered by six countries: Nigeria, Chad, Central African Republic, Congo, Gabon, and Equatorial Guinea (Figure 2.1). Its northern provinces have witnessed the rise and fall of various Sudanic civilizations for the past 2,000 years, and its southern provinces are the possible origin of the Bantu tribes some 2,500 years ago (Mbuagbaw, et. al., 1987). The Portuguese, the first Europeans to visit the area, arrived in the late 1400s, but it was not until the late 1800s that the region as a whole was colonized by the Germans (although most activity was concentrated in the south). After World War I, France and Great Britain divided the territory and colonized their respective shares.

French Cameroon gained independence in 1960, and British Cameroon became independent in 1961. The two northern provinces of British Cameroon merged with Nigeria while the southern province merged with the former French colony to form the Federal Republic of Cameroon.

Today, the Republic of Cameroon is officially a bilingual country (French and English) governed by an unitary republic. The country is divided into ten administrative provinces, two of which were formerly under British rule while the remaining eight were under the French. The 1976 census estimated the population to be 7.66 million people, and the 1987 census estimate was 10.49 million, indicating an annual population growth rate of 2.9% (National Directorate of the 2nd General Population and Housing Census, 1990). The 1987 census estimated that roughly 80% of the population were living in the French-speaking provinces.

2.1.2 Monetary Policy and Trade Status

Cameroon's currency is the *franc de la Communauté Financière Africaine* (fcfa), exchanged at a fixed rate of 50 fcfa per French franc (1992). Economists familiar with the fcfa zone of West-Central Africa generally agree that Cameroon's currency is currently overvalued by about 40%[1]. Overvaluation reduces the competitiveness of the country's exports and underprices the real cost of imports.

Cameroon's principal trading partners are France, the United States, the Netherlands, Japan and Germany. Crude oil, coffee, cocoa, timber and cotton are the country's principal exports. Industrial equipment, semi-finished goods, food, drink, tobacco, and vehicles are the principal imports. Over the period 1980 to 1989, the market value of annual exports averaged $1.75 billion while the market value of annual imports averaged $1.34 billion.

The economy experienced a period of rapid growth and overspending in the late 1970s and early 1980s, fueled by the discovery of oil off Cameroon's coast. For example, real GDP growth reached 12.6% in 1980 and 13.3% in 1981. The general economy declined after 1986, primarily due to drastic falls in world prices for all of Cameroon's exports. Restructuring of the economy and rescheduling of the external debt began in 1987, but the government has not yet fully implemented IMF austerity measures (1991). Table 2.1 summarizes major macroeconomic indicators and trade figures for the past ten years.

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[1]Estimate based on interviews with personnel from the World Bank and USAID/Cameroon. Salinger and Stryker (1991) found similar over-valuation (50%) in other West African fcfa countries (Mali, Senegal, and Ivory Coast). According to these authors, estimates of overvaluation are calculated by either comparing purchasing power between trading partners, or by adjusting the exchange rate for unsustainable external imbalance of payments and trade distortions.

Table 2.1 Macroeconomic Indicators and Trade Figures for Cameroon, 1980 to 1989.

Macroeconomic Indicators	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
GDP, market prices[a], fcfa bn	1410	1796	2173	2618	3195	3992	4166	4022	3768	3560[b]
Real GDP growth[a], %	12.6	13.3	6.1	6.9	7.6	7.4	9.2	-2.8	-8.6	-6.0[b]
Consumer price inflation[b]	7.7	9.9	13.1	16.7	11.3	11.5	12.4	11.2	5.0	4.0[b]
Exports fob[a], US$ bn	1.40	1.53	1.46	1.72	1.99	2.34	2.00	1.71	1.64	1.70[b]
Imports cif[a], US$ bn	1.44	1.40	1.16	1.22	1.11	1.09	1.48	1.73	1.48	1.25[b]
Current account[a], US$ mn	-250.2	-447.5	-351.9	-372	-382	337	-601	-1171	-880	-320[b]
External debt service ratio, %	na	na	na	na	na	22.7	25.9	30.6	30.9	19.4
Crude oil prod., mn tons	na	na	na	5.75	7.00	9.16	8.86	8.35	8.30	8.00[b]
Coffee prod.[c], mn tons	na	na	na	64.0	114.5	101	133.7	116.0	153.0	na
Cocoa prod.[c], mn tons	na	na	na	108.9	120.5	119	127.0	130.0	123.0	115[b]
Cotton prod.[d], mn tons	80.3	84.5	79.8	72.4	94.6	97.4	115.5	122.8	113.7	165
Exchange rate, fcfa/US$	211.3	271.7	328.6	381.1	437	449.3	346.3	300.5	297.8	319.0

[a]) Years ending June 30. [b]) Estimates. [c]) Crop years begin October 1. [d]) Crop years begin April 1.
"Na" indicates that data not available; "bn" and "mn" indicate billion and million, respectively.

<u>Sources</u>: Economic Intelligence Unit, World Bank, IMF, & SODECOTON documents.

2.2 Cameroon's Agricultural Sector

2.2.1 Overview

Cameroon's agricultural sector is highly diverse, due in part to the wide range of ecological zones found within the country's borders. These zones, and their areas of crop production as a percentage of the national land base, include highlands (27%), savanna (22%), semi-arid plains (19%), equatorial rain forests (18%), and coastal lowlands (14%); as shown in Figure 2.2[2].

This study focuses on the northern region of the country, which ranges from a wooded, Guinea savanna in southern Adamaoua Province, to Sudanian and Sudan Sahalian savannas in northern Adamaoua Province, all of the North province and much of the Far North province, to the Sahel region of the Lake Chad area.

2.2.2 Northern Cropping Systems

The three northern provinces are generally subdivided by principal cropping systems and the underlying annual rainfall, which declines from south to north (Figure 2.3).

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[2]Estimated from data on shares (by province) of total land planted as reported in the 1984 Agricultural Census (National Directorate of the Agricultural Census, Yaoundé). The Southwest and Littoral Provinces were classified as coastal lowlands; the South, 60% of the East, and 50% of the Center were classified as rain forests; the West and Northwest were classified as equatorial highlands; 40% of the East, 50% of the Center, the Adamaoua, and the North were classified as savanna; and, the Far North was classified as semi-arid.

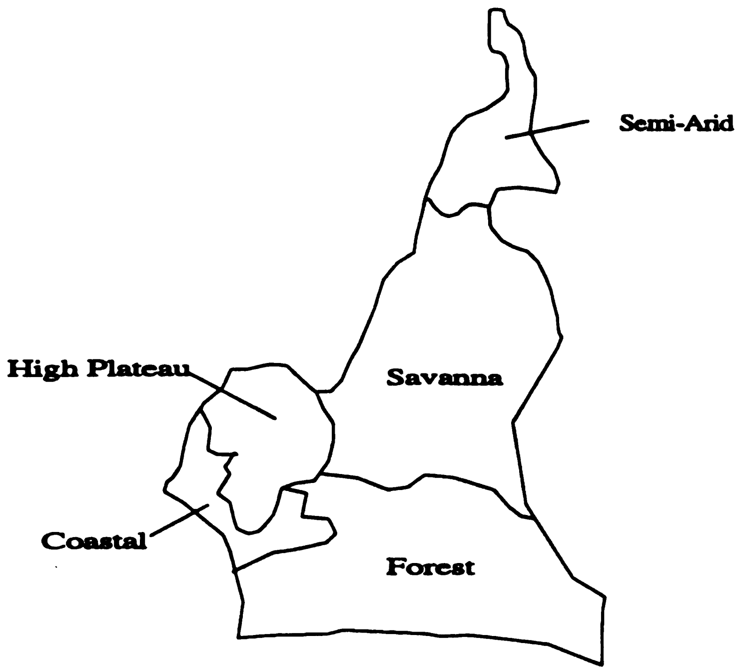

Figure 2.2 Agro-ecological zones.

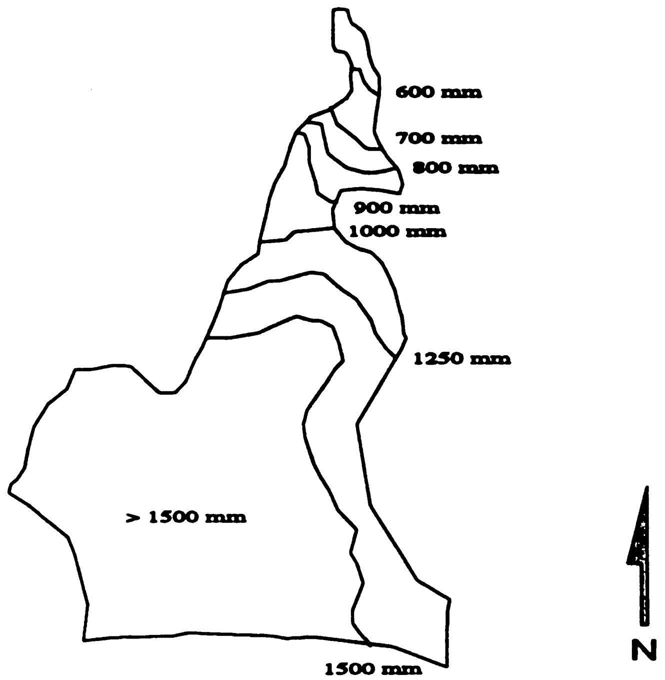

Figure 2.3 Rainfall isohyets.

Maize-Tuber Belt

Southern Adamaoua is a sparsely-populated area where maize is the principal cash crop, and maize and tubers are the principal sources of food. Although this area, with an annual average rainfall of 1750 mm, has great agronomic potential, tsetse fly has historically been a constraint to production.

Cotton-Maize Belt

Northern Adamaoua and nearly all of the North Province, with an average annual rainfall of 1100 mm, is best described as the cotton and maize belt. Cotton was first grown north of this zone, but northern Adamaoua now leads the country in cotton production, primarily because the cotton parastatal has shifted its efforts southward into areas of higher and less variable rainfall. Maize has traditionally been a garden/compound crop in this zone, but since the mid-1980s, maize has evolved into an important cash crop. This development has been partially due to the creation of MAISCAM, a private sector maize oil processing plant in NGaoundéré, the provincial capital of the Adamaoua Province.

Cotton-Sorghum Belt

The Center-North zone[3]--including the Mayo Louti Department of the North Province and the bulk of the Far North Province south of Waza--is the core of the cotton-sorghum belt. With an average annual rainfall of only 800 mm, this area is also plagued by erratic and uneven rainfall. Both low total annual rainfall and poor rainfall distribution constrain production and often lead to drought-like conditions during the growing season.

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[3]This area is referred to as the Center-North zone because of a World Bank rural development project by the same name that targeted this area over the period 1982 to 1987.

Cropping Patterns for the Cotton-Sorghum Belt

This case study focusses on the low rainfall Center-North zone where the principal cropping patterns are either a cotton-sorghum two-year rotation, or a cotton-sorghum-legume three-year rotation. Frequent variations within this general pattern include the intercropping of sorghum with legumes, particularly cowpea but also groundnut and bambara groundnut, the planting of a second crop of sorghum[4] late in the growing season, and the substitution of pearl millet for sorghum in the production cycle. In the Mandara Mountains, an area in the Far North Province but outside the Center-North zone, farmers practice a biennial crop rotation--planting sorghum one year and then intercropping pearl millet and a legume the next year. This rotation has evolved as a strategy for controlling weeds and pests, especially the parasitic weed striga (*Striga Hermonthica*).

2.2.3 Land in Crop Production

Two data sources report harvested area for Cameroon. First, the Ministry of Agriculture (MINAGRI) reported sorghum and cowpea production and area harvested in northern Cameroon for the period 1972/73 to 1989/90. These time series indicate large year-to-year fluctuations and no discernable trend (Appendix, Tables A.1 and A.2). Many key informants interviewed in Cameroon cautioned that these data were unreliable because MINAGRI has historically had limited resources for data collection and compilation.

Recognizing the need for more reliable data, the National Directorate of the Agricultural Census (DEAPA), with support from USAID, initiated a project in 1984

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[4]Second crop sorghum in northern Cameroon, commonly called "mouskwari", is seeded in small, often irrigated, garden plots and then transplanted to the field late in the growing season. It then matures on residual soil moisture.

with the explicit goal of estimating crop area and yields, based on farmer surveys and in-field measurements. Researchers and other in-country agriculturalists consider these data to be the best available. Yet, given the large year-to-year fluctuations in estimated harvested area and the short (six years) length of the time series, it is impossible to discern historic trends or to project future levels of production and land use from these data.

Grain Sorghum

Sorghum, and to a lesser degree pearl millet, are the traditional cereal grains of the region and the primary sources of calories. In an average year, sorghum comprises approximately 70% of total land harvested (Table 2.2). While MINAGRI and DEAPA estimates of area planted to sorghum differ considerably in a given year, both data series show that sorghum production is the most important food crop in the Far North Province. For example, over the 1984-1989 period, DEAPA reports[5], on average, an estimated 332,000 ha in sorghum (73% of cropped area) while MINAGRI reports an estimated 313,000 ha (54% of cropped area).

As reported in Table 2.2, two crops of sorghum are grown in northern Cameroon. Dry season sorghum (mouskwari) is planted on vertisols late in the growing season, maturing on residual soil moisture. Rainy season sorghum varieties are more heterogeneous relative to mouskwari, differing by a greater degree in stalk length, grain color (usually red or white) and length of growing cycle (short, medium, or long).

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[5]Census data estimates combined sorghum and millet data. Hence, to estimate the sorghum area, the reported data were multiplied by 0.9 to remove pearl millet and the adjusted data are reported. This factor is based on the judgments of key informants involved in agricultural research in northern Cameroon.

Farmers' preferences reflect this heterogeneity, with each farmer choosing varieties which have specific traits that he or she desires.

Table 2.2 Sorghum and Total Harvested Crop Hectares, Far North Province, Cameroon, 1984 to 1989.

	Grain Sorghum, (Ha)			All Crops	
Year	Rainy Season	Dry Season	Total	Total (Ha)	Sorghum share (%)
1984	135,902	119,502	255,404	383,983	66.5
1985	185,424	135,030	320,454	445,380	72.0
1986	178,777	201,531	380,308	511,352	74.4
1987	95,676	147,856	243,532	335,154	72.7
1988	161,138	224,056	385,194	511,299	75.3
1989	172,313	232,116	404,429	519,143	77.9
mean	155,000	177,000	332,000	451,000	73.1

Source: National Directorate of the Agricultural Census, Cameroon.

Although sorghum production dominates the agriculture sector in northern Cameroon, farmers face a host of constraints. Russell notes the following examples:

> poor and erratic rainfall, often disastrously distributed during the growing season; striga, which is increasing in importance as both soil fertility and the length of fallow period decrease; labor constraints at the time of sowing and weeding, which impede improvement in land preparation and weed control; and lack of credit for yield-enhancing inputs such as animal traction, fertilizer, and pesticides (1991, p. 8).

Other constraints include a variety of insects and endemic leaf diseases.

<u>Cowpea</u>

Cowpea, the second crop on which this study focuses, accounts for an estimated 5% of the harvested area. Like sorghum, cowpea is a traditional food crop in northern

Cameroon. In 1979, Perez, on an International Institute of Tropical Agriculture (IITA) plant exploration tour, collected 396 samples of cowpea while in Cameroon, noting "an impressive wide variability" in cowpea varieties grown by farmers.

Although a relatively minor crop in terms of hectares harvested, several studies (Ta'Ama, 1984; Wolfson, 1989; Kitch, 1990) have found that cowpea contributes significantly to household food security in northern Cameroon. First, because cowpea matures early, households are able to harvest leaves and green pods during the "hungry season" (late June through August) when grain reserves from the previous harvest are depleted and farmers have yet to harvest this year's crops. Second, cowpea is an important source of protein, especially for the rural poor. Singh and Rachie estimate that cowpea contains 23 to 30% protein, with variations in content due to varietal differences and environmental factors. Third, as a drought-tolerant crop that matures in 60 to 80 days on as little as 300 mm of rain, cowpea reduces farmers' exposure to risk. Finally, cowpea hay (leaves and stems) is used by limited-resource farmers to feed their livestock during the dry season and to earn cash through sales in local markets.

Time series data for area planted to cowpea are even less reliable than the sorghum estimates. As with sorghum, DEAPA data cover only a six-year period and MINAGRI estimates are considered unreliable. In addition, neither agency reports production figures specifically for cowpea. For example, DEAPA data classify cowpea in the general category of "beans"--which includes common beans, kidney beans, and cowpea. Similarly, the MINAGRI time series reports nine years of data for "*haricots doliques*", after which data are reported for "*haricots/niébé*"[6]. Finally, since cowpea is

[6]*Haricots doliques* is a French horticultural term referring to plants of the Dolichos species and/or Vigna species, which would include cowpea. *Haricot/niébé* translates to beans/cowpea.

generally intercropped, it is extremely difficult to accurately estimate yields, implying that even the DEAPA data is not entirely reliable.

Since cowpea is the only "bean" crop grown on a large scale in the Far North Province, this study assumes that 100% of the quantities reported for this province are for cowpea (Table 2.3 and Appendix A.2). The large amount of year-to-year variability reported in Table 2.3 may be attributable to weather, changes in farming practices, and/or human error in data collection and compilation. Yet, these best available data indicate an average annual harvested area (1984-1989) of 23,600 ha which accounted for, on average, 5.3% of the area harvested.

Table 2.3 Cowpea and Total Harvested Crop Hectares, Far North Province, Cameroon, 1984 to 1989.

Area Harvested (Ha)			Cowpea Share
Year	Cowpea	All Crops	(%)
1984	23,470	383,983	6.1
1985	30,232	445,380	6.8
1986	24,109	511,352	4.7
1987	16,744	335,154	5.0
1988	29,975	511,299	5.9
1989	16,998	519,143	3.3
mean	23,600	451,000	5.3

Source: National Directorate of the Agricultural Census, Cameroon.

2.2.4 Rainfall

In northern Cameroon, virtually all sorghum and cowpea production is rainfed. Rainfall distribution is monomodal, usually beginning in late May, peaking in August and ending in late October. However, there is a great deal of variability in this distribution, due to late and unpredictable onsets of the rainy season, and a highly erratic distribution of rainfall between localities. Russell notes that:

> Northern Cameroon has suffered from an extended drought episode, that is, a period in which droughty years are more frequent than usual. Farmers tend to think that the current drought episode, which has lasted more than a decade and a half, is due primarily to decreasing rainfall. Nicholson (1986) cites several factors that may have contributed to drought, including overgrazing, overcultivation, and removal of vegetation, but concludes that the fundamental cause of the current drought is meteorological (1991, p. 2).

In setting the research agenda, agricultural scientists working in northern Cameroon have sought to take into account rainfall patterns. Any evaluation of the research system needs to include some measure of the effects of rainfall on the general state of the agricultural sector of northern Cameroon, and of how rainfall influenced research agendas, the selection of technologies for extension, and ultimately, the returns to research and extension efforts.

2.3 Agricultural Research in northern Cameroon

2.3.1 Overview

A detailed history of the agricultural development efforts of northern Cameroon is presented in Chapter 5, including a more expansive description of the research system. The following discussion presents a brief overview of both the Maroua research center, and the research specific to cowpea and sorghum.

In 1974, the government "nationalized" the research system, creating the *Office National de la Recherche Scientifique et Technique* (ONAREST) as a national umbrella organization for agricultural research throughout the country. Since 1974, the government has restructured its research system several times. Currently (1991), agronomic research is conducted by the *Institut de Recherche Agronomique* (IRA) within the *Ministère de l'Enseignement Supérieur, de l'Informatique et de la Recherche Scientifique* (MESIRES).

While the current agricultural research system is organized along major ecological zones, with one research center per zone, budgeting and staffing for these centers are organized on a commodity basis. At the Maroua center, research units[7] have been established to address production constraints for the principal cash and food crops of northern Cameroon--cotton, sorghum, millet, rice, peanuts and cowpea.

2.3.2 Sorghum and Cowpea Research

The sorghum and cowpea units primarily screen varieties and test various agronomic and post-harvest technologies. Sources of plant material for screening include both promising local farmers' varieties and exotic varieties. Introduced varieties are distributed regionally for multi-locational evaluation by the International Institute for Tropical Agriculture (IITA), the International Center for Research in Semi-Arid Tropics (ICRISAT), the Semi-Arid Food Grain Research and Development project (SAFGRAD), and the Bean/Cowpea Collaborative Support Project (CRSP). Although a sorghum breeding program was initiated in 1982, none of the developed hybrids were released to farmers and the breeding program was significantly scaled down after 1988. Cowpea research initially focused on screening local and introduced cultivars. In 1987, this research agenda shifted to identifying improved post-harvest storage technologies

[7]Maroua currently has research units for cotton breeding, cotton entomology, sorghum and pearl millet breeding, sorghum and pearl millet agronomy, cowpea agronomy, peanut breeding and agronomy, rice agronomy, farming systems research and extension, and soil science (1991).

and to establishing a breeding program to develop high-yielding cowpea varieties with tolerance to the storage pest bruchids (*Callosobruchus maculatus*).

2.3.3 Staffing and Financing

Historically, a combination of expatriate and host country nationals have staffed the research system. Initially, senior research staff were expatriates, employed by *l'Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières* (IRAT), *l'Institut de Recherche sur le Coton et Fibres Textiles* (IRCT), or donor projects while mid-level staff and hourly workers were Cameroonian. Today, Cameroonians hold many of the senior staff positions due, in part, to resources provided by USAID to train nationals in the U.S. at the masters and doctorate level. Since the mid-1960s, increased state and donor funding and training opportunities have enabled the Maroua center to expand its scientific staff (Table 2.4)[8] and broaden its disciplinary mix.

Table 2.4 Number of Senior Researchers, IRA Research Center, Maroua, Cameroon, Selected Years.

Year	Expatriate	Cameroonian	Total
1967	4	0	4
1977	6	3	9
1981	7	4	11
1987	15	15	30
1991	7	19	26

Source: Various IRAT and IRA documents.

[8]The totals reported in Table 2.6 include researchers directly employed by IRA and those affiliated with IRA through donor projects.

The research system has been funded jointly by the Cameroonian government and donor projects. In recent years, the Cameroonian government has paid basic operating costs (e.g., electricity, fuel, water), some capital improvements, and salaries for Cameroonian researchers. Donor projects have usually financed equipment, vehicles, capital improvements, staff training, and the salaries of expatriate staff.

Typically, donors have given priority to specific commodities. The French, through the *Caisse Centrale de Coopération Economique* (CCCE) and the *Fonds d'Aide et Coopération* (FAC) have supported most of the cotton research. SAFGRAD, the European Economic Community (EEC) Development Fund, the World Bank, and various national governments have funded food crop research. The United States, a major supporter of food crop research, has provided (1979 to 1994) $46.7 million through the National Cereals Research and Extension Project (NCRE), plus an additional $1.97 million (1981-1992) through the Bean/Cowpea CRSP[9].

2.4 Agricultural Extension

In northern Cameroon, extension-type activities are implemented by the farming systems research team at IRA-Maroua, by MINAGRI's extension service, and by the internal extension system of the regional cotton parastatal, *la Société de Développement du Coton* (SODECOTON).

2.4.1 IRA's Farming System Research Efforts

Since 1979, the research system in northern Cameroon has embraced an on-farm testing approach as a means of linking research to extension. The Center's pre-extension

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[9]The NCRE program supports research throughout Cameroon, whereas the CRSP research is conducted only through the Maroua center.

program was first organized under a SAFGRAD project (Joint Project No. 31). In 1986, on-farm testing was institutionalized into the national agricultural research system when the NCRE created the Testing and Liaison Units (TLU's) at four of IRA's research stations, including the Maroua Center.[10]

2.4.2 MINAGRI's Extension Efforts

The Ministry of Agriculture supports a structured extension program, staffed by Cameroonian civil servants. The various facets of extension, including farmer groups, demonstration plots, credit programs, market outlets, and data gathering, have been implemented with varying degrees of success. Most key informants within the research and extension complex reported that these efforts have had a negligible impact, due to financial and logistic constraints within MINAGRI.[11]

In 1990, the World Bank funded the "National Agricultural Extension and Training Project" to supplement MINAGRI's extension program throughout Cameroon. In northern Cameroon, this project, based on the World Bank's Training and Visitation (T&V) model, targets the extension areas where SODECOTON is not present.

2.4.3 SODECOTON Extension Efforts

Since its creation forty years ago, SODECOTON has invested heavily in both training farmers to use improved farming techniques and technologies, and training a large corps of village level extension agents ("*moniteurs*"). In the mid-1980s, SODECOTON employed over 1,000 agents, although by 1990 this number had fallen to

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[10]In the early 1980s, a prototype TLU was established at the Bambui Research Center in the Northwest Province, operating for several years before other TLUs were created.

[11]Based on personal interviews with USAID contractors, IRA researchers and SODECOTON personnel.

about 500 due to internal restructuring and financial constraints. Originally, SODECOTON's extension efforts targeted only cotton, but in the mid-1970s the parastatal expanded its focus to include some food crops (primarily groundnut as an additional source of vegetable oil). Beginning in 1982, with the creation of the World Bank-funded *Projet Centre-Nord* (PCN), SODECOTON's food crop extension activities expanded rapidly.

The 1984 Agricultural Census data reported that 87,200 of the 268,500 farms in the Far North Province planted cotton, indicating that thirty-two percent of the Province's farmers were exposed to SODECOTON's extension efforts. Parastatal reports indicate that the number of farmers growing cotton rose from 88,315 in 1986/87 to 91,425 farmers in 1987/88. Since SODECOTON makes no effort to estimate the total number of farmers (cotton plus non-cotton) in their extension zone, it is difficult to use SODECOTON data to accurately estimate the percentage of farmers in this zone who are exposed to SODECOTON's extension system.

Data on the current number of farmers growing cotton may underestimate SODECOTON's effect on agriculture since the number of farmers who once grew cotton, but now do not, is unknown. Farmers may drop out of SODECOTON'S program for a variety of reasons, including SODECOTON's dissatisfaction with the farmer's performance, the farmer's dissatisfaction with the program, and logistical constraints such as inputs being unavailable when needed. At a minimum, more than one-third of all farms in any given year have had some exposure to SODECOTON's extension system--either as a current or former cotton farmer or as a relative or neighbor of someone growing cotton. Most likely, over fifty percent of all farmers in the Far North Province have been influenced by SODECOTON's extension system.

For farmers affiliated with SODECOTON, the extension program has effectively organized farmers into groups and has provided access to short-term credit, advice from technicians, market outlets, and equipment, seed and chemicals.

Part of the success of SODECOTON's extension system lies in its close linkages to IRA, which were strengthened considerably by the PCN. As IRA generated appropriate cotton and food crop technology, SODECOTON was readily available to extend them through its extension network, provide feedback on their performance, and suggest topics for future research. These relationships are discussed in detail in Chapter 5.

CHAPTER 3 LITERATURE REVIEW AND METHODOLOGY

This chapter is divided into four sections. The first section reviews the technology assessment literature. The second discusses the benefit-cost approach to impact assessment, focusing on its application to cowpea and sorghum research in northern Cameroon. The third describes the methods used in this study to analyze the role and impact of institutions supporting cowpea and sorghum research. The fourth summarizes how data were collected for this study.

3.1 Review of Literature

3.1.1 Introduction

Since the 1950s, agricultural economists have sought to assess the impact of agricultural research. T. W. Schultz (1953) and Z. Griliches (1958) report two of the earliest efforts to determine the economic returns to public investments in agricultural research. As Griliches noted, "expenditures on 'research and development' have grown very rapidly in the last decade. Quantitatively, however, we know very little about the results of these investments. We have some idea of how much we have spent but very little of what we got in return (ibid, p. 419)." Thirty-five years later, the questions related to assessing research investments are more focused and the methodologies employed to estimate economic returns are more refined. Yet, the ability to quantify the benefits of agricultural research is still limited by fundamental assumptions that, at times, are little more than "educated guesses".

Anderson and Herdt noted two broad perspectives in assessing the impact of a given research activity. "The first is more concerned with the mechanisms and process of research. Observers with this perspective are interested primarily in what the direct products of research have been (1990, p. 36)." In this case, the actual technologies (eg., new varieties, new agro-chemicals) that are developed are considered the "impact" of research. The second category is the more interesting, but paradoxically the more complex issue of how those technologies affect the clientele of research. Issues relevant to this line of inquiry include how a technology changed what is done on the farm, and its impact on household nutrition and rural income. To address this second level of inquiry, more comprehensive analytic approaches have been developed.

3.1.2 Methodologies

Researchers employ a wide range of approaches to assess impact. At one end of the spectrum are those who limit their analysis to qualitative check lists (Jahnke, 1987; Jaeger, 1987; Busch, 1989). These approaches attempt to describe how products of a research and/or extension system have influenced macro-economic and social indicators. This methodology uses "informed" descriptives to assess project implementation and may attempt to identify research outputs. Evaluation is limited to speculative linkages of the relationship between research outputs and changes at the aggregate level (eg., changes in GDP, employment rates, household incomes and diet, infant mortalities). At the other end of the spectrum are those who employ detailed, quantitative econometric models to calculate elasticities, supply and production functions, and the marginal rates of return on investments (Griliches, 1964; Evenson et al., 1979; Lu et al., 1978).

Within this qualitative-to-quantitative continuum, there are a variety of methods for describing and quantifying research and extension impact. For example, Evenson specifies six "evaluation types", differentiated by whether or not economic values are assigned to research outputs, and the type of statistical methodology applied in the analysis. His six evaluation types are managerial, technical, invention studies (non-statistical), invention studies (statistical), meta-studies (statistical), and studies on economic consequence (1990, p.4).

Most published impact assessments attempt to quantify benefits as economic or financial returns to "investments" in agricultural research. Echeverría (1990) groups these methods into two general classes, the economic surplus approach (consumer-producer surplus, benefit-cost, and index number methods) and the econometric approach (production, profit, and supply functions and their derivations). The former "estimates returns on investment (generally an average rate of return) by measuring the change in consumer and producer surplus from a shift to the right in the supply curve due to technological change (ibid, p. 2)."[12] The latter "treats research as a variable and allows a marginal rate of return on investment to be calculated (ibid, p. 2)."[13]

Economists employ several different measures of profitability when evaluating an investment's return. The internal rate of return (IRR) is one such measure, as defined below:

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[12] Examples include Akino and Hayami's (1975) estimate of the returns to rice research in Japan, and Enamul Haque et al.'s (1989) estimate on the returns to broiler chicken research.

[13] Examples include Thirtle and Bottomley's (1988) study of public investments in research and Nagy's (1978) assessment of rapeseed research in Canada.

Internal ROR — The interest rate that equates the net present value of cash flows to zero, as calculated by the equation:

$$\sum_{t=1}^{n} \frac{B_t - C_t}{(1 + r)^t} = 0 \qquad (3.1)$$

where "B" and "C" are the values of the benefit and cost streams and "r" is the IRR, the interest rate that solves the equality. There are "t" = 1 to "n" time periods in the analysis.

An IRR of zero indicates a return sufficient to cover the initial investment, but no more. The IRR must be equal to or greater than the target rate of return (the opportunity cost of capital) in order for the investment to be considered "profitable".

Economists make further distinctions when measuring profitability, two pairs of which are listed below. The first pair accounts for the difference between real and nominal valuation. The second addresses the question of which investments are being analyzed--total or marginal.

1. Financial ROR — An IRR where the benefits and the costs are in terms of market prices and domestic currency, unadjusted for shadow exchange rates or inflation.

   Economic ROR — An IRR where the benefits and costs are valued in terms of their opportunity costs, reflecting such factors as scarcity values and shadow exchange rates.

2. Average ROR — An ROR where the returns to the sum of total project expenditures are calculated.

   Marginal ROR — An ROR where only the rate of return to the last, "marginal" dollar invested is calculated.

Early impact studies focused on *ex post* assessments. In recent years, economists have extended the *ex post* methods to develop *ex ante* methodologies to compare the returns to alternative research strategies. For example, Contant and Bottomley (1989) include a benefit-cost analysis as one of several methods proposed for setting priorities in agricultural research. Similarly, the World Bank (Gittinger, 1982) regularly calculates an expected rate of return for proposed projects. Applications of *ex ante* analysis to specific research projects include de Frahan's (1990) estimates for farming systems research in Mali, and Seré and Jarvis' (1990) analysis of expected returns to pasture research in Latin America.

Several economists have recently refined impact assessment methodology to incorporate effects previously ignored. Evenson (1989, p 447) incorporates "spillin and spillout" effects into his analysis. Prady and Wood (1991, p. 10) modify Evenson's approach by first differentiating research programs along "their technology foci" and then look at their spillover effects. Horton (1990, p. 52) identifies two types of impact, production and institutional, noting that most of the literature to date has ignored the institutional factors. Capalbo and Antle (1989, p. 458) incorporated social costs (eg., pollution, soil erosion) in the calculation of the returns to research. While these advances represent empirical improvements, they make the analysis increasingly more complex and more dependent on the availability of extensive amounts of data.

3.1.3 An Underlying Assumption

All of these methods assume the existence of a reliable data base. Generally, there is a positive correlation between data detail and quality, and the degree of methodological sophistication. The more statistically advanced the model, the greater the data needs (and potentially the greater the cost to collect these data). Out of concern about the costs of ROR studies, Anderson and Herdt (1990, p. 42) have tried to estimate the impact of an impact assessment study. Although their results were inconclusive, their efforts reflect the need to justify impact assessment, given its potential high costs. On the other hand, Little and Mirrlees (1990) quite strongly advocate the need for and benefits from benefit-cost analysis. Furthermore, there are theoretical tradeoffs between alternative methods for assessing impact. Impact studies which quantify and value the returns to research generate either an average or a marginal rate of return. With an average rate of return, the "benefits can only be calculated for the total investment, rather than small increases in the research budget. Thus, policy makers can only use the ARR technique to estimate the return to an entire project expenditure--not how much to increase research spending (Oehmke, et al., p. 6)", or how to allocate among projects. In theory, studies that generate a marginal rate of return help determine the optimal allocation of funds for the research project. However, marginal RORs require highly accurate and detailed time-series data on inputs, outputs and research expenditures.

For a project that is already completed or is going through a final evaluation phase, an ARR approach is generally regarded as appropriate. On the other hand, managers of on-going research activities who regularly allocate capital (financial and human) will generally find the MRR approach more informative. Ultimately, for the practitioner, data availability usually dictates the methodology employed when assessing the impact of a given project.

3.2 Benefit-Cost Approach

3.2.1 Overview

The results of benefit-cost analysis are reported as benefit-cost ratios, net present values, or internal rates of return. All of these measures use the same underlying data base, comprised of two discounted time series--the benefit stream and the cost stream. The benefit (cost) stream is a time series of benefits (costs), valued in some currency.

Because of the time-value of money, these streams are discounted, usually based on assumptions about the opportunity costs of capital.

3.2.2 Advantages of Benefit-Cost Analysis

Choosing a method for assessing impact depends on several key factors. These include the availability of data, the objectives of the assessment exercise, and the timing of the study.

Data availability in northern Cameroon is discussed in detail in the fourth section of this chapter. Available data were sufficient for some but not all forms of quantitative analysis. Data could be organized into benefit and cost streams, but data were not sufficient to accurately estimate demand and supply curves (and elasticities) for the cowpea and sorghum subsectors. Without estimates of elasticities, some types of econometric analysis were impossible, thus eliminating some types of quantitative analyses from consideration (eg., index number approach).

All relevant expenditures for this study have occurred in the past. The analytic objective is limited to estimating the average rate of return over the sum of these historical expenditures. Since the marginal rate of return to incremental increases in past or present expenditures was not an objective of the study[14], benefit-cost analysis, which generates an ARR, satisfies this study's needs.

Thus, this study calculates benefit and cost streams for cowpea and sorghum research and extension in northern Cameroon, which are used to calculate an internal rate of return for the historical investments made in research and extension (Chapter 4).

[14]Karanja (1992) provides an example of calculating an MRR using historic data on maize research in Kenya.

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3.2.3 Potential Disadvantages of Benefit-Cost Analysis

Two factors potentially limit the validity and reliability of the benefit-cost approach for assessing impact. First, it uses several simplifying assumptions about prices, slopes of the demand and supply curves, and the extension of benefits into the future. Second, since the results are usually aggregated, distributional issues are typically not evaluated.

With the benefit-cost approach, prices are usually held constant when quantifying the benefits of an improved technology. This suggests that supply is perfectly inelastic and demand is perfectly elastic. This assumption implies that supply can be increased without lowering prices or flooding the market with overproduction. For relatively small increases in total supply, as was the case for the technologies extended in northern Cameroon, this assumption is reasonable.

The second set of assumptions concerns the extension of the benefit stream into the future. Although discounting effectively negates benefits in the distant future (greater than 20 years), benefits in the immediate future must be projected. Thus, assumptions regarding the lifetime of the technology and the degree of adoption (the adoption ceiling) are required. As Evenson notes, "for most imputation-accounting studies the analyst must make some assumptions regarding the continuation of the benefit stream beyond the period of analysis (1991, p. 12)." The alternative is to assume all benefits stop as of today, which clearly underestimates total benefits. Hence, well-informed assumptions about the short-term future are the preferred alternative[15].

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[15]Extending benefit streams into the future is not unique to benefit-cost analysis. This is an issue for nearly all assessment methods.

Evenson (1991) notes an additional disadvantage to the benefit-cost approach. In general, both consumers (due to decreased prices) and producers (due to increased yields) benefit from a yield-enhancing technology. The benefit-cost approach determines total net gains, but it generally does not determine how these gains are distributed among the various segments of society. Hence, in evaluating the gains from cowpea and sorghum research, qualitative statements about their distribution are subjective. This limits critical aspects of impact assessment since tradeoffs between such groups as rural producers and urban consumers, and men and women in households are not fully identified. To partially address this problem, this study combines the benefit-cost approach with an institutional analysis that employs qualitative evaluation techniques to assess how improved technologies affect different segments of northern Cameroon society.

3.3 An Approach to Institutional Analysis

3.3.1 Overview

Schmid broadly defines "institutions" as "sets of ordered relationships among people that define their rights, their exposure to the rights of others, their privileges, and their responsibilities (1987, p. 6)." In Cameroon, important institutions that affected the productivity of research included the government's system of research and extension (i.e., IRA, MINAGRI), input suppliers like the NCSM Project and SODECOTON, output markets, donor projects, and the government's policies towards food crop marketing (*de facto laissez-faire*).

In the context of impact assessment, institutional analysis examines how institutions affect the benefit and cost streams. Institutional analysis is generally done by comparing a system's performance with and then without a given institution. A specific case of this is "before/after" analysis which compares a system's performance before a given set of institutional arrangements were created to the system's performance once this set is operative.

3.3.2 The Contribution of Institutional Analysis

Institutional analysis can help identify factors that contributed to the productivity and "success" of a new technology. Quantitative analyses (eg., IRR calculations) simply estimate the financial and/or economic returns to investments. Policy decisions based solely on quantitative results are limited to choices between alternative investments with high, low, or negative returns. Qualitative analyses (eg., institutional analyses) seek to explain *why* an investment had high, low, or negative returns. With these insights, the policy choice set is greatly expanded to include policies that alter the potential returns of investments. For example, an investment which historically has had low returns still may be investment-worthy, if institutional constraints that caused the low returns are altered by policy changes.

Qualitative analyses may also help to explain *how* returns are distributed. For example, investments with high returns that benefit only a small group may be valued differently from investments with high returns that benefit a much broader constituency. Hence, analysis to identify the beneficiaries of the research and extension system of northern Cameroon is an important complement to calculating the net benefits of the system.

This study first identifies key institutions of northern Cameroon and describes their histories. The evolution of the research and extension system is then synthesized, in part, with a detailed time-line of the development of the key institutions. Qualitative comparing a system's performance with and then without a given institution. A specific case of this is "before/after" analysis which compares a system's performance before a given set of institutional arrangements were created to the system's performance once this set is operative.

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This study first identifies key institutions of northern Cameroon and describes their histories. The evolution of the research and extension system is then synthesized, in part, with a detailed time-line of the development of the key institutions. Qualitative descriptive data on the system are based on interviews with key informants and syntheses of project documents. The focus of the analysis is to evaluate the linkages between each component of the system and how these linkages affected the system's performance. This analysis is detailed in Chapter 5.

3.4 Data Collection

Impact assessment literature seldom discusses data constraints, which is a critical failing since available data usually determine the assessment methodology employed. The following details this study's data collection process, including a description of the available data, how they were compiled and their reliability.

3.4.1 Data Availability

This study used the "rapid appraisal" methodology recommended by Holtzman (1986). The approach, which relies heavily on existing documents and oral histories provided by system participants, was used since primary data collection, based on long-term monitoring of the system and formal surveying of sector participants, was beyond the scope of this study. Data for the research and extension system of northern Cameroon were obtained primarily from project reports (usually annual) and research summaries. When these sources failed to provide sufficient detail for the needs of the analysis, "key informants"[16] were interviewed.

Documents detailing research activities and resources employed were available from the research libraries of the IRA-Maroua research center, EEC-Garoua's and USAID-Yaoundé's reference rooms, and from the personal libraries of researchers and

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[16]Key informants were individuals within the research and extension system and the cowpea and sorghum subsectors (eg., plant breeders, extension agents, farmers, grain merchants) who were knowledgeable about the data in question.

administrators of SODECOTON, MINAGRI, IRA, and the NCRE project. The data needs spanned thirteen years of research and extension efforts (1979 to 1991) that were associated with the work of five large development projects[17]. Considerable effort was required to find copies of all relevant documents, since some were over ten years old. Also, since annual reports and research summaries constituted the bulk of available documents, interviews with key informants were necessary to meet information gaps.

In an attempt to identify all available data, the interview process, when possible, was iterative. During the initial interview, key informants in the research and extension system were provided an overview of the study and data needs, and documents from the interviewee's personal library were solicited. After reviewing these documents, a follow-up interview was conducted as the documents were being returned.

Plant breeders and agronomists provided information about the local farming systems and technologies that had been developed and extended. Administrators provided much of the institutional history, as well as data on research costs. Extension and input delivery personnel provided information on costs, rates of adoption, and institutional linkages within and outside the SODECOTON system. Farmers, grain merchants, and village extension workers were interviewed to confirm the opinions of research and extension personnel.

3.4.2 Data Base Compilation

As stated above, sufficient data were available for calculating the benefit and cost streams necessary for ROR analysis. However, the available data had not been collected and organized specifically for this type of study. Thus, this "secondary data" had to be

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[17]The projects were SAFGRAD's Joint Project No. 31, the World Bank's *Projet Centre-Nord*, and USAID's NCRE project, Bean/Cowpea CRSP, and NCSM Project.

sorted and compiled into data sets appropriate for analysis. These sets included time series data on: (1) general economic parameters such as the inflation rate, exchange rates, and interest rates, (2) the benefits of the research-extension system, and (3) the costs of creating and maintaining this system.

For example, estimating the benefit streams required a broad range of data, including information on land in production, prices, adoption rates, and yield gains and changes in input mixes resulting from the adoption of extended technologies. These data were compiled from project reports, Agricultural Census reports, and interviews with key informants. Similarly, estimating the cost streams required detailed time series of expenditures. Since these series were not always available, proxies and estimates of costs had to be compiled from project documents and key informant interviews. The entire process is detailed in Chapter 4.

3.4.3 Data Reliability

Although information gathered during interviews with key informants is critical to this study, the analysis relies heavily on secondary data. For example, the benefit streams include estimates of land in production of various crops, which are based on census estimates, extrapolated from a sample of farmers' fields judged to be "representative" of all farms in the Far North Province. Sampling and aggregation errors for this methodology are likely, given the limited resources for survey work in northern Cameroon. Other components of the benefit and cost streams that represent "best estimates" include the commodity and input price data, the adoption rates, and extension costs. Thus, given the heavy reliance on secondary data, the integrity of this study's results depends, in part, on the reliability of this secondary data. The specific limitations of the data sets and the assumptions made to correct for their limitations are included in Chapter 4.

CHAPTER 4 RATE OF RETURN ANALYSIS

This chapter is divided into two major sections, one for each of the commodities studied. Each section (1) specifies the cost and benefit streams, (2) describes the components which comprise each stream, (3) presents the underlying data, their sources and their limitations, (4) specifies the assumptions made in interpreting these data, and finally, (5) reviews critical parameters of the analysis, applying sensitivity analysis to examine the effects of modifying their estimated values.

4.1 General Approach

The cost streams represent estimates of annual research and extension expenditures by donor projects and host country programs. The benefit streams are estimates of the annual dollar value of project benefits--calculated as the market value of gross benefits, minus the value of additional on-farm costs of using the technologies. Gross benefits are calculated as the product of gains in yield from the improved technologies, adoption rates, and land in production.

Data for the benefit-cost analysis are presented in nominal US dollars, having been converted from fcfa when necessary[18]. Over the entire period of the analysis, the exchange rate between the fcfa and the French franc was fixed at 50 fcfa per one French franc. Thus, fluctuations in the value of the fcfa should simply reflected changes in the exchange rate between the US dollar and French franc. Some research (Salinger and Stryker, 1991) indicates that the fcfa is overvalued. While no effort was made to

[18]Prady and Rosenboon note that "there is...no option but to convert research expenditures measured in current local currency units into some numéraire currency or unit of measurement (1989, p.24)."

calculate a shadow exchange rate for the base runs, the exchange rate was included as a variable in the sensitivity analysis.

A second simplifying assumption about costs and benefits was made regarding the inflation rate applicable to the subsistence economy of northern Cameroon. While inflation rates (IMF and World Bank internal documents) have been calculated for the urban centers of southern Cameroon (Yaoundé and Douala), these data have little applicability to the economy of subsistence farming 800 kilometers to the north. Further, available market prices (MINAGRI Annual Reports) indicate no discernable price trends. Also, since weather effects dominate price fluctuations in northern Cameroon, it is impossible to identify short-term inflationary trends in price. Hence, the base runs of the analyses are estimates without any adjustment for inflation.

4.2 Cowpea

4.2.1 Overview of Improved Cowpea Technologies

Cowpea, a crop indigenous to northern Cameroon, is traditionally intercropped with either sorghum or millet. Both the leaves and grain pods are harvested for food. Although cowpea leaf consumption fills an important niche in the region's household food security, cowpea research (from 1979 to 1987) focused almost exclusively on increasing grain yields since many farmers already grew local varieties that produced high leaf yields.

The first technology package developed by the research system included a new cowpea variety, TVX 3236 OG1. This indeterminant, medium cycle (75 to 80 days to maturity) cultivar was selected from IITA regional screening trials for its high yield potential, white grain color, and insect (thrips) tolerance. IRA and SODECOTON recommended that farmers monocrop the variety on a quarter-hectare plot and, when possible, treat the standing crop with insecticide.

Although TVX 3236 was first "extended" to farmers in 1980 through SAFGRAD's on-farm testing program, SODECOTON did not begin to extend the variety widely until 1984. Widespread extension was facilitated by the North Cameroon Seed Multiplication Project, which produced and sold approximately twenty metric tons of TVX 3236 from 1984 to 1986. SODECOTON continued to recommend and extend the "TVX package" through the 1987 growing season. In addition, IRA introduced Ife Brown (a local Nigerian cultivar) and VYA (a local Cameroonian cultivar from the Moutourwa area) in 1985 and 1986-1987, respectively, two promising cultivars identified through SAFGRAD/CRSP screening trials.

During this period (1980-1986), researchers and extension workers observed significant (sometimes total) storage losses due to bruchid infestations. As a result, SODECOTON reduced the recommended plot size from a quarter to an eighth of an hectare. SODECOTON's contention was that until the storage constraints could be lessened, farmers should grow cowpea as a garden/compound food crop for the hungry season, not as a commercial grain crop.

In 1987, IRA released two sister lines from IITA with several advantages over TVX 3236 including comparable yield, larger grain size, significantly less shattering of seed pods, and most important, greater tolerance to bruchids. These two varieties, BR1 and BR2 (IITA cultivars IT81D-985 and IT81D-994, respectively), were judged sufficiently tolerant to bruchids to allow farmers to store cowpea grains for an additional month before bruchid damage became significant. Table 4.1 summarizes the chronology of extension recommendations.

Table 4.1 Extension Recommendations for Cowpea, Northern Cameroon, 1984 to 1991.

Improved Technologies	Years Extended				
	1984	1985	1986	1987	1988 to 1991
Monocropped cowpea	***	***	***	***	***
Insecticide	***	***	***	***	***
1/4 ha "block" plot	***	***	***	***	***
1/8 ha "garden" plot				***	***
Variety TVX 3236	***	***	***		
Variety Ife Brown		***			
Variety VYA			***	***	***
Varieties BR1 and BR2				***	***

Source: Annual reports for IRA, CRSP, SODECOTON, and SAFGRAD.

"****" indicates the years in which the improved technology was extended to farmers.

Since 1987, researchers have continued to advise farmers to plant cowpea as a monocrop in quarter-hectare plots, sowing BR1 and BR2, and applying 2 to 3 insecticide sprayings. In addition, in recognition of the importance of post-harvest losses, the research agenda shifted to give greater priority to developing improved grain storage technologies and to establishing a breeding program directed, in part, at increasing tolerance to storage pests (bruchids). However, as this research initiative is beyond the scope of this study, its costs and impacts are not included in the benefit-cost streams.

4.2.2 Cowpea Cost Stream

Principal Cost Components

The package extended to farmers consisted of an improved variety (first TVX 3236, then BR1 and BR2) and a set protocol that differed considerably from traditional farming practices. Three donor projects (the Bean/Cowpea CRSP, SAFGRAD's J.P. No. 31, and the NCRE project) and two host country institutions (IRA and SODECOTON) contributed to the development of this technology package. Annual expenditures attributable to cowpea research and extension are compiled and detailed below for each of the five institutions involved.

Since research specific to the improved technology was initiated in 1979, moved into on-farm testing as a technological package in 1981 (for TVX 3236, in 1984 for BR1 and BR2) and extended to farmers in 1984 (for TVX 3236, in 1987 for BR1 and BR2), only costs incurred during this nine-year period are included in the cost stream.

SAFGRAD Expenditures

SAFGRAD Joint Project No. 31, which began in 1979, was mandated to conduct both on-station and on-farm research on four food crops widely grown in the semi-arid environment: sorghum, millet, maize, and cowpea. The project employed one expatriate researcher during each of the nine years of its existence. While IRA provided support staff and some research funding, all other operating costs were covered by SAFGRAD.

SAFGRAD project costs for the period 1979 to 1983 are summarized in a final report submitted by Owen Gwathmey, the first of two expatriate researchers assigned to the project. The report provides five-year totals in nominal dollars by main expenditure categories.

Since cowpea was only one of four crops researched by the project, it was necessary to adjust total project expenditures to reflect the commodity's share of the total project's cost stream. Based on interviews with both Gwathmey and Martin Fobasso, Gwathmey's Cameroonian counterpart, the cowpea share of total expenditures was estimated at 25%. The adjusted five-year totals were converted into annual expenditures by using the following assumptions: for salary allowances, housing, and other direct costs, an annual 4% "institutionalized" increase was assumed; for travel, per diem, and shipping and storage, 35% shares of the total were allocated to the first and last years, and 10% shares for the three middle years; for equipment, supplies and materials, a descending share series was assumed with 35% of the total allocated to the first year, followed by annual shares of 30, 15, 15 and 5% to the subsequent years, respectively. The resulting cost stream for the period 1979-83 is reported Table 4.2.

Jerry Johnson, the second expatriate to work on the project, provided estimates of project and salary costs (nominal US dollars) for the years 1984 to 1987 (personal interview). These data are drawn from his personal files, directly from past contracts and canceled voucher reports. Since these data were not available by detailed expenditure category, they are reported in Table 4.2 as salary allowances and non-salary expenditures. Personal services contracts varied from 13 to 27 months and never coincided with the calendar year. Hence, to estimate annual contract costs, the expenditures associated with a given contract are divided by the number of months for which the contract was written and then summed over the calendar year. The cowpea share of total expenditures was estimated at 25%, based on interviews with Johnson. The resulting cost stream for the 1984-87 period is also reported in Table 4.2.

Bean/Cowpea CRSP Expenditures

The CRSP began work in northern Cameroon in 1982, in affiliation with two host institutions (IRA and SODECOTON) and the on-going SAFGRAD project. Cost data for CRSP activities were provided by the Bean/Cowpea CRSP management office at Michigan State University. These annual expenditures were listed by expenditure category in nominal dollars. Since all direct fiscal outlays were ultimately authorized and paid for through this office, these cost data are considered complete (Table 4.3).

One caveat is that from 1982 to 1986 the project contractor (the University of Georgia) apparently paid the salary and benefits of the project's principal investigator, but these costs are not included in the contractor's expenditure totals reported in the original CRSP documents. Similarly, in 1987, the local USAID mission in Cameroon, instead of the contractor, paid this expense. Hence, these costs had to be estimated from available data and added to the CRSP cost totals. Information on the salary and benefits of the principal investigator was only available for 1989[19]. By extrapolating backwards and assuming a 5% per annum increase in salary costs, the PI's salary history was estimated for the period 1982 to 1987.

A second caveat is that "US Matched Funds", as reported by the CRSP management office, are not included in the CRSP cost stream used in this analysis. These funds are excluded because they are not part of the CRSP budget, rather they mainly represent the value of services provided to the CRSP by the US institutions. Although the research efforts in northern Cameroon were indirectly supported by these financial outlays, most of the resulting benefits were not realized in Cameroon. Since these benefits are not included in the benefit stream of the analysis, their costs are also excluded.

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[19]Bean/Cowpea CRSP - Purdue University (internal document provided by Katy Ibrahim) reported that the 1989 salary and benefits of the principal investigator, Dr. Mofi Ta'Ama, totaled $89,544. Annual costs in previous years were not available, although this expenditure was reported to be relatively constant over the lifetime of the project, increasing only slightly (3 to 5%) each year.

Table 4.2 Estimated Total Expenditures (Nominal $US), Cowpea Research, SAFGRAD Joint Project No. 31, Maroua, Cameroon, 1979 to 1987.

Year	Travel & Per Diem	Shipping & Storage	Housing	Other Direct Costs	Equipment Supplies Materials	Subtotal Non-Salary Expenses	Salary[a] Allowance	Total Costs
1979	2,400	564	2,835	128	6,083	12,011	7,890	19,901
1980	686	161	2,943	133	5,214	9,137	8,188	17,325
1981	686	161	3,065	139	2,607	6,658	8,530	15,187
1982	686	161	3,188	144	2,607	6,786	8,871	15,657
1983	2,400	564	3,311	150	869	7,294	9,212	16,505
1984	na[b]	na	na	na	na	10,157	24,760	34,916
1985	na	na	na	na	na	13,542	24,760	38,302
1986	na	na	na	na	na	6,771	25,867	32,638
1987	na	na	na	na	na	0[c]	26,974	26,974
Totals	6,858	1,611	15,342	694	17,380	72,356	145,052	217,405

Source: Project Documents; Interviews with O. Gwathmey, M. Fobasso, and J. Johnson.

[a]Benefits are included in the salary data (eg., cost of living allowances, guardians, utilities).

[b]na signifies data "not available" by specific expenditure category.

[c]The SAFGRAD project was originally scheduled to end in 1986. In an accord with the NCRE project, SAFGRAD agreed to pay the PI's salary in 1987 while NCRE paid for operating expenses, as noted in the cowpea cost section on NCRE expenditures.

Table 4.3 Estimated Total Expenditures (Nominal $US), Bean/Cowpea Collaborative Research Support Project, Maroua, Cameroon, 1982 to 1987.

Year	Travel & Per Diem	Equipment Supplies Materials Facilities	Other Direct Costs	Indirect Costs & Overhead	Local Mission USAID	Personnel	Total Costs
1982	5,908	40,729	0	13,654	0	71,275	131,565
1983	25,934	58,155	66,413	41,485	0	86,702	278,689
1984	41,587	102,969	45,980	48,463	0	93,004	332,003
1985	28,113	99,202	21,099	41,090	0	109,032	298,535
1986	7,181	130,404	1,236	42,970	0	91,101	272,893
1987	7,548	59,051	817	17,794	81,219	20,023	186,452
Totals	116,271	490,510	135,545	205,456	81,219	471,137	1,500,137

Source: Financial Summaries from CRSP Management Office, Michigan State University.

NCRE Expenditures

The NCRE project began in 1982, but had a very limited role in the development and extension of cowpea technologies during the early 1980s. Given that the project was mandated to research cereals and that both the CRSP and SAFGRAD project were researching cowpea, there was little need for the involvement of the NCRE staff and resources beyond informal collaboration with on-farm tests. However, in 1986, as the SAFGRAD project was drawing to a close, and as the NCRE project was expanding into on-farm testing, the NCRE project negotiated a technical "buy-in" (during the last two years of the SAFGRAD project) which financed some on-farm research costs. The share of these operating expenses associated with cowpea research (estimated at 25% of total costs incurred) was approximately $4,890 in 1986 and $9,780 in 1987.

IRA Expenditures

IRA, as the host country research institution, assumed part of the cost of developing the new cowpea technologies--including the salaries of host country research staff and unskilled labor, and some operating expenses (eg., fuel, electricity, water, office materials, per diem, temporary hires).

For years 1982 to 1987, the CRSP management office reported estimates of financial contributions (in nominal $US) to the project by "host country institutions". Assuming that these estimates represent total outlays by IRA for the cowpea project, the data (Table 4.4) are added directly to the cost stream.

Prior to 1982, IRA collaborated with the SAFGRAD project, although no document quantifying the value of this contribution was found. To make up for this deficiency, an annual IRA cost stream was created, based on IRA documents reporting staff and operating costs. A history of IRA staff (researchers and administrators) involved in on-farm testing and cowpea research and their salaries was constructed from IRA documents. The history was then converted to an annual cost stream of IRA salary costs. Combining data provided by IRA's accountant at the Maroua research station with data from various documents, operating expenses were also estimated. The resulting cost stream (Table 4.4) underestimates IRA's contribution since it does not include "in-kind" costs such as land and buildings, although these costs are included in the CRSP estimates.

For the benefit-cost base run, the CRSP cost estimates were used during the years for which they were available (1982-1987). For earlier years (1979-1981), the constructed cost stream was used.

SODECOTON Expenditures

As part of its general activities, SODECOTON maintains a large extension network. The adoption of the cowpea package and its subsequent impact is, in part, dependent on the extension and distribution system of SODECOTON.

SODECOTON officials estimated that their extension and management staff spent approximately 10% of their time on food crops. Since agricultural census data indicate that cowpea is planted to 5% of all food crop land in the Far North Province, it was assumed that 5% of food crop extension costs were allocated to the extension of cowpea technologies. Further, since available data were only for staff salaries and benefits, an overhead adjustment (20% of the costs of salaries and staff benefits) was included in the cost stream to account for such costs as fuel, supplies, equipment, and materials. Hence, the cost of cowpea extension activities was estimated as total staff costs, M_t, multiplied by the factor C_{CE} (Equation 4.1).

Table 4.4 Estimated Total Expenditures in Nominal $US for the IRA-Cowpea Program, Maroua, Cameroon, 1982-1987, Costs Estimates from Two Sources.

Year	Staff & Operating Costs Estimated from IRA documents	Total Costs Estimated by Bean/Cowpea CRSP
1979	10,771	na[a]
1980	11,001	na
1981	13,278	na
1982	20,687	33,478
1983	21,022	41,847
1984	32,451	58,585
1985	35,493	55,103
1986	46,116	26,462
1987	45,954	84,954

Source: Financial Summaries from CRSP Management Office, Michigan State University and from IRA documents and interviews with the IRA-Maroua accountant.

[a]na signifies that data are "not available/estimated" since the Bean/Cowpea CRSP did not exist in northern Cameroon prior to 1982.

$$
\begin{aligned}
TC_t &= M_t * (S_{FC} * A_{CP} * S_{OV}) \\
&= M_t * C_{CE} \\
&= M_t * 0.006
\end{aligned}
\qquad (4.1)
$$

where:

TC_t = Total extension costs for cowpea, year t
M_t = SODECOTON agricultural staff costs, year t
C_{CE} = Cowpea extension cost factor = 0.006
S_{FC} = Percent of extension staff costs allocated to food crops = 0.10
A_{CP} = Percent of food crop extension costs allocated to cowpea = 0.05
S_{OV} = Overhead adjustment = 1.20

Since the annual cost figures were reported in nominal fcfa, they were converted to nominal $US by using annual average market exchange rates reported by the IMF. Extension costs were estimated for seven years (1981 to 1987), given that the SAFGRAD project and the CRSP relied on the SODECOTON extension system for both on-farm research and for general extension of the improved technologies (Table 4.5).

Aggregate Costs

Annual costs for the nine-year period associated with the development and extension of the improved cowpea technology are summarized in Table 4.6. The last column, "Total Annual Costs" is the cost stream used in the benefit-cost analysis.

Table 4.5 Estimated Total Expenditures (Nominal $US), SODECOTON Extension Costs for Cowpea Technologies, Far North Province, Cameroon, 1981 to 1987.

Year	Annual costs for extension staff, food and cash crops	Total Costs
1981	2,552,541	15,317
1982	2,461,364	14,769
1983	1,839,374	11,035
1984	1,858,072	11,147
1985	2,539,872	15,239
1986	2,507,110	15,043
1987	2,614,626	15,688
Total	16,372,959	98,238

Source: Estimates based on internal documents supplied by SODECOTON accounting office, 1991.

Table 4.6 Estimated Total Costs (Nominal $US) for Cowpea Research and Extension Programs, Far North Province, Cameroon, 1979 to 1987.

Year	SAFGRAD J.P. 31	CRSP	NCRE	IRA	SODE-COTON	Total Annual Costs
1979	19,901	0	0	10,771	0	30,700
1980	17,325	0	0	11,001	0	28,300
1981	15,187	0	0	13,278	15,317	43,800
1982	15,657	131,565	0	33,478	14,769	195,500
1983	16,505	278,689	0	41,847	11,035	348,100
1984	34,916	332,003	0	58,585	11,147	436,700
1985	38,302	298,535	0	55,103	15,239	407,200
1986	32,638	272,893	4,890	26,462	15,043	351,900
1987	26,974	186,452	9,780	84,954	15,688	323,800
Totals	217,405	1,500,137	14,660	335,479	98,238	2,165,919

Source: Tables 4.1 to 4.5

4.2.3 Cowpea Benefit Stream

Principal Benefit Components

To estimate the benefits of an improved technology, three time series of data are needed: (1) the annual market value of production (price times total amount of output produced) since the introduction of the technology; (2) the annual market value of production for this same time period, albeit conjectural, had the technology never been developed and extended; and, (3) the annual on-farm costs of adopting the technology.

Specific data needed to estimate the cowpea benefit stream were: (1) yields under three different sets of farming practices (total adoption of the cowpea package, partial adoption of the package, and traditional practices)[20]; (2) corresponding adoption rates of the new technologies, including adoption ceilings and the life span of the technology; (3) total area harvested; and, (4) annual input and output prices.

Cowpea Yields - Grain

Numerous sources report cowpea yields for one or more types of farming practices (trial data and annual reports by the SAFGRAD and NCRE projects, the CRSP, SODECOTON and MINAGRI). Reported yields (Table 4.7) range from 3,158 kg/ha, representing an upper limit achieved in on-station trials, to a low of 10 kg/ha, which was one farmer's response as reported in a survey of cowpea farmers (Ta'Ama, 1984; Kitch, 1990, respectively).

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[20]Estimating the benefit stream requires estimates of cowpea yields (under each farming practice) for grain, leaves for food, and forage for animal feed. With traditional practices, yield data were also needed for intercropped sorghum (grain and stover).

Table 4.7 Cowpea Yield Estimates, Various Sources, Far North Province, Cameroon, 1983 to 1990.

Data Source	Years Reported	Yield Range (kg/ha)	Cropping System
Agricultural Census	1984-89	231 - 1033	Aggregation over all cropping systems
SODECOTON on-farm production estimates	1986, '87, '91	770 - 1200	Monocropped, 2 to 3 insecticide applications, 1/4 ha block plots
CRSP, farmer survey	1990	10 - 800	Aggregation over all cropping systems
CRSP, on-station research trials	1983-87	262 - 3158	Monocropped, insecticide applications, varietal screening trials
CRSP, on-station agronomy trials	1983	151 - 1292	Monocropped, no insecticide, two dates of planting, variety TVX 3236
CRSP, on-station agronomy trials	1983, '84, '88	67 - 516	Intercropped, with & w/o insecticide, two dates of planting
IRA/SAFGRAD/NCRE on-farm trials	1983-87, '89	342 - 2500	Monocropped, 2 to 3 insecticide applications, 1/4 ha plots
IRA/SAFGRAD/NCRE on-farm trials	1989	110 - 204	Intercropped, no insecticide, varieties BR1 and VYA, 6 sites

Given the range of estimates and their aggregated nature, merging data from these sources is not a straight-forward exercise. For example, the Agricultural Census and the CRSP farmer survey data are not differentiated by variety or farming practice. In contrast, SODECOTON yields, on-station CRSP results, and IRA/TLU estimates are all associated with specific farming practices and one of the three extended varieties-- TVX 3236, BR1, or BR2. The high yields reported in the CRSP on-station varietal screening trials are for monocropped cowpea, with insecticide treatments and intensive management. Both the SODECOTON yields and the IRA/TLU on-farm trial data represent production under the strict protocol dictated by the research and extension agencies. The Agricultural Census data are aggregations of crop cuts and sample data collected from representative farms, where annual yields are estimated from the reported total production divided by the reported area harvested.

Yields used in the benefit stream are derived from the data described above and insights gained through interviews of key informants. Yields for improved cowpea varieties cultivated in accordance to the complete extension package (monocrop, insecticide, seed treatment, etc.) are estimated at 1,000 kg/ha. Data explicitly indicating that the yield for this package is 1,000 kg/ha do not exist, although farmers enrolled in the SODECOTON extension program reported yields of 770 to 1,200 kg/ha (1985/86 Annual Report, SODECOTON). Cowpea researchers in Cameroon are uncomfortable suggesting average yields. Responses during key informant interviews ranged from "yields with the package will outperform local varieties by 200 to 300 kg/ha" to "if the entire package is adopted, a good farmer will have yields of 1,500 to 2,000 kg/ha." Given that Kitch's farmer survey (1990) indicated farmer yields no higher than 800 kg/ha, a relatively conservative estimate (1,000 kg/ha) was set as the study's "best guess".

Yields for improved cowpea varieties that are monocropped, but not treated with insecticide, are estimated at 400 kg/ha. Although several key informants contended that "there would be no net gain in yield from adopting the new varieties over local varieties unless insecticide is used," others argue that some gain would be possible with the shift in management practices. Researchers have noted that when farmers grow improved varieties, they almost universally grow them in monoculture, planted in rows in 1/4 ha plots. The shift in farm management practices should result in higher yields per hectare, due in part to better weed control. Further, since during screening, researchers selected improved varieties primarily for their grain-yield potential, they should outyield many local cultivars that are grown for both their grain and forage production. This parameter is conservatively estimated at 50 kg over the intercropped yield (in terms of pure stand equivalents).

The pure stand equivalent yields for traditional cowpea varieties intercropped with sorghum are estimated at 350 kg/ha. Several sources of information were used to derive this estimate. One source was interviews of researchers, who estimated yields under traditional practices to be 200 kg/ha or less. However, these figures appear to have represented actual yields and not monocropped equivalents. Research trial data indicate that monocropped equivalent yields for intercropped cowpea are approximately 100 to 500 kg/ha, although the range is negatively skewed. Also, Kamuanga (1991), in estimating production costs for traditional cowpea farmers, set cowpea yields at 350 kg/ha. Finally, Agricultural Census data estimated average yields of nearly 600 kg/ha over the six-year census period (1984-89). From this range of values, yield estimates of 350 kg/ha are used in the base run, and then a range of yields are tested in the sensitivity analysis section.

Cowpea Yields - Leaves

Although the CRSP has documented the importance of leaf consumption in the traditional diet of northern Cameroonians (Ta'Ama 1984, Wolfson 1989, Kitch 1990), there exist no empirical estimates of the quantities of leaf production from traditional or improved varieties.

While research in other countries[21] indicates that cowpea can yield up to two tons (wet matter) of leaves per hectare without reducing seed yield, lower leaf yields are set for this study, based on the following assumptions. To estimate leaf yields, this study assumes that leaf harvesting is limited to 30 to 40 days of the crop's eighty-day growth cycle. During this forty day period, if total leaf harvest is set at one ton per hectare, then leaf yield is approximately 25 kg of leaves per day. An average household grows approximately 1/2 ha of cowpea[22], implying a daily harvest of 12.5 kg (27.5 lbs). This study considers this level of harvesting and consumption to be unrealistic. While leaves are sold in northern Cameroon, key informants contend that there is a thin, intermittent market which would discourage harvesting the maximum possible amount of leaves. Hence, a lower value of leaf production is set at 300 kg/ha for monocropped improved varieties grown without insecticides and 400 kg/ha for intercropped traditional varieties. A higher leaf yield for traditional varieties is based on two assumptions--traditional varieties are grown specifically for leaf production, and the leaf flavor and/or texture of

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[21]Imungi and Potter quote work by Oomen and Grubben. Other sources reporting leaf production include Mehta for Uganda, Martin for Senegal, and Conniff for Botswana.

[22]This figure is based on the 1990 CRSP survey which estimated that the average amount of land in cowpea production per farming household is 0.62 ha (Kitch, 1990). This figure is biased upward since the survey's sample frame consisted of "important" cowpea farmers in villages in the principal cowpea cropping zone.

traditional varieties is preferred over improved varieties since the latter were selected only for grain yield potential. When insecticides are used, leaf yields are set at zero since farmers rarely harvest leaves from fields sprayed with insecticide due to chemical residue. A range of yields are assumed during sensitivity analysis and these results are reported below.

Cowpea Yields - Forage

Farmers produce forage (cowpea hay) by uprooting and drying the entire cowpea plant once grain pod harvesting is complete. Farmers store this hay and then either feed it to their livestock or sell it during the dry season.

In 1989, the Maroua IRA/TLU unit measured cowpea hay production in an on-farm trial conducted over 9 sites. Yields over all sites for two of the extended varieties were reported to average 833 kg/ha for BR1 and 607 kg/ha for TVX 3236 (NCRE 1989 Annual Report). It is unclear whether the yields are for dry or wet matter, although this analysis assumes that the data are for dry matter. Given that these data are based on researcher-managed on-farm trials, on-farm yields could be lower. Yet, improved varieties were not selected for their forage production traits, implying that, genetically, traditional varieties probably producer higher forage yields. Also, in the field, the primary insect damage is to the plant's flowers and pods, not leaves. Insect-damaged plants tend to compensate for the loss of flowers/pods with more leaf production, implying greater forage production when insecticides are not used. Based on these three points, forage yields (monocropped equivalents) are assumed to be 750 kg/ha for intercropped traditional varieties, 725 kg/ha for monocropped, but not sprayed, improved varieties, and 700 kg/ha for insecticide-treated, monocropped improved varieties.

Sorghum Yields - Grain and Stover

Both the CRSP and the IRA/TLU conducted trials for intercropped cowpea and sorghum. Again, results are difficult to compare due to different protocols used across trials. Ranges of sorghum yields reported by researchers are presented in Table 4.8.

As noted by key informants, farmers seldom adopt new varieties and chemical treatments (eg., insecticide applications for cowpea and urea for sorghum) without also converting from an intercropped to a monocropped farming practice. Hence, the IRA/TLU on-farm trial data when no chemicals are used are most indicative of actual farm yields for intercropped sorghum. Further, cowpea is generally grown in drier conditions where sorghum yields will be lower than average, suggesting that intercropped sorghum yields will be below the province-wide average monocropped yield. Although the base run for the analysis assumes a monocropped equivalent sorghum yield of 600 kg/ha, a range of yields are tested during sensitivity analysis and these results are reported below.

Stover yields are not available, although sorghum stalks have a variety of uses in northern Cameroon (eg., animal feed, fencing, roofing, raw material for toys). Minimal values (5 fcfa/kg market value, 200 kg/ha yield) are assumed in recognition that sorghum stalks have some value and that this value needs to be included in the benefit stream. In the absence of reliable data, sensitivity analysis is used to test the importance of this parameter.

Table 4.8 Sorghum Yield Data, Various Sources, Northern Cameroon, 1983 to 1990.

Data Source	Years Reported	Yield Range (kg/ha)	Cropping System
Agricultural Census	1984-89	685 - 1,467	Aggregation over all cropping systems
SODECOTON on-farm production estimates	1985, 87, 89-91	600 - 1,300	Monocropped, variety S35, with 50 kg urea/ha, seed treatment, seeded in rows, mechanical tillage
SODECOTON on-farm production estimates	1987	650 - 1,200	Estimates for traditional farming practices and rainy season varieties
IRA/SAFGRAD/NCRE on-farm trials	1984-87	719 - 1,825	Traditional varieties, with 50 kg/ha urea, seed treatment, planting in lines
IRA/SAFGRAD/NCRE on-farm trials	1984-87	1,333 - 1,888	Monocropped, Variety S35, with 50 kg/ha urea, seed treatment, seeded in rows
IRA/TLU/NCRE on-farm trials	1989	448 - 583	Variety S35, intercropped with two cowpea varieties, no fertilizer, 6 sites
IRA/TLU/NCRE on-farm trials	1990	1,070 - 1,253	S35 intercropped with VYA, with & w/o 100 kg of urea, 16 sites
CRSP, on-station agronomy trials	1983, '84, '88	736 - 5,588	S35 and local vars. intercropped with cowpea, with & w/o insecticides and fertilizer, 2 dates of planting

Adoption Rates

Adoption is conceptualized as a cumulative process, increasing over time and finally reaching a ceiling. Since estimates of adoption were not available for all years of the analysis, available estimates for selected years were used as parameters to estimate annual adoption rates. For the improved cowpea package, point adoption rates were derived from IRA and SODECOTON documents and two surveys--both conducted in 1990--of farmers in northern Cameroon. To estimate the adoption ceiling and the annual adoption rates for the years prior to and after 1990, a logistic functional form was assumed for the adoption/diffusion pattern.

The first survey, reported by the CRSP, indicated that 25% of cowpea farmers sampled grew improved varieties. The second survey, reported by IRA/TLU/NCRE, indicated that the 1990 adoption rates for improved cowpea varieties were 12.6, 26.6, 29.6, and 39% of all cotton farmers for the Guider, Tchatibali, Kaélé, and Maroua SODECOTON extension zones, respectively.

The best indicator of farmer adoption of the complete package is the use of insecticides. Kitch reported that 34% of the farmers surveyed "used insecticides regularly" while the TLU reported that only 10% of the farmers surveyed "used insecticides on cowpea". Since Kitch's survey did not determine usage of insecticides by commodities, the 34% overestimates insecticide use on cowpea. Conversely, the TLU surveyed cotton farmers, a target population which excludes several large cowpea growing areas. Hence, the TLU's 10% probably underestimates insecticide usage by cowpea farmers.

Given these data, a 25% adoption rate of the improved package is assumed for 1990 in the base run of the analysis and is used as a parameter in the logistic function used for estimating annual adoption rates (Equation 4.2).

Using these surveys to estimate adoption rates had two limitations. First, the sample frames used for the two surveys may not be truly representative of cowpea farmers in the Far North Province. The CRSP survey purposively targeted villages from the principal cowpea production areas and "important" cowpea farmers within these areas, who were administered a brief, sixteen question survey on cowpea production and its constraints. The second survey was based on interviews of 1,003 SODECOTON farmers throughout the region. Surveyed farmers were selected at random from SODECOTON producer lists, considered the most complete sample frame available in the region. However, the cotton and cowpea production zones do not completely overlap, suggesting that many cowpea farmers were excluded from the interview process.

A second constraint in interpreting the results of the two surveys is that both collected only qualitative data on adoption of new varieties--whether or not new varieties were grown by the interviewee. Data as to actual area in production of new varieties was not solicited during the interview, nor was the production mix of area in the new package versus traditional practices.

These various data sources were combined to estimate the adoption pattern as described below. Initial adoption figures for 1984 and 1985 are estimated from SODECOTON production figures and IRA/SAFGRAD/CRSP on-farm trial data. In 1984, SODECOTON extended the then experimental cowpea package on 11.25 ha. Given that the package protocol required that each plot be 1/4 ha, it is assumed that 45 farmers participated. That same year, IRA/SAFGRAD/CRSP conducted on-farm trials at 28 sites, using the same protocol as SODECOTON for a total of 73 participating farmers. In 1985, SODECOTON reported 81 ha in production, implying 324 farmers "adopting", while IRA conducted on-farm trials at 24 sites--for a total of 348 farmers "adopting" the package in the second year it was extended.

Since the two surveys in 1990 only report the percentage of farmers adopting the new variety, initial adoption figures (1984/85 data) need to be converted to the same base units (percent of farmers, not number of farmers). Assuming that the average cowpea area per farming household is 1/2 ha[23], the number of cowpea farming households is estimated by dividing the cowpea area by 1/2 ha. For 1984, the Agricultural Census reported that 23,470 ha were harvested, implying 46,940 farming households. Dividing 73 (i.e. number of adopters of the complete package) by 46,940 leads to an estimated adoption rate of 0.2% for the first year the technology was extended. Similarly, for 1985, the census reported that 30,232 ha were harvested, implying 60,464 households growing cowpea and an adoption rate of 0.6% for the second year.

Using the estimated percentage of farmers adopting in 1985 and in 1990, the parameters for a logistic function (Equation 4.3) were calculated by solving the following two-variable, two-equation algebraic problem.

$$\begin{aligned} 0.6 + (0.6 * be^{-2}) &= K \\ 25.0 + (25.0 * be^{-7}) &= K \end{aligned} \qquad (4.2)$$

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[23]Kitch's findings are reported above. The Agricultural Census also reported, by stratum, the number of farms and area planted per farm for 1984: 130,000 farms planted less than 0.25 ha cowpea, averaging less than 0.1 ha; 14,000 farmers planted between 0.25 and 0.5 ha of cowpea, averaging 0.4 ha; and, 12,000 farmers planted more than 0.5 ha, averaging 1.1 ha.

The values for K and beta are 35.2 and 444.1, respectively, where K is the adoption ceiling (i.e., the maximum percentage of farmers adopting the complete cowpea package). These parameters are substituted into the following logistic equation to project annual adoption rates.

$$P(t) = \frac{K}{1 + be^{-t}} \tag{4.3}$$

where:

P(t) = Cumulative total of farmers adopting technology, period t
K = Adoption ceiling, a parameter of the logistic function
b = A parameter of the function
t = Time period, number of years since extension of technology

From equations 4.2 and 4.3, annual adoption rates were projected over a thirteen-year period (1986 to 1998), while the adoption rates for 1984 and 1985 were based on IRA and SODECOTON production figures (Table 4.9).

Cowpea researchers in northern Cameroon have noted that farmers do not adopt the improved package on all of their land in cowpea production[24]. Although there exists no data on the shares of improved vs. traditional cowpea, estimates used in this study were based on the area planted per farm and on the extension protocols for cowpea production. Since, on average, cowpea farmers grow approximately 1/2 ha of cowpea, and the protocol for the extended package requires 1/4 ha of land, the base run assumes that the initial production mix is equally divided between new and traditional varieties. As farmers gain confidence in the new technology, it is assumed that the

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[24] Some land will remain in traditional varieties due to the preferred tastes and texture of leaves and grain of these varieties.

production mix will gradually shift so that by 1994 1/2 ha is planted in the new package and a small residual (1/8 ha garden plot) is kept in traditional varieties, implying a long term production mix of 80% new, 20% traditional (Table 4.9).

So far, discussion on the adoption rate has assumed total adoption of the extended package--new varieties, insecticide sprayings, improved farm management practices, etc. However, there is considerable anecdotal evidence that some farmers adopt the new variety and farming practices (monocropped blocks of cowpea), but do not use insecticides. Since pod yield gains are small and leaf gains negative with partial adoption, the adoption rate will probably be low. Although the improved varieties were introduced in 1984, diffusion of these varieties beyond areas under the direct influence of SODECOTON and IRA is assumed to begin in 1986. Partial adoption of the package represents an additional impact of the improved technologies (especially improved varieties) and more benefits from research. The partial adoption rate is assumed to be a fixed proportion (15%) of the adoption rate for the complete package[25], since the total number of farmers exposed to the new varieties will increase as more farmers adopt the complete package. It is also assumed that the use of new varieties without insecticide represents a smaller share (25%) of the farmers' production mix of new and old varieties/practices in their cowpea fields (Table 4.9).

Prices - Inputs

Inputs used for cowpea production include seed, seed treatment, labor, and insecticide. However, for this analysis, the key point is not the actual cost of inputs,

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[25]Survey data indicated that 38% of the farmers were growing cowpea in monoculture, but only 34% were regularly using insecticides (Kitch, 1990). The fixed proportion is based on these data and comments from interviews of key informants.

Table 4.9 Projected Adoption Rates for Cowpea Technologies, Far North Province, Cameroon, Years 1984-1998.

Year	Cumulative % Farmers Adopting Extended Package	Producer Mix, Cowpea cropland allocated to complete package (%)	Adoption Rate One (%)	Cumulative % Farmers Adopting only the varieties	Producer Mix, Cowpea cropland allocated to partial package (%)	Adoption Rate Two (%)
1984	0.2	50	0.1	0	na	na
1985	0.6	50	0.3	0	na	na
1986	1.5	50	0.8	0.2	25	0.05
1987	3.9	50	2.0	0.6	25	0.2
1988	8.8	50	4.4	1.3	25	0.3
1989	16.8	55	9.2	2.5	25	0.6
1990	25.1	60	15.1	3.8	25	1.0
1991	30.6	65	19.9	4.6	25	1.2
1992	33.4	70	23.4	5.0	25	1.3
1993	34.5	75	25.9	5.2	25	1.3
1994	35.0	80	28.0	5.3	25	1.3
1995	35.1	80	28.1	5.3	25	1.3
1996	35.2	80	28.2	5.3	25	1.3
1997	35.2	80	28.2	5.3	25	1.3
1998	35.2	80	28.2	5.3	25	1.3

rather whether expenditures on inputs at the farm level changed with the adoption of the package extended to farmers.

The opportunity cost of cowpea seed is relatively high since the annual peak in cowpea market price coincides with planting time (late June/early July). However, no documentation was found which indicated that improved varieties command a premium price in the market over traditional varieties, a view confirmed in interviews with key informants. If this is the case, then seed costs can be left out of the benefit stream.

On the other hand, the market may fail to reflect actual costs of seed production. Seeds for improved varieties were probably more costly to produce, at least in the initial stages of diffusion since they were produced by either IRA or the NCSM project. Since cowpea is self-pollinated, varieties can be propagated at the farm level without a supporting seed industry. This implies that after the initial distribution of improved seed, seed costs do not differ between new and traditional varieties. Again, seed costs, with the possible exception of the costs of the "starter" seed, can be left out of the benefit stream.

Further, on-farm seed costs may be lower when the improved package is adopted. Although extension recommendations for seeding densities for improved varieties are greater than traditional seeding densities (20 verses 10 kg/ha), fields of monocropped cowpea require no sorghum seed.

In the aggregate, differences in the cost of seeds between traditional and new farming practices are assumed to be minor, relative to the magnitude of the cost and benefit streams of the analysis. Hence, seed costs of the improved package are not included in the base run of the analysis.

Chemical seed treatment, usually thioral, is part of the extension recommendation, but is not usually applied on traditional cowpea varieties. Although seed treatments are usually provided at zero to minimal cost to farmers by either SODECOTON, IRA, or MINAGRI, their distribution is a cost to these institutions. In 1991, SODECOTON reported that thioral, delivered to Garoua, costs 1,295 fcfa/kg (SODECOTON internal document, 1991). Extension agencies distribute seed treatments in pre-packaged 50-gram packets. The extension package recommends that each of these small bags of thioral will treat 5 kg of seed, the amount needed for a 1/4 ha plot. These costs are included in the analysis (Table 4.10).

Insecticide cost estimates are based on an aggregation of data available on several general purpose insecticides distributed by SODECOTON[26]. Costs (quoted in fcfa per liter) for each of these insecticides were very similar across types of insecticides and for the years when prices were available (1987-1991). The overall average price of 3,200 fcfa/liter is used as the base cost of insecticide for the analysis (Table 4.10). Application rates were uniform for each type of insecticide--1 liter/ha per spraying with two sprayings per growing season. Investments in insecticide spraying equipment are considered sunk costs incurred by present or past cotton farmers and are not included in the benefit-cost analysis. Throughout the region, spraying equipment has been distributed to cotton farmers for over thirty years. Given that this equipment is already available to farmers, it is assumed that no additional costs for sprayers are incurred when adopting the cowpea technology.

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[26]These insecticides include monocrotophos 300, Nurelle-Dursban 30-280, Nurelle-Dursban 30-450, cypermethrine-monocrotophos 30-300, Fenom N324, and Cymbush.

Table 4.10 **Input Prices for Cowpea Production and Costs Associated with Adopting the Improved Cowpea Package, Far North Province, Cameroon, 1984 to 1998.**

Year	Per Unit Cost Seed Treatment (fcfa/kg)	Cost per Ha Seed Treatment ($/ha)	Per Unit Cost Cowpea Insecticide (fcfa/liter)	Cost per Ha Cowpea Insecticide: 2 Sprayings ($/ha)	Total Additional Annual on-farm Input Costs of Adoption ($/ha)
1984	1,300	0.59	3,200	14.65	15.24
1985	1,300	0.58	3,200	14.24	14.82
1986	1,300	0.75	3,200	18.48	19.23
1987	1,300	0.87	3,200	21.30	22.17
1988	1,300	0.87	3,200	21.49	22.36
1989	1,300	0.82	3,200	20.06	20.88
1990	1,300	0.95	3,200	23.44	24.39
1991	1,300	1.03	3,200	25.44	26.47
1992	1,300	0.95	3,200	23.27	24.22
1993	1,300	0.95	3,200	23.27	24.22
1994	1,300	0.95	3,200	23.27	24.22
1995	1,300	0.95	3,200	23.27	24.22
1996	1,300	0.95	3,200	23.27	24.22
1997	1,300	0.95	3,200	23.27	24.22
1998	1,300	0.95	3,200	23.27	24.22

Source: SODECOTON Internal Documents; IMF publications for exchange rates.

Labor costs are not included in the analysis. Although IRA reports the production costs/partial farm budget for cowpea production (Kamuanga, 1991), a comparative study between new and traditional practices was not available. Speculative differences include lower weeding costs with monocropped cowpea, additional labor needs for insecticide application in monocropped cowpea, and different harvest labor needs for the two practices--monocropped cowpea requires more time to harvest cowpea grain due to higher yields, but require no effort to harvest leaves or sorghum, labor demands in the traditional intercropped system.

Prices - Outputs

The analysis quantifies the economic value of the five outputs generated by the three cropping systems employed by cowpea farmers[27]. Time series of prices for each of the outputs are generated from data when possible and from comments by key informants when data are insufficient. Established markets exist only for cowpea and sorghum grain. Thin markets with intermittent sales exist for cowpea leaves (for food), and for sorghum and cowpea hay, although no records were available on the historic prices of these three products.

MINAGRI reported monthly retail prices for cowpea and sorghum grains over a six-year period (1985 to 1990) for five "urban" markets in the Far North Province[28]. However, these series are incomplete, with as many as six months of price data unreported for a given year and market. Further, sorghum prices are disaggregated into

[27]The five outputs are cowpea grain, leaves, and forage and sorghum grain and stover. The three cropping systems are traditional intercropping of cowpea and sorghum, complete adoption of the improved technology, and partial adoption.

[28]The five cities are the *préfectures* (equivalent to county seats in the United States) for the Far North Province: Kaélé, Maroua, Mokolo, Mora, and Yagoua.

two time series, one each for white and red sorghum. The TLU provided a second source of prices, reporting average monthly prices across six rural markets. These averages, based on two years of price data (1989-90), ranged from a low of 101 fcfa/kg in December to a high of 196 fcfa/kg in August.

Although these two data sets indicate that seasonality and annual rainfall greatly influence the market price, the series are too incomplete to be used to calculate a representative price for the analysis. The base run price is an average price (calculated from MINAGRI data) for the five markets at harvest time (November) in a year (1988) of "normal" rainfall. A second assumption set the market share of white and red sorghum at 50% each; thus, the mean price of the two was used during the cowpea analysis. A range of prices is then tested during sensitivity analysis.

Prices for cowpea leaves, and cowpea and sorghum stover were based on comments from key informants. Although these outputs are sporadically marketed, they do have economic value within the farmers' households. Since these prices are based on qualitative data, they are tested during sensitivity analysis. Price data for outputs are summarized below (Table 4.11). Prices are reported in fcfa but are converted to $US in the analysis.

Table 4.11 Estimated Average Annual Market Prices for Cowpea and Sorghum By-Products, Far North Province, Cameroon, 1984-1998

By-Products	Market Price fcfa/kg
Cowpea grain	155
Cowpea leaves	35
Cowpea forage	25
Sorghum grain	60
Sorghum stover	5

Source: Estimates based on MINAGRI and TLU data and interviews of key informants

4.2.4 Base Run for Cowpea ROR

Area Harvested

To conduct the analysis, annual total harvested area was disaggregated into three subsets: area in traditional practices, area under complete adoption of the improved package, and area where only the new variety (and not the complete package) had been adopted. The relative shares of each of these cropping systems are calculated by multiplying the adoption rates times total cowpea area harvested. For the period 1984 to 1989, total areas harvested are based on Agricultural Census data reported in Table 2.3. The six-year mean of these data were then used as the annual total area harvested for the period 1990 to 1998.

Production Totals

For each of the cropping systems, production totals are estimated based on the yield data reported above. Estimated per hectare yields are multiplied by area in production per cropping system to give total production figures for each system. The production figures for the three systems are then aggregated to determine the total annual production, given the introduction of the extension package[29]. A second total production figure is estimated for the region, based on the assumption that the improved package had never been developed and extended. It is calculated by multiplying estimated total area harvested by the estimated per hectare yields for the traditional system (i.e., local cowpea and sorghum intercrop). The difference between these two totals represents the gain in production due to the adoption of the improved package[30]. The market value of this gain in production is then estimated, using the price data discussed above.

Input Costs

For the two "adopted" cropping systems, aggregate input costs are calculated by multiplying the total area in production times the total per hectare cost of inputs. Per hectare input costs for the adoption of the complete package include both the cost of seed treatment and the cost of insecticide sprayings. Input costs for partial adoption only include the cost of seed treatment. These aggregated input costs are then subtracted from the benefit stream.

Gross Benefits

Gross benefits are determined by summing the market value of the gains in production, minus the increases in input costs incurred by farmers who adopt the package. For this analysis, gains and costs are reported in $US (Table 4.12).

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[29]For example, in 1989, total production of cowpea grain is estimated to equal (16,988 ha * 9.2% * 1,000 kg/ha) + (16,988 ha * 0.6% * 400 kg/ha) + (16,988 ha * 90.2% * 350 kg/ha) = 6,970 metric tons of cowpea.

[30]For example, in 1989, the estimated gain in cowpea grain production equals 6,970 - 5,950 = 1,020 metric tons.

The time horizon of the benefit stream is fifteen years, beginning in 1984, the first year TVX 3236 was extended by SODECOTON to farmers. By 1991, the year of this analysis, the improved varieties and farming technologies were experiencing a relatively high level of adoption (estimated to be 25%, as noted above). Key informants contend that cowpea is becoming an alternative cash crop to cotton in many of the more drought-prone areas of the Far North Province. Hence, projections of the improved varieties being grown for seven more years appears quite plausible.

Cowpea Base Run Benefit-Cost Stream

The internal rate of return for the base run is 15.5%, calculated for the net benefit-cost flow reported below (Table 4.13).

Table 4.12 Gross Benefits, in '000 $US, from the Development and Extension of Improved Cowpea Technologies, Far North Province, Cameroon, 1984 to 1998.

Year	Value of Gain in Cowpea Grain Production	Reduced Value of Cowpea Leaf Production	Reduced Value of Cowpea Forage Production	Reduced Value of Sorghum Grain Production	Reduced Value of Sorghum Stover Production	Total Annual On-farm Input Cost	Gross Benefits from Improved Package
1984	5	-1	-0	-2	-0	0	2
1985	20	-3	-0	-7	-0	1	8
1986	53	-7	-1	-20	-1	3	21
1987	110	-15	-1	-42	-1	7	43
1988	449	-63	-6	-171	-5	30	174
1989	499	-70	-6	-189	-5	33	195
1990	1318	-185	-17	-498	-14	87	517
1991	1888	-265	-24	-710	-20	125	744
1992	2030	-285	-26	-761	-21	134	803
1993	2246	-315	-28	-839	-23	148	892
1994	2430	-340	-31	-906	-25	160	967
1995	2437	-341	-31	-908	-25	161	970
1996	2444	-342	-31	-911	-25	161	973
1997	2444	-342	-31	-911	-25	161	973
1998	2444	-342	-31	-911	-25	161	973

Table 4.13 **Estimated Benefit-Cost Flows (in '000 $US) for the Improved Cowpea Package, Far North Province, Cameroon, 1979 to 1998.**

Year	Gross Benefits from Cowpea Package	Gross Costs of Research & Extension	Net Benefit Flow
1979	0	-31	-31
1980	0	-28	-28
1981	0	-44	-44
1982	0	-195	-195
1983	0	-348	-348
1984	2	-437	-434
1985	8	-407	-399
1986	21	-352	-331
1987	43	-324	-281
1988	174	0	174
1989	195	0	195
1990	517	0	517
1991	744	0	744
1992	803	0	803
1993	892	0	892
1994	967	0	967
1995	970	0	970
1996	973	0	973
1997	973	0	973
1998	973	0	973

4.2.5 Sensitivity Analysis - Cowpea

Although the base run is the best-judgment estimate of the returns to cowpea research and extension in northern Cameroon, sensitivity analysis is conducted to test the robustness of that estimate. Further, given that some data used in the analysis are estimates based on informed assumptions and not actual empirical findings, sensitivity analysis indicates how each assumption affects the results.

Over sixty additional estimates of the IRR to cowpea research and extension have been calculated, modifying the values of one or more of the model parameters/variables for each of the 60 runs. From this analysis, eight parameters/variables were identified as having a significant influence on the estimated rate of return (Table 4.14). Other parameters/variables, whose values were varied, changed the IRR by 20% or less from its base run value and hence, these results are not reported. The thirteen runs in which the rate of return was affected by more than 20% are discussed individually.

Table 4.14 **Sensitivity Analysis, Modifying Values of Key Variables and Subsequent Changes in the ROR for Cowpea Research & Extension, Far North Province, Cameroon, 1979-1998.**

Key Variables	Base Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Yield (kg/ha): cowpea grain, extended pkg.	1000	b[a] ± 10%	b ± 25%	b	b	b	b	b
cowpea grain in intercrop	350	b	b	b ± 25%	b	b	b	b
sorghum grain in intercrop	600	b	b	b	b ± 25%	b	b	b
Price (fcfa/kg): cowpea grain	155	b	b	b	b	b ± 25%	b	b
sorghum grain	60	b	b	b	b	b	b ± 25%	b
Area Harvested (ha)	23,600[b]	b	b	b	b	b	b	b ± 25%
Adoption Rate (% farmers adopting)	35.2[c]	b	b	b	b	b	b	b
Total Costs ('000 $)	2,166[d]	b	b	b	b	b	b	b
IRR (%) for:	15.5							
a decrease in value of variable		9.5	-18.0	19.6	18.3	3.5	18.3	11.9
an increase in value of variable		19.9	24.8	10.0	12.1	22.2	12.1	18.5
Change in Value of IRR from:								
a decrease in value of variable		-6.1	-33.5	+4.1	+2.8	-12.0	+2.8	-3.6
an increase in value of variable		+4.4	+ 9.3	-5.5	-3.4	+ 6.7	-3.4	+3.0

[a]"b" represents base run values for the variable

[b]Annual area harvested is reported in Table 2.3. During 1984-89, DEAPA reports that average area harvested is 23,600 ha.

[c]Annual adoption rates are reported in Table 4.9. The adoption ceiling for the base run is 35.2%.

[d]Total cost is an aggregate of the annual cost stream reported in Table 4.6.

Table 4.14, cont. **Sensitivity Analysis, Modifying Values of Key Variables and Subsequent Changes in the ROR for Cowpea Research & Extension, Far North Province, Cameroon, 1979-1998.**

Key Variables	Base Run	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14
Yield (kg/ha): cowpea grain, extended pkg.	1000	b	b	b - 25%	b	b	b	b ± 10%
cowpea grain in intercrop	350	b	b	b - 25%	b	b	b	b
sorghum grain in intercrop	600	b	b	b - 25%	b	b	b	b
Price (fcfa/kg): cowpea grain	155	b	b	b + 50%	b	b	b	b ± 10%
sorghum grain	60	b	b	b + 50%	b	b	b	b
Area Harvested (ha)	23,600	b	b	b	39,400[e]	↑ p.a. by 10%[f]	b	b ± 10%
Adoption Rate (% farmers adopting)	35.2	b ± 25%	b	b	b	b	b	b ± 10%
Total Costs ('000 $)	2,166	b	b ± 25%	b	b	b	2,150	b ± 10%
IRR (%) for: a decrease in value of variable an increase in value of variable	15.5	 11.7 18.6	 19.4 12.7	20.1	22.5	19.5	11.4	 1.3 27.0
Change in Value of IRR from: a decrease in value of variable an increase in value of variable		 -3.8 +3.1	 +3.9 -2.8	+4.6	+7.0	+4.0	-4.1	 -14.3 +11.5

[e]For this run, MINAGRI data for annual cowpea area harvested replaces DEAPA data, otherwise ceteris paribus. MINAGRI data are reported in the Appendix, for which the average area harvested (1981-1990) is 39,400 ha.

[f]For this run, area harvested in 1990 is assumed to be 23,600 ha, after which (1991-1998) a 10% per annum increase in area of cowpea harvested is assumed, otherwise ceteris paribus.

Runs 1 and 2: Cowpea Yield, complete package

The analysis was most sensitive to one parameter--the cowpea grain yield for the complete adoption of the improved technology package. Originally fixed at 1,000 kg/ha, four alternative values are reported, indicating rates of return ranging from +24.8 to -18.0 percent. In Run 1, the parameter was varied by plus or minus 10%, implying yields of 1,100 and 900 kg/ha, respectively. Similarly, in Run 2, the yields varied from the base run by 25%, implying parameter values of 1,250 and 750 kg/ha. Although the parameter's value greatly affects the returns to research, key informants have a high degree of confidence in the expected yield of the complete package. Hence, varying its value by 25% is probably excessive, and the resulting negative rate of return is unlikely. Thus, Run 1 better represents the range of values proposed by key informants, indicating a possible range in the IRR of 9.5 to 19.9%.

Run 3: Cowpea Yield, traditional system

When the value of the cowpea grain yield estimate for the traditional, intercropped farming system was varied by plus or minus 25% (±87.5 kg/ha), the IRR ranged from 10.0 to 19.6, respectively. Since the traditional system is being replaced by the improved technology, a decrease (increase) in the value of this parameter will result in a higher (lower) rate of return. By setting a lower output value (263 kg/ha) for the "defender crop", the new technology will inevitably appear better than before. Although the base run estimate for this parameter, set at 350 kg/ha, is the best available, key informants generally skewed their estimates of intercropped cowpea yield downward, indicating that the base run, if wrong, more likely overstates the yield and underestimates the IRR.

Run 4: Sorghum Yield

By varying the value of the yield parameter for intercropped sorghum by plus or minus 25%, the IRR ranged from 12.1 to 18.3%, respectively. Again, by diminishing the value of the output of the "defender crop", the returns to adopting the new technology are increased. However, estimates of intercropped sorghum yield are generally skewed upward, indicating that the base run yield of 600 kg/ha, if wrong, underestimates the output of the traditional farming system and overestimates the rate of return. Even if this is the case, a twenty-five percent increase in the parameter (to 750 kg/ha), resulted in only a 22 percent decrease in the rate of return, relative to the base run.

Run 5: Cowpea Price

The rate of return estimate varied considerably when the cowpea price parameter was varied by plus or minus 25 percent. As price was increased to 194 fcfa/kg, the rate of return increased to 22.2%. As price fell to 116 fcfa/kg, the rate of return decreased to 3.5%. Trends indicate that prices, if misspecified, are underestimated. Recently developed (since 1987) improved storage technologies should allow farmers and grain merchants to delay sales to capture higher post harvest market prices which occur during the dry season. If this holds true, then the base run underestimates the returns to research and extension.

Run 6: Sorghum Price

Varying the sorghum price parameter had less dramatic effects on the estimated IRR than similar variations in the cowpea price parameter. When sorghum price is set at 45 fcfa/kg (75% of the base run value), the IRR is 18.3%. When the same price is set at 75 fcfa/kg (125% of the base run value), the IRR becomes 12.1%. Again, the rate of return decreases when there is an increase in the value of the crop which adopting farmers no longer produce--in this case, intercropped sorghum. Although varying this parameter's value significantly affected the IRR, interpreting this result is extremely difficult. Sorghum price, depending on the weather, can vary significantly from year to year (Kamuanga, 1991, Johnson, 1987). Hence, the range of values for the rate of return in this run simply indicates the most likely returns, assuming relatively stable prices in the food-crop market.

Run 7: Area Harvested

Area harvested data are estimated from the published reports of DEAPA, the Cameroonian agency responsible for the annual Agricultural Census. By testing the robustness of these data, the analysis determines to what degree the rate of return estimate relies on the accuracy of this secondary data. When varied by plus or minus 25% of the reported values, the IRR estimate was 18.5 and 11.9% respectively. Given the assumptions of the analysis, an increase (decrease) in the amount of land cropped to cowpea leads to an increase (decrease) in the returns to the project.

Run 8: Adoption Rate

The annual estimate of the percentage of farmers adopting the new technology was varied by plus or minus 25%, resulting in IRRs of 18.6 and 11.7%, respectively. By increasing (decreasing) the number of farmers adopting the new technology each year, the returns to the project increase (decrease). The annual adoption rate is a difficult parameter to estimate. Hence, this run indicates that although the analysis is sensitive to this parameter's value, a 25% decrease in the annual percentage of farmers adopting still leads to a positive, albeit lower, rate of return to cowpea research and extension.

Run 9: Total Costs

Total annual costs were varied by plus or minus 25%, resulting in IRRs of 12.7 and 19.4%, respectively. Although most cost figures were directly quoted from project and institution documents, there is still a possibility of incorrectly estimating cost variables. The decision to include or exclude a given expenditure is not always clear cut. Serendipity within a well-established research system, spill-over benefits from other projects, and complementary research expenditures (eg., some training costs) are examples of potential costs that may not be included in the cost stream. Hence, by varying the cost variable, an estimate is made of how sensitive the IRR to cowpea research and extension is to higher or lower total costs. For this analysis, the IRR was still favorable at 12.7%, even with a projected 25% increase in annual costs.

Run 10: Drought Trend

This run projects a droughty future in which yields for all crops are 25% lower and prices are 50% higher. Given that cowpea is more drought tolerant, the returns to this scenario should be, and are, higher than for the base run--20.1% as compared to 15.5%. Run 10 is more than an academic exercise since much of the cowpea zone is in an area which has been experiencing a decade long period of drier than normal weather. With cowpea's comparative advantage in such conditions, the base run may actually underestimate the returns to cowpea research and extension.

Run 11: Area Harvested

The two sources of data for total cowpea area harvested are discussed in Chapter 2, as are the justifications for using DEAPA's data over MINAGRI's. However, for Run 11, MINAGRI's data are substituted for DEAPA's and a resulting IRR is calculated. For Run 11, the IRR to cowpea research and extension is 22.5%, which is expected since

MINAGRI's estimates of total cowpea area are consistently higher than DEAPA's. As with Run 7, as total area in cowpea increases, so does the area where the new technology has been adopted, and thus an increase in the returns to research and extension.

Run 12: Future Production

Given some anecdotal evidence presented by key informants, the amount of land grown to cowpea may actually be increasing. If this true, than the assumption used in the base run--fixing the total cowpea area harvested at 23,600 ha for the years 1990 to 1998--underestimates the IRR. As storage constraints are addressed by the research and extension system, and as cotton, an alternative cash crop, becomes less profitable due to structural changes within SODECOTON, cowpea may become a much more significant crop in northern Cameroon. Run 12 tests this scenario by assuming that total area in production in 1990 is 23,600 ha and that this area increases by 10% each year after 1990. The resulting IRR is 19.5%.

Run 13: Shadow Exchange Rate

This run relaxes the assumption that Cameroon's currency is not overvalued. Given that some anecdotal evidence in 1991 indicated that the fcfa in Cameroon was overvalued by approximately 40%, this run assumes that the overvaluation gradually increased to this level during the 1980s. Starting in 1981, an annual 5% incremental increase in the percentage of overvaluation is assumed (i.e., in 1981, the currency is overvalued by 5%, in 1982, by 10%). Thus, a 40% overvaluation is reached in 1988, which is then held constant for the remainder of the analysis (i.e., through 1998). The shadow exchange rate is calculated by multiplying the market exchange rate by a conversion factor (1 plus the foreign exchange premium, where the premium equals the percent of overvaluation divided by 100). The shadow exchange rate is then used to convert the values of all tradable goods within the cost and benefit streams to $US. The resulting IRR is 11.4%.

Run 14: Upper/Lower Bounds

A best case/worst case scenario is tested in Run 14, whereby five of the key variables are simultaneously modified by plus or minus 10%, resulting in IRR's of 27.0 and 1.3%, respectively. This range in the IRR is relatively academic since it is unlikely that the base run misspecified all five of the parameters/variables in such a way that all affect the IRR in the same way (negatively or positively). However, these results indicate that the returns to cowpea research and extension are most likely positive, and potentially quite favorable--even under the most extreme set of assumptions.

4.3 Sorghum

4.3.1 Overview of Sorghum Technologies

Grain sorghum has been one of the primary foci of agricultural research in northern Cameroon for over three decades. Early work (mid-1960s through the mid-1970s) conducted by IRAT and the SAFGRAD J.P. 26, a regional SAFGRAD project preceding J.P. 31, included the collection and classification of local germplasm and the screening of local varieties for desired traits. A short-lived breeding program was also initiated in 1970. In 1974, IRAT terminated its work in Cameroon and in 1976 J.P. 26 came to a close, leaving only the Cameroonian government, through IRA, to fund sorghum research. As a result, over the next several years sorghum research was limited to maintaining germplasm and seed stock. In 1979, sorghum agronomy and varietal screening trials were reinstated by the SAFGRAD Joint Project No. 31. In 1982, the

NCRE project greatly expanded sorghum research through the creation of a sorghum breeding program. In 1986, the NCRE project expanded its focus on sorghum, establishing a sorghum agronomy program in Maroua to complement the breeding research.

Throughout its history, sorghum research has focused on increasing grain yield, given the production constraints of the region. In the mid-1980s, yield stability emerged as a second research objective, as scientists recognized that yield stability across a wide range of environments and varied production constraints was as critical for meeting the needs of farmers as higher yields.

The IRAT and SAFGRAD research programs identified several sorghum varieties (IRAT 55, CE 99, E 35-1, and 38-3) for extension to farmers. However, these varieties were never extended on a large scale, in part due to constraints in both seed multiplication and extension resources. Not until 1986 were "improved" sorghum varieties (NCRE selected varieties S34 and S35) extended across large segments of northern Cameroon.

S-35 is unquestionably the sorghum research program's most significant technological output. This variety, originating from India, is a short cycle (90 day), medium height (2.5 m), white-grained sorghum that has some resistance to disease and insects. It was first grown in northern Cameroon in 1982 as one of several hundred varieties screened by the IRA/NCRE sorghum breeding program. From 1983 to 1986, the variety was tested both on-station by the sorghum breeding and cereal agronomy programs and on-farm as part of the SAFGRAD research program. In 1985, the NCSM project began multiplying S35 seed, producing 42 metric tons which, in 1986, much of which was extended (purchased and resold to farmers) by SODECOTON in 1986.

4.3.2 Sorghum Cost Stream

Principal Cost Components

Two donor projects and two host country institutions contributed to the development and extension of S35. SAFGRAD J.P. 31 conducted many of the early on-farm trials that helped identify S35 as an appropriate "improved" variety for the region. Within the NCRE project, the sorghum breeding unit in Maroua and the cereal agronomy unit in Garoua contributed to the selection of S35. Given that IRA is the host institution for the NCRE project, a portion of its expenditures also supported S35's development. As the only effective extension agency in the region, SODECOTON also contributed to the "success" of S35 both as a collaborating institution with on-farm trials and as the principal conduit for extending the technology to farmers.

The cost streams for the development of S35 extends from 1979, the first year of the SAFGRAD project, to 1986, the first year SODECOTON recommended S35 to farmers.

SAFGRAD Expenditures

As stated in the discussion on cowpea costs (section 4.2.2), sorghum was one of four food crops targeted by the SAFGRAD Joint Project No. 31, although it received a disproportionately larger share of staff time and project resources. From 1979 to 1983, SAFGRAD researchers allocated approximately 30% of their efforts to sorghum research. From 1984 to 1987, that percentage increased to 60%, shifting emphasis away from maize and millet. Since project costs are not disaggregated by commodities, these percentage shares--based on interviews of key informants--are multiplied by total project costs to estimate the relative share of costs for sorghum research[31]. Otherwise, the estimation of SAFGRAD cost streams for sorghum research follows the approach and set of assumptions concerning detailed cost accounts that was applied to the cowpea cost stream reported in Section 4.2.2. The resulting cost stream is reported in Table 4.15.

SAFGRAD costs prior to 1982 were included in the cost stream, even though S35 was not tested in Cameroon until 1982. This is justified since much of the early SAFGRAD work laid the foundation on which the later development of S35 depended. From 1982 to 1986, SAFGRAD was responsible for testing S35 in its on-farm research/pre-extension program.

NCRE Expenditures

In the early 1980s, two research programs within the NCRE project allocated a portion of their resources to sorghum research--the sorghum and millet breeding unit based in Maroua, and the cereal agronomy unit based in Garoua. Other NCRE programs which focused on sorghum were established after S35 was initially extended, including the TLU's on-farm program, and the Maroua-based sorghum and millet agronomy unit. Since these latter two NCRE supported programs began after the technology was extended, their costs are not included in this analysis.

[31]Estimates of each commodity's share of total project costs are based on interviews with Owen Gwathmey, Jerry Johnson, and Martin Fobasso--the three principal researchers working on the SAFGRAD project.

Table 4.15 Estimated Total Expenditures (Nominal $US), Sorghum Research, SAFGRAD Joint Project No. 31, Maroua, Cameroon, 1979 to 1986.

Year	Travel & Per Diem	Shipping & Storage	Housing	Other Direct Costs	Equipment Supplies Materials	Subtotal Non-Salary Expenses	Salary[a] Allowance	Total Costs
1979	2,880	677	3,403	154	7,299	14,413	9,468	23,881
1980	823	193	3,531	160	6,257	10,964	9,826	20,790
1981	823	193	3,678	166	3,128	7,989	10,236	18,225
1982	823	193	3,826	173	3,128	8,143	10,645	18,788
1983	2,880	677	3,973	179	1,043	8,752	11,054	19,807
1984	na[b]	na	na	na	na	24,376	59,423	83,799
1985	na	na	na	na	na	32,501	59,423	91,924
1986	na	na	na	na	na	16,251	62,080	78,331
Totals	na	na	na	na	na	123,389	232,155	355,545

Source: Project Documents; Interviews with O. Gwathmey, M. Fobasso, and J. Johnson.

[a]Benefits are included in the salary data (eg., cost of living allowances, guardians, utilities).

[b]na signifies data "not available".

Within the sorghum and millet breeding unit, researchers targeted approximately seventy percent of their resources to sorghum and thirty percent to millet. Sorghum research activities included a breeding program for rainfed sorghum, and varietal screening trials for both rainfed sorghum and mouskwari. As stated above, the principal technology generated by these activities was S35, an output of the varietal screening trials. However, due to the highly correlated and complementary nature of the breeding and screening activities, the costs of both are included in the sorghum cost stream.

Within the cereal agronomy unit, researchers allocated approximately thirty percent of their resources to sorghum and seventy percent to maize (Talleyrand, et al., 1985). Sorghum research within this unit examined the yield stability of "improved" varieties in a range of cultural and management practices (eg., tied ridging, seed treatments, fertilizer use, multiple planting dates). Since this research contributed to the identification of S35 as an appropriate variety for northern, semi-arid Cameroon, its cost is included in the analysis.

Because actual project expenditures for these activities were not available at the time of the analysis, operating expenses, administrative overhead costs, and the cost of the salaries and benefits of the expatriate research staff were estimated (Table 4.16).

Operating expenses were estimated from annual budget requests that had been submitted by each research unit. Although researchers suggested during interviews that these budgets were good proxies for actual expenditures, project administrators noted that in past years budgeted and actual expenditures had varied by as much as plus or minus fifty percent. Further, budget requests were not instituted within the NCRE project until 1987, which explains why budget request data were not available for the period 1982 to 1986. However, both researchers and administrators contend that annual expenditures have not fluctuated significantly over the lifetime of the project and that the budget requests are the best available proxies.

Hence, for the period 1982 to 1986, the operating cost estimates are based on the average annual budget requests submitted by the two research units during the four-year period 1987 to 1990. The averages are adjusted to include only sorghum expenditures by multiplying the costs of the sorghum and millet breeding unit by 0.7 and the costs of the cereal agronomy unit by 0.3. Actual estimates of sorghum's share of annual operating costs are 8.4 million fcfa for the breeding unit and 2.7 million fcfa for the agronomy unit.

Administrative costs are estimated as a function of total estimated operating costs. A twenty-percent administrative overhead charge is assumed, implying that total annual operating costs are multiplied by 0.2 to derive an estimate for administrative costs. Hence, estimated annual administrative costs are 2.2 million fcfa.

The salaries and benefits of expatriate researchers are estimated from available cost data for the NCRE project. An internal document from IITA, the principal contractor for the NCRE project, listed total "professional salaries and allow[ances]" of $128,960.87 for the month of November, 1985. By assuming that salary and benefits did not fluctuate significantly on a month to month basis, this total represents the "average" monthly costs of salaries and benefits. Given that there were eleven expatriate staff[32] involved in the project in November, 1985, the annual cost per researcher is:

$$(\$128{,}960.87 \;/\; 11 \text{ researchers}) \times 12 \text{ months} \approx \$140{,}000/\text{researcher}/\text{year}$$

[32]The eleven researchers/administrators were Almy, Atayi, Dangi, Empig, Everrett, Janakiram, Kikafunda, McHugh, Roy, Talleyrand and Welch (NCRE Annual Reports, 1984 and 1986)

For the period 1982 to 1986, one expatriate researcher was assigned to each of the two research units involved in the development of S35. As with operating costs, the total salaries and benefits of these two researchers are adjusted to reflect the proportion of total time and effort allocated to sorghum research, multiplying sorghum and millet breeding salary costs by 0.7 and cereal agronomy costs by 0.3. Hence, the estimated total salaries and benefits spent on the development of S35 is $140,000 per annum.

Table 4.16 Estimated Total Expenditures (Nominal $US), Sorghum Research within the National Cereals Research and Extension Project, Northern Cameroon, 1982 to 1986.

Year	Operating Expenses	Administrative Expenses	Salaries & Benefits	Total Expenditures
1982	33,780	6,756	140,000	180,536
1983	29,126	5,825	140,000	174,951
1984	25,400	5,080	140,000	170,481
1985	24,705	4,941	140,000	169,646
1986	32,053	6,411	140,000	178,464
Totals	145,065	29,013	700,000	874,077

Source: NCRE documents and interviews with NCRE researchers and project administrators.

<u>IRA Expenditures</u>

IRA's financial contribution to the development of S35 is divided into four cost categories: operating expenses, salaries and benefits of host nationals employed in the system, administrative costs, and in-kind contributions (eg., buildings, land). Due to data constraints, the cost streams in this analysis only include estimates for the first three categories, thus underestimating total costs and overestimating the system's rate of return. Total costs are modified during sensitivity analysis to estimate the impact of this underestimation.

For the period 1983 to 1986, total operating expenses for the IRA cereals program were provided by the accountant at the IRA-Maroua research center. Since records for years previous to this were not available, estimates were based on a report summarizing national IRA expenditures in 1980 and budgeted expenditures in 1981 (Ekelbee). From these records, annual operating expenses for the period 1979 to 1982 were estimated.

The estimates of sorghum's share of operating expenses for the IRA-Maroua research center were based on several estimations and assumptions. Expenses for IRA's Maroua Research Center are recorded by programs, one of which is the cereals program. Within this program, there were two research units during the 1979 to 1986 period: the sorghum and millet research unit based in Maroua and the cereal agronomy unit based in Garoua. The first assumption is that these two units received an equal share of the cereal program's budget. Within each of these units, the same allocation of resources are assumed as is applicable to the NCRE project (70% of costs for the sorghum and millet unit and 30% of costs for the cereal agronomy unit).

As was the case with cowpea, salaries and benefits of IRA research staff involved with sorghum research were not readily available for analysis. Hence, a history of the staff involved in sorghum research and estimates of their salaries and benefits was constructed from IRA and NCRE documents. Included in this history are the research staff associated with the SAFGRAD on-farm program, the sorghum and millet breeding program and the cereal agronomy program, as well as the administrative staff based in

Maroua. As before, salary expenditures are adjusted to reflect the fact that sorghum research represented only a portion of each staff member's research and/or administrative efforts (Table 4.17).

SODECOTON Expenditures

As with cowpea, the successful adoption of the improved sorghum technology depended in part on the extension efforts and input distribution capacity of SODECOTON. The method for estimating the cost of these activities parallels the one used with the cowpea analysis. The sole exception is in computing sorghum's relative share of total hectares in food crop production. With sorghum, agricultural census data indicate that, on average, sorghum comprises 73% of food crop hectares harvested in the Far North Province. Hence, by assumption, 73% of SODECOTON's food crop extension costs are allocated to the sorghum extension cost stream. As with cowpea, the estimates were based on SODECOTON'S total annual expenditures for extension staff multiplied by a cost factor. In the sorghum case, this factor equals (10% * 73% * 1.2), or simply 0.0876. The resulting estimates of annual costs are reported in Table 4.18. SODECOTON costs are included for the period 1981 to 1986, since IRA, and the SAFGRAD and NCRE projects collaborated with the parastatal during these years in both on-farm research and in extending the improved sorghum technologies.

Aggregate Costs

Annual costs for the eight-year period during which the sorghum technology was developed and then extended to farmers are summarized in Table 4.19. The last column, "Total Annual Costs", is the cost stream used in the benefit-cost analysis.

Table 4.17 **Estimated Total Expenditures by IRA, in Nominal $US, for Sorghum Research at IRA's Maroua Research Center, Cameroon, 1979 to 1986.**

Year	Research Staff	Admin. Staff	Operating Expenses	Total Expenses
1979	4,552	3,348	18,642	26,542
1980	4,611	3,505	19,099	27,215
1981	3,977	2,835	14,337	21,149
1982	18,373	2,438	12,068	32,879
1983	18,262	2,186	21,441	41,889
1984	25,503	1,983	18,347	45,833
1985	27,212	2,006	16,409	45,626
1986	36,546	2,706	16,826	56,077
Totals	139,036	21,006	137,168	297,210

Source: NCRE and IRA documents and interviews with the IRA-Maroua accountant.

Table 4.18 Estimated Total Expenditures, Nominal $US, SODECOTON Extension Costs for Sorghum Technologies, Northern Cameroon, 1981 to 1986.

Year	Annual Costs for extension staff, food and cash crops	Annual Costs for Sorghum Extension
1981	2,552,541	223,603
1982	2,461,364	215,615
1983	1,839,374	161,129
1984	1,858,072	162,767
1985	2,539,872	222,493
1986	2,507,110	219,623
Total	13,758,333	1,205,230

Source: Estimates based on internal documents and interviews of SODECOTON staff, 1991.

Table 4.19 Estimated Total Costs, Nominal $US, Sorghum Research and Extension Programs, Northern Cameroon, 1979 to 1986.

Year	SAFGRAD J.P. 31	NCRE	IRA	SODE-COTON	Total Annual Costs
1979	23,881	0	26,542	0	50,423
1980	20,790	0	27,215	0	48,005
1981	18,225	0	21,149	223,603	262,977
1982	18,788	180,536	32,879	215,615	447,818
1983	19,807	174,951	41,889	161,129	397,776
1984	83,799	170,481	45,833	162,767	462,880
1985	91,924	169,646	45,626	222,493	529,689
1986	78,331	178,464	56,077	219,623	532,495
Totals	355,545	874,077	297,210	1,205,230	2,732,063

Source: Tables 4.15 to 4.18.

4.3.3 Sorghum Benefit Stream

Principal Benefit Components

The benefit stream associated with sorghum research in northern Cameroon was estimated from data on: (1) farmers' yields for local sorghum varieties and for S35, the improved variety extended to farmers; (2) the frequency of drought conditions; (3) annual adoption rates of the improved technology; (4) hectares in sorghum production; and, (5) market prices for inputs and outputs.

These data are the basis for the estimates of the market value of the annual aggregate gain in sorghum production due to the development and extension of S35. Thus, this value, in US dollars, quantifies the gains from sorghum research and forms the benefit stream used in the benefit-cost analysis.

Sorghum Grain Yields

Numerous sources report sorghum yields for one or more sets of farming practices, including trial data reported by the SAFGRAD and NCRE projects, and on-farm yields reported by SODECOTON and MINAGRI. Crop management practices include both intercropped and monocropped systems, although monocropped systems vary considerably in the degree and breadth of adoption/application of improved technologies. Reported yields (Table 4.8) range from 448 kg/ha for a TLU-sponsored on-farm intercropped sorghum trial to 5,588 kg/ha for a CRSP-sponsored on-station cowpea/sorghum intercropped trial (NCRE Annual Report, 1989; Ta'Ama, 1988, respectively).

Sorghum yields are estimated by combining available yield data with qualitative data on rainfall patterns in northern Cameroon. Although the data in Table 4.8 indicate yield potentials, yields in any given year are highly dependent on the quantity, timing and dispersion of rainfall in the region. Further, sorghum researchers concede that the improved variety outyields local varieties only in years when the onset of the rainy season is late and/or total rainfall is below average.

Hence, there was a need to estimate three yields: an average yield for both traditional and improved varieties under normal rainfall conditions, an average yield for the improved variety under drought, and an average yield for traditional varieties under drought. An estimate of the probability that rains will be late and/or below normal levels was also needed.

Estimated yields for farmers producing sorghum under normal rainfall conditions are the most similar to published results. Although Agricultural Census data and SODECOTON estimates set farmers' yields relatively high, ranging from 650 to 1,467 kg/ha, one sorghum researcher in IRA suggested that sorghum farmers in the Center-North zone have yields averaging 600 to 700 kg/ha. While trial results surpass either of these yields, some by almost a factor of 10, they were discounted since on-station trial results have limited predictive power of farmers' yields. Hence, sorghum yields for normal rainfall conditions are set at 800 kg/ha. This value represents the middle ground of available data[33].

Yield estimates under drought conditions are based on trial data from 1984, a drought year, and from anecdotal evidence provided by key informants. Yield data from on-farm varietal screening trials indicate that S35 yields in 1984 averaged 73% of yield for S35 during the subsequent three years (IRA/SAFGRAD/TLU, various reports).

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[33]Sorghum yield was estimated to be 600 kg/ha for the cowpea benefit-cost run. This discrepancy is intentional. Intercropped cowpea and sorghum are generally grown in more droughty areas of the region, implying lower average yields for intercropped sorghum relative to average region-wide yields.

Similarly, traditional varieties yielded only 42% of the subsequent three year average. Even more dramatic gains for S35 were suggested by an IRA researcher who proposed that in drought years, S35 will typically outyield local varieties by 500 kg/ha. Based on this evidence, drought-year yields were set at 650 kg/ha for S35 and 300 kg/ha for local varieties.

For northern Cameroon, limited time-series data on rainfall are available. IRA-Maroua reports annual rainfall data *par décade* (by ten-day periods) for twenty sites in the cotton growing area of its research zone. These series, depending on the site, extend back in time for fourteen to thirty-six years. Eleven of these sites are in the same area where the highest levels of S35 adoption have been reported.

As a crude estimate of the probability of drought at these sites, the ratio of years with total rainfall below 600 mm to total years in the times series was calculated for each site. The average value of this ratio was one drought year in every four years. However, this ratio only considers total rainfall and not the possibility of late onsets of the rainy season. Also, as noted in Chapter 2, Section 2.2, northern Cameroon has experienced an extended drought period for the last fifteen years, and key informants in northern Cameroon speculate that drought conditions may occur at any given site in any given year. Hence, the benefit-cost analysis sets the probability of drought at one in every three years, implying triennial yield patterns of 800, 800, 650 kg/ha for S35 and 800, 800, 300 kg/ha for local varieties.

Sorghum Stover Yields

Although in northern Cameroon farmers primarily grow sorghum for grain, stover is an important and valued by-product. Stalks are used as livestock feed during the dry season and as building materials for fences, roofs and walls. S35 is a medium height (2.5

meters) variety, a trait cited by some farmers as a reason for nonadoption (Kamuanga, 1990). Clearly, these farmers value the longer stalks common to many of the local varieties.

By adopting S35, farmers forego the preferred stalk length and/or total quantity of stover production, traits that have some economic value. However, no data exist indicating the net loss in stover production from adopting S35 nor its economic value. In the cowpea section of this thesis, an estimate of stover production and its market value were reported. Although similar estimates could be made for this analysis, key additional information needed to estimate the stover losses are still absent--the net difference in stover production between improved "medium height" and traditional "tall" varieties, and the percentage mix of tall, medium and short varieties traditionally grown by farmers. Without these data, it is impossible to estimate of the loss of stover production. Hence, this analysis ignores any loss in stover production, and consequently, overestimates the returns to sorghum research (although this overestimation is probably quite small).

<u>Adoption Rates</u>

A prefatory statement is necessary to understand the potential level of adoption of S35 in northern Cameroon. It is provided by Kamuanga, who notes that:

> North Cameroon is a region endowed with an enormous variety of local materials. More than 1,800 accessions have been evaluated by IRA in collaboration with ICRISAT (Dangi et al., 1989)...Any new introduced variety in the release process should be considered as a complementary addition to the farmers' 'pool' of varieties and not as a replacement of local materials (1991, p. 12).

Given S35's advantage in drought conditions, its adoption should depend, in part, on the climatic conditions faced by farmers. If farmers could perfectly predict drought years at planting time, they would choose the appropriate variety for the expected levels and timing of rainfall. Clearly, this is not possible. Only in years when the onset of the rainy season is late can farmers plant S35 with the explicit purpose of capitalizing on its drought tolerance and short growing cycle.

Yet, farmers have adopted a strategy that incorporates the improved variety as an apparent attempt at lowering risk. Some adopters of S35 crop the improved variety with traditional varieties in the same field, thus diversifying the crop mix in the field and lowering their risk exposure. Although Russell (1991) found few advantages to these mixed sorghum stands in northern Cameroon, he notes that, "farmers themselves are growing mixed stands, even with the newly-introduced varieties, [which] indicates that more information is needed on farmers' strategies and motives (p. 158)."

Since rainfall patterns in northern Cameroon are so erratic, S35 may be the appropriate variety for any given site in any given year. As Kamuanga notes, "the diversity of sorghum grown in north Cameroon makes it possible for farmers to select, for any given planting date, those varieties that are very likely to mature with or soon after the rains (1991, p. 9)." Hence, the adoption of S35 on a per hectare basis was assumed to be relatively constant from year to year, although the same farmer may not grow S35 in two consecutive years.

Annual adoption rates are quantified using available indicators of adoption, including production figures from IRA and SODECOTON documents, seed sales reported by the NCSM project, and an adoption survey conducted in 1990 by the TLU. These data are incorporated into a logistic function to predict annual adoption rates and the adoption ceiling.

Initial adoption figures (years 1984 and 1985) were limited to on-farm trials conducted by the SAFGRAD J.P. 31 in collaboration with IRA and SODECOTON.

Technically, these figures do not represent actual adoption since collaborating farmers were simply following a strict protocol, including which varieties to grow. However, these trials do represent a form of extension whereby improved varieties were introduced to local farmers.

In 1984, 7 ha of S35 were grown in farmers' fields as part of the on-farm research program; similarly, 24 ha were grown in 1985. These areas seeded to S35 represent 0.004% and 0.012%, respectively, of total area in sorghum production. Given that 1984 was a drought year in which S35 clearly and consistently outperformed all other available varieties, it is highly likely that many of the farmers involved in on-farm trials in 1984 continued to grow S35 in 1985. However, there is no record of this level of adoption, implying that the 1985 adoption estimate of 0.012% is an underestimation, perhaps by as much as a factor of 10. The significance of this underestimation is tested during sensitivity analysis.

In 1987, Jerry Johnson surveyed farmers who had participated in on-farm trials during one of the previous three growing seasons (1984 to 1986). He reported that 23%, 29% and 48% of farmers who participated in 1984, 1985, and 1986, respectively, still grew S35 in 1987, indicating that some farmers had adopted S35. This is confirmed by SODECOTON production records which indicate that in 1986, 649 ha of S35 were harvested as part of the parastatal's food crop extension program. But SODECOTON data underestimate the adoption of S35 in 1986, since in that year the NCSM project produced and sold 42.34 metric tons of S35 seed. At the recommended planting density of 20 kg/ha, this represents 2,117 ha seeded to S35. Since 1986 was the first year that S35 was extended to farmers on a large scale, seed sales are assumed to be the most accurate proxy for total adoption for that year. This implies an adoption rate of 1.03%.

Seed sales in subsequent years were not as good a proxy for adoption since the improved variety is open pollinated, implying farmers can propagate their own seed stock. Hence, in 1990, motivated by the need for a more accurate measure of adoption, the TLU conducted a large-scale adoption survey throughout the Center-North zone, focusing primarily on the adoption of S35. Results from this survey indicated that S35 comprised 3.3% (pure stand equivalents) of the sorghum area harvested in 1991 (Kamuanga, 1991).

Using the adoption rates of S35 in 1986 and in 1990, the parameters for the logistic function (Equation 4.3) were calculated by solving the following two-variable, two-equation algebraic problem:

$$\begin{aligned} 1.03 + (1.03 * be^{-3}) &= K \\ 3.30 + (3.30 * be^{-7}) &= K \end{aligned} \tag{4.4}$$

The parameter values for K and beta are 3.44 and 47, respectively, where K is the adoption ceiling, in percentage of land planted to sorghum.

Using equation 4.3 and these parameter values, annual adoption rates were calculated for years 3 to 15 of the benefit stream (1986 to 1998). Since actual adoption figures, in the form of on-farm trial results, are available for the first two years that S35 was extended to farmers, these are used for 1985 and 1986. Annual adoption rates and hectares in production[34] are reported in Table 4.20.

Prices - Inputs

Sorghum production in northern Cameroon requires, at a minimum, seed, labor and land. Extension recommendations add seed treatment and fertilizers to the list of possible inputs, which, if used, clearly add to the cost of production. However, for this analysis, the key point is not the actual cost of inputs but whether expenditures on inputs at the farm level changed with the adoption the improved variety.

As noted in the sorghum yield section above, researchers concede that S35 does not outyield local varieties in normal rainfall years. Implicit in this comparison is that all other levels of inputs are the same. The analysis requires that one of two simplifying assumptions be chosen: either assume that the level of inputs used by an individual farmer is independent of the variety grown or that farmers growing S35 achieve higher yields during normal rainfall years because the adoption of S35 implies a more intensive level of input usage. Anecdotal evidence suggests both assumptions are true for some farmers, although the former appears to be the dominate behavior. Thus, this analysis assumes that farmers choose levels of inputs independent of the variety(ies) grown, so no additional farm-level input costs are associated with the adoption of S35. Consequently, farm-level input costs were not included in the benefit-cost analysis.

[34]Total area harvested for rainy season sorghum ("first crop" sorghum) is estimated from Agricultural Census data for the Far North Province plus the Mayo Louti Department of the North Province. These estimates are detailed in Section 4.3.4 under the heading "Area Harvested".

Table 4.20 Projected Adoption Rates and Estimated Area Harvested for S35 Sorghum, Northern Cameroon, Years 1984-1998.

Year	Total Area Harvested, Rainy Season Sorghum (Ha)	S35 Adoption Rate, % of area harvested	Total Area Harvested, S35 (Ha)
1984	172,260	0.004	7
1985	208,577	0.012	25
1986	205,607	1.030	2,117
1987	114,787	1.849	2,122
1988	183,700	2.613	4,799
1989	193,516	3.081	5,962
1990	179,800	3.299	5,931
1991	179,800	3.387	6,089
1992	179,800	3.420	6,149
1993	179,800	3.433	6,172
1994	179,800	3.437	6,180
1995	179,800	3.439	6,183
1996	179,800	3.440	6,184
1997	179,800	3.440	6,185
1998	179,800	3.440	6,185

Prices - Outputs

Quantifying the economic value of sorghum production in northern Cameroon for improved varieties requires time-series price data for white sorghum grain. Two average prices are needed for the analysis: the price of white sorghum during normal rainfall years and the price during drought years. Kamuanga, et al., report that sorghum grain price fluctuations are extreme, varying by as much as 400% in response to supply fluctuations.

MINAGRI reports monthly retail prices for white sorghum over a six-year period (1985 to 1990) for five "urban" markets, as detailed above in Section 4.2.3. Since this series is incomplete, prices in representative years are used as proxies for average annual prices.

Since the 1984 growing season was a drought year, pre-harvest prices in 1985 reflect the economic value of sorghum production after drought years. Prices, available for three markets (Maroua, Kaélé and Mora) for the months of July through September, ranged from 160 to 206 fcfa/kg of white sorghum. Given the severity of the drought in 1984, these prices probably represent an upper limit of the normal range of sorghum prices. They also are "hungry season" prices, representing not the price at harvest but rather the price eight to ten months after harvest. Hence, for the base run of the analysis the drought year price for sorghum was set at 130 fcfa/kg, approximately twice the normal rainfall year price.

The normal rainfall year price is based on the average market price for white sorghum across all five markets for November, 1988--which ranged from 35 to 75 fcfa/kg and averaged 63 fcfa/kg. November prices were chosen since this month represents the peak period of sorghum harvesting and marketing by farmers. The year 1988 was chosen since rainfall that year was at a historically normal level for the region[35].

These two prices are incorporated into the benefit stream as part of the assumption that drought years come once every three years. Thus, a triennial price pattern of 130, 63, and 63 fcfa/kg is repeated throughout the time-frame of the analysis, beginning with 1984 as a drought year.

4.3.4 Base Run for Sorghum ROR

Area Harvested

Two estimates are needed concerning area harvested: the annual total harvested area and the annual area harvested for the variety S35. The former is an estimate based on Agricultural Census data. The latter is simply the former multiplied by the adoption rates reported in Table 4.20.

To use Agricultural Census data to estimate area planted required two sets of adjustments. First, annual data on area harvested are only disaggregated to the provincial level. However, the extension zone for S35 includes the northern most department (Mayo Louti) of the North Province in addition to all of the Far North Province. Since disaggregated, department-level data were only available for 1984, the ratio of sorghum area harvested in the Mayo Louti Department to the total sorghum area in the North Province is assumed to be constant over time. Multiplying this ratio times the annual provincial-level data of the North Province gives an estimate of the sorghum area harvested annually in the Mayo Louti department. Second, as noted in

[35]The Maroua TLU reported monthly prices for six rural markets which were averages of 1989 and 1990 prices. The overall 24 month average price was 64 fcfa/kg, while average price in November was 56 fcfa. These data combine white and red sorghum prices, even though white sorghum commands a premium in the market place.

Chapter 2, the Agricultural Census reports sorghum and pearl millet data combined together. Hence, census data are multiplied by 0.9 to remove millet from the estimated totals.

Production Totals

Total production is estimated by multiplying yield estimates by the areas harvested. Annual production totals for the two cropping systems, given the two rainfall scenarios, are then aggregated to determine the total annual production, given the introduction of S35. A second total production figure is estimated for the region, based on the assumption that the improved package had never been developed and extended. The difference between these two totals represents the gain in production due to the adoption of S35. The market value of this gain is then estimated, using the price data and exchange rates discussed above.

Gross Benefits

Gross benefits from the development and extension of S35 are simply the annual market values of the gains in production, converted to $US. The estimate of gross benefits is based on several key assumptions, summarized as follows: (1) stover loss from the adoption of S35 is marginal and therefore can be ignored; (2) farmers choose their level of inputs (seed treatments, fertilizer, etc.) independent of the variety grown; and, (3) rainfall has a triennial pattern where "good" rains occur two out of three years and drought occurs during the third.

The time horizon of the benefit stream is fifteen years, beginning in 1984, the first year S35 was tested widely in farmers' fields. Key informants generally believe that S35 is now "out there" as part of the pool of sorghum varieties from which farmers select each year. Because the variety has been extended widely and has noticeable advantages during drought conditions, the assumption that its benefit stream will continue for another seven years from the time of this analysis (1991) is relatively conservative.

Sorghum Base Run Benefit-Cost Stream

The internal rate of return for the base run is 0.9%, calculated for the net cost/benefit flow reported below (Table 4.21).

4.3.5 Sensitivity Analysis - Sorghum

Although the base run estimate of the IRR is the best judgment possible of the returns to sorghum research and extension in northern Cameroon, sensitivity analysis is conducted to test the robustness of the estimate. Key assumptions and parameter values are tested to see how changes in their values affect the reported IRR.

Approximately forty alternative sets of assumptions and/or parameter values were tested, and IRRs were calculated for each of them. Ten of these runs, judged to be the most telling, are reported in Table 4.22 and are discussed below. With these runs, IRR values ranged from -5.6% to +7.9%.

The reported IRRs generally differ only slightly from the base run, indicating that the IRR estimate is relatively robust. The values of the IRRs tend towards zero to slightly positive, indicating that sorghum research and extension probably broke even (i.e., was "able to pay for itself" in financial terms), but most likely failed to earn sufficient returns to be "profitable" in economic terms (i.e., where "profitability " implies returns greater than 10%, the approximate opportunity cost of capital in northern Cameroon).

Table 4.21 Estimated Benefit-Cost Flows (in '000 $US) for the Development and Extension of the Improved Sorghum Variety S35, Northern Cameroon, 1979 to 1998.

Year	Gross Benefits of S35	Gross Costs of Research & Extension	Net Benefit flow
1979	0	-51	-51
1980	0	-48	-48
1981	0	-263	-263
1982	0	-448	-448
1983	0	-398	-398
1984	1	-463	-462
1985	0	-530	-530
1986	0	-530	-530
1987	294	0	294
1988	0	0	0
1989	0	0	0
1990	601	0	601
1991	0	0	0
1992	0	0	0
1993	943	0	943
1994	0	0	0
1995	0	0	0
1996	1,119	0	1,119
1997	0	0	0
1998	0	0	0

Table 4.22 **Sensitivity Analysis, Modifying Values of Key Variables and Subsequent Changes in the ROR for Sorghum Research & Extension, Northern Cameroon, 1979-1998.**

Key Variables	Base Run	Run 1	Run 2	Run 3	Run 4	Run 5
Yields in Drought Years (kg/ha): sorghum grain, variety S35	650	b[a] ± 25%	b	b	b	b
sorghum grain, local varieties	300	b	b ± 25%	b	b	b
Yields in Normal Years (kg/ha): sorghum grain, variety S35	800	b	b	b	b	b
sorghum grain, local varieties	800	b	b	b	b	b
Price in Drought Years (fcfa/kg): sorghum grain	130	b	b	b ± 25%	b	b
Area Harvested (ha)	179,800[b]	b	b	b	b ± 25%	b
Frequency of Drought Conditions (years)	triennial	b	b	b	b	b
Extension Costs ('000 $)	1,205[c]	b	b	b	b	zero
Total Costs ('000 $)	2,731[d]	b	b	b	b	1,527
IRR (%) for:	0.9					7.7
a decrease in value of variable		-5.6	3.0	-2.2	-2.2	
an increase in value of variable		5.2	-1.7	+3.3	3.4	
Change in Value of IRR from:						+6.8
a decrease in value of variable		-4.7	+2.2	-3.0	-3.1	
an increase in value of variable		+4.3	-2.6	+2.5	+2.5	

[a] "b" represents base run values for the variable

[b] Annual area harvested is reported in Table 4.20. During 1984-89, DEAPA reports that average area harvested is 179,800 ha.

[c] "Extension costs" is an aggregate of the annual cost stream for extension reported in Table 4.18.

[d] "Total costs" is an aggregate of the annual cost stream reported in Table 4.19.

Table 4.22, cont. **Sensitivity Analysis, Modifying Values of Key Variables and Subsequent Changes in the ROR for Sorghum Research & Extension, Northern Cameroon, 1979-1998.**

Key Variables	Base Run	Run 6	Run 7	Run 8	Run 9[f]	Run 10	Run 11
Yields in Drought Years (kg/ha): sorghum grain, variety S35	650	b	b	b	700	b	b ± 10%
sorghum grain, local varieties	300	b	b	b	b	b	b ± 10%
Yields in Normal Years (kg/ha): sorghum grain, variety S35	800	b	b	b	900	b	b
sorghum grain, local varieties	800	b	b	b	800	b	b
Price in Drought Years (fcfa/kg): sorghum grain	130	b	b	b	b	b	b ± 10%
Area Harvested (ha)	179,800[b]	b	214,628[e]	b	b	b	b ± 10%
Frequency of Drought Conditions (years)	triennial	b	b	biennial/ quadrennial	b	b	b
Extension Costs ('000 $)	1,205[c]	b	b	b	b	1,032	b
Total Costs ('000 $)	2,731[d]	b ± 25%	b	b	b	2,529	b ± 10%
IRR (%) for:	0.9		3.9		0.8	-1.4	
a decrease in value of variable		4.1		-0.4			-5.6
an increase in value of variable		-1.5		7.9			7.0
Change in Value of IRR from:			+3.0		-0.1	-2.3	
a decrease in value of variable		+3.3		-1.3			-6.5
an increase in value of variable		-2.4		+7.0			+6.2

[e]For this run, MINAGRI data for annual sorghum area harvested replaces DEAPA data, otherwise ceteris paribus. MINAGRI data are reported in the Appendix for which the average annual area harvested (1981-90) is 214,628 ha.

[f]For this run, it is assumed that the adoption of S35 implies the adoption of a complete package, including seed treatment (thioral) and fertilizer (urea) applied at 50 kg/ha. The costs of these inputs are included in the IRR calculation.

Run 1: Drought Yield, S35

The drought year yield for the improved variety was varied by plus or minus 25% (±162.5 kg/ha), resulting in IRRs of 5.2 and -5.6%, respectively. The increase in the IRR is expected with an increase in the yield of S35. Conversely, the IRR declines with a decrease in S35's competitive advantage (i.e., lower yields) over local varieties in drought years. The higher IRR is somewhat suspect since a 25% increase in drought yield implies that S35 has a slight yield increase in drought years when compared to its yield in normal years (812 verses 800 kg/ha). Clearly, this is unlikely and the analysis was adjusted accordingly, setting both S35 yield parameters at 800 kg/ha, resulting in an IRR of 4.9%. Conversely, a 25% drop in the value of S35's yield in drought years drastically affects the IRR, lowering it to -5.6%. A more conservative 10% drop in this parameter's value resulted in an IRR of -1.3%, implying that the analysis is sensitive to the assumptions made about S35's drought yield.

Run 2: Drought yield, local varieties

The IRR was less sensitive to changes in assumptions about the drought yield for local varieties, relative to similar changes in the drought yield for S35. With a 25% plus or minus change in the parameter's value (±75 kg/ha), the IRR changed to -1.7 and 3.0%, respectively. A decrease in the returns to research and extension is expected if the "defender crop" is assumed to be more competitive. Such is the case when the drought year yield parameter for local varieties is increased to 375 kg/ha. The opposite is true as well--if the "defender crop" becomes less competitive, the benefits of the improved variety increase. The likelihood of yields falling within the 225 to 375 kg/ha range depends almost entirely on the severity of drought assumed and/or experienced. Hence, interpretations of this run are difficult, and limited to an obvious conclusion: as drought conditions become more severe and/or frequent, the more likely the benefits of S35 will translate into positive returns for research and extension.

Run 3: Drought Year Prices

The returns to research and extension were also sensitive to the assumptions made about sorghum prices in drought years. Again, this parameter's value depends on the severity of the drought and the magnitude of the resulting shortfall in supply. A 25% decrease in the drought year price resulted in a decrease of over three percentage points in the IRR estimate--falling from 0.9% to -2.2%. An increase of 25% in drought year prices led to an IRR of 3.3%. Given the extreme volatility of the sorghum market in northern Cameroon, a drought year price range of 98 to 162 fcfa/kg is quite possible. However, anecdotal evidence suggests that to set prices in drought years are even higher than those proposed in the sensitivity analysis, implying that the price parameter in the base run IRR is more likely to underestimate rather than overestimate the IRR.

Run 4: Area Harvested

Total sorghum area harvested is varied by plus or minus 25%, resulting in IRRs of -2.2% if the area is reduced and +3.4% if the area is increased. Identical results are obtained when varying the adoption rate by plus or minus 25%. These results indicate that as more land is cropped to S35, the returns to research and extension increase. They also point out that the results of the analysis are sensitive to area estimates drawn from the Agricultural Census.

Run 5: Extension Costs

Aggregate costs of the sorghum research and extension program are reported in Table 4.19. One noteworthy statistic from that data is that extension costs for the sorghum program represents approximately 44% of total estimated aggregate costs.

Although this analysis assumes that part of the success of S35 research, in terms of farmer adoption, is due to the extension efforts of SODECOTON, an alternative assumption is to ignore extension efforts and only calculate an IRR for sorghum research. With no extension costs included in the cost stream, the IRR for sorghum research is 7.7%. Given the high degree of collaboration between IRA and SODECOTON, and the breadth of SODECOTON's extension program, excluding extension costs is suspect because it likely ignores expenditures that were critical to the adoption of the improved variety. However, due to methodological inconsistencies in the literature as to what costs to include or ignore, this alternative is presented.

Run 6: Total Costs

Estimates of total annual costs were varied by plus or minus 25%, resulting in IRRs of -1.5% and 4.1%, respectively. Cost data for the sorghum program were incomplete, requiring the use of proxies and informed assumptions. Only in the case of the SAFGRAD project were cost data readily available. Hence, the IRR may be under- or overestimated due to errors in estimating total costs. The sensitivity analysis indicates that the IRR estimate is sensitive to total costs, although it is more sensitive to overestimation.

Run 7: Area Harvested

The two data bases concerning total sorghum area harvested are discussed in Chapter 2, as are the justifications for using DEAPA's data over MINAGRI's. However, to test the significance of choosing one data base over another, MINAGRI's data were substituted into the analysis, resulting in an IRR of 3.9%. The analysis assumes that the total amount of S35 harvested is a proportion of total sorghum area harvested for all varieties. Since the MINAGRI estimates of total sorghum area harvested are consistently higher than estimates made by DEAPA, the use of MINAGRI data leads to a higher adoption rate (in terms of area harvested) and thus to a higher IRR estimate.

Run 8: Frequency of Drought

A very critical assumption, from a theoretical point of view, pertains to the frequency of drought conditions in northern Cameroon and its subsequent impact on overall sorghum production. Given the assumption that the improved varieties only generate benefits in drought years, the hypothesized frequency of drought conditions are fundamental to the IRR estimation. The base run estimate fixed a three-year rainfall pattern of two years of normal rains followed by one year of drought. Sensitivity analysis was used to test the significance of this estimated pattern of rainfall. Two alternatives were tested--drought conditions once every four years and drought conditions once every two years. The former resulted in an IRR that was just slightly negative, -0.4% while the latter resulted in an estimated IRR of 7.9%, the highest IRR reported in Table 4.22. These results highlight the advantage of S35 in drought conditions and the potential for payoffs to research targeted to marginal production conditions.

Run 9: Adoption Patterns

This run tests the assumption that input use is independent of the adoption of the improved variety. An alternative assumption is that farmers adopt an entire package of inputs, including the improved variety, seed treatment, specific management practices (eg., planting in lines), and fertilizer. This assumption implies that S35 will yield more than local varieties, even in normal rainfall conditions due to higher input usage. However, these inputs increase the cost of production, a change which must be factored into the analysis. With yields and costs adjusted accordingly, the resulting IRR is 0.8%, virtually the same as the base run estimate. Run 9 increases the confidence in the base run IRR estimate, given that a very different, although plausible, set of assumptions led to essentially the same conclusions--sorghum research, in financial accounting terms, "broke even".

Run 10: Shadow Exchange Rate

Given some anecdotal evidence that Cameroon's currency is overvalued, this run estimates a shadow exchange rate and tests the assumption that inputs and outputs should be valued at the market exchange rate. The methodology is identical to that used with the cowpea sensitivity analysis (Run 13: Shadow Exchange Rate). The resulting IRR for sorghum is -2.3%. It is lower than the base run IRR because the value of the outputs, when converted to $US, is less after devaluation.

Run 11: Upper/lower Bounds

A best case/worse case scenario is tested in Run 10, whereby five of the key variables were simultaneously modified by plus or minus 10%. The resulting IRRs were 7.0% and -5.6%, respectively. Although the worse case scenario implies a negative rate of return to sorghum research and extension, the general trend in the sensitivity analysis has indicated a program which had a zero to slightly positive IRR. Either extreme (best or worst) is unlikely since it is improbable that all five parameters were misspecified in such a way that they all affect the IRR estimate in the same way. This run simply confirms that sorghum research and extension in northern Cameroon was not a resounding economic success. However, sorghum research throughout West-Central Africa has been notoriously difficult (Johnson, 1987; Kamuanga, 1991), implying that a program that at least "paid its own way" in financial accounting terms is an exception and a relative success.

CHAPTER 5 INSTITUTIONAL ANALYSIS

The general objective of this chapter is to analyze the institutional factors, linkages and characteristics associated with the research-extension system of northern Cameroon. This analysis will help determine how these institutional traits interacted to complement and/or impede the performance of the cowpea and sorghum subsectors. The chapter is divided into three sections, the first being a detailed, forty-year chronology of agricultural development activities in northern Cameroon. The latter two sections focus on a specific time period, 1979 to 1986--the period during which the improved technologies discussed in Chapter 4 were developed. This two-part section first evaluates linkages within the research-extension system and assesses how these linkages affected the system's performance. This is followed by a brief discussion on the distribution of benefits resulting from the development and extension of the improved technologies.

5.1 Agricultural Development in Northern Cameroon

Agricultural development efforts in northern Cameroon have spanned forty-years. The following discussion divides this history into four distinct periods, each of which is identified by a particular development theme and/or project. Although the following is an incomplete reckoning of the past[36], it highlights the defining events and key institutions that guided northern Cameroon's agricultural development and transformation from 1948 to the present (1991).

[36]For a more complete history, refer to *Bilan Diagnostic du Secteur Agricole de 1960 à 1980*, published by Cameroon's Ministry of Agriculture, March 1980.

5.1.1 Efforts Prior to 1970s - King Cotton

Records indicate that agricultural research in northern Cameroon began in 1948 with the establishment of an agricultural research station in Guetalé, located northwest of Maroua on the Koza-Mora road.[37] The limited documentation found describing this early period suggests that research focused on collecting basic data (eg., the identification of rainfall patterns, soil types, farming systems). A French firm, *la Campagne Française pour le Développement des Fibres Textiles* (CFDT), introduced cotton to the area three years later, although CFDT had been promoting cotton production in neighboring Chad prior to its 1951 arrival in northern Cameroon. In 1952, a French research organization, *l'Institut de Recherche sur le Coton et Fibres Textiles* (IRCT), established a cotton research station in Maroua. With CFDT and IRCT, the French laid the foundation for the cotton industry that still exists today.

Food crop research began in 1964 when the French agency, *l'Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières* (IRAT), established a food crop research station in Guetalé, which they relocated to Maroua in 1972. Although IRAT research targeted the principal food crops of the region (sorghum, maize, groundnut and cowpea), its implicit goal was to enhance cotton production.

Cotton production has become a way of life for two generations of Cameroonian farmers. But it was during this establishment of this cash crop system that agriculture in northern Cameroon was significantly transformed. Numerous improved production techniques (i.e., chemical fertilizers, animal draught power, row planting and seed treatment), as well as more general programs to promote farmer literacy and to improve

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[37]This statement implies a very narrow definition of what comprises agricultural research, and is limited to research based on "the scientific method". Local farmers have been researching agriculture in a less formal sense for centuries, if not millennia.

household nutrition were introduced in the name of cotton. Subsidized by the French and Cameroonian governments, these activities had a dramatic impact on the farming practices of northern Cameroon.

5.1.2 Early 1970s - Era of Government Interventionism

As the newly founded nation of Cameroon came into its own, government began to expand its role in promoting development. As part of this growing sense of a national purpose, the government recognized the critical importance of agriculture and adopted numerous policies to redress traditional sources of uncertainty and production constraints: limited market outlets for farm produce, unavailable credit, unstable prices, and an underdeveloped rural sector. In addition, steps were taken to nationalize various components of the agricultural sector, including research, and specific subsectors, namely cotton and rice. The following describes several key institutions created during this period of government interventionism--three government agencies, two large-scale rural development projects, and one agricultural parastatal.

MIDEVIV and FONADER

In 1973, MIDEVIV and FONADER were created to address two fundamental market failures--unavailable credit for farmers and inaccessible consumer markets. MIDEVIV, an acronym for *la Mission de Développement des Cultures Vivrières, Maraîchères et Fruitières*, was mandated to improve village-level market access to food crops. In practice, the agency was to purchase food crops in areas where there were surpluses and then transport these commodities to food deficit areas (urban centers and/or rural areas suffering from production shortfalls). FONADER, an acronym for *Fonds National de Développement Rural*, was mandated to supply short and intermediate term loans to individual farmers. When the first OPEC oil crisis occurred in 1973, FONADER was mandated to supply credit to enable farmers to purchase fertilizer whose price had increased considerably due to the oil shock. Even though the oil shock provided an important impetus to the formation of FONADER, it was the recognition of the general need for agricultural credit that led to the agency's creation and continuation.

Since FONADER declared bankruptcy on June 30, 1988, only MIDEVIV is still functioning (1991). Neither agency appears to have been particularly successful, as both were constrained by limited capital resources and inadequate government support. MIDEVIV faced the additional problem that surplus agricultural products tended to only flow one direction. Although surplus fruits and vegetables from southern Cameroon could be marketed in the northern region, there was little demand in the south for the north's surplus grains--sorghum and millet had little appeal to consumers, and Asian rice imported into Douala was less expensive than locally produced rice from SEMRY. Key informants observed that the agency simply suffered from too many defaulted loans, poor management, and corruption.

Office Céréalier

Office Céréalier, founded in 1975, was created to address the problems of price instability in the cereal markets of northern Cameroon. As noted earlier, supply and prices in northern Cameroon are prone to extreme fluctuations within a given marketing year, as well as from year-to-year. To address this problem, Office Céréalier was mandated to buy grains (millet, sorghum, maize, and rice) when market supply was high and store these grains for resale at subsidized prices when market supply became low. In carrying out these activities, the agency had an additional mandate to address food security issues and maintain emergency food stocks.

Internal documents summarizing Office Céréalier's purchases for the eleven year period 1979/80 to 1989/90 indicate that the agency's annual purchases never exceeded 5,000 metric tons of sorghum and millet, or 4,000 metric tons of maize. For either commodity, total purchases rarely represented more than 10% (usually much closer to 1 to 3%) of estimated total production for the two northern provinces. With such low levels of market intervention, the agency had minimal influence on market prices. Granted, on days that the agency sold or bought, it is likely that in the very short term (same day, perhaps same week) local spot market prices would be affected. However, regional price levels were probably little influenced by the agency's actions.

SEMRY

Northern Cameroon's first large scale development project was *la Société d'Expansion et de Modernisation de la Riziculture à Yagoua* (SEMRY), an irrigated rice project on the Logone River that involved a huge capital investment (eg., the creation of a 300 km^2 lake) and drastically transformed the region's ecology and farming systems. Initiated in 1971, the SEMRY project is currently funded by the EEC (1991), although its first two phases were funded through the FAC. Probably the most telling commentary on the success of the initiative is that although SEMRY's rice production costs are among the lowest in West Africa, it is still cheaper to import rice into Douala and transport it north[38]. Yet, since food self-sufficiency has been an important policy consideration for the Cameroonian government, SEMRY was touted as a demonstration of the production capability of the country's northern region.

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[38]This comment is based on conversations that the author had during the two and a half years that he lived and work in the region as a Peace Corps volunteer and on comments made by key informants during interviews conducted for this study.

<u>NEB</u>

In 1972, a second large-scale development project was initiated in the upper valley region of the Bénoué River, east of Garoua. This integrated rural development project, *Projet Nord-Est Bénoué* (NEB), is in its fourth phase (1988-1992) and has historically targeted a wide range of issues including infrastructure development, resettlement of farmers, public health and education, as well as agricultural production. NEB has had a marginal role in the transformation of the cowpea and sorghum subsectors of the Far North Province, mainly because the project's extension zone targeted a region outside of the province. However, most of the farmers participating in NEB's resettlement program migrated from the densely populated Mandara Mountain's of the Far North Province, a pivotal area for cowpea and sorghum production. Quantifying the degree of rural migration and its influences on agricultural production are beyond the scope of this analysis. NEB is mentioned principally to document one of the earliest government efforts to initiate a comprehensive, integrated rural development project in the northern region of the country.

<u>SODECOTON</u>

In 1974, CFDT was nationalized, creating the Cameroonian parastatal SODECOTON. In the same year, CFDT's sister organization, IRCT, was placed under the newly formed *Office National de la Recherche Scientifique et Technique* (ONAREST), a national umbrella agency overseeing all facets of agricultural research in Cameroon. The relative "success" of SODECOTON and the agricultural research system are discussed in Chapter 4 of this thesis, but are mentioned here as additional examples of the nationalization policies pursued in the early 1970s.

5.1.3 Early 1980s - The PCN Era

By the early 1980s, the agricultural research and extension system had reached a critical mass in its development. All of the pieces were in place: a functioning agricultural research system, a large, active extension system, a capacity for seed multiplication, and a shift in government policy towards an emphasis on food crop production. It is unclear whether serendipity or particular individuals deserve credit for recognizing this confluence. Regardless, in 1982 the World Bank initiated *Projet Centre-Nord* (PCN), a rural development project which explicitly linked together these various agencies.

Specific objectives for the PCN included improving the area's rural infrastructure, and strengthening of the agricultural research and extension network, particularly its management. The project, which targeted the cotton growing regions of the current Far North Province and the Mayo Louti Department of the North Province, was implemented by SODECOTON under a World Bank contract.

Although the timing of PCN was fortuitous, the selection of SODECOTON as the project's managing entity probably contributed more to the project's success. As a business concerned with profit and the efficient use of its resources, SODECOTON's internal accountability and incentive structure provided the viable and relatively strict set of checks and balances required for successful project implementation. Further, SODECOTON's functioning network of extension agents and input suppliers for cotton farmers was relatively easy to expand to food crop production.

The PCN era is most noteworthy for the successful forging of a multidisciplinary, multifaceted effort for developing the region's agricultural sector in general, and food crop production in particular. Prior to PCN, each agency in the region functioned independently of each other. Although the shift in government policy[39] set the stage for more collaboration, the PCN acted as the catalyst that molded food crop research and development in northern Cameroon into an integrated, interactive system.

5.1.4 Late 1980s - Restructuring

In 1987, the Cameroonian government declared a national economic crisis, precipitated by the dramatic decline in world prices for all of Cameroon's major export crops and by the burden of foreign debt. Although these problems were real, much of the distress that characterized the government's decrees about the crisis was simply a smoke screen to cover the implementation of IMF-recommended austerity measures. Fearing the political ramifications of restructuring, government chose a conveniently construed scapegoat--the "economic crisis".

The research-extension system fared poorly in these tighter budgetary times. Program budgets, salaries, and subsidies were all curtailed or eliminated. For IRA, budget outlays for operating expenses dwindled to zero. By 1990, nearly all research operating costs were being paid for by donor projects, while staff salaries for civil servants were often paid months late and scheduled pay increases were ignored. When PCN was phased out in 1987, food crop extension became costly for SODECOTON, mainly because the government was unable to reimburse SODECOTON for these activities. As a result, SODECOTON began charging IRA for the parastatal's expenditures for on-farm research trials. For all of the supporting agencies--NCSM project, MIDEVIV, Office Céréalier, MINAGRI--the crisis translated into much smaller

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[39]This shift is documented in the Fifth-Five-Year Economic, Social and Cultural Development Plan (p. 834-836, 851) in which IRA-Maroua's research center is mandated to expand its activities in food crop research and to adopt a systems approach.

operating budgets, liquidation of assets (eg., most government-owned vehicles were sold), and a general reduction in activities.

Two other noteworthy changes were motivated, at least in part, by the economic crisis and subsequent redefinition of participating institutions[40]. First, starting in 1989, SODECOTON drastically reduced its guaranteed price for cotton, essentially pegging it to the world price. Historically, in years when the world cotton price fell below the set price, SODECOTON subsidized the price paid to farmers rather than lower the guarantee. This shift in pricing policy has led cash-crop farmers in northern Cameroon to look for alternatives. In regions of lower rainfall, anecdotal evidence indicates that cowpea grain production is one promising alternative farmers are adopting.

A second change in the region was motivated by both governmental restructuring measures and the coming in vogue within USAID of "privatization". In 1991, the USAID sponsored NCSM project was sold to Pioneer Seed. While this analysis does not consider how this change in property rights has affected or will affect northern Cameroon's agricultural sector, the privatization of the only seed company in the region bears witness to the extent of the government's retraction from its former hay days of interventionism[41].

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[40]By 1991, nearly all donor and government institutions had signed "performance contracts" with the central government. These contracts defined the roles, responsibilities, and performance criteria for both the central government and the signing institution.

[41]This shift in property rights provides an excellent opportunity to compare two types of institutional arrangements. The NCSM project functioned for 15 years (1976 to 1991) and data on its performance are available. Once Pioneer Seed has been established for several years, this case seems to offer fertile ground for future inquiry.

5.2 Key Institutional Linkages, 1979-1987

Chapter 4 of this thesis estimated the net benefits of cowpea and sorghum research and extension. Using an IRR criterion, the chapter's conclusions indicate that the development of improved cowpea and sorghum technologies was relatively "successful", particularly for the case of cowpea. Yet, these conclusions beg the question, "*Why* were the programs successful?" The discussion that follows addresses this fundamental question.

Analysis of key institutions, and their inter- and intra-relationships partially explain how "successes" were achieved in northern Cameroon. Linkages within and between such institutions as IRA, SODECOTON, and donor projects (eg., Bean/Cowpea CRSP, SAFGRAD J.P. 31, NCRE and NCSM projects) proved critical to achieving positive rates of return. The fact that an integrated rural development project, PCN, was implemented, in part, for the explicit purpose of linking together these institutions seems, in hindsight, especially fortuitous.

Three insights are particularly clear from this analysis: (1) linkages within the research-extension system were critical; (2) linkages between the system and international research institutions were equally important; and, (3) government agricultural policies influence the system's performance.

5.2.1 Linkages within the local system

Numerous efforts were made within the research-extension system to link together all of the "pieces" of the development "puzzle". For example, the PCN made investments to improve IRA's management practices, hiring a coordinator to oversee the agronomy research program. His responsibilities included creating and maintaining links between SODECOTON and IRA staff, which proved essential for the management of off-station research (at research substations and in farmers' fields). The coordinator's efforts facilitated information flows and fostered collaboration between IRA and SODECOTON, and among each of IRA-Maroua's commodity-based research units and independent donor projects. Second, regularly scheduled staff meetings, organized by the IRA-Maroua station director, provided an opportunity for interdisciplinary interaction among researchers and staff. A third example was an annual planning meeting at which each research unit presented the previous year's results and the coming year's research agenda. Participants included representatives from SODECOTON, MINAGRI and various NGO projects, as well as local farmers--all of whom were encouraged to provide their input and evaluation of the planned research agenda.

These linkages among actors involved in the research-extension system enhanced the technology development process in northern Cameroon in two key ways. First, greater information flows served to inform system participants and proved an effective means of identifying farmer constraints and setting the research agenda. For example, as a consequence of this process, the cowpea research agenda shifted from a primary focus on producing high grain yields to addressing post-harvest storage constraints. This shift was significant since post-harvest losses are now considered to be the largest constraint to higher adoption of the already extended improved cowpea varieties. Second, the linking of SODECOTON to the research system proved to be critical in the overall performance of the system. SODECOTON, with its input distribution system and 500 to 1000 extension workers, provided a conduit for both the extension of technologies and feedback from the farm to researchers. In turn, researchers knew that as they developed appropriate technologies, a system was in place, ready to widely diffuse these innovations. Knowing this proved to be an important motivating element for IRA's research staff.

5.2.2 Linkages beyond the local system

Linkages, via donor projects, between the agricultural research system and international agricultural research centers (IARCs) also enhanced the technology development process in northern Cameroon. Multilocational varietal screening trials were organized at the international level by either IITA, SAFGRAD, ICRISAT, or the Bean/Cowpea CRSP, and then implemented at the local level by either the CRSP, SAFGRAD J.P. 31, or by the NCRE project. These trials became an important source of alternative cultivars. Most of the varieties that were extended to farmers as part of the "improved" technology packages were actually introduced varieties first identified as appropriate for the area through the international varietal screening trials. Hence, IARCs and other international networks (CRSPs and regional projects), by collecting, maintaining and distributing germplasm, acted as important catalysts for the agricultural development process in northern Cameroon.

Further, donor projects in northern Cameroon had the capacity to access other resources beyond those available to the national system, since all of the projects were directly linked to international networks. This access clearly enhanced the performance of the research-extension system. Projects were able to provide, in addition to introduced varieties, links to other research activities in the region, logistic support for on-going research in Cameroon, and access to a network of other researchers who could provide additional feedback relevant to the work being conducted by IRA-Maroua.

5.2.3 Government Policies

From 1979 to 1987, the Cameroonian government played a very limited role in the agricultural sector of northern Cameroon. The ineffectiveness of MIDEVIV, FONADER, Office Céréalier, and MINAGRI's extension system are all documented in earlier sections of this thesis. Speculating on how the research-extension system would have performed under a different set of government policies is, at best, difficult. However, one issue merits comment. While farmers connected to SODECOTON's system of extension and input delivery are much more likely to adopt improved technologies, cotton farmers represent perhaps as few as 36% of all farmers in northern Cameroon[42]. Hence, the adoption of technologies is dependent, in part, on which and how many farmers are served by SODECOTON's system. Had the extension and input delivery system served a wider range of clientele, it is likely that the adoption of cowpea and sorghum technologies in northern Cameroon would have been higher. However, it is uncertain whether the benefits from attaining a higher adoption rate would compensate the additional costs of establishing an extension system which served a broader constituency.

5.3 Distribution of Benefits

There is little documentation on the distribution of benefits from the development and subsequent adoption of improved cowpea and sorghum technologies in northern Cameroon. Two sources that gave some consideration to differentiated impact

[42]For the PCN region, the World Bank estimate was 36%, as reported in the 1980 PCN project paper. In 1991, during interviews conducted for this research, key informants estimated that from 40 to 70% of the farmers in northern Cameroon cultivate cotton.

among groups are: (1) data reported by Johnson on differences between cotton and non-cotton farmers and (2) data reported by Wolfson on gender differences in cowpea production and storage.

Johnson reports that "cotton sales dominate farm revenues in the Far North. The mean annual revenue for a cotton-growing family is 83,000 fcfa and for a non-cotton-growing family is 26,800 fcfa (p. 48, 1987)." He also notes that the only other important sources of income for these farmers are off-farm and livestock revenues. Given the research-extension system's dependency on SODECOTON, many of the benefits of research were probably captured by cotton farmers, particularly early on in the adoption cycle. This indicates that initially the beneficiaries, by income strata, were probably the more affluent farmers in the region. Given the improved cowpea technology's dependency on insecticide usage, this bias may still continue. With sorghum, since the improved technology is an open-pollinated variety that did not depend on a complementary technological package, lower income farmers probably also captured some of the benefits of S35 as the technology was diffused.

In 1989, Wolfson, through work with the Bean/Cowpea CRSP, surveyed 112 households in the principal cowpea growing regions of northern Cameroon. Although it is unclear as to the representativeness of Wolfson's sample of cowpea farmers, her results do indicate distinct gender differences in the production of cowpea. For example, she notes:

> Eighty-seven percent of the farmers produced cowpeas primarily for home consumption. [Yet,] there was an association between the primary purpose of cowpea cultivation in a household and the gender of the producer. When women were responsible for production, the primary purpose was always for home consumption (although some of the crop might get sold). In 17% of the households in which men were involved in production either as sole producer or co-producer, the primary purpose was for sale...Women grew their cowpeas

> intercropped with peanuts or sorghum whereas men more frequently grew their cowpeas in pure stands (p. 1-2; 1990).

One of Wolfson's conclusions was that since women sell some of their cowpea crop, changes in cowpea technologies could affect women's access to this source of cash income, indicating a need for researchers to be sensitive to this distributional change.

Based on Wolfson's findings, the improved cowpea technologies probably favored men, since the new system required monocropping and the use of insecticides. Wolfson reported that both of these practices were found to be more prevalent with men. On the other hand, cowpea production in general was reported to be more important to women, implying that at least some of the benefits resulting from improvements in cowpea production are likely to be captured by them.

More conclusive discussions on distributions of benefits between income strata and genders are limited, and other distributional issues (eg., differences between rural producers and urban consumers, trade-offs between current and future generations) are not explored due to data constraints. Yet, because cowpea and sorghum are grown in one of the poorest regions of Cameroon, the new technologies have enhanced the welfare of these producers, vis-a-vis farmers in the higher rainfall, more well-endowed regions of the country.

CHAPTER 6 SUMMARY AND CONCLUSIONS

This chapter is divided into four sections. The first summarizes the research findings of the benefit-cost analysis, noting important issues affecting their interpretation. The second compares the two rates of return estimated for the sorghum and cowpea programs, reviewing possible causes for differences between the returns. The third section summarizes the chapter (and thesis) with a succinct listing of key lessons learned during this study. The final section looks beyond this work by considering the potential implications for institutionalizing impact assessment.

6.1 Reported Rates of Return

During the period 1979 to 1986/87, investments in the cowpea and sorghum research programs and extension systems of northern Cameroon earned positive rates of return. The estimated internal rate of return (IRR) for cowpea research and extension is 15%. The estimated IRR for sorghum research and extension is 1%. These two IRR estimates do not stand on their own. Rather, their interpretation require a clear understanding of both the assumptions and data supporting the IRR estimates, including which costs and benefits were included/excluded, which prices (real or nominal) were used, and how qualitative issues such as institutional relationships and the distribution of benefits were incorporated.

6.1.1 A critique of IRR Estimates

The rates of return are estimated for specific sets of investments and resulting benefits. The delineation of which costs and benefits to include in the benefit-cost streams was based on an iterative process that attempted to pair investments to their corresponding benefits.

Investments in research that were included in the cost streams were limited to only those commodity programs directly linked to the development of the improved technologies. This delineation cuts both ways. By including all costs of a commodity-based research program, some costs (eg., the breeding program in the case of sorghum) were included in the cost streams even though they did not contribute directly to the improved technology's development. On the other hand, the existence of a cadre of researchers at the Maroua center provided support and interaction which enhanced the overall performance of all of the individual programs. Would the new technologies have been developed if there had existed only a cowpea or a sorghum program? The question is unanswerable, although limiting the cost streams to include only individual program costs and not aggregate system costs--as was done in this study--implies an answer in the affirmative.

A similar issue applies to extension costs. The costs of the entire extension system were not included in the cost stream. Rather estimates were made of the proportion of overall costs directly attributable to the specific commodity. It is uncertain that an independent sorghum (cowpea) extension program with a $200,000 ($15,000) per annum budget would have had the same impact as a $2.5 million per annum cotton and food crop extension program. Yet, with this study, by partitioning out portions of the food-crop component of SODECOTON's total extension program, these assumptions were implicitly made.

Other costs which were excluded from the analysis include investments made in supporting industries, particularly the seed multiplication project and in supporting research (eg., IITA's costs for maintaining and extending germplasm).

Furthermore, only benefits that increased the net market value of on-farm production, which resulted from the adoption of the improved technologies, were included. This excluded a number of benefits, most of which were empirically difficult to quantify. For example, both of the improved cowpea and sorghum varieties are drought tolerant, contributing to improving the household food security of hundreds of thousands of rural households in northern Cameroon. Yet, this benefit is not incorporated into the benefit-cost analysis. Other excluded benefits include the value of enhanced human capital from project-trained host-national researchers, and the contribution of the sorghum and cowpea research efforts to the general pool of knowledge pertaining to agricultural development in West-Central Africa.

These assumptions and delineations about costs and benefits do not invalidate the estimated IRRs. Such assumptions are required in order to carry out benefit-cost analysis, but an awareness of which investments and which benefits netted internal rates of return of 15 and 1% is necessary to put these numerical values in proper perspective.

6.1.2 Are these financial or economic returns?

Estimates of financial returns are based on nominal prices and expenditures valued at purchased price, with no adjustments made for inflation, opportunity costs, or over/undervaluation of local currency. When all of these adjustments are made, ROR estimates represent economic returns. The exception is when there is no inflation, shadow exchange rates equal market rates, and the opportunity costs of farm produce is equal to its market values. In this case, estimated rates of return represent both the financial and economic returns.

Since no adjustments were made for inflation or the opportunity costs of the resources included in the benefit-cost streams, the reported IRRs are the financial returns to the investments in research and extension. However, it is uncertain that adjusting for inflation was necessary to represent the economic situation in northern Cameroon. Given the extreme fluctuations in supply and prices in the region's food-crop markets, price trends indicating inflationary changes in the price level were not discernable and may not exist.

Further, over the entire period of time framing the analyses, the exchange rate between the fcfa and the French franc was fixed at 50 fcfa per one French franc. Thus, fluctuations in the value of the fcfa simply reflected changes in the exchange rate between the US dollar and the French franc. Overvaluation of an exchange rate that is implicitly floating is only possible if certain conditions exist, such as differences in purchasing power between trading partners, or unsustainable external imbalance of payments and trade distortions. No published data were found that determined if and/or to what degree Cameroon's currency was overvalued during the full period considered, although key informants in Cameroon estimated that, in 1991, the currency was overvalued by 40%. It is uncertain whether any overvaluation existed during the 1979 to 1986/87 period. Hence, no devaluation was deemed necessary during the base runs, although assumptions about overvaluation were tested during sensitivity analysis, resulting in lower IRR's whenever the fcfa was devalued.

Finally, sorghum and cowpea are produced primarily for home consumption with small surpluses marketed locally. Since these goods are not usually exported, their economic value (i.e., opportunity cost) is the market price they command.

If, in fact, there was no inflation in northern Cameroon, no overvaluation of the Cameroonian currency, and the opportunity costs of farm inputs and outputs are valued at their market price, then the estimated IRRs represent both the financial and economic returns to research and extension.

6.1.3 Qualitative Issues

Qualitative analyses seek to explain *why* an investment had high, low or negative returns. In the case of northern Cameroon, evidence indicated that certain institutional relationships were critical to the attainment of positive returns since they acted as catalysts for the agricultural development process. First, explicit linkages within the research-extension system, particularly between SODECOTON and IRA, were essential to the system's overall performance. These linkages established effective information flows that helped identify farmers' constraints and provided vital feedback from farmers and extension agents to researchers. Second, important institutional linkages were established between the local research station and various international and regional research centers and projects. Most of the improved varieties extended to farmers were first tested in northern Cameroon as part of a network of international varietal screening trials. In addition to introduced cultivars, these networks provided links to other research activities in the region, logistic support for on-going research in Cameroon, and access to other researchers who gave additional feedback relevant to the work being conducted by IRA-Maroua.

Qualitative analyses also may help to explain *how* returns are distributed. There was some evidence that cotton farmers, particularly male cotton farmers, benefitted the most from the development of the improved technologies. Two factors contributed to this observation. First, IRA was closely linked to SODECOTON and depended on the parastatal for support with on-farm research, for input delivery, and for the extension of improved technologies. Cotton farmers, a class of farmers dominated by males, were more likely to be exposed to these innovations, have the means for adopting them, and thus, most likely to benefit from their development. Second, in the case of cowpea, the technologies extended depended on such management practices as monocropping and the use of insecticides, both of which were found to be more prevalent with men.

6.2 Differences in the Rates of Return

The significant difference in returns to the two commodity-based research programs raises the obvious question, "Why?" Although a definitive answer to that question is not possible, certain key characteristics differed between the two programs.

First, the improved cowpea technology extended to farmers represented a completely new cropping system, while the improved sorghum technology was simply a complement to traditional practices. Although cowpea is indigenous to northern Cameroon, it was traditionally grown more as a garden crop, harvested for its leaves as much as for its grain. The improved cowpea technology filled an existing need of farmers in the region--an early maturing food crop to relieve hungry season food shortages and to provide an alternative cash crop to cotton. On the other hand, under normal rainfall conditions, S35 is just one more variety in the pool of over 1,800 accessions that have been identified in the region by the NCRE sorghum breeding unit.

S35 has enjoyed some success because it also addresses a need of farmers in the region--a sorghum variety that is extremely drought tolerant. However, this need is not nearly as predictable or regular as the needs met by the cowpea technologies. Hence, the most obvious difference between the two programs was that cowpea research generated a technology that netted benefits *every year* while the sorghum technology led to net benefits only in drought years, whose frequency was estimated as *one out of every three years*.

Second, given that this is a case study, little can be said about the general appropriateness of funding screening programs versus breeding programs within research projects. Yet, the higher returns were found with the cowpea program, which focused entirely on varietal screening to "develop" improved varieties. Even the success of the sorghum program depended not on a variety developed by its breeding program but on a variety identified in screening trials. Both cases imply higher returns were found for screening activities. This conclusion is underscored by two important insights. First, screening programs are cheaper to a given national research program because many of the costs of generating an "improved" variety have already been incurred by other projects and institutions. Second, the appropriateness of screening versus breeding depends on its timing relative to the region's overall state of development. Screening is likely to be most successful early in the life of a research program. As a first pass at introducing improved technologies, high yielding varieties developed for a wide range of growing conditions (eg., TVX 3236) will likely have positive returns. However, after these initial benefits are captured, and as researchers gain a greater understanding of the constraints faced by farmers within a specific region, breeding programs may be required to address constraints which cannot be met with borrowed technologies (eg., cowpea breeding program established in 1988, targeting, in part, bruchid tolerance).

Third, another difference between the two commodities is that cowpea is a relatively minor food crop, whereas sorghum dominates the region's cropping systems. A priori, conventional wisdom suggests that the largest impact would result from research targeted to the major crop. But is this so? In the late 1980s, the cowpea market was poised for considerable expansion. SODECOTON had cut its price subsidy for cotton, leaving cash-crop farmers looking for alternatives. Cowpea had a competitive advantage in production (drought tolerance) and in consumption (affordable protein source), and could be readily sold in local markets, making it a viable alternative to cotton. The change in cotton price represented an institutional shift in the incentive structure faced by farmers, which may explain some of the relative "success" of cowpea technologies. Hence, the incentives that farmers face may influence the impact of research more than the relative share a given commodity represents in a region's cropping system.

Fourth, the relative difficulty of the problems addressed by the two research programs may also explain some of the differences in the returns. Sorghum has presented a formidable problem to researchers throughout West and Central Africa for over thirty years. Low returns to sorghum research, though undesirable, may simply reflect long-run historical trends.

6.3 Summary of Key Lessons

The following is a succinct listing of the most salient conclusions of this study. These conclusions present several insights on assessing the net benefits of technological innovations in agriculture, particularly in a Sub-Saharan setting.

1. When assessing impact, three issues need to be addressed: what were the returns; why did the investments earn the returns that they did; and, how were the returns distributed among the various segments of society?

2. Institutions have a major impact on the rate of return since they influence the performance of the research-extension system, determine the incentives faced by farmers, and define the means by which agricultural transformation can be achieved.

3. Since available data influence the assessment methodology employed, issues of data availability and reliability are fundamental to benefit-cost analysis.

4. Higher RORs are possible if costs can be reduced through cost sharing or borrowing technologies. Examples from this study include insecticide sprayers used by cowpea farmers (i.e., farmers already owned the sprayers and used them on their cotton), and introduced cultivars borrowed through international screening networks.

5. Research topics (eg., commodities, farmer constraints) differ in terms of both potential for impact and in the degree of difficulty that they pose to the researchers attempting to generate technological innovations. Hence, selection of the constraint to research can influence the ROR as much as the actual research that follows.

6.4 Institutionalizing Assessment Methodologies

Underlying the issues of agricultural technology assessment is a more fundamental issue concerning the costs and benefits of data. If impact assessment is to be institutionalized within Sub-Saharan NARSs, financial resources must be committed to generate appropriate data to support these analyses. This study confirmed that administrators, plant breeders, and agronomists are not well versed in the methods and scope of data collection necessary for economic analysis. Assessing the economic returns of projects and/or research-extension systems is highly dependent on specific types of data. Historically, these data have not been collected or have been given a low priority in the research agenda.

The following list is provided as a field guide for project managers and researchers as to the minimum data needed if impact assessment is to be conducted: yields, prices, area in production, indicators of adoption, project expenditures, and economic indicators.

Data are needed for yields associated with all major crop management practices observed in farmers' fields and for all of the products harvested (eg., grains, leaves for food, stalks for fodder) under each set of practices. This includes yields under traditional practices, and yields under various levels of adoption (eg., variety adopted verses variety and insecticide adopted). In general, plant breeders and agronomists are hesitant to estimate an "average yield" for a given set of crop management practices, recognizing the plethora of factors that influence yield. To obtain these data, research programs must establish protocols for representatively sampling farmers' yields under the major systems observed in the target research environment.

Input and output prices are absolutely necessary, if the dollar values of the benefits and impacts of an improved technology are to be estimated. Further, input costs must be described (e.g., formulation, brand) for each crop management practice, since it is impossible to estimate farmers' input costs if the list of specific inputs is unknown. With respect to output prices, the need to capture price fluctuations and long run price trends requires periodic collection of price data (eg., monthly or, when possible, weekly prices over several years). Prices also vary across space. This implies that data must be collected on prices received by farmers, prices paid by urban consumers, and border prices of tradable goods. Finally, since plant by-products (eg., leaves for food, stalks for fodder) have economic value and may be marketable, prices must be collected for these markets as well.

Census data such as area harvested by commodity, area encompassed by the research-extension system, and number of farmers in these areas are fundamental to assessing impact. Area in production data at the farm level (eg., average farm size, land allocations between commodities) are also important, especially if "people-level" impact assessment is an objective.

Indicators of adoption are necessary since these data are required to estimate benefits from the development of improved technologies. Seed sales, farmer surveys and market surveys are all possible proxies for adoption. If farmer surveys are used, then enquiries must go beyond the bimodal observation of whether or not the farmer is using the improved technologies. Questions must ask about the production mix (total adoption versus adoption on only a portion of the land cultivated to the given crop) since this information is needed to estimate total area under the improved cropping practices.

Finally, farmer surveys must follow sampling procedures that guarantee that these data are collected from a representative sample of the producers in the targeted area.

Records are almost universally kept of project and station expenditures. Simple annual summaries of these records would greatly facilitate impact assessment efforts. An annual one-page summary of expenditures on staff salaries, operating costs, administration costs, training costs, and capital improvements would be sufficient for benefit-cost analysis. If each entity within a research-extension system (eg., IRA, SODECOTON Extension Services, NCRE) prepared these summaries, then the estimation of cost streams for benefit-cost analysis would be limited to compiling these records.

The last type of data needed for economic analysis--indicators of inflation, exchange, interest, and labor-wage rates--may be beyond the scope of most agronomic/production-oriented research projects. Information on inflation and exchange rates may be available in-country from the IMF or World Bank. If so, project managers can glean this information at low cost. Local interest rates and labor wage rates, like most socio-economic data, can be collected by surveys and/or monitoring of local markets.

Finally, institutionalizing impact assessment depends not only on data collection, but also on trained social scientists to analyze these data. Additional investments within NARS would be necessary to develop human capital capable of conducting economic analyses and impact assessments.

APPENDIX

Table A.2 Cowpea, Hectares Harvested, Far North Province, Cameroon for Years 1972/73 to 1989/90.

	Area Harvested (Ha)		Cowpea's Share
Year	Cowpea	All crops	(%)
1972/73	67,006	438,000[44]	1.53
1973/74	4,900	429,000	1.14
1974/75	4,000	382,000	1.05
1975/76	138,000	775,000	17.81
1976/77	149,000	689,000	21.63
1977/78	86,000	636,000	13.52
1978/79	156,000	649,000	24.04
1979/80	159,000	696,000	22.84
1980/81	28,000	543,000	5.16
1981/82	40,069	445,514	8.99
1982/83	22,329	443,689	5.03
1983/84	24,345	337,925	7.20
1984/85	66,254	463,257	14.30
1985/86	42,252	571,313	7.40
1986/87	45,174	633,483	7.13
1987/88	45,360	617,055	7.35
1988/89	36,785	598,659	6.14
1989/90	32,120	618,436	5.19

Source: MINAGRI, various national and provincial reports.

[44]Data available prior to 1981/82 are for the former North Province which is now divided into the 3 northern provinces of Adamaoua, North and Far North. To convert these data to Far North province "equivalents", total cropped area was multiplied by a factor of 0.64 and a factor of 0.83 was used to convert total cowpea area. These factors were based on the relative shares reported in the Agricultural Census figures, years 1984-89.

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