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GLOSSARY OF ACRONYMS

ISRA	Institut Senegalais de Recherche Agricole
UCR	University of California at Riverside
CRSP	Collaborative Research Support Project
USAID	United States Agency for International Development
MT	Metric ton
FCFA	franc Communaute financiere africaine
MSU	Michigan State University
SODEVA	Societe de Developpement et de Vulgarisation Agricole
IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria
EEP	External Evaluation Panel

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EXECUTIVE SUMMARY

A project of the Bean/Cowpea CRSP (Collaborative Research Support Program) in Senegal is a collaborative effort of the Senegalese Institute for Agricultural Research (ISRA) and the University of California, Riverside (UCR). Michigan State University (MSU) manages the global Bean/Cowpea CRSP which has 13 projects in 11 countries in Africa and Latin America. It is financed by USAID and the participating U.S. and host country institutions. The objective of the CRSP project in Senegal is "to increase production and yield stability of cowpeas grown in hot semi-arid zones by subsistence farmers (CRSP-MSU, 1988, p.117)."

This impact study delineates and quantifies the effects of the Bean/Cowpea CRSP from 1985 - 1987 on Senegalese farmers and agriculture, the international research community. Emphasis is placed on the impact on cowpea farming practices and production in Senegal, and the training of research scientists.

Rate of return analysis of those benefits quantifiable in dollar terms results in an estimated return of 63%. The interpretation of the rate of return is the annual interest rate required to get the same returns to the investment if the funds used for the project were instead placed in a bank. This is a postive rate of return and reflects well on the economic value of the project.

The four major impacts of the CRSP's Senegalese efforts are:

- Preservation and enhancement of the stock of cowpea germplasm
- Improvements in household food security in Senegal
- Improvements in the yields, yield stability, and output of Senegalese farmers.
- Nurturing of the Senegalese cowpea research capacity, and international research system links.

Preservation and enhancement of the stock of cowpea germplasm benefits all cowpea farmers, those in the U.S. as well as in Senegal and West Africa. Germplasm preservation and enhancement make possible the development of varieties with desirable characteristics such as early harvest, high yields, resistance to pests and disease, and drought tolerance. The capacity for seed multiplication, which is being developed by ISRA, will allow easier access to newly developed and extant improved varieties.

Improvements in yields and yield stability arise from the introduction and distribution of higher yielding cultivars (CB5 and 58-57) and modern inputs such as insecticide and improved cropping practices, as recommended by the CRSP research. Improvements in output come not just from higher yields, but also because of a successful effort to increase the area cropped to cowpeas during low-moisture conditions.

Household food security has been improved by increasing the capability of each household to produce more calories. Not only has cowpea production increased, but the nutritional qualities of cowpeas make them excellent protein complements to the more traditional cereal diets.

Some of the benefits of the Bean/Cowpea CRSP are not quantifiable in economic terms. One of the most important of these benefits is that short-cycle varieties provide farm households with food prior to the main harvest. This period, called the "hungry season," occurs before traditional food crops are mature, and when household food reserves are at their yearly nadir.

The CRSP has strengthened U.S. and Senegalese cowpea research systems by training scientists from both countries and establishing strong working relationships between them, as well as through the exchange of germplasm. Senegalese scientists' primary work on cowpeas prior to the CRSP was the development of an impressive germplasm collection of two hundred and fifty accessions and some research on breeding and agronomy. When the CRSP project was initiated, however, ISRA had only one technician working on cowpea. The CRSP has assisted ISRA to put together a national team of scientists conducting research on all major aspects of cowpea production.

1. INTRODUCTION

1.1 Background of Cowpea Research in Senegal

Cowpea most likely originated in Africa and varieties have spread throughout the world. Cowpeas have a diversity of characteristics, including days from planting to harvest which range from 53 to 200 days (Singh and Rachie, 1985). The main constraint to crop production in northern Senegal is rainfall and the case of cowpeas is no exception. A hydrologic budget analysis for Senegal based on 44 years of rainfall data indicates an average annual rainfall of 440 mm., and a growing season of 75 to 80 days in the main cowpea growing region. However, the average rainfall from 1968 to 1985 was only 269 mm., "indicating that varieties with cycle lengths as short as 60 days may be needed in some years (Hall, p.1)." As discussed throughout this report the Bean/Cowpea CRSP is working to improve medium and short cycle varieties as both have characteristics desirable to farmers.

Research on cowpeas and on the establishment and maintenance of cowpea germplasm was carried out between the early 1950's and 1974 at the Federal West African Agricultural Research Station at Bambey, Senegal which became the National Agronomic Research Center (CNRA) at independence in 1960.[1] Djibril Sene, a Senegalese scientist, conducted invaluable work in the collection and breeding of germplasm since the 1940's, traveling as far east as Niger to aquire additional cowpea strains.

Early work on cowpeas focused on grain production and quality through breeding with less emphasis on on-farm production and storage problems (Bingen et al. 1988). However, research on these latter two issues is necessary to address the problems of cowpea growers. "Traditional varieties of cowpeas in Africa have low yields of dry seed (250 - 300 kg/ha) compared to yields in Asia and Latin America (400 - 500 kg/ha) and the U.S.A. (600 - 800 kg/ha).[2] The low yields in West Africa are attributed to pest damage, disease, rain shortage, poor cropping techniques and poor plant types (Coulibaly, 1987, p.49)."

Cowpea production in Senegal has increased dramatically largely due to the work of the CRSP to improve cowpea production. This work was begun in 1981 by the Senegalese Institute for Agricultural Research (ISRA) and the University of California, Riverside (UCR)[3]. The research objective is "to increase production and yield stability of cowpeas grown in hot semi-arid zones by subsistence farmers (CRSP, 1988, p.117)."

The work of the CRSP teams in Senegal and the U.S. is dedicated to increasing yields by addressing all of these issues comprehensively. Breeding efforts to improve plant types focus on the characteristics necessary to raise yields such as resistance to pests, diseases, drought and heat tolerance. Complementary work

is being done on identifying optimal cropping techniques such as seeding rates, spacing, varietal intercropping, crop management, storage and seed production.

1.2. Statement of Purpose

The purpose of this report is to quantify the impact of the Bean/Cowpea CRSP on Senegalese farmers and agriculture, the international research community. Emphasis will be placed on 1980's research on cowpea farming practices and production in Senegal, and on the training of research scientists.

1.3 Data Collection and Methodology

The information used in compiling this report was found in a variety of secondary data sources. A number of unpublished reports from the CRSP and it's external evaluators provide details of the project. Data on local prices for seven different cowpea varieties were provided by Ismael Ouedraogo, an MSU agricultural economist at ISRA.

The methodology used throughout is to evaluate the benefits and costs of various aspects of the project in pecuniary and nonpecuniary terms. The impacts of particular components of the project differ and require analysis utilizing different methods.

The report contains seven chapters including the introduction. Chapter two describes the 1985 Operation Cowpea and the research priorities of the CRSP's present work. The ramifications of increased production are covered in chapter three in terms of input costs, opportunity costs of increased production and the value of germplasm enhancement. Chapter four addresses Senegalese food security impacts in terms of calories and nutrition. The benefits of the increased cowpea production, both direct and indirect, are presented in chapter five. The contributions of the CRSP training program to human resource development are covered in Chapter six. The rate of return analysis in chapter seven summarizes the costs and some of the economic benefits of the project. The overall impacts of the project are reviewed briefly in the concluding chapter.

2. RESEARCH PRIORITIES

2.1. Operation Cowpea: 1985

Increases in cowpea production were marked in 1985 when after three years of particularly severe drought, the Bean/Cowpea CRSP project was requested by Senegal's national agricultural research institute - ISRA - to provide technical assistance and scientific information to help expand research on cowpeas and to help implement a major cowpea project to meet rural food needs. The one million dollar project, sponsored by the European Economic Community Delegation, the USAID Mission in Senegal and the Government of Senegal, primarily involved the massive importation and distribution of seven hundred tons of a Californian sixty day variety (CB5) to farmers in Northern Senegal. The estimated result of this effort was that area sown to cowpeas doubled and national production increased from the previous fifteen year average of 17,800mt to 66,000mt. Additional impacts of the 1985 effort were that cowpeas were given a higher priority in the national agricultural development agenda and that farmers gained confidence in cowpeas as an alternative crop to peanuts (Bunting, 1987).

2.2 The Aftereffects of Operation Cowpea

Production was sustained during 1986 as the CRSP project advised the government of Senegal to provide farmers with seed of a locally developed medium-cycle variety, 58-57, which has higher yields and fodder production than CB5. However, CB5 is still being planted in cowpea growing areas and continues to be an overall important source of green pods available for consumption before the main pea harvest (CRSP, 1987 and 1988a).

Output in 1987 fell partly due to lower yields (31% lower compared to the same farmer's 1986 yields) caused by mid-season drought stress (CRSP, 1988a). Additionally, a forty percent reduction in the total land planted to cowpeas was brought on by a multitude of factors related to the ending of the 1985 emergency cowpea project. These problems included inadequate marketing, low producer prices and problems with on-farm and large scale local storage as well as with the availability and timeliness of adequate supplies of good seed and critical insecticides. However, large areas of cowpeas were still being planted (71,480 ha.) (CRSP, 1988a). The recommended practices and new varieties developed by the CRSP project were being adopted in cowpea growing areas. Continued work on increasing production focuses on breeding, agronomy and the use of on-farm "mini-kit" experiments which serve to test new varieties, cultivation and storage practices before extension.[4]

2.3 Areas being Investigated

Exploratory and adaptive research on cowpeas in Senegal and the U.S. focuses on the identification of factors influencing yield stability. Interaction in terms of collaboration and cooperation between ISRA and UCR is excellent according to 1986 and 1988 external reviewers from University of Reading and the EEP.

"The initial step in any breeding program is the identification of genetic variation. This is normally done by screening as much of the available germplasm as possible for the desired characters. Once the desired character has been identified, it may be possible to arrive at a superior cultivar merely by selection ... or by combining desired characteristics through selection and hybridization (Hulse, Rachie and Billingsley, p. 47)." This process is the basis for the Bean/Cowpea CRSP's breeding program. The characteristics focused on by the CRSP researchers are heat tolerance, drought resistance, yield potential and resistance to disease and insects (CRSP, 1987).

2.3.1 The ISRA cowpea research team

Work in Senegal is being continued by the research team on a variety of topics utilizing "mini-kit" experiments "in which different cowpea strains and advanced storage and cultural practices will be evaluated on farms in the Sahelian and northern Sudanian zones of Senegal (CRSP work plan, FY1989)." Firstly, they are looking at the advantages and disadvantages of varietal intercropping compared with sole cropping. Secondly, the breeding program is investigating adaptation of short and medium cycle varieties to drought, resistance to bacterial blight, mosaic diseases and insects, evaluation of nitrogen fixation in advanced lines and evaluation of UCR lines for heat tolerance and "stay green" characteristics. Thirdly, climatic studies are being done on the "mini-kit" and other research sites. Finally, evaluation of sealed drum storage is being continued.

2.3.2 Research at UCR

In addition to an extensive crossing program focused on developing new varieties, experiments at UCR address a variety of topics. Spacing studies are being done to identify the optimal space within and between rows for specific varieties. Potential replacements for CB5 are being developed with improved heat tolerance and drought resistance (CRSP, 1987). Breeding for resistance to diseases and insects is also ongoing. Research is being done on the development of a new set of vegetable-type cowpeas to provide snap peas and southern peas for U-pick markets in the U.S., and for food during the Senegalese hungry season and a market crop for Senegalese farmers to send to urban areas and to earn income.

Basic research on the way different varieties discriminate against ^{13}C is being done to investigate differences in water-use efficiency and adaptability to drought prone environments (CRSP, 1987).

3. COWPEA PRODUCTION

3.1 Characteristics Desired by Farmers

In a survey of "mini-kit" (on farm experiments with all inputs supplied) farmers in Senegal the characteristics found to be desirable were early harvest, higher yields, resistance to insects, heat and disease, taste, color of grains, and diameter of grains (Bal, 1987). The extension service (SODEVA) carried out a survey in 1986 and found that fifty-four percent of the farmers surveyed preferred CB5 over local varieties. They liked the early harvest and large grains with good taste and cooking quality. Forty-six percent preferred local varieties because they have higher grain yields and forage (in an average rainfall year) and better resistance to insects. The overall conclusion is that the farmers appreciate having several varieties for different reasons.

Cowpea farmers in other West African nations consider earliness of harvest as a primary factor when choosing a variety of cowpea seed followed by high yields and fodder production. The importance of an early harvest is due to the need to produce a source of food during the hungry season. In Coulibaly's study of farmers in Cinzana, Mali, early maturation was unanimously perceived as important and cited by eighty percent as the preeminent reason they adopted an improved variety. The second most important reason was higher yields. In Niger the main characteristics which require development are early maturation (60 days) with high yield potential and disease and insect resistance (Gadbois and Rassas, 1988). These characteristics are closely matched by the research objectives at ISRA and UCR discussed in the previous section.

3.2 Production Practices

Unfortunately, there are no available farm level surveys of Northern Senegalese farming practices. The following description is based on related research carried out in Senegal and other West African nations as well as the perceptions of key informants.

The traditional cropping system of cowpeas is to plant them in "...several, separate, small individual plots, following village land tenure arrangements and spreading the risk of crop losses to insects, disease and highly localized rainfall (Bingen et al., 1988, p.861)." Wide plant spacing of 1 meter by 1 meter is the norm for leafy, spreading traditional varieties. Sprayers, fertilizer, certified seed and insecticides are not commonly used on small farms in Northern Senegal (Crawford, personal communication).

Input use between traditional and improved varieties of cowpeas differs primarily due to the requirement of using purchased inputs

(such as insecticide, additional labor, a higher seeding rate and improved seed) on high yielding varieties.

When the 1985 project to increase cowpea production was implemented, inputs purchased with Operation Cowpea funds such as improved seed, insecticide and sprayers were distributed by the government to producer's groups at low or no cost (Bingen et al., 1988). Sprayers were intended for the shared use of producers groups on cowpea fields (Ndoye, 1989, personal communication). Unfortunately, many farmers did not apply the recommended doses of insecticide for one or more of the following reasons: lack of adequate supplies, inappropriate advice from extension agents, or use of cowpea insecticides on other crops.

In terms of purchased inputs, insecticides for use in the field and in storage are the most important input for insuring expected yields. Cowpeas are attacked by hairy caterpillars, cowpea aphids, flower thrips and other insects in the field and bruchid beetles in storage. Fertilizer is not a high priority input on cowpeas. The Bean/Cowpea CRSP has obtained yields from on-farm trials ranging from 100 to 200% greater than the national average prior to 1981 without the use of fertilizer. However, one to two applications of insecticide were made to achieve these yields. In a study on Malian cowpea production, the use of insecticides is considered essential for new varieties to "make economic sense (Coulibaly, 1987, p.89)."

Local off-farm storage is a serious problem. Approximately six months after the 1985 harvest was stored many local storage facilities contained stocks of 25 to 30 tons of cowpeas which had been entirely destroyed by bruchid beetles. Small scale storage seemed to fare better with the use of various types of airtight containers successfully preventing damage without insecticides (Bingen et al., 1988).

Labor requirements are likely to increase with the adoption of improved varieties due to the added task of insecticide application and the increased yields of approximately forty-six percent.[5] The entirely manual harvest in particular will require an increased labor supply (CRSP, 1987).

Farmers will need a larger supply of seed for planting improved varieties . This is due to the recommended seeding rates of 20-25 kg/ha. for good yields from improved varieties.

3.3 Inputs and Input Costs

All inputs recommended for use in various types of cowpea cropping system are listed in Table 1.

TABLE 1
COWPEA PRODUCTION INPUTS

Animal team and harrow or other traction tools	
Mechanical seeding plate	
Fertilizer with NPK or Manure	
Sprayer	
Insecticide:	one treatment Endosulfan (thiodan)
	one to two treatments deltamethrine
Land, Seeds and Labor	

Source: Martin, 1988

The following rationale was used in the process of estimating the costs of production to a typical small farmer in the northern zone. Because of the low input use characterizing traditional cowpea cropping systems, a budget for traditional varieties is calculated for labor and seed costs only. Due to the importance of insecticides with respect to decreasing insect damage on improved varieties it is prudent to develop an improved variety budget including labor, insecticides and seeds.[6]

TABLE 2
COWPEA FARM BUDGETS: TRADITIONAL vs.
IMPROVED VARIETIES

Traditional Varieties - Labor and Seeds		
Labor	64 man days x 500 FCFA/day	32,000
Seeds	20kg @ 120 FCFA/kg	2,400
		34,400
Improved Varieties - Minimal Inputs		
Labor	67 man days x 500 FCFA/day	33,500
Insecticides	one application (two types)	11,850
Seeds	20kg @ 120 FCFA/kg	2,400
		47,750

Source: See Footnote 7

3.3.1 Labor

In Senegal's Northern Peanut Basin, the cultivation of cowpeas requires relatively intensive manual labor compared to that of sorghum/millet or peanuts.

n average cowpea production season in Mali requires 68 person days per hectare (Coulibaly, 1987) versus 42 for millet/sorghum or 38 for peanuts (Martin, 1988a p.42 and 1988b: figures for Zone 1). A liberal valuation of labor can be based on Martin's calculation of a wage rate of 500 FCFA/person day.[8]

In Niger, estimates of labor use are ten days each for planting and weeding. It is indicated that a "typical" plot of cowpeas in Niger (1 - 5 ha) requires eleven days for harvest (Gadbois and Rassas, 1988). The Niger estimate total for labor inputs, if preparation of grain is added, could fall in the neighborhood of fifty person days.

A study done of cowpeas in Mali (Coulibaly, 1987) lays out a detailed budget for labor use in cowpea production in terms of person days per hectare (Table 3). The Mali study is based on two high-yielding (average yield of 780kg/ha) varieties: KNI and TN88-63. The latter is a spreading, medium-cycle variety similar to 58-57 which is widely planted in Senegal.

TABLE 3
ESTIMATED LABOR USE ON IMPROVED VARIETIES OF COWPEAS IN MALI

Task		Person Days/Hectare
Land prep (light plowing and ridging with multipurpose plow)[a]		10
Fertilization (hoe)		1
Planting (hoe)		2
Weeding (two times with plow and hoe)		9
Insect Control (Sprayer :three times, 3.0 pds)		3
Harvest (manual)		28
first	17	
second	10	
third	1	
Threshing and winnowing (manual)		15
TOTAL		68

Source: Coulibaly, 1987, p.87
pds = person days
[a]Plowing and ridging are not practiced in the main cowpea production zone of Senegal.

3.3.2 Insecticides

The insecticides commonly used on improved cowpeas are Endosulfan (Thiodan) and deltamethrine. In Martin's budget for cowpeas he estimates per hectare insecticide use at three liters per application. The costs (1984 - 1986) of these insecticides,

assuming only one application of each, are 6,750 FCFA/ha (Endosulfan) and 5,100 FCFA/ha (deltamethrine) (Martin, 1988a).

The Mali study indicates that 2.5 ltr/ha of these insecticides, are used two to three times (Coulibaly, 1987, p.86). The farming system described in the Mali study area includes the application of insecticides with branches or brooms. We have no evidence to indicate that Senegalese farmers are also using this method but it does introduce the possibility that farmers with no access to sprayers may nonetheless be using insecticides on improved varieties.

3.3.3 Seeds

Generally, farmers save seed from the previous year to plant during the next growing season. However, the seed they are planting has a value and must be included as an input in both production budgets. The cost of improved seed in the budgets is based on consumer price data from ISRA on seven varieties of cowpeas (Figure 1). The average price used in the budget may be higher than the actual average producer prices for cowpeas. The recommended seeding rate for improved varieties is twenty kilograms per hectare. Therefore, at an average cost of 120 FCFA/kg and a 20 kg/ha seeding rate, the total cost of improved seed will be 2,400 FCFA/ha. Since the 120 FCFA/kg figure is the pre-planting seed price, and represents a large premium over the harvest season price, it is assumed to include the cost of storing seed.

3.4 Opportunity Costs of Increased Cowpea Production

The net benefits of improved varieties equals the gross value of production less the costs of production. Since explicit land costs are not available it is only possible to calculate the non-land costs of production. In order to account for land costs an opportunity cost is used: land is valued at the net margin (gross value less non-land production costs) of the next-best crop after improved varieties of cowpeas. The following analysis assumes that these next-best crops are either traditional varieties of cowpeas or peanuts.

3.4.1 Traditional Versus Improved Varieties

Considering that drought conditions were present both before and after 1985, improved varieties have been largely responsible for increased hectarage of 134 percent and yields of 46 percent (Table 7). The increase in yields of the improved varieties of cowpeas relative to the traditional varieties was 128kg/ha. The value of this increase when measured in terms of the annual average cowpea acreage from 1980-84 (21,684 ha) amounts to 2.7 million kilograms

of cowpea grain worth 333 million FCFA. In 1985, northern cowpea farmers planted a mixture of improved and traditional varieties (average yield 403kg/ha) on an additional 41,873 hectares due to the availability of improved varieties and operation cowpea. This increase in production was worth approximately 1.4 billion FCFA (US$4.7 million).

3.4.2 Comparison Between Cowpeas and Peanuts

Due to the perception that in Northern Senegal peanuts "will become a secondary crop in the near future (Martin, 1988a, p.4)," it is difficult to find farm budgets for peanuts in the Northern Peanut Basin. However, Martin's budget estimates for peanuts in the central zone for a year with low rainfall which starts late in the growing season can be used as a proxy for the northern zone.[9] Other factors which differ between the northern and central regions, such as soil type and availability of labor, are not taken into consideration in the budget for peanuts.

By looking at the comparison of cowpeas to peanuts it is clear that if rainfall is very low farmers are unlikely to choose peanuts over cowpeas as their main legume crop (Table 4). In a good year in which peanuts can be planted profitably there are three main contributions which cowpeas make to northern Senegalese farm families: reduced risk from drought, a source of income, and food from an early harvest of green pods and short cycle grain. Almost all the farmers surveyed in a cowpea study in Mali (98%) said that new varieties of cowpeas did not decrease their areas cropped in basic cereals and groundnuts (Coulibaly, 1987). This shows that there is a place for cowpeas in the farming system even if rains are good. Additionally, cowpeas command a good price relative to peanuts (120 FCFA/kg vs. 90 FCFA/kg), and even higher returns when sold outside of Senegal to neighboring countries.

3.5 Value of Germplasm Enhancement

The economic value of germplasm enhancement and the establishment of domestic germplasm research is associated with increases in yield and income and decreases in risk and input requirements.

TABLE 4
COMPARISON OF COWPEA AND PEANUT NET MARGINS
NORTHERN PEANUT BASIN (Zone 2)

Cowpea Revenue	Grain	48,000FCFA/ha
	Hay	27,200
Variable Costs[a]		55,250
Net Margin (FCFA/ha)		19,950
Peanut Revenue	Grain	22,500
	Hay	20,140
Variable Costs[a]		23,700
Net Margin (FCFA/ha)		18,940

Source: (See Footnote 10)
[a]Includes labor, seed and insecticides.

3.5.1 Increases in Yields and Income

Even under drought conditions, increased yields for improved cowpea varieties grown in "mini-kit" experiments in villages in northern Senegal have been 250 percent higher than the fourteen year average of 275 kg/ha.

Early maturing varieties benefit from the high prices for cowpeas before the regular harvest. In 1986 for example, the beginning of September price was 250 FCFA/kg but during the main harvest in October and November the price fell to 50-70 FCFA/kg. The market for good quality seeds for planting also provides a market with a higher than average price during the dry season from June to September.

3.5.2 Decreased Risk

The harsh conditions of the northern region make risk associated with weather a serious problem for farmers. Improved varieties suited to the needs of small farmers are helping to decrease this risk. In 1986 five farms in the Louga region involved in on-farm "mini-kit" experiments had good cowpea harvests with average yields of 818 kg/ha with only 200 mm of rain -- but the millet crop was a total failure. Farmers who did not use improved seed or insecticide had average yields of 131 kg/ha (CRSP annual report, 1987).

3.5.3 Decreases in Inputs

In order to decrease the amount of insecticide farmers must use to get good yields with improved varieties, CRSP researchers are working to develop varieties with greater resistance to insects. Increased resistance to pests is important. As long as yields for resistant varieties are good, limiting the use of insecticides will lower the costs of production (Coulibaly, 1987). Health hazards and environmental problems related to insecticide use are also incentives to breed for pest resistance.

Seeds as an input are usually taken from a farmer's own stock. Small scale storage of seeds in sealed clay pots has been effective at the household level. However, methods by which the seeds can be effectively stored on a large scale are being developed. Sealed drum storage without pesticides or fumigation has proven to be very successful. Storage experiments with these methods have resulted in damage limited to sixteen percent.

4. HOUSEHOLD FOOD SECURITY

The foremost issue in household food security is the provision of a sufficient number of calories; another issue is the provision of a nutritionally complete diet. The annual hungry season in semi-arid climates such as northern Senegal makes meeting these basic requirements very difficult for several months of the year. The early harvest of cowpea grain and fresh green pods made possible by improved early-maturing varieties help to alleviate this constraint.

Direct benefits to a farm family from planting improved varieties of cowpeas and using good storage practices to limit post-harvest losses are estimated below in terms of calories per farm family. Based on a daily calorie requirement of 2380 per person recommended by the FAO (FAO, 1977) and an average family size of 10.2 people (Kelly, 1988)[11] ,the yearly family food requirement is 8.56 million calories. If on an average farm (2.5 ha[12]), the land planted to cowpeas is 0.5 ha, and one kilogram of cowpeas provides 3450 calories (see Table 5), average farm production using improved varieties can feed the average family for one month, which is about the duration of the hungry season.

In addition to providing calories during the hungry season and in drought years, cowpeas are a good source of nutrients relative to other food sources. Cowpeas, like other food legumes, are a good source of dietary protein. The actual protein content varies from 23 to 30% due to varietal differences and environmental factors (Singh and Rachie, 1985).

The two amino acids listed in Table 5 are a reminder that cowpeas in combination with cereals increase overall protein digestibility of the diet. This is a result of cowpeas complementing the lysine deficiencies of cereals, and cereals complementing the methionine deficiencies of cowpeas.

As a prepared food, cowpeas have two limiting factors. First, as is true with all beans, cowpeas have a "beany" smell and taste in foods prepared with cowpeas, cowpea meal or cowpea flour. The second factor is the relatively large amount of time and effort involved in preparing the raw crop for consumption. Preparation may include soaking, removing the seed coat by hand, drying, grinding and then cooking the paste (Singh and Rachie, 1985).

TABLE 5
NUTRITIONAL COMPARISON OF COWPEAS AND OTHER FOOD CROPS

crop[a]	protein g/100g	calories kcal/ 100g	carbo-hydrates g/100g	lysine mg/gN	methi-onine mg/gN
cowpeas	23.1	345	62.2	411	87
peanuts	23.8	556	22.6	213	60
millet	11.1	371	73.3	156	137
sorghum	9.8	343	74.3	156	104

Source: FAO,1982.

[a]Values are for the raw, whole grain, edible portion.

5. DIRECT AND INDIRECT BENEFITS TO INCREASED COWPEA PRODUCTION

The direct economic benefits of increased cowpea production arise from the fact that improved varieties have higher yields, resulting in higher production, with little increase in the cost of inputs used. With higher production, at reasonably stable prices, the value of output increases relative to the input costs. This increased net margin is a direct economic benefit of improved varieties and cultivation techniques. This chapter is concerned with quantifying that benefit. Benefits to the nonfarm portion of the food system will also be discussed.

5.1 The Gross Value of Increased Pea Production

The gross value of cowpea production is equal to the quantity produced multiplied by the relevant price. Prior to 1985, national output ranged from 13,000 to 29,000 MT/year (Table 6). The 1985 emergency drought relief program lead to a large spurt in production which has tapered off somewhat, resulting in average annual output of cowpeas of about 50,000MT. The gross value of these increases in cowpea production, resulting in part from the distribution of improved varieties, will be analyzed in terms of world, regional and domestic prices. Cowpea production in the Louga region, which is the primary constituent of the Northern Peanut Basin, follows a similar pattern (Table 7).

TABLE 6
TOTAL COWPEA PRODUCTION AND ITS GROSS VALUE IN SENEGAL, 1980 - 1988

Year	Total Production (MT)	World Price ($/MT)	$ Value(000)
70-79	18,568[a]		
80	17,080	567	9,684
81	28,777	665	19,137
82	13,245	617	8,172
83	13,000	540	7,020
84	16,000	586	9,376
85	66,000	556	36,696
86	54,863	558	30,614
87	28,625	633	18,120

Production is from the Crop 1988 Executive Summary. Prices are from FATUS - Calendar Years 1981 (tbl.12),'82 (tbl.3),'85 (tbl.10) and '87 (tbl.11). Prices are derived from the value of U.S. cowpea exports divided by the quantity of total U.S.cowpea exports.

[a]Average

TABLE 7
INCREASES IN COWPEA PRODUCTION AND ITS GROSS VALUE
LOUGA REGION

YEAR	YIELD	AREA PLANTED	ANNUAL PRODUCTION	VALUE OF PRODUCTION[b]
				(000)
1980 - 1984[a]	275kg/ha	21,684ha	6,803MT	715,572
1985	434	63,557	27,588	3,311,000
1986	451	53,733	24,001	2,908,030
1987	325	35,114	11,412	1,369,446

Source: CRSP 1988 Annual Report
[a]Average values
[b]Priced at 120 FCFA/kg.

The future of cowpeas as a Senegalese export crop is in part dependent on the world market price. World cowpea prices reflect the marginal valuation of domestic output as savings from not having to import food equivalent to the domestic production of cowpeas. Regional prices are an important indicator of the viability of an export market to neighboring countries. Domestic prices reflect the Senegalese internal valuation of cowpeas.

5.1.1 Green Pod Production

The consumption of cowpeas early in the season in the form of fresh green pods (Southern peas) is an important element in the crop's ability to provide a supply of food during the hungry season. CB5 and Bambey 21, both early maturing varieties, are especially well suited to this use. The production figures given for 1985 and after include a relatively high proportion of CB5 and are therefore underestimated as they do not include the harvest of fresh pods. The EEC estimate of 80,000 MT for 1985 production does include fresh pods. Assuming that pod production roughly represents the difference between the ISRA and EEC estimates, fresh pod production represented 17.5 percent of total production of cowpeas (CRSP, 1988).

5.1.2 Cowpea Prices

The world market for cowpeas has been fairly stable as the 1980's have seen only moderate fluctuations in prices for this commodity. Total production in Senegal for 1985 (following the implementation of the cowpea project) represented five percent of world production compared to an average of 1.26 percent for the previous 10 years (FAO, 1987).

Following the 1985 increase in production, private marketers were selling cowpeas to Mali, Mauritania and Guinea-Conakry for 480

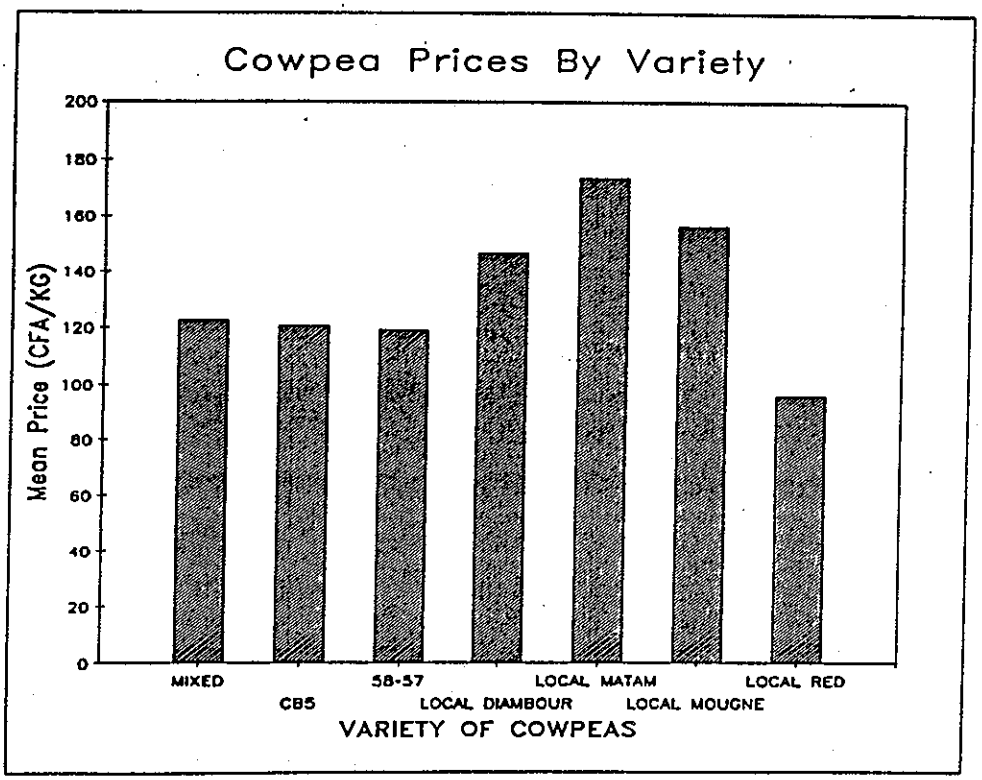
FCFA/kg, or four times the domestic price for local varieties and 624 FCFA/kg for CB5 (CRSP, 1986). This indicates that even in years when peanuts and millet can be grown in the dry Northern Zone, cowpeas, particularly CB5, provide the opportunity to produce a cash crop aimed at inter-regional markets. Improved cowpea

varieties are thus a boon not only to Senegalese farmers but also to West African regional trade.

The domestic gross value of cowpea production is a function of which variety is grown since prices differ by variety. New varieties may not command as high a price locally as traditional varieties due to differences in taste and preparation,[13] although their prices do not represent a significant departure from the average (Figure 1).

FIGURE 1

CONSUMER PRICES FOR YEARS 1984 - 1989



5.2 Gross Value of Increased Fodder Production

5.2.1 General Use of Fodder

Fodder production is an important aspect of the returns from growing cowpeas. The plant material remaining after harvest is sold or stored to feed livestock during the dry season. Peanut plants have been the primary source of fodder in the Northern Peanut Basin, but when drought conditions lead to the failure of the peanut crop, cowpeas provide an alternative. Additionally, the nutritional value per kilogram of cowpea fodder is roughly equivalent to that of peanut fodder (Cullison and Lowrey, 1987). The medium-maturing, spreading varieties which are being developed by the CRSP will incorporate the characteristic of good fodder production together with high pea yields as well as drought, disease and insect resistance.

5.2.2 Value of Increased Fodder Production

Tony Hall, head of cowpea research at UCR, claims that farmers do not sell much cowpea fodder but store it to feed to their own animals (CRSP, 1988a). Additionally, key informants familiar with Senegalese local markets state that they are not familiar with any regular sale of fodder in the marketplace.[14] However, in Niger where cowpeas are an important cash crop, the returns to hay sales are substantial (Gadbois and Rassas, 1988). Substantial peanut hay is available in Senegal and cowpea fodder production levels may have been too low for farmers to have a surplus for sale. The early maturing variety, CB5, does not produce fodder as well as the spreading medium maturing varieties such as 58-57 and TN 88-63. If farmers are successful in implementing a farming system incorporating both short and medium cycle varieties they may develop a supply of fodder for sale. Regardless of whether fodder is sold for cash it has an implicit value since farmers would otherwise have to buy animal feeds. Table 8 below presents a valuation of cowpea fodder.

5.3 Assessment of Indirect Benefits

The impact of changes in cowpea production of pods, peas and fodder affects a wide range of economic activity due to forward and backward linkages. A linkage in this section refers to impacts of changing cowpea production practices and output on different segments of the rural market economy.

TABLE 8
COWPEA FODDER PRODUCTION AND ITS APPROXIMATE GROSS VALUE, LOUGA, SENEGAL 1980 - 1988

YEAR	TOTAL HA. PLANTED	PRODUCTION (kg/ha)	PRICE FCFA/kg	GROSS VALUE millionFCFA	US $ VALUE[a]
80	54,247	800	34	1,476	4.9
81	68,484	800	34	1,863	6.21
82	47,930	200	40	383	1.28
83	40,000	200	40	320	1.07
84	53,000	200	40	424	1.41
85	121,000	1200	28	4,066	13.55
86	117,607	1200	28	3,952	13.17
87	71,480	800	34	1,944	6.48

Source: Area planted is from CRSP, 1988. Production is based on Frederic Martins 1988 budgets which give the figures for "good", "average", and "bad" years. The classification of a given year is based on rainfall and total production of cowpeas during that year.

[a] Estimated at FCFA 300 = $US1

5.3.1 Forward Linkages: Benefits to the Marketing Community

The CRSP project advised the Government of Senegal to set up a marketing system in 1985 during the planning stages of the cowpea project. However, despite an extensive marketing campaign the government purchased only a small percentage of the marketed harvest compared to the seventy-eight percent bought by private traders. Thirty percent of the total marketed harvest was exported by private traders at prices of 480 FCFA/kg, or four hundred percent above the Senegalese price.[15] Exported CB5 was sold at a price an additional thirty percent higher than local varieties or 624 FCFA/kg (CRSP 1986).

Export markets for cowpeas are important in the sense that they can provide income. The crop not only provides food and income to farm families during the drought season but also may take up part of the slack in export markets left by decreased peanut production. Improvements in storage systems are essential to facilitate development of cowpea markets (CRSP, 1986).

5.3.2 Backwards Linkages: Benefits to the Rural Economy

Effective demand for rural goods and services is primarily driven by growth in farm income. Cowpeas have the potential to increase

farm income by providing a saleable product sixty days after planting in a period when many farm families have little or no cash to buy food, clothes, medicines and other necessities. Additionally, expanding cowpea production will increase labor demand due to the labor intensive nature of cowpea cropping systems. Farmers surveyed in Niger said that they required hired labor for the peak periods of work in cultivating cowpeas. (Gadbois and Rassas, 1988). This can be a benefit for the rural economy as it will provide an extra source of income for those families dependent on off-farm income to supplement their own production. Additionally, exchange labor may be used whereby farm families could assist each other in tasks requiring intensive labor during a short period of time.

5.3.3. Decreased Dependence on International Markets

The purchase of improved seed from overseas markets requires the use of scarce foreign exchange. Although germplasm itself is available for research at low cost[16], there is a high cost of importing improved seed, and this seed may not be perfectly adapted to local conditions. CB5, although it was well liked by farmers in Senegal, is not the optimal short-cycle variety for northern Senegal as it suffers greatly from insect attack and pod rot. The Government of Senegal and the CRSP are collaborating in the development of a national agricultural research system in Senegal that can breed varieties to fit the specific needs of local farmers and have the expertise to manage it's own certified seed multiplication program.

6. HUMAN RESOURCE IMPROVEMENTS

6.1 Training

Students working with the Senegal Bean/Cowpea CRSP during the period from 1980 to 1987 have completed seven masters and five doctoral degrees. Seven additional degree students, (five doctorate and two bachelors) were currently enrolled in 1987. The CRSP project has trained one Senegalese student at the M.Sc.level and two at the B.Sc.level. Two Senegalese students are pursuing M.Sc. degrees at this time. Additionally, the CRSP project provided six non-degree training courses on specific technical topics to four Senegalese students between 1980 and 1987 (CRSP, 1987a).

6.2 Benefits of Training

Training Senegalese scientists affects the productivity of the research system and improves the welfare of the individual participants.

6.2.1 Benefits to the Senegalese Research System

It is notable that prior to the CRSP's training component the primary work being done with cowpeas in Senegal was the maintenance of the germplasm collection (Bingen et al., 1988). "Since 1981, the project has assisted ISRA to develop a team conducting research on all major aspects of cowpea production and storage (Unpublished CRSP 1989-1992 Extension Proposal p.9)."

The impact of the CRSP training program on the productivity of the research system is clearly illustrated by comparison with the alternative of hiring experienced foreign scientists. The current CRSP expenditure of approximately $200,000 per year would buy one project conducted by a foreign scientist. Alternatively, the CRSP has executed multiple research projects concerning cowpea breeding, physiology, agronomy and plant pathology, provided technical assistance and trained domestic scientists who are providing permanent increased research capacity. The continued training of scientists will enable the cowpea research team to maintain it's strength in the face of promotions and reassignments of staff (CRSP, 1986). Finally, providing additional education for members of the research community improves productivity.

Although the turnover of Senegalese scientists at ISRA has been unusually high from 1985 to 1987 (average of 12.5 percent or twenty nine total researchers in two years), the subgroup of plant breeders and agronomists has had relatively lower turnover than general agriculturalists, administrators or trainees. The high turnover rate between 1985-1987 was caused in part by the ending of many donor funded projects and subsequent decline in financial

support for research (Wesson 1988). The CRSP trained scientists who returned to Senegal in 1983 and 1988, Ndiaga Cisse and Samba Thiaw are presently working on cowpea research at ISRA. Therefore, it is possible that CRSP trained staff have a lower turnover rate than other scientists at ISRA. This view was also supported by James Bingen (personal communication).

6.2.2 Personal Benefits

Senegalese students are trained in the U.S. and may have some access to U.S. job opportunities resulting from their education; also, eight of the students trained under the Senegal project are from the U.S. Therefore the figures in Table 9 are relevant in estimating their potential personal benefits in terms of increased income from their education.

TABLE 9
U.S. AVERAGE MONTHLY SALARY OFFERS FOR CHEMSITRY GRADUATES, 1985.

Degree	Salary ($)	Percentage Change
B.A.	1,897	
M.Sc.	2,177	15[a]
Ph.D.	3,032	39

Source: Statistical Abstracts of the United States
[a]Relative to Previous Degree

The monetary and nonmonetary benefits of a college degree in the U.S. are presented to illustrate the potential opportunities for salary increases as a result of completing higher level education in the sciences. The U.S. paradigm shows that on average, people earn more as their level of education rises.

While the above estimated figures describe the potential income increases available to graduates of the training program, the CRSP is dedicated to returning foreign students to their home countries.

6.2.3 Surveys On Training Benefits

The monetary and nonmonetary returns to training which accrue to individual Senegalese or African student/scientists who return to their home country are examined in this study. To that end, a survey of two different groups was carried out. Those groups were African students presently enrolled in the College of Agriculture at Michigan State University and alumni of that college who have

returned home to work in West African countries. The analysis of the alumni survey will be started in December.

Eighteen African students presently enrolled at MSU were given a questionnaire on the monetary and nonmonetary benefits they expect to result from their training as part of a pilot survey. The demographic characteristics of the pilot survey respondents are as follows: sixteen men and two women; thirteen Ph.D. candidates and five M.S. candidates; seven from francophone countries, seven from anglophone countries and four from other African nations.

The results of the pilot survey indicated that both M.S. and Ph.D. respondents expect an increase in salary of between thirty and forty percent as a result of their MSU training. Seventy percent expected that their opportunities to earn additional income would increase. The primary sources given for earning outside income were presenting papers at conferences and/or working as consultants.

The changes respondents expect in nonmonetary benefits as a result of training were primarily a change in job title or position and improved housing conditions. Other areas where people expect changes are job responsibilities, access to education for their children, access to health care, diet and nutrition, housing, transportation and access to leisure activities (Table 10). Forty-three percent of respondents (n=14) marked that the non-monetary benefits of training represented more than fifty percent of the total gain of their education.

TABLE 10
NONMONETARY BENEFITS TO TRAINING

	Percentage of Respondents Answering Positively	
Change in job title/position	65	n=17
Increased job responsibility	18	n=17
Increased Access to Health Services	17	n=18
Improved Housing Conditions	50	n=18
Improved Personal Transport	42	n=12
Access to Education for Children	33	n=14
Improvement in One or More Category	67	n=18

Source: Pilot Survey 1988
n = total number of responses

6.3 Women in Training

One aspect of the training which is of particular interest is the number of women involved. Out of the total (19) degrees completed and still in progress in 1987, sixteen percent (3) have been undertaken by women. In the typical development setting where the constraints on research are the lack of trained personnel, it is important to take full advantage of available human resources by training both male and female scientists. Typically women constitute far less than 16% of the research scientists in a national research system.

7. THE RATE OF RETURN

The standard measure of the economic success of an agricultural research project is the rate of return (ROR) to the project (Evenson, Waggoner and Ruttan, 1979). The ROR measure combines the costs and benefits of the project at different points in time into a single, evaluative measure. This measure can then be compared to the interest rate or some other cost of capital. If the ROR exceeds the cost of capital then the project has yielded above average returns and is considered to be economically successful. If the ROR falls below the cost of capital then the project has yielded below average returns and cannot be considered a success on economic grounds.

7.1 Methodology

To calculate the ROR the total benefits and costs of the research project at each period in time need to be ascertained. Using the notations B(t) for the benefits at time t and C(t) for the costs at time t, the ROR can be defined using the formula

$$(1) \quad \sum_{t=0}^{T} \frac{1}{1+r}^{t} (B(t)-C(t)) = 0$$

where t=0 represents the starting date of the project and T represents the ending date. The value of r that makes this equality hold is called the rate of return.

The total, quantifiable, net economic benefits of cowpea research, extension, and scientist training are approximated by the sum of net benefits from the increased cowpea production in Senegal, and the personal benefits from training of scientists (details of the calculations of benefits and costs can be found in the Appendix). While there are other economic benefits accruing from the CRSP, such as the salary savings to the Senegalese research system from employing domestic rather than foreign scientists (section 5.2.1.), estimation of these benefits in dollar terms is untenable and hence we use only the benefits quantified earlier in this document. The yearly benefits used in calculation of the ROR are listed in Appendix Table A.4.

Not all of these benefits can be attributed solely to the CRSP. For example, the huge increase in production in 1985 is attributable at least in part to Operation Cowpea's distribution and extension efforts. During the 1985 project the Senegalese extension service, SODEVA, participated in the distribution of

seeds, supplies and information to farmers. The Senegalese research service, ISRA, now assists SODEVA and the Seed Production Service with development of certified seed which has low levels of seed-borne disease and weevil damage. Thus it is not possible to calculate a ROR solely to the CRSP; rather, the ROR must be calculated to the government of Senegal's and international donors' investments in cowpea research, distribution, and extension. Of course, this ROR is a relevant measure for the evaluation of programs which receive donor funds, such as the Bean/Cowpea CRSP.

Since the ROR being calculated is the ROR to the total cowpea effort, the costs of all the programs involved must be included. A list of these costs is presented in Appendix Table A.3. These costs are used as the values for C(t) in equation (1).

7.2 Results

Solving equation (1) for the ROR shows that the rate of return is 63%. This is an extremely favorable number, and it is in line with previous estimates of ROR's to successful agricultural research projects (Evenson, Waggoner and Ruttan, 1979). The ROR of 63% implies that if all the CRSP, Operation Cowpea, and other Senegalese cowpea funds had been invested in a bank, then the bank would have to pay a 63% annual interest rate in order to generate the same returns as did the cowpea research, extension, and distribution systems that were in place from 1981 to 1987.[17] The estimated ROR clearly indicates that the cowpea initiative has been an economic success.

Several caveats to this analysis must be injected. First, several economic benefits have not been quantified due to lack of adequate data. These benefits include benefits from linkages, from greenpod consumption, and from the increased productivity of the Senegalese and international research systems. Second, in the ROR calculation it was assumed that land not planted in cowpeas would be planted in peanuts. However, especially in the Louga region, rainfall in recent years may not support even minimal peanut production, so that the estimated benefits from cowpea production relative to the alternatives may be underestimated. Both these caveats mean that the estimated ROR may be underestimated, so that the true ROR may be higher than 63%. The third caveat is that projections of future benefits may be high. It has been assumed that in the absence of the distribution and extension programs improved varieties will still be grown on large acreages with adequate insecticide use. However, the reduced acreage and output in 1987, when extension and distribution funds were slashed, indicates that germplasm alone may not be enough to improve cowpea production. The conversion of projected FCFA returns to US$ returns may also overstate benefits, since the recent strong dollar may tend to erode the real value of these benefits. Hence the third caveat suggests that these forces would cause the 63% figure to be biased upward. Nonetheless,

sensitivity analysis indicates the 63% figure is robust to changes in the assumptions.

The result of the above discussion is that the estimated ROR of 63% should be taken as an approximation and not as an exact figure. However, even if the estimated ROR overstates the "true" value by a factor of 3, so that the true ROR is 21%, this still reflects favorably on the economic benefits of the project. If the estimated ROR underestimates the true value by a factor of 3, then the ROR could approach 200%.

8. CONCLUSION

The economic benefits of the Bean/Cowpea CRSP project at the farm level are numerous. Firstly, farmers are able to minimize risk and to increase yields through intercropping and/or planting separate monocrops of both short and medium-cycle varieties of cowpeas. Secondly, a crop is provided during the "hungry season" or soudure (the period between the beginning of the rainy season when food becomes scarce and the harvest), thereby eliminating large swings in income and food supplies. Thirdly, farmers can choose from an array of improved cowpea varieties with different characteristics based on their specific production requirements, ability to afford inputs and tastes. Finally, post-harvest losses are decreased by improving on-farm storage.

At the regional level, the semi-arid northern Louga region of Senegal will have increased food security by incorporating a crop into the farming system which can provide higher yields relative to traditional varieties. In drought years cowpeas provide a food source when no other is available and in years with sufficient rains for growing peanuts they provide a source of food early in the season, and a nutritional complement to other foods after the regular harvest.

An important long term benefit of the Bean/Cowpea CRSP project is the training of Senegalese scientists whose efforts will contribute to increased food production and rural incomes. As Hayami and Ruttan point out "...the most serious constraint on the realization of potential gains from new knowledge and new technology... [has been] ...the limited capacity of many national research systems (Hayami and Ruttan 1985)." The training program of the Bean/Cowpea CRSP is providing Senegalese national research system scientists with the education they need to both generate and borrow and adapt new technologies of cowpeas and other crops. Strong linkages have been built between ISRA and the U.S. institutions involved in the project which will continue to facilitate research efforts in cowpeas and other crops.

NOTES

1) The Station became ISRA headquarters in 1975.

2) The average yields in California are 2,000 Kg/ha.

3) " USAID finances cowpea research through four separate projects: The Bean and Cowpea Collaborative Research Support Project (CRSP) with the University of California-Riverside is the most important; other projects are managed by the Inter-State Committee for Drought Control (CILSS); The International Institute of Tropical Agriculture (IITA); and the Semi-Arid Grain Research and Development Project (SAFGRAD)" (p.864 Bingen).

4) These are on-farm trials that are conducted by farmers who are provided with all necessary inputs, information and supervised by researchers and extension. In 1987 and 1988 thirty-five such trials were carried out.

5) Average "mini kit" yield calculated from averages for three varieties (58-57, Ndiambour and CB5) over two years of on-farm trials in four northern villages.

6) The improved varieties most widely planted are locally developed 58-57, Ndiambour and imported CB5.

7) The figures in the budgets were developed as follows: Coulibaly's labor estimates and Martin's figures on other input costs were adapted to our assumptions about inputs explained in the text.

8) The wage rate is taken from F.Martin's budgets and should be interpreted as an upper bound.

9) Martin's estimates for peanut production in a bad year with late rains are slightly less than half of an average year's production (Martin budgets).

10) The cowpea figures are based on a low input model (zone 2). The peanut data is taken from a low input model for a bad year with late rains (zone 1). All information is taken from Martin's budgets with adjustments that are described in the text such as a different average price for seed and exclusion of various inputs. The revenue from cowpea hay production is an imputed figure.

11) The figure for average family size is for the Southern region of Senegal and includes all family members (adults and children).

12) The EEP report notes that the 5-6 Ha. that can be farmed by one family with animal traction is 3-4 times greater than the area the same family could farm with manual labor.

13) New varieties of cowpeas are sweeter and have a tighter, wrinkled seed coat which is more difficult to remove by pounding. Malian housewives overcame this problem by soaking the beans overnight. (Coulibaly p.62)

14) Dr. James Bingen, Associate Professor of Agricultural Economics who has worked extensively in Senegal and Ousseynou Ndoye a Senegalese Agricultural Economics PhD. student: both presently at Michigan State University.

15) The average local price of 120FCFA/kg. cowpeas is based on the ISRA price data.

16) "A small quantity of seeds of all available germ-plasm collections at IITA... (11,800 accessions of cowpea and 200 accessions of wild "Vigna")... are freely distributed to scientists around the world on request" (Singh and Rachie p.21)

17) While cowpeas were grown before 1981, little research was done before that date (see section 1.1.1). Also, the 1985-86 emergency relief projects benefitted from CRSP expertise, and hence CRSP costs from as early as 1981 are certainly relevant.

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APPENDIX

The first step in calculating a rate of return is to quantify the improvement in productive value that occurs when cowpeas are grown instead of competing crops. Following the discussion of section 2.6, it is possible to calculate the gross value of the post-1985 cowpea cropping systems relative to the 80-84 systems employing either peanuts or traditional varieties of cowpeas. This gross value is calculated by subtracting the value of a counterfactual production that would have occurred in 1985-1987 in the absence of any cowpea programs from the value of actual production in 1985-1987.

Two hypothetical scenarios are imposed as assumptions about what would have happened from 1985-1987 in the absence of the CRSP, Operation Cowpea, and other programs impacting the Senegalese cowpea sector. The first scenario assumes as a hypothetical situation that the acreage planted to cowpeas and the yields from 1985-1987, in the absence of programs, would have been equal to the 1980-84 average acreas planted and yields. This scenario also assumes that the increased acreage planted to cowpeas from 1985-1987 would otherwise have been idle; that is, without the programs, there would have been no profitable use for this land. The second scenario differs from the first in that it assumes that the increased acreage from cowpeas was taken from marginal peanut producing acreage. The truth is probably somewhere between these extremes, so that values based on the first scenario probably overestimate the benefits from planting improved varieties, while the values based on the second scenario probably underestimate the benefits.

The calculated values are presented in Table A.1. Under either scenario the values for 1985 and 1986 are in the billions of FCFA. In 1987 estimated values fall substantially, although both 1987 values are still in the range of 1.0 billion FCFA.

The second step in calculating the ROR is to calculate the net value of the improved variety cowpea production. This is accomplished by subtracting off any increase in productive input costs that is associated with farming the improved varieties. As discussed in section 2.5, the major cost changes are insecticides and additional labor. Based on the budgets developed in these sections, the increased input costs are listed in col. (2) of Table A.2. The net values are listed in col. (3) of Table A.2.

The third step is to project benefits of increased production of improved variety cowpeas into the future. The following simple method was used to do this. The average annual net value of increased production from Table A.2 was taken over the years 1985-87. It was assumed that in 1988 the net value would be 90% of the 1985-87 average value, and that the future value would decline by 10% of the 1985-87 average value, per year, over the years 1988-

1997. This assumption is made to reflect increased pest tolerance to chemicals, depreciation in sprayers and equipment, and other depreciating forces. The projected net benefits are presented in the first column of Table A.3

The fourth step in calculating the ROR is to quantify the benefits of trained scientists. The number of B.S., M.Sc., and Ph.D. degrees granted through the CRSP's Senegal component, and the year granted, was collected from CRSP documents. The personal benefits to graduates in terms of salary increases was placed at $5,000/yr for a B.S., and additional $5,000 for an M.Sc., and an additional $3,000 for the Ph.D., based on preliminary survey returns (section 5.2.3). It is assumed that the working lifetime of a degree recipient is 30 years, and that the value of these degrees depreciate by 1/30th of their original value every year. The depreciation assumption is made to reflect the facts that over time seniority or experience may account for a greater proportion of salary than does education, and that accidents, early retirement, or other forces may curtail the graduate's worklife. These salary figures are then adjusted upwards by a factor of 1.3 to reflect the nonpecuniary personal benefits associated with education (see section 5.2.3, Table 10). The benefits to the productivity of the research system are not quanitfiable. The final figures for benefits of trained scientists are given in the second column of Table A.3.

The fifth step is to calculate the research, education, extension and distribution costs associated with the CRSP, Operation Cowpea, and scientist training. These costs are given in Table A.4.

The final step is to use equation (1) of the text to calculate the ROR. The starting and ending dates of the summation in this equation, 0 and T, are set to 1981 and 2015, resp. The benefits, B(t), are given in the last column of Table A.3. The costs, C(t), are given by the last column in Table A.4. Equation (1) is solved numerically for the ROR using the GAUSS software package and non-linear equation algorithm. The estimated ROR is 63%.

Two sensitivity analyses are carried out. The first assumes that the programs increased production only during the years 1985 and 1986, when large scale efforts were made to distribute input packages to farmers. This assumption is consistent with the pattern of acreage planted to cowpeas, which saw a large drop-off between 1986 and 1987. It is also assumed that there are no benefits from the training of scientists. These assumptions lead to conservative estimates of benefits, which may impart a downward bias to the calculated ROR. Nonetheless, the calculations reveal an ROR of 66%, which is consistent with the previous estimation.

The second sensitivity analysis assumes that the drop-off in acres planted to cowpeas bewteen 1985 and 1987 was because 1987 was a relatively high rainfall year, so that peanuts could be grown

instead of cowpeas. It is further assumed that this rainfall pattern occurs 1/2 the time. This means that the expected benefit from utilizing cowpeas instead of peanuts accrue in any particular year is 1/2 times the actual benefit in a drought year. The benefit in a drought year is calculated to be the average of the 1985-1986 benefits, depreciated to the future year using a ten-year, straight-line depreciation method. It is still assumed that there are no benefits from training. Under this scenario, the estimated ROR is 88%.

TABLE A.1
GROSS VALUE OF IMPROVED VARIETY COWPEA PRODUCTION
RELATIVE TO ALTERNATIVES

SCENARIO 1: The increased cowpea acreage would otherwise be idle. Traditional varieties would be planted with output equal to the 1980-84 average output.

YEAR	ACTUAL PROD. WITH IMPROV. VARIETIES (1)	VALUE AT 120FCFA/kg (2)	HYPOTHETICAL PRODUCTION; TRAD. VAR'S. (3)	VALUE AT 120FCFA/kg (4)
1985	66,000mt	7.9×10^9FCFA	17,600mt	2.1×10^9FCFA
1986	54,800mt	6.6×10^9FCFA	17,600mt	2.1×10^9FCFA
1987	28,600mt	3.4×10^9FCFA	17,600mt	2.1×10^9FCFA

SCENARIO 2: The increased cowpea acreage otherwise would have been planted to peanuts. Traditional cowpea varieties would have been planted on the 80-84 average cowpea acreage, with output equal to the 80-84 average output.

YEAR	DISPLACED PEANUT ACREAGE (5)	HYPOTHETICAL PEANUT YIELDS (6)	VALUE OF HYPOTHETICAL PN. PRODUCTION. (7)
1985	68,300ha	250kg/ha	1.54×10^9FCFA
1986	64,900ha	250kg/ha	1.46×10^9FCFA
1987	18,700ha	250kg/ha	0.42×10^9FCFA

YEAR	VALUE OF INCREASED COWPEA PRODUCTION RELATIVE TO SCENARIO 1[a] (9)	RELATIVE TO SCENARIO 2[b] (10)

1985	6.8×10^9 FCFA	5.3×10^9 FCFA
1986	4.5×10^9 FCFA	3.0×10^9 FCFA
1987	1.3×10^9 FCFA	0.9×10^9 FCFA

[a]Calculated as (2)-(4).

[b]Calculated as (2)-[(4)+(7)].

TABLE A.2
NET VALUE OF IMPROVED VARIETY COWPEA PRODUCTION

YEAR	GROSS VALUE OF COWPEA PRODUCTION RELATIVE TO SCENARIO 2 (1) [a]	INCREASED INPUT COSTS OF IMP. VAR. COWPEA PRODUCTION (2) [b]	NET VALUE OF IMPROV. VAR. PROD. (3)
1985	5.3×10^9 FCFA	3.1×10^9 FCFA	2.2×10^9
1986	3.0×10^9 FCFA	2.7×10^9 FCFA	0.3×10^9
1987	0.9×10^9 FCFA	1.6×10^9 FCFA	-0.7×10^9

[a]Taken from column (9) of Table A.1.

[b]Increased costs are assumed to include the cost of insecticide, 3 additional labor days for insecticide application, and 12 additional labor days for harvesting the additional yield. Increased costs relative to peanut production include 17 additional labor days.

[c](2)-(1).

TABLE A.3
ANNUAL BENEFITS AND PROJECTED BENEFITS, 1981-2015

YEAR	BENEFITS OF INCR. PEA PRODUCTION	BENEFITS OF TRAINED SCIENTISTS	TOTAL BENEFITS
1981	$ 0x10^3	$0	$ 0.0x10^3
1982	0	0	0.0
1983	0	16,900	16.9
1984	0	39,700	39.7
1985	7,300	52,400	7,352.4
1986	1,000	50,600	1,050.6
1987	-2,300	65,700	-2,234.3
1988	900[a]	76,300	976.3
1989	800	73,500	873.5
1990	700	70,700	770.7
1991	600	67,900	667.9
1992	500	65,000	565.0
1993	400	62,000	462.0
1994	300	59,400	359.4
1995	200	56,500	256.6
1996	100	53,800	153.8
1997	0	51,000	51.0
1998	0	48,100	48.1
1999	0	45,300	45.3
2000	0	42,500	42.5
2001	0	39,700	39.7
2002	0	36,900	36.9
2003	0	34,100	34.1
2004	0	31,200	31.2
2005	0	28,400	28.4
2006	0	25,600	25.6
2007	0	22,800	22.8
2008	0	20,000	20.0
2009	0	17,200	17.2
2010	0	14,300	14.3
2011	0	11,500	11.5
2012	0	7,900	7.9
2013	0	5,900	5.9
2014	0	3,600	3.6
2015	0	2,200	2.2

[a]Benefits from 1988 on are assumed to decrease by 10% of the 1987 benefits every year for ten years.
[b]Benefits from 1988 on are assumed to decrease by 1/30th of the 1987 value every year for thirty years.

TABLE A.4
ANNUAL COSTS, 1981-1987

YEAR	CRSP RESEARCH[a] COSTS	"OPERATION[b] COWPEA" COSTS	EDUCATION[c] COSTS	TOTAL
1981	$160,000	$ 0	$190,000	$ 350,000
1982	160,000	0	200,000	360,000
1983	160,000	0	235,000	395,000
1984	160,000	0	230,000	390,000
1985	160,000	1,000,000	165,000	1,325,000
1986	160,000	600,000	106,000	866,000
1987	160,000	0	166,000	326,000
1988	160,000	0	154,000	314,000

[a]CRSP annual reports for 1986-1988 indicate that annual budgets have been relatively constant over time at $200,000. The 1987 reports details the CRSP's education costs at $40,000. The figure of $160,000 used here is the difference of the two figures.

[b]These expenditures include the research, extension, distribution, administration and other expenditures of donors contributing to the 1985 drought relief program known as "Operation Cowpea."

[c]Total educations costs are estimated at an average of $30,000/yr. for a Ph.D., including dissertation research costs; $5,000/yr. for an M.Sc., and $2,000/yr. for a B.Sc.