ADOPTION AND THE ECONOMIC IMPACT IMPLICATIONS OF STORAGE TECHNOLOGY AND IMPROVED COWPEA VARIETIES IN THE NORTH CENTRAL PEANUT BASIN OF SENEGAL

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EXECUTIVE SUMMARY

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In 1982 the Senegalese Institute for Agricultural Research (ISRA) and the Bean/Cowpea Collaborative Research Support Program (CRSP) started a long term research collaboration focused on cowpea production and storage. The primary outputs of this collaboration are a non-chemical method of storing cowpea in airtight metal drums, and two short season cowpea varieties, Melakh and Mouride. ISRA and the CRSP were also key players in a drought emergency program that provided cowpea seed and production inputs to Senegalese farmers in 1986 and 1987.

This analysis evaluated the economic impact of the ISRA/CRSP collaboration based on adoption and use of the technologies developed. Farmers in eighteen (18) villages in the cowpea growing region of north central Senegal were interviewed in May and June of 2004 about their cowpea production and storage practices. A standard economic surplus analysis was used to estimate the annual benefits of these technologies. ISRA and the Bean/Cowpea CRSP training costs were deducted. Internal rate of return (IRR), net present value (NPV) and annualized NPV were calculated and used to summarize the net benefits. Benefits of Operation Cowpea were based on an evaluation done by Schwartz *et al.* (1993) shortly after implementation of that program in the 1980s.

This 2004 survey found that approximately 83% of cowpea production is stored in metal drums and that about 68% of households surveyed use this storage technology. Some 73% of the cowpea grain stored in metal drums is also treated with the storage insecticide, phostoxin. Research and on-farm trial results have demonstrated that cowpeas can be successfully stored in airtight drums without insecticide, so the addition of phostoxin to the storage drums may be an insurance measure to protect against air leaks and other problems.

A similar survey of farmers in the same region in 1996 showed that about 95% of cowpea production was stored in drums and phostoxin was added to drums only by a few farmers in one village. The decline in use of metal drums from 95% to 83% may be related to the growing use of phostoxin. If the storage insecticide is widely available, low cost (75 FCFA/dose or about $0.20/dose), and users are not concerned about adverse health effects, lower cost storage containers, such as sacks can be used instead of drums. It remains to be determined if the increase in phostoxin use is due to a regulatory change, chemical company marketing strategy, larger farm size or other influence.

For the cowpea varieties the 2004 survey showed that Melakh and Mouride accounted for 3.4% and 0.5% of cowpea production respectively. Thus, improved short season cowpea varieties

developed by the ISRA/CRSP collaboration were almost 4% of cowpea production. This represents an increase in the use of these varieties over the findings of a 1996 survey that found that only about 1% of cowpea seed was Melakh and Mouride.

A high proportion of short season cowpea production is used as "green pods", that is they are consumed fresh as shell peas. This is a high value use, either for the farm family during the hungry ("soudure") period before the main crops mature, or for sale along roadsides. Because it is very early and the grains are relatively large, Melakh is particularly desirable for green pod use. Thus, while the area planted to Melakh and Mouride remains modest, the value of production of these varieties is quite high.

The baseline economic analysis which included benefits and costs of the storage technology, improved varieties and Operation Cowpea, showed an IRR of 224% and an annualized benefit of $1.9 million. The baseline financial analysis is dominated by Operation Cowpea benefits; as these are substantial and are accrued early in the 1982-2020 analysis period.

Operation Cowpea was an emergency program with benefits concentrated in 1986 and 1987. The benefits of the storage technology and the improved varieties seem to be more long term. A sensitivity test was done to explore the contribution of each research area alone to the benefits. Key findings from this test revealed that: (1) if the costs and benefits of Operation Cowpea are dropped from the analysis, the IRR is 20% and the annualized benefit is about $1.1 million; (2) when the analysis is done with only the storage benefits the IRR is almost 15% and the annualized value $371,432; and (3) when only the benefits from the breeding program are included, the IRR is almost 13% and the annualized value is $541,483. In all cases the IRRs are substantially greater than the cost of capital to the U.S. government and the annualized value is greater than the average real research cost. This result indicates that the storage technology, and variety improvements alone could easily justify the ISRA/CRSP research program.

The benefits of these technologies appear to be relatively evenly distributed in the rural population. Female headed households are using the drum storage and the improved varieties. Further, approximately 68% of households are using metal drum storage. The cost of the metallic drums, however, is a concern for some households and may be limiting the continued use of this technology.

Overall, this analysis indicates that the ISRA/CRSP program has been a good investment for the U.S. and Senegalese governments, the U.S universities which contribute in the form of cost share, and other donors. Even without the substantial benefits of the emergency Operation Cowpea program, the storage technology and the varieties yielded a rate of return much higher than the cost of capital and comparable to the long term return on the U.S. equity markets.

This research revealed the need to develop a better understanding of the increasing use of phostoxin in cowpea storage in Senegal. Can this be attributed to an insurance motive? Is it related to the growing scale of some Senegalese farms? Hermetic storage in metal drums works well for a certain size farm, but may not work as well for larger producers.

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List of Acronyms

AV	Annualized Value
CNRA	Centre National de Recherches Agricoles (National Agronomic Research Centre; Senegal)
CRSP	(Bean/Cowpea) Collaborative Research Support Program
EEC	European Economic Community
IRR	Internal Rate of Return
ISRA	Institut Sénégelaid de Recherches Agricoles. (Senegal Institute for Agricultural Research)
MSU	Michigan State University
NPV	Net Present Value
PRONAF	Project Niebe pour l'Afrique (Project for Cowpea in Africa)
USAID	United States Agency for International Development
(UN)FAO	(United Nations) Food and Agriculture Organization
WV	World Vision

INTRODUCTION

INTRODUCTION TO IMPACT ASSESSMENT

To justify the expenditure of public funds, it is important to assess the impact of those funds. In addition, organizations must demonstrate their ability to implement and support publicly valuable programs in a cost-effective manner if they are to demonstrate their public accountability and to justify continued or augmented funding. Further, when making the case for additional funding for future program changes or initiatives, an estimation of the potential impact of the proposed expenditures is always useful and often essential. For all of these reasons, conducting an economic impact assessment is desirable. Impact assessment can provide information on the effectiveness of past research, and can assist in optimizing the allocation of future research and program expenditure.

An impact assessment can take many forms and will very dependent upon the objective of the analysis. It is important to note that benefits measured by impact assessment must be those experienced by 'ordinary' people. While there is value to scientific achievements (e.g. technologies patented, varieties improved, and papers published), such benefits are more appropriately considered as 'intermediate products.' These achievements can only make an impact when they are adopted beyond the scientific sphere. Thus, an impact analysis takes into consideration the effect of the practical translation of scientific achievements into metrics that relate to 'ordinary' people such as higher profits, improved nutrition, a cleaner environment, or other similar benefits.

Although at times difficult, it is important to quantify rather than to simply qualify the impact. While often readily available and a powerful testament to the impact of projects, qualitative information such as antidotes and testimonials may not be used in the impact assessment itself; such information, instead may be used to communicate the results of an impact assessment. Instead, quantitative information is required to perform impact assessment. The use of numerical techniques reduces the subjectivity of the analysis and permits a true 'accounting' of the relative magnitudes of expected or experienced benefits and costs. Further, since the analyses can often make use of secondary data (e.g. commodity prices, interest rates, and crop production statistics) which is often available from national and/or regional governments, for many problems the cost of an economic impact assessment is relatively low. In the situations where primary data collection is necessary, either because data are not available or a 'non-standardized' analysis is required, careful planning can result in a completion of the analysis at a relatively low cost. In general, all forms of impact assessment follow the basic procedure of estimating the relative benefits and costs and then the relative consumer and producer surpluses generated by a project. Effort has been made by several authors to develop a systematic methodology to quantify economic impact. The work by Alston *et al*., (1995), and Masters *et al*., (1996) are among the most comprehensive and widely used for such efforts.

Key parameters for impact assessment, which can significantly affect the impact assessment results, are adoption estimates. In instances where the impact of public funds is being evaluated, adoption must assess the impact of a 'public good' in which the 'public' in general receives the benefit. This concept may be contrasted to a 'private good' in which the benefit is experienced by a limited number of specific individuals. Through the use of adoption studies, the extent of the dissemination and adoption of a particular technology can be assessed. Given the importance of obtaining good adoption estimates it is generally accepted that, when funding for an impact assessment is limited, the appropriate strategy is to devote a considerable portion of funds to adoption studies. The economic implications of these adoption estimates can be later assessed in combination with other (often secondary) data and through the use of spreadsheet models and expert opinion.

INTRODUCTION TO THIS STUDY

The purpose of the present investigation is to assess the impact of products from collaboration between the Senegal Institute for Agricultural Research (ISRA) and the Bean/Cowpea Collaborative Research Support Program (CRSP). Of particular interest are impacts of a hermetic drum technology for the storage of cowpea grain and two improved varieties of cowpeas which have been generated through this collaboration. These initiatives started in 1982 and were actively pursued through 1998. The impact of these technologies, however, has extended well beyond this period and is anticipated to continue well into the future. For the purposes of this analysis, a planning period from 1982-2020 is used. The geographic area of interest of this study is Senegal's Peanut basin, which due to similar environmental characteristics is also Senegal's primary cowpea production region.

The following sections serve to introduce the remainder of this study. General background information concerning cowpea research initiatives in Senegal is provided along with details about the specific programs. Following this, the research objective and the approaches and methods used in this investigation are summarized.

COWPEA RESEARCH IN SENEGAL

Cowpea research has a long history in Senegal. In 1950, efforts at Senegal's National Agronomic Research Centre (CNRA) began to focus on cowpea varietal improvement, agronomic practices and grain storage techniques. Among the early products of this research were the development and dissemination of several improved cowpea varieties, including 58-57 (1962), Ndiambour and Mougne (1969) and Bambey21(1975). In addition during this period, improvements were made to cowpea agronomic practices. In 1975, however, reductions in financial support from the French government forced several staff changes, and resulted in a research lull within the organization. This period of relative inactivity continued until the early 1980's when the Bean/Cowpea Collaborative Research Support Program (CRSP) was started. In collaboration with ISRA/CNRA, the CRSP supported efforts of Senegalese researchers to continue their earlier breeding, agronomy, and grain storage initiatives. To date, there have been several noteworthy outcomes of this collaboration between ISRA and the Bean/Cowpea CRSP. Of greatest interest to this present investigation are the following primary products:

Operation Cowpea

> A program which provided large amounts of cowpea seed and production support to farmers from 1985-1986 when drought made cultivation of the traditional peanut crop risky. This program was principally supported through the University of California at Riverside.

Varietal Improvement

Development of the short season cowpea varieties Melakh and Mouride

Storage Practices

Techniques for hermetic storage of cowpea grain in metallic drums.

Further detail concerning each of these programs and areas of impact are presented below.

Operation Cowpea

In the mid-1980's several years of drought severely reduced the availability of peanut seed and raised questions about the future of profitable peanut production in northern Senegal. Operation Cowpea was organized in 1985 in response to this and as an effort to offer Senegalese farmers an alternative cash and food crop to peanuts. Specifically, Operation Cowpea organized the export of cowpea seed, insecticides, and equipment from the US to Senegal. Among the seed, about 650 metric tons of California Blackeye 5 (CB5) cowpea seed, and 200 tons of local cowpea varieties were donated. Although not used by households at the time, ISRA/CRSP research had previously shown that CB5 produced well in on-station trials and was relatively well adapted to Senegal; this variety was also the only cowpea variety available in sufficient quantity on international markets. (Bingen *et al.*, 1988) This program was funded by the United States Agency for International Development (USAID), the European Economic Community (EEC), and the United Nations Food and Agriculture Organization (FAO).

Initially, the production response to the efforts of Operation Cowpea was quite substantial. In 1985 this program was responsible for almost doubling Senegal's cowpea production. This magnitude of effect, however, was relatively short lived as CB5 was found to be susceptible to insect and disease problems. With the end of subsidies for insecticides and other production inputs in 1986, cowpea production quickly fell and returned to levels of the early 1980's.

In spite of the short duration, Operation Cowpea had considerable economic impact. A study using data through 1986 found that if green pod (use of green cowpeas as a vegetable) production were included, the research and extension program which produced Operation Cowpea had an internal rate of return (IRR) of 92% (Schwartz *et al*., 1993). Due to its integral part in the overall ISRA/CRSP collaboration, Operation Cowpea is included in this impact assessment. The same research program that allowed Operation Cowpea to import CB5 with some confidence and recommended agronomic practices, also led to the development of storage technology and new varieties. It would thus be very difficult to separate pre-1985 research expenditures by whether or not they contributed to Operation Cowpea. In addition, CB5 has continued to be used by some Senegalese cowpea growers, thus generating benefits that were not captured in the analysis completed by Schwartz *et al.* (1993).

Varietal Improvement

Through the use of conventional plant breeding methods, cowpea researchers at the Bambey station of ISRA, have developed improved cowpea varieties though crossing local varieties with exotic germplasm. Among the most successful are two early varieties, Melakh and Mouride, which mature in about 60 days. Mouride is a semi-erect variety with cream colored seeds and beige eyes while Melakh is a sprouting variety with white seeds and brown eyes. Both varieties were extensively tested in ISRA/CRSP on-farm trials. Mouride was released in 1991 and first grown on a large scale in 1992. Melakh is a dual purpose dry grain/fresh cowpea that was bred by ISRA in Senegal. The first seeds of Melakh were distributed to farmers in the summer of 1993. World Vision International (WVI) has distributed substantial quantities of Mouride and Melakh in their cowpea program. While other cowpea varieties have been developed and tested in on-farm trials (e.g. Diongama) they have longer cycles than Melakh and Mouride, and as such do not as successfully fill the niche need for early maturing varieties. As such, the only varieties included in present analysis are Melakh and Mouride.

Storage Practices

Hermetic storage of cereals and legumes is an ancient technique. Respiration by insects in sealed storage uses up oxygen and results in anaerobic conditions that limit infestation. This is the idea behind the ISRA/CRSP development of techniques that allowed closed top metal drums to be used effectively as cowpea grain storage vessels. In contrast with traditional storage methods, closed-top drums offer substantially reduced grain loss levels and are themselves less difficult to store. Metallic drums come to Senegal as shipping containers for liquid industrial products including petroleum derivatives and liquid sugar. As the cowpea production area is relatively close to the port, and because Senegal has substantial industrial activity relative to other West African countries, these drums are readily available. Further, many farmers have access to horse carts, so transporting the drums to the farm is not a major problem. For these reasons, selection of the metallic drum as an alternative storage container was both practical and logical.

To improve storage results, ISRA tested, determined optimal conditions, and made recommendations concerning best practices for storing grain in drums. It was recommended that cowpeas should be dried to 10% moisture or less, that drums be filled completely and that they be kept closed for at least 2 months (Cissé *et al*., 1996). Recommendations were also made concerning the use of storage insecticides. Use of metal drums for cowpea storage was introduced to farmers in on-farm trials starting in 1985. As farmers had long used open topped drums for grain storage, the transition to a closed top drum was not a radical shift (drum filling was instead completed through the bunghole using a funnel). Overall, the idea was well received and appears to have spread mainly by farmer-to-farmer contact.

RESEARCH OBJECTIVE

The objective of this research is to assess the impact of the products resulting from the collaborations between the Senegal Institute for Agricultural Research (ISRA) and the Bean/Cowpea CRSP. Of specific interest to this research are the impacts of the metallic drum storage technology for cowpea grain and of two improved cowpea varieties, Melakh and Mouride, which were developed through this collaboration.

APPROACHES AND METHODS

This study is organized in two major sections: 1) the adoption survey and 2) economic impact assessment. Building upon existing country level impact assessments, this study follows the standard methods outlined by Alston *et al.*, (1995) and Masters *et al.* (1996). In 1996, Lowenberg-DeBoer and Faye (1996) did a survey of adoption in Senegal of these same CRSP technologies. The 1996 research, which estimated the net present value (NPV) and internal rate of return (IRR) for drum storage and improved varieties, is the basis for the present study.

As previously noted, estimates of technology adoption are of key importance to the final outcome of impact assessment analysis. Therefore, considerable attention and effort was dedicated, in this study, to obtaining good estimates of adoption. It is important to note that the technology products of interest in this investigation were extended by organizations other than the CRSP (i.e. World Vision (WV), PRONAF, FAO and various national extension agencies) and the extent of the dissemination of these products is largely unknown. It was therefore important that an adoption study be conducted in order to obtain an estimate of adoption rates. Due to funding limitations, human subject requirements, and increasing costs to travel (particularly within West Africa), it was necessary to focus the efforts to measure adoption. In particular, for this research the adoption assessment was focused in regions where there is the greatest opportunity for potential impact. As such, the attention of the present investigation is focused within the region termed Senegal's 'Peanut Basin'.

In performing this adoption assessment, a modified Rapid Rural Appraisal approach, previously used by Lowenberg-DeBoer (1994) was used. Three subsets of villages were selected for inclusion in this investigation; villages included in the earlier impact assessment (1996), mini-kit communities, and additional communities which were chosen randomly from the cowpea growing area of Senegal. Time and financial considerations limited the total number of villages which were visited to eighteen.

In each village adult farmers were interviewed concerning their use of cowpea production and storage technologies; semi-structured questionnaires were used to guide personal interviews with village chiefs and randomly selected individual cowpea producers. The interviews were initiated by explaining the purpose of the study and asking the individual if they would be willing to participate. As many Senegalese farmers are illiterate verbal consent to participate was accepted. Overall, the interviews took an average of approximately 25 min, but varied from a few minutes to an hour. The interviews were conducted in Wolof, however, subject responses were recorded in French and were later translated into English. Once completed, the collected data was entered into a database (Excel), that data analyzed, and an impact assessment preformed.

This study assesses the impact of several products which were generated through the collaboration between ISRA and the Bean/Cowpea CRSP. The economic surplus method is used to estimate the social rate of return to public investment in Operation Cowpea and in research resulting in storage technology and varietal improvement. Subsequent sections of this report describe the methodology used to conduct the adoption assessment and to determine the economic surplus generated from this program, the sources of data used, and the results of this analysis.

METHODOLOGY

In order to adequately address the research objectives, both qualitative and quantitative research methodologies were employed. At the outset, qualitative research methods were used to generate research ideas and approaches, and to collect data through in-depth interviews. Quantitative research methods were subsequently used to analyze the results, perform an impact assessment and evaluate the research findings. A complete description of the research protocol and the techniques used in the analysis of data follows.

DATA COLLECTION METHODOLOGY

Given limited time and financial resources, and the desire to minimize instrument bias, it was decided that a written survey administered in an in-depth interview format would be the most appropriate means by which to collect data. Other data collection methodologies, such as a questionnaire would not have adequately identified the thoughts, feelings, and opinions of individuals and, as such, would be an inappropriate methodology. Further, due to limited levels of literacy among subjects in the study area, and language differences between researchers and subjects, self-completed surveys were deemed to be an inappropriate tool for this study.

The interview framework selected for this research was the semi-standardized interview. This framework permits the flexibility of having a predetermined series of questions but permits the interviewer to interject additional questions in order to gain further clarification and elaboration on subject comments. Further, due to the somewhat personal nature of the research questions, the cultural setting in which the research was being conducted, and a desire to get the most complete and accurate information possible, it was deemed important that a rapport be developed between the research team and the respondents. Both the village and the individual questionnaires followed the same general structure. Through the in-depth interview format, guided by a well-developed survey, considerations of instrument bias, literacy, and an opportunity for development of a rapport with respondent were addressed. Language considerations were also addressed through use of this methodology as it permitted interviewers to directly translate and record interviewee responses from the local language of Wolof to the language common to the research team (French).

QUESTIONNAIRE DESIGN AND PRE-TEST

The questions included on the survey were derived from a number of sources. Questionnaires used in the previous impact assessment of cowpea storage technology in Senegal (1996) and those developed by Aitchedji of the International Institute for Tropical Agriculture (IITA) in Cotonou, Benin provided an important base. Additional questions were developed through consideration of published literature, consultation with subject experts, and consideration of the specific objectives of this study. A combination of short answer, long answer, and multiple selection questions were used; for both organization and interviewer ease, where possible a 'fill-in-the-box' tabular format was used on the surveys.

Separate questionnaires were developed for each of the individual and village interviews. Both questionnaires began with questions about the interviewer and village identification. In the interest of saving time during the actual interview, there were instructions at the beginning of this section noting that this information was to be completed prior to beginning the interview. The village and individual interview surveys differed in several other respects. The village survey contained questions related to the general demographics of the village, the village's agricultural activities, and access to markets for agricultural inputs and outputs. Other questions included in the village survey addressed the village-level perspective on cowpea production, cowpea storage processes, and cowpea consumption patterns. For the purpose of assessing less direct implications of the introduction of drum storage technology, the survey used for this study contained questions about injuries and deaths related to agricultural activity.

The survey developed for individual household heads was divided into six main sections. As noted above, the first section contained questions related to general information about the village. The other sections contained questions about the respondent and their agricultural activities (Section II), the respondent's cowpea production (Section III), the respondent's cowpea storage methods (Section IV), the respondent's marketing of cowpea (Section V), and the allocation of decision making and work in the household (Section VI). Each questionnaire was initially written in English and then later translated into French. To the extent possible effort was made to 'back-translate' the French surveys to English to ensure that the initial translation conveyed the intended meaning. Copies of the final Village and Individual Surveys are presented in Appendices II and III respectively.

Pre-testing of the survey instrument occurred in three steps and involved members of the research team and the interview results from one village. The first step was a question by question review of the survey performed by Boys and Faye. The second step involved review of the questionnaire and a simulation mock-interview. This second step had a number of purposes. Of critical importance, this process provided the research team an opportunity to ensure that the interview questions are translated and interpreted correctly, and, in some cases, to identify points of potential confusion caused by either question translation or wording. Finally, the mock-interview process provided an opportunity to time a 'typical' interview and it was found that each of the village and individual surveys would take approximately 25 to 35 minutes. This information was important when planning for the visits to the villages for data collection. The third step involved obtaining results and feedback from the series of interviews conducted at one village, which were later incorporated into the survey.

As a result of the pre-test process, changes were made in the phrasing and format of several questions. Feedback received from the preliminary review of the questionnaires indicated no major issues regarding the clarity and/or appropriateness of the questions. On the basis of this feedback, however, a few questions were added and the response options provided for several questions were modified.

CONSENT

The procedures associated with this research were reviewed by the Purdue University Committee on the Use of Human Research Subjects and approved as exempt on February 27, 2004 (Reference #: 04-106E).

SAMPLE SELECTION

As outlined in the introduction, the research objectives for this study were numerous and covered a variety of topics. In order to address these objectives, it was decided that the subject pool include the following community subsets: villages included in the 1996 sample, mini-kit communities, and new communities. A list of the surveyed villages is provided in Appendix I (Table 11).

'Repeat' Villages

In order to gain a sense of how experiences and opinions regarding cowpea varietal choice and use of storage technology have changed over time, effort was made to return to communities which were visited during the 1996 study. This earlier study included fourteen randomly selected villages; among these were two communities where the mini-kit project had been extended. In reviewing this list of villages, however, it was determined that a majority, if not the entire, population of several of these communities had immigrated to larger urban areas. As such, among these initial fourteen communities, 8 remained (including two mini-kit) for inclusion in this study.

'New' Villages

In order to supplement the list of original communities, and to partially address any response bias which may have been generated through repeated visits to the original villages, a random selection of villages was again drawn. The process by which this was accomplished was similar to that previously employed in the 1996 impact assessment. Using reports available through Senegal's Ministry of Agriculture (Republique du Senegal, 1999 (1), (2)), a list of villages which were located in the geographic area of interest was compiled. The relevant geographic area is Senegal's Peanut Basin which encompasses a majority of the regions of Diourbel, Louga, and Thies. Initially a total of 1915 villages were included on the village list.

A random number generator (an Excel Function) was used to select numbers, which were then matched against the numbered village list. In the order they were drawn, numbers were matched against community names and the communities marked on a map. In instances when the village was located beyond the area of interest, that number was discarded and a replacement number (and community) was again randomly drawn. It was desirable that the maximum number of villages possible be surveyed. Initially a total of six new communities were selected; this number is the same as the number of repeat non-Mini-Kit communities which were again to be visited and permitted a balanced sample of new to repeated villages. Following this initial selection process, an additional six communities were randomly chosen; it was decided that, dependant upon time availability, as many as possible of this latter group of communities would also be surveyed.

MINI-KIT VILLAGES

In the mini-kit program, which ran from 1985 to 1994, eight communities were chosen to run on-farm trials. As part of this program, ISRA extension efforts introduced families in these communities to the hermetic storage of cowpeas in metallic drums. Thus, inclusion of mini-kit villages in this study provides an interesting opportunity to measure the impact of prolonged interaction with extension workers and researchers. As described above, two mini-kit communities, which were included in the 1996 study, were again included among the communities to be surveyed. In addition to this, following the method described for the selection of 'new' villages, random selection of two additional mini-kit villages was made. Thus, a total of four such communities were included in this study.

THE INTERVIEW PROCESS

Upon arriving at each village, effort was made to seek out the community leader or, in instances where he was not available, his representative. Once he was found, introductions were made and general information was provided about the nature of the study. Community leaders were asked of their willingness to participate in the study through responding to the village survey and random selection of participants for the individual interviews. The standard depth interview process dictates that only general information be provided to interviewees in order that "testimony be elicited in as unobtrusive, non-directive manner possible" (McCraken, 1988, p. 21). Thus, with the hope of soliciting a wide range of honest information, a general description of the study was provided, and the provision of specific information about the study was initially limited.

After receiving consent of participation, the community leader was asked to retrieve a list of the members of their community. Leaders of each community hold and keep relatively current such lists for tax-collection and election purposes. It should be noted, however, that frequently these lists contain only the names of the head of the household (concession) and indicate the number of other individuals who live in the family unit. Once retrieved, the list of concessions in the community were numbered and tallied. In order to randomly select the households to be interviewed, a 'ticket' was made to represent each concession in the community. These tickets were dropped into a container and random draws were made until the required number of households was selected. In the interest of garnering community support these draws were performed by the village chief, other senior community members, or children. It was hoped that five individual interviews could be conducted in each community. In most instances, the community leader was sufficiently familiar with the activities with those in the village that he was able to indicate at the time of drawing if a selected individual was not available (away); in such instances, another random selection was made. Despite this input, on occasion the community leader was not aware of the absence of a concession head and it was necessary to find a replacement. To facilitate the replacement process additional names were drawn at the beginning and used when required. The completed surveys were numerically coded and filed.

DATA ENTRY AND VERIFICATION

The data from completed surveys was inputted into an Excel spreadsheet with separate spreadsheets used to record the village and individual surveys. Once all the surveys had been inputted, the databases were then 'spot checked' through a review of the data inputted for a random selection of the completed surveys. Any discrepancy between what was originally inputted and what should have been inputted was corrected. As this process revealed very few errors, it was decided that the accuracy of the data input was sufficient to proceed with the analysis without further verification

DATA ANALYSIS

Data analysis was preformed using Microsoft® Office Excel 2003. As the sample size does not permit statistical testing, analysis of the survey data was performed primarily through the use of descriptive statistics.

IMPACT ASSESSMENT METHODOLOGY

The intent of this research is to perform an ex post assessment of the impact of research into the impact of investment in cowpea varietal and storage technique improvement in Senegal. The methodology used in this analysis adopts many of the conventions in a previous assessment of the impact of cowpea storage technology in Senegal by Lowenberg-DeBoer and Faye (1996). In similarity with that earlier study, this analysis has adopted the general methodological approach described by Alston *et al.* (1995). More specifically, the model describing the impact of storage technologies which was developed by Fulgie (1995) is used to estimate the generated economic surplus.

NET BENEFIT CALCULATION : MEASUREMENT OF ECONOMIC SURPLUS

A widely accepted procedure for economic evaluation of benefits and costs of a technological change is the economic surplus method (e.g. see Alston *et al.*, 1995; Masters, 1996). The base idea driving the economic surplus method is that technology adoption reduces the per unit cost of production, and hence shifts the supply function of the commodity down and to the right. If the market for this commodity is perfectly competitive, this shift will lead to an increase in the quantity of the goods exchanged in the market and a fall in the market price. As a result of these changes, consumers benefit from the price reduction and producers may benefit from selling a greater quantity. Combined, these 'net benefits' can be used to assess the impact of a particular research and development investment.

Capital Budgeting

The economic surplus method is used to determine annual flows of research benefits and costs. To assist in the assessment and comparison of this project with other alternative investment options, it is useful to assess these flows as summary measures (Alston *et al.* 1995). Using the tools of cost-benefit analysis, anticipated annual project costs and benefits can be determined and from this information, comparative measures can be calculated.

In this analysis, three summary measures were used to evaluate the benefits derived from investment in development and extension efforts of the metallic drum storage technology. The first two assessment techniques used, the net present value (NPV) and the internal rate of return (IRR) are considered the two most popular methods of evaluating the allocation of resources (Anderson *et al.,* 2004). A third technique calculates the annualized value (AV) of the project; this method provides an annualized value of the project life cycle cost. The different purposes and methodologies employed in deriving these measures are detailed below.

Net Present Value (NPV)

Net Present Value (NPV) is a measure of the expected value of the impact of a project. This value is calculated using the following formula:

$$\text{NPV} = \sum_{t=0}^{\infty} \frac{B_t - C_t}{(1+r)^t}$$

where r is the discount rate, B_t is the calculated value for annual research benefits t years in the future, which is obtained by calculating the total annual economic surplus, and C_t is the annual research cost expended t years into the future. In this analysis, as is typically assumed for analytical and empirical convenience (Alston *et al.*, 1995), the discount rate is assumed to be constant over the life of the investment.

For this study, the NPV is calculated as the costs and benefits generated through the CRSP/ISRA collaboration in the development and extension of the metallic drum storage technology and improved cowpea varieties. For this analysis, the average long term cost capital to the US government during the period from 1980-2003 of 4.785% was used (International Financial Statistics (IFS) Database, 2004).

Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is the discount rate that makes the present value of the income stream generated from the investment in the cowpea storage technology equal to the cost of that investment. In practice, it is computed as the discount rate that would result in a value of zero for the NPV of a project; it can be derived from the following formula:

$$\sum_{t=0}^{\infty} \frac{B_t - C_t}{(1+IRR)^t} = 0$$

The value derived from this calculation is comparable to an interest rate; for investments which require an initial investment outlay and which will generate positive incomes later. Better investments have higher internal rates of return (Becker, 2000).

Annualized Value (AV)

The Annualized Value (AV) is used to standardize the allocation of costs, over the useful life of a project. This method treats the net benefits of a project as an annuity and determines the annual value 'paid' for each year of the project. For this analysis, the long term US government cost of capital (long term government bond yield) is again used as the interest rate.

Expected 'Life'

In order to facilitate the communication of results and allow for comparison of between-study results, economic impact results will be summarized using the following financial tools: annualized value, internal rate of return, and net present value. Building upon the results presented in Lowenberg-DeBoer and Faye (1996), this study updates the impact assessment and provides new projections of the future benefits which are expected. In this study it is assumed that the storage and varietal use benefits extend 15 years beyond the present (same projection period used in the earlier study); as such the planning period used in this investigation is 1982-2020 (38 years). While it is recognized that some technologies may have some benefits beyond this period, as these benefits would be realized in the 'distant' future, the impact of their omission would have little influence upon the IRR or other summary measures. The 1982 start date was assumed to be logical given as this year marked the beginning of both the CRSP project in Senegal, and the redirection of ISRA activities into cowpea programs.

Data

Data collected from villages and individual interviews are available from the authors and are summarized in Tables 12 through 17 contained in this report. Parameters used in the estimation of the economic surplus generated through the use of the metallic drum storage technology are presented in Appendix IV (Table 18). Data presented in this Appendix adopts the labeling conventions established by Fuglie (1995). Further detail concerning data sources, parameter estimation, and the assumptions which underlie this analysis outlined in the following sections.

Impact of Storage Technology

An important component of this impact assessment analysis is to examine the implications of the adoption estimates. This impact analysis will focus upon identifying which factors have the most significant economic impact and to estimate the approximate magnitude of these impacts. While to the greatest extent possible this analysis uses available statistics and the collected data, it is recognized that there are limitations to this available information. In several instances, quantitative measures are not available and informal field observations must be used to make informed estimates. Following the baseline evaluation, sensitivity analyses have been completed to assess the importance and impact of these estimates.

PARAMETER ESTIMATION/DETERMINATION

Adoption Rate of Storage Technology

Once a new technology is developed, in almost every instance there are lags between its development and that technology's dissemination and adoption. This time requirement is perhaps even more pronounced in the examples of developing countries where logistical, educational, and capital barriers may impede the adoption process. In order to account for these time delays, effort has been made to develop models which describe and account for some or all of research, development, and adoption lags. Research lags, for example describe the lag between the initiation of the research and the 'pre-technology' knowledge, a development lag occurs during the period in which the 'pre-technology' results are incorporated into a useful technology, and an adoption lag describes the period of release of the agricultural technology and maximum adoption by producers (Alston *et al.*, 1995).

Dependant upon the technology and the location for adoption, simple linear functions, polynomial lags or trapezoidal lags have been used to describe the relationship between lags and the adoption of new technology (Alston *et al.*, 1995). Alternatively, following the work of Griliches (1958) who used a logistic curve, an 'S' curve is frequently used. This suggests that adoption begins slowly, is followed by a period of steep growth, and finally reaches a plateau level of adoption. As it is anticipated that this pattern best describes the adoption of the metallic drum storage technology and the new varieties, this latter pattern is used in this study.

Estimation of the level of adoption in a particular period is determined using the following formula:

$$A_t = M / (1 + b * \exp(-t))$$

Where: A_t = *the level of adoption in year t*
M = the plateau adoption level
b = the adoption rate coefficient

A number of assumptions are required to determine an estimated plateau adoption level. It is assumed, for example that, due to the relative per-unit storage cost, producers with low yields will not use the metallic drum storage technique. Therefore, it is not anticipated that there will be significant adoption of this technology outside of Senegal's Peanut Basin (located in the regions of Diourbel, Louga and Thies). Using cowpea production levels from the 1990-1991 through the 2000-2001 crop years, it was calculated that an average of 85% of the nation's cowpea production originates in this region. To determine the proportion of production within the Peanut Basin which was stored in metallic drums, results of the Individual surveys were used. These results indicate that 83.3% of cowpea production is stored in metallic drums. This estimation includes production that was stored in metallic drums to which phostoxin was added or sand was mixed with the grain. Combining these values, it is estimated that nationally, the percentage of production stored in metallic drums is 70.8% (0.8504*0.8330 = 0.708); this value describes the plateau adoption level parameter, 'M', in the equation above.

Consistent with the study by Lowenberg-DeBoer and Faye, it is assumed that adoption of use of metallic drums as a cowpea grain storage tool started in 1986 and that initial adoption levels in that year were 0.1%. The annual adoption rate coefficient (b) is estimated using the plateau level of adoption.

Demand and Supply Elasticities

In recent years, although the availability of information concerning cowpea supply and demand has expanded significantly, specific effort has not yet been made to empirically estimate cowpea supply and demand elasticities in Senegal. Therefore, this study employs the logic outlined by Masters *et al.* (1996), to determine these parameters. In this guide, it is stated that supply elasticities typically fall within the range of 0.2 to 1.2, while those for demand typically are in the range of -0.4 to -10. This broader range of demand elasticities reflects the size and relative openness of the market in question. For example, large international markets could experience demand elasticities at the lower end of this scale, while local markets would have demand elasticities near the upper end of this range (Masters *et al.*, 1996). Although Senegal is a major producer of cowpea, and trade does occur between Senegal and her neighbors to the north and south (Langyintuo *et al.*, 2003), due to the location of this grainshed relative to the external demand markets (e.g. Nigeria) and transportation problems associated with accessing those markets, Senegal's cowpea production is largely isolated from external markets influence (Langyintuo *et al.*, 2003). The demand and supply elasticities selected for the baseline analysis are therefore relatively inelastic and, for ease of comparison, were initially set at the same level as those used by Lowenberg-DeBoer and Faye (1996). A mid-range estimate of 0.8 was used as a measure of the elasticity of supply. The elasticity of demand was considered separately in the period immediately during/following cowpea grain harvest (October - March; Period 1), and in the period during which stored grains are used (April - September; Period 2); the elasticity of demand for each of these periods was initially set at -0.5.

In many instances, elasticity values do not have a significant effect on the level of economic surplus obtained. They do, however, impact the relative allocation of economic surplus between different economic agents (i.e. producers and consumers). Since the focus of this analysis is to evaluate the total realized economic surplus, it is felt that the elasticity values will not have a significant impact upon the final results. Although other impact assessments of cowpea storage have found this assumption to hold true (Diaz-Hermelo *et al.*, 2000), this assumption will again be verified through sensitivity analysis.

Cowpea Storage Loss

Ideally an initial loss parameter would be estimated using the weighted average loss given the distribution of storage technologies used at the time the project started. As this information is not available, an estimate of the level of loss was required. Cowpea storage loss can occur through a variety of means; most commonly grains can suffer from insect damage, but insufficient drying leading to mold and/or pre-mature sprouting can also be problematic. Without use of adequate storage processes, there exists the potential for losses to be up to 100% of stored grain (Lowenberg-DeBoer and Faye, 1996).

Traditional storage techniques use only a container, most frequently with an open top, and do not add any storage insecticides. In this study, however, due to the high use of both the metallic drum storage and the storage insecticide, phostoxin, very few observations (4) could actually be classified as using a traditional technology. Further, among these limited observations, only two (2) reported any production in 2003. As the average of this small set of values is not extremely meaningful, it was decided to use the loss level estimate previously used by Lowenberg-DeBoer and Faye (1996). This estimate of a 25% loss, is lower than that observed elsewhere (e.g. Langyintuo *et. al*. 2003) and is the approximate median of the loss estimates with traditional technology observed in this and previous studies.

Under the improved drum storage technology, very few respondents noted any grain loss. One village interviewee noted that about 1% of grain stored in metallic drums was lost; across all villages using the new technology this results in an average 0.08% grain loss. Individual survey respondents indicated that an average of 0.6% of grain stored in metallic drums was lost. As it is felt that individual survey results yield a more reliable estimate of this parameter, the baseline analysis assumes a 0.6% stored production loss when using this technology.

Storage Costs

'Traditional' Storage Containers

Prior to the introduction of metallic drums, an array of other 'traditional' storage methods were used in Senegal for cowpea grain storage. Most commonly, a variety of sacs and other containers were used to store various, although frequently small, quantities of grain. In the absence of an ex ante assessment of storage technology use prior to the introduction of the sealed metallic drum, estimates of storage costs are, at best, rough. Although several of these 'traditional' technologies continue to be used, and are available through local markets, the manner in which they are used and stored has changed since the introduction of the sealed metallic drum technology. Previously, stored grain would be mixed with sand or other substances such as ash to help reduce storage losses. In this study, however, it was found that some storage techniques introduced with the sealed metallic drum technology were extended to other storage methods. In several instances respondents not using the sealed metallic drum noted the need to completely fill storage containers to reduce infestation; additionally, a number of respondents reported that they add storage insecticide (i.e. phostoxin) to other storage containers. Due to these changes, and without additional information concerning traditional techniques, such as average size of containers and/or relative proportions of grain compared with other materials, it is difficult to estimate the unit cost of using 'traditional' storage techniques.

In the previous assessment of the impact of the metallic drum storage technology (Lowenberg-DeBoer and Faye, 1996), costs of traditional grain storage were estimated using a proxy technology of an open top metallic drum. This technology was selected due to its wide-spread use, and the relative ease with which its cost could be estimated. As traditionally done, layers of sand are alternated with layers of cowpea grain (with both the top and bottom layers being sand), it was assumed that the full 200L capacity of the metallic drum was reduced to a 80 kg storage capacity. The present assessment will adopt this proxy measure for the technology and capacity of the 'traditional' technology.

During the 2004 data collection process, no subjects in either the village or the individual interviews, reported using an open top metal drum. It was returned as the storage alternative for the economic surplus calculation because previous surveys indicate that it was widely used early in the adoption period and because the costs and storage loss have been documented. Previously the cost of the open top metallic drum was estimated to be about one-half of the cost of a closed top drum. As a conservative estimate of a closed-top metallic drum with a cost of 8000 FCFA was used in the baseline analysis (described below). It is thus assumed that the cost of an open-top is 4000 FCFA. In terms of useful life, as the open topped drums do not need to be sealed, it was determined that they can be used longer than the closed-topped variety; previous study results added three years to the useful life of the open versus closed top drum. In this study, the same treatment will be applied; it is thus estimated that the open-top drums can be used up to 12 years.

Improved Storage Containers

Purchase costs of the closed-top metallic drums required for the improved storage technique were collected as part of the 2004 individual surveys. Here respondents using closed-top metallic drums (200L) were asked to indicate the year of their purchase, the price paid, and their estimate of the cost of that drum in 2004 FCFA. The maximum drum price reported was 8000 FCFA. Since this interviewee purchased the drum during 2004, no inflationary adjustment of this price was required. In this analysis, and consistent with the cost approach employed in other impact assessments (i.e. Lowenberg-DeBoer and Faye, 1996), this value was used in the analysis as a conservative estimate of the cost of this storage input. It is assumed that this reported price includes any costs incurred by the farmer for transportation of the drum to his/her farmstead, and for cleaning and preparation of the drum for storage purposes. It is further assumed that at its full capacity, a 200L metallic drum can conserve 160 kg of cowpea grain (Faye, 1997).

The useful life of closed top-metallic drums was estimated by Lowenberg-DeBoer and Faye (1996) to be 7 years. Results of individual interviews that were conducted as part of this study suggest that farmers are now keeping drums longer. On average farmers estimated that these drums had an average useful life of 9 years. It is important to note that, when calculating the average life a value of 10 was used in those cases where the respondent indicated a useful life of closed-top metallic drums as '10+' years (several instances). Overall, an average useful life of 9.32 years initially calculated. This average value was rounded down to an estimated useful life for the improved storage container of 9 years and is the value used in this impact assessment. It is interesting to note, however, that in some instances the drums used by a farmer had already exceeded the 'anticipated life' of the metallic drums which was reported by that farmer.

Total Storage Costs

For both traditional and metallic drum storage methods there are additional financial considerations beyond the cost of the drum that are important in determining the total cowpea grain storage costs. In particular, the cost of storage insecticides and labor must also be included. The storage insecticide Phostoxin is used by a significant number of respondents and is included in the storage cost, on the basis of the proportion of production in which it is added to metallic drums. Additionally, although not relevant to metallic drum storage, in some instances storage and possibly transportation of the storage containers themselves (i.e. sacs) must be included as additional storage costs.

Labor to fill drums was also taken into consideration. Abdoulaye (1995) reported that although there are differences in labor productivity for agricultural activities, for livestock and non-agricultural activities men, women and children are equal contributors. Since labor utilized for storage purposes is neither deemed 'skilled' nor requires extraordinary physical strength or stamina, for the purposes of this analysis labor contributions from these groups will be equally weighted. Although the data collected in 2004 did enquire about the number of individuals involved in cowpea grain storage activities, and the amount of time dedicated to each activity, in a review of these responses there appeared to be some inconsistency among these responses. In several instances, for example, respondents would report a low number of individuals involved in the storage process (i.e. one or two men), but later indicated that a relatively large number of days (i.e. 20+) were devoted to grain threshing, winnowing, sorting and filling of the storage containers. Given that many of these storage activities are traditionally done by women, and the significant demands on men's labor during this period of the year, it is unlikely that these estimates are consistent. As such, the convention of Lowenberg-DeBoer and Faye (1996) was adopted herein: for both the old and the new technology, it is assumed that one hour is needed to fill and empty the drum. The opportunity cost of labor of 113.2 FCFA/hour was used in this analysis. This value is adjusted using Senegal's CPI from estimates made by Martin (1988) who reported an agricultural wage rate of 500 FCFA/ 7-hour day. For validation purposes, this hourly rate was compared with that used by Lowenberg-DeBoer and Faye (1996) which was 109.9 FCFA/hour when adjusted to a 2003 value.

For the purpose of this analysis, annual storage costs are required. To this end, the opportunity cost of capital (simple interest calculation; described below) is added to the drum cost, and the total figure annualized by straight line depreciation. This analysis assumes that there is no salvage value for the metallic drums at the end of their useful life. A summary of these annual storage expenses is presented in Table 1.

Opportunity Cost of Capital

In the case of 'perfect' complete markets, the opportunity cost of capital reflects the expected return that is forgone by investing in a project rather than in comparable financial securities. In the case of developing nations, however, alternative measures of the opportunity cost of capital must be used. In Lowenberg-DeBoer and Faye's 1996 study, the opportunity cost of capital was calculated as the average simple rate of return on storage in closed top metal drums for the 1994-1995 marketing year. That analysis used monthly average cowpea grain prices in several markets (Louga, Sagatta, Thilmakha, Bambey Sérére, and St. Louis) which were obtained from the Direction of Internal Commerce and Prices. In this study, seasonal differences in these average market prices during the period from April through September (Period 2) reflected the benefit producers could realize from storing their product rather than marketing it directly after harvest during October through March (Period 1). On average, Period 2 prices were estimated to be 118% of the average annual price, while Period 1 prices were calculated to be 85% of the average annual price. Thus, the average price increase between these periods was used as a proxy of the opportunity cost of capital and was determined to be 28.8% annually.

While a replication of this method to update this figure would be desirable for the present study, the required monthly price data was not available. Therefore, the decision was made to use the opportunity cost of capital rate calculated in the previous research. As there were no serious monetary or financial market disruptions during the intervening years, it is anticipated that the price relationships between these periods would remain relatively constant. Further, as the opportunity cost of capital for cowpea producers in Senegal is probably higher relative to equivalent rates in industrialized countries, and as the opportunity cost of capital in other Sahelian countries have been noted at over 50% annually (Lowenberg-DeBoer *et al.*, 1994), this approximated rate is within an anticipated range.

Proportion of cowpea consumed in 'Period 1'

Lowenberg-DeBoer and Faye (1996) reported that informal observations suggest that more than half of cowpea grain is consumed during the first 6 months after harvest, but the proportion is not precisely known. As the present investigation was not able to collect additional information about this parameter, estimates made in the 1996 study are used in this initial impact assessment. As such, the baseline analysis will assume that 70% of production is consumed in Period 1

(October - March), and the remainder consumed in Period 2 (April - September). This analysis assumes that no grain is stored for a period beyond one year.

Price and Quantity Projections

Future levels of cowpea grain production and prices (Period 1, Period 2) are taken as the simple average of production and prices in each period over the last 5 years (1998-2003). The results of this analysis are presented in Table __ below. For comparison, data used in the 1996 study by Lowenberg-Deboer and Faye is also included in this Table. It appears overall it appears that the price spread had decreased slightly in the more recent period as compared to the previous analysis. Interestingly trend this may be linked, in part, to the use of the storage technology; the increased preservation of grain would lead to a decreased supply of grain in the early period (and thus increased price) and would lead to an increased availability of grain in the later period (and thus a decreased market price in Period 2). It is assumed that these average production levels and grain prices hold to the end of the planning period (2020); this analysis further assumes that damaged cowpea grain has no salvage value.

Table 1: National Cowpea Price and Price Ration Information for Senegal

Period	Annual Average Price FCFA/kg (Oct. – Sept.)	Early Period Price FCFA/kg (Pd. 1; Oct. – March)	Late Period Price FCFA/kg (Pd. 2; April – Sept.)	Percent Season Price Increase	Early Price as a % of Average	Late Price as a % of Average
1994 – 1995	134	122	150	28%	89%	113%
1998 – 1999	188	181	194	7.07%	96.6%	103.4%
1999-2000	146	135	156	16.0%	92.3%	107.4%
2000-2001	294	252	337	33.9%	85.5%	114.5%
2001-2002	351	308	384	24.6%	87.8%	109.5%
2002-2003	642	601	683	13.7%	93.6%	106.4%
Average 1998-2003	328.4	295.3	353.8	19.1%	91.2%	108.2%
Notes: Information for 1994-1995 is replicated from Lowenberg-Deboer and Faye, 1996 Data for 1998-2003 was provided by staff at ISRA (Bambay)						

VARIETAL IMPROVEMENT AND OTHER IMPACTS

A cost-benefit approach was used to estimate the impact of Operation Cowpea, the use of CB5 (after 1986), and efforts to extend the use of Melakh. Economic benefits derived from Operation Cowpea were previously calculated by Swartz *et al.* (1993) and the results of this earlier work are used herein. CB5 and Melakh are early term cowpea varieties which are used primarily for consumption as green pods. Unfortunately, however, only limited information is available about the green pod markets and this information is inadequate to estimate economic surplus from these activities.

Green-Pod Production and Prices

Benefits accrued from the use of CB5 assume that after 1986, with the exception of a small percentage of crops which were permitted to mature for seed, virtually all CB5 was used for consumption as green pods. In 1994, green pod production and market information was collected by ISRA. As more current information is not available on this product, results of this study (Faye, 1995) are used here; these results are replicated in Table 29. This research indicates that the average ratio of green pod to dry cowpea production is 8 to 1. Further, this study found that in the first few weeks of the green pod season (usually in September), when weight adjusted to be made equivalent to dry grain, the value of green pods is 565 FCFA/kg. In the absence of more current information, this price was adjusted to 2003 values using Senegal's CPI. This analysis assumes that green pods consumed at home have the same value as those which are marketed.

It is important to note that while most other cowpea impact assessments do not separately value green-pod output, the figures used herein are quite different then those used in other studies. Of particular relevance, in Schwartz *et al.* 1993 study of cowpea research and extension in Senegal, the green-pod:grain ratio was estimated to be 0.21, and the value of green-pod production to be 150 FCFA/kg. In comparison, the values used in the present study clearly surpass those of this earlier research. The values used in Schwartz *et al.,* however, were based upon estimates from secondary rather than from primary data, and, although likely the best estimates which could be obtained from such data, are arguably flawed in their magnitude. Schwartz *et al* (1993) calculate green-pod production as the difference between the Bean and Cowpea CRSP estimate of cowpea 'grain production for Senegal (66,000 t, 1985) and the EC estimate of grain and green-pod production (80,000t; 1985); from this difference the ratio of 0.21 was determined. As this value is determined using information from two separate sources, however, one can not be certain if the difference is actually due to green-pod production, or to combination of it and measurement differences (due, for example to different sampling methods, term definition etc.) and/or measurement error. Similarly, green-pod prices were estimated to be that the highest average cowpea price prior to the main agricultural harvest. This measure, however, does not discern between prices paid for cowpea grain prior to harvest and that for green-pods, and does not adjust the price of green-pods to account for the green-pod:grain weight ratio. As such, in one manner, this measure is significantly underestimated, an in another it is quite overestimated. Overall, as the values used in the present analysis are based upon primary data collected explicitly for such an analysis, despite these significant differences in values, this author is satisfied with the measure employed. Although variations on green-pod price and yields are not assessed in the present analysis, this research will test the impact of including green-pod production in the sensitivity test.

Adoption Rate of Improved Varieties

In conducting their economic impact analysis, Lowenberg-DeBoer and Faye (1996) used adoption of Melakh and Mouride in former mini-kit villages as the plateau level of adoption (2.8%) because "it is the best estimate of an equilibrium use when farmers are well informed about the varieties characteristics and when there is no subsidy". This current study, however, found a great deal of variation in the adoption levels of these varieties between communities and even within mini-kit villages. Combined use of Melakh and/or Mouride were reported in 2 of the 4 mini-kit villages where reported production of these varieties accounted for between 7.6% and 11.8% of production in 2003. The other two former mini-kit villages included in this study reported no use of either of these varieties; it should be noted, however, that through village level surveys, the community leader in one of these two villages did report that Melakh was grown at that location.

Using a weighted average of the results of the mini-kit compared to non-mini-kit villages, it was determined that Melakh and Mouride together were found to account for 3.584% of production. When CB5 is included 3.587% of production is of improved cowpea varieties. As would be anticipated, differences continue to exist in the use of improved varieties between the randomly selected villages and the former mini-kit communities. Among the randomly selected villages these new varieties represented 1.88% of production whereas in former mini-kit communities 9.6% of cowpea production was of improved cowpea varieties. Varietal production practices for both randomly selected and mini-kit villages are summarized in Appendix I (Table 18).

Results of the 1996 study (Lowenberg-DeBoer and Faye) found that, in randomly selected communities, improved varieties accounted for 0.8% of cowpea seed. The results of this study suggest that the previously estimated plateau level of adoption has been surpassed (2004 observed 3.59% improved varieties compared with 1996 estimated plateau of 2.8%). In separately examining the results of former mini-kit communities and randomly selected communities, it appears that, even twenty years after their introduction, randomly selected communities still have not reached the anticipated 'plateau' level of adoption of improved varieties. Given this increase in adoption rates, and the long period of time which has passed since this technology was first introduced, it is difficult to estimate what a revised plateau level of adoption would be. Further complicating this issue is the fact that, although a proportion of 2003 production among the interviewed villages could be calculated, it represents only a partial 'snap-shot' of the region's cowpea production and does nothing to indicate trends over time. Indeed, even within the data collected concerning the 2003 field season, four villages reported planting cowpea varieties (including Melakh) for which, due to adverse climatic conditions, they had no yield.

For a baseline, this study will adopt the methodology employed by Lowenberg-DeBoer and Faye (1996) and make an assumption that the rate of adoption of improved varieties of cowpea will move toward and plateau at adoption levels of former mini-kit villages. As CB5 is used in only one mini-kit village, the adoption of this variety does not appear to be expanding to other communities (indeed, use of this variety went from 0.2% in 1996 to 0.0% in 2004 adoption among randomly selected communities), this variety will be excluded from an estimate of the potential plateau rate of improved variety adoption. As such, the baseline estimate of this parameter is the proportion of production of improved varieties (Melakh and Mouride) in former mini-kit communities; this parameter value is 3.584%. Following the methodology used in the 1996 study, CB5 is specified as 0.2% production from 1987 to 1996 and a declining portion thereafter reaching negligible levels in about 2010.

Yield Advantage from use of Improved Varieties

Information concerning the cowpea grain yield advantage gained through the production of improved varieties was estimated based upon on-farm trial results reported by Thiaw *et al.* (1994, 1996). In this study the results of the 1993 mini-trials were used to estimate this parameter. The finding that Melakh boasted a 40% yield advantage over Ndiambour (a common local variety) is adopted here. In using this result, however, it is recognized that these on-farm trials made use of insecticide and since this is not a common practice among the surveyed cowpea producers, this yield advantage may be overstated.

Estimates of Future Parameter Values

Predictions of several parameter values are required to extend estimates of economic impact into the future. The anticipated area planted to cowpea and expected cowpea yield are assumed to hold at the average of levels over the last five years (1999-2003) until the end of the planning period (2020). Similarly Senegal's exchange rate is projected into the future at levels equal to the average of the past five years. In making projections of Senegal's CPI, the average rate of change of the CPI since 1994 (since devaluation of currency) was determined and projected as an annual increase in the future; it was calculated that Senegal's CPI increased an average of 2.0978 units each year. A similar process was used to predict changes in the US GDP deflator; the average rate of change of this measure over the past ten years was calculated (10.866 units each year) and added to each future year in the planning period.

Research Costs

Available cowpea research and extension costs incurred by CRSP, ISRA, and by Operation Cowpea are included in this analysis. The details of the costs attributed to each of these projects are described below. Although it is recognized that other organizations may have invested in similar projects related to this crop, as such data is not presently available, no consideration is given to those expenses herein. It is assumed that the CRSP costs relevant to this project are those which were incurred either in Senegal or in the US to purchase materials for use in Senegal. For the period from 1980 - 1998 these figures were approximated by using the sum of the 'Host Country', and 'US for Host Country' expenses for the University of California/Senegal project less expenditure on long term training costs which are assumed to be attributable to US benefits. Bean/Cowpea CRSP cost data were provided by the CRSP accounting office at Michigan State University. As degree training is primarily an institution building effort which cannot be linked with specific technologies or outcomes, long term training costs were not included in this analysis.[1] Through a review of Bean/Cowpea CRSP work plans, it was discovered that since 1998, most research has been focused on improving cowpea varieties other than Melakh and Mouride, and upon making modifications to existing storage techniques (e.g. use of natural insecticides). Indeed, although work with Melakh and Mouride continues through the self-supporting 'Foundation Seed' program, since the 1997-1998 fiscal year, no mention has been made in the CRSP's work plans. As these other activities are beyond the scope of interest of this assessment, no research costs after this date are included in this analysis.

ISRA research costs for the period of 1982-1996 were previously furnished to Lowenberg-DeBoer and Faye (1996) by Jacob Diatta, then head of Financial and Accounting Services at ISRA Bambey. This data is used again in this analysis. These costs include all sources of cowpea related financing which was made available to this organization including allocations from Senegal's national budget which is used to cover most salary expenditures. The CRSP total

[1]As an example of the tenuous link between long term training and development of specific technologies, Lowenberg-DeBoer and Faye (1996) noted that at the time of their research, none of the Senegalese scientists trained by the Bean/Cowpea CRSP were employed in the ISRA/CRSP cowpea program. Since that time it is estimated that __?__ (Cisse Ndiaga?) have retained this connection.

in the ISRA accounts is money which is transferred to Senegal. As previously noted, effort has been made to include in these figures all purchases in the US which were used in Senegal, but this may not be a complete record of such expenditures. CRSP was the largest single source of cowpea funding in the period from 1982-1996, and accounted for 20% to 60% of ISRA's cowpea budget. Due to a change in the accounting system, however, records of ISRA expenditures prior to 1986 are no longer available; as such, this analysis assumes that ISRA non-CRSP expenditures in the period of 1982-1985 were the average of those for the 1986-1988 period. ISRA non-CRSP cowpea expenditures since 1996 were not available at the time of the current analysis. As CRSP is among the largest sponsors to ISRA research, and as CRSP expenditures since 1996 have not been dedicated to these activities, it is anticipated that not including these figures will not have a significant impact upon the final results of this analysis.

'Coordination' of Time periods

The data used in this study is collected from several sources who operate with different fiscal years causing some mismatch between the 'years' under each data source. CRSP operates under the US Federal government fiscal year which runs from October 1 through September 30. ISRA Bambey, however, uses a calendar year for their accounting purposes. Senegal's cowpea price statistics, however, are collected on a marketing year basis which starts in October and extends into the next calendar year, while green pod consumption and sales occur in September and October.

In common, each of these data sources share the date September 30 - October 1. As the IRR and NPV analyses assume that all benefits and costs are accrued at the end of the period, in using these figures in these calculations, for each labeled year it is thus implicitly assumed that CRSP storage costs are generated at the beginning of the fiscal year, ISRA costs are accrued nine months into their accounting period, and that costs to CRSP are incurred at the end of their fiscal year.

Inflation Adjustments

To account for inflation, benefits and costs are adjusted from nominal to real values using the US GNP deflator. A US-based measure was selected as the US government was the largest single donor to this project, and this impact assessment seeks to determine the impact of that expenditure; as such, all benefits and costs have been expressed in US dollars. The GNP deflator was selected as this measure is considered a broad based inflation index which, as this study does, takes into account both consumption and production goods.

SENSITIVITY TESTS

A number of sensitivity tests were performed on the baseline scenario to determine the impact of changes in the values of key parameters.

Estimated Adoption Level

Results from the village and individual interviews suggest different rates of adoption of the metallic drum storage technique. Specifically, while the village level interviews suggest that 63.9% of cowpea production in the Peanut Basin is stored in metallic drums, the results from the individual interviews indicate that 85.0% of cowpea production is stored in this manner. Sensitivity analysis was conducted to determine the impact of adjusting this base assumption concerning the technology adoption level.

Demand and Supply Elasticity Assumptions

The baseline analysis was evaluated using an elasticity of supply of 0.8 and an elasticity of demand of -0.5. As these baseline values were informed estimates, alternative assumptions of these values may impact the outcome. More extreme elasticity values are evaluated in this sensitivity analysis. Supply elasticities of 0.5 and 1.0 are tested, and demand elasticities of -0.2 and -0.8 are evaluated.

Aside from Operation Cowpea no explicit extension costs are included in the analysis, though it is well known that World Vision, the Project for Cowpea in Africa (PRONAF) and other organizations have included both the storage technologies and varieties in their technology transfer programs. It is assumed here that these technology transfer programs would have existed with or without the ISRA/CRSP technologies, and that these organizations did not explicitly dedicate expenditures for the dissemination of ISRA/CRSP storage methods or varieties.

Assumed Rate of Storage Loss – 'Traditional' Technology

Individual responses reported losses in non-drum technologies which ranged from 0.5% to 50% . Using guidance of the village level data, an estimate of 25% storage loss using traditional techniques was used. Individual response data and the estimated grain loss level employed in the 1996 study was used to inform the levels at which sensitivity analysis of this parameter is preformed. Specifically, loss levels of 0.5%, 12.5% and 50% are also evaluated.

Assumed Rate of Storage Loss –New Technology

Although few respondents reported any storage loss while using the new technology, in a few instances a low level of loss was reported. The baseline analysis evaluated the impact of a 0% storage loss; to evaluate the impact of low loss levels, a 1% storage loss is evaluated through this sensitivity analysis.

Storage Costs

A conservative estimate of the maximum amount which was paid for a closed-top metallic drum was used in the baseline analysis. Alternatively, this analysis could have been preformed using the minimum reported cost of these drums, the average cost actually paid for metallic drums (adjusted by CPI), or the average estimated 2004 cost of these drums. Several respondents reported receiving their drums as gifts from friends, family members, or through the extension efforts of organizations such as ISRA. Since these individuals did not pay for their drums, the responses were not considered in determining the least conservative price paid for this input. Adjusting the lowest paid price for inflation, a minimum of 2000 FCFA could be expected to be paid for a drum. Interestingly the latter two price options, average purchase price adjusted for CPI and average estimated price in 2004, ended up being quite similar; these values were determined to be 4737.43 FCFA and 4922.73 FCFA respectively. Given how close these values are, it was decided that only the CPI adjusted drum price would be evaluated in the sensitivity analysis.

The average annual storage cost, was also heavily influenced by the estimated useful life of the metallic drum. As previously described, an average of the individual survey responses was used in the baseline analysis. Respondents, however, reported a wide variety of expected useful-lives which ranged from a minimum of two to a maximum of twenty years. Average annual storage costs, considering various combinations of drum costs and useful drum life, are presented in Tables 1 and 2 and are evaluated through sensitivity analysis.

Table 2 Sensitivity analysis estimates of alternative storage costs for metallic drums

Item[1]	Traditional Technology - Open Top Drum			Improved Technology - Closed Top Drum		
	Baseline (Maximum Observed Price)	CPI Adjusted Average	Min	Baseline (Maximum Observed Price)	CPI Adjusted Average	Min
Base Drum Price	4000	2368.72	1000	8000	4737.43	2000
Annualized Drum[2] Price	1485.33	879.58	371.3	3192.89	1890.76	798.22
Insecticide/Drum [3]	0	0	0	73	73	73
Labor/Drum	226.4	226.4	226.4	226.4	226.4	226.4
Total Annual Cost per Drum	1711.43	1105.98	597.7	3492.29	2190.16	1097.62
Total Per kg Stored[4]	21.4	13.82	7.47	21.83	13.69	6.86

Notes:

[1] Prices adjusted to year 2003 equivalent

[2] Drum costs include consideration of the opportunity cost of capital, and are annualized using straight-line depreciation. It is assumed that drums have no salvage value at the end of their useful life.

[3] From individual interviews it was determined that Phostoxin was added to 73% of cowpea grain stored in metallic drums. As such, in determining average cost per drum, the actual cost of storage insecticide was multiplied by this percentage.

[4] It is assumed that open top drums have a storage capacity of 80kg, and closed top drums are assumed to have a storage capacity of 160kg.

Table 3 Sensitivity analysis estimates of alternative durations of metallic drum 'useful life'

Item	Traditional Technology - Open Top Drum			Improved Technology - Closed Top Drum		
	Baseline (12 years)	Minimum (5 years)	Maximum (23 years)	Baseline (9 years)	Minimum (2 years)	Maximum (20 years)
Base Drum Price	4000	2368.72	1000	8000	4737.43	2000

Annualized Drum[2] Price	1485.33	1972	1325.9	3192.89	6304	2704
Insecticide/Drum [3]	0	0	0	73	73	73
Labor/Drum	226.4	226.4	226.4	226.4	226.4	226.4
Total Annual Cost per Drum	1711.43	2178.4	1552.3	3492.29	6603.4	3003.4
Total Per kg Stored[4]	21.4	27.23	19.4	21.83	41.27	18.77

Notes:
[1] Prices adjusted to year 2003 equivalent.
[2] Drum costs include consideration of the opportunity cost of capital, and are annualized using straight-line depreciation. It is assumed drums have no salvage value at the end of their useful life.
[3] From individual interviews it was determined that Phostoxin was added to 73% of cowpea grain stored in metallic drums. As such, in determining the average cost per drum, the actual cost of storage insecticide was multiplied by this percentage.
[4] It is assumed that open top drums have a storage capacity of 80kg, and closed top drums are assumed to have a storage capacity of 160kg.

Opportunity Cost of Capital
The opportunity cost of capital was calculated from one year of cowpea price data. As this data was limited to one year and was not able to be updated for this analysis, it is possible that the estimated opportunity cost of capital of 28.8% is not accurate. Therefore, alternative rates of the opportunity cost of capital are evaluated through this sensitivity analysis. As previously described, industrialized countries have such rates of approximately 10%; alternatively, studies investigating such rates in Sahelian countries (i.e. Lowenberg-DeBoer *et al.* (1994)) found that these rates may exceed 50% annually. As these values are likely to mark the lower and upper limits of this parameter, these values will be evaluated through this analysis.

Proportion of Cowpea Consumed in 'Period 1'
In the baseline analysis it was assumed that 70% of the harvested cowpea grain is consumed in Period 1 (October - March). As this value was estimated through informal observations, this value may be inaccurate. This sensitivity analysis will evaluate the impact of 60% and 80% levels of harvested grain consumption in Period 1.

Adoption Levels of Improved Varieties
The baseline analysis evaluates the scenario that adoption rates of Melakh and Mouride will plateau at a level of 3.58% of cowpea production. As this value is a forward-looking prediction and is estimated through the present adoption rate of these varieties in former mini-kit villages it is, at best, difficult to anticipate. Further, results in Lowenberg-DeBoer and Faye (1996) indicate that the selection of this parameter value is quite important in the estimation of economic benefits. As such, several potential rates are examined through this sensitivity analysis; adoption levels of 7.17% (twice the baseline estimate), 17.92% (five times the baseline estimate), and 35.80% (ten times the baseline estimate).

Yield Advantage of Improved Varieties
Based upon on-farm trial data, the baseline analysis assumes that the improved varieties of Melakh and Mouride have a yield advantage of 40% over local cowpea varieties. However, unlike typical cowpea producers, these trials used insecticide and as such may overestimate the practical yield advantage potential. In this sensitivity analysis, yield advantage rates of 0% and 20% are evaluated.

Operation Cowpea
Operation Cowpea had a significant impact upon the varietal costs and benefits realized in Senegal. Due to its implementation and effect early in the planning period, the impact of this program, will drive, and indeed dominate, much of the analysis of this impact assessment. This sensitivity analysis considers the effect of using 'Scenario 1' described by Schwartz *et al*.1993, which does not include green pod value and which excludes Operation Cowpea benefits and costs; this analysis thus values what the economic impact of this cowpea storage and varietal improvements would have been had the EEC, FAO, and USAID decided not to fund Operation Cowpea as an extension effort. This sensitivity analysis retains the benefits of CB5 as green pods; as ISRA/CRSP were testing and disseminating CB5, farmers may have used it even without the major extension push from Operation Cowpea.

Storage and Agronomy Programs Only
To evaluate if either the plant breeding or storage could bear the whole cost of the research effort, the economic value of the agronomy and storage programs were independently assessed. In performing this analysis, the benefits for each of these programs were evaluated alone with all other benefits excluded. For the agronomy program, the benefits are improved varieties and associated agronomic practices. As little information is available to guide cost allocation between the various aspects of cowpea research, no attempt was made to portion research cost between agronomy and storage.

Extension Costs
Due to the nature of funding allocations, the amount of money dedicated to extension efforts after 1986 is not available. As such, the impact of various extension funding allocations on the return to cowpea storage are estimated using a variety of extension expenditures which were estimated as spent between 1987-2020. The levels of extension spending evaluated are the same as those which were considered in Lowenberg-DeBoer and Faye (1996); the evaluated amounts are $20,000, $50,000, $100,000, and $200,000USD.

SUMMARY OF SENSITIVITY TESTS
The parameters evaluated through sensitivity testing are summarized in Table 3.

Table 4 Summary of Sensitivity Tests

Measure	Test Number	Baseline Value	Variation Value
1. Estimated Adoption Level	Baseline 1a	83.3%	 63.9%
2. Demand Elasticity	Baseline 2a 2b	-0.5	 -0.2 -0.8

Measure	Test Number	Baseline Value	Variation Value
3. Supply Elasticity	Baseline 3a 3b	0.8	 0.5 1.0
4. Rate of Storage Loss - Old Technology	Baseline 4a 4b 4c	25%	 0.5% 12.5% 50%
5. Rate of Storage Loss - New Technology	Baseline 5a	0.6%	 1.0%
6. Storage Costs - Traditional Technology, Base Drum Cost	Baseline 6a 6b	4000	 2368.72 1000.00
7. Storage Costs - New Technology, Base Drum Cost	Baseline 7a 7b	8000	 4737.43 2000.00
8. Storage Costs - Traditional Technology, Drum Useful Life	Baseline 8a 8b	12 years	 5 years 23 years
9. Storage Costs - New Technology, Drum Useful Life	Baseline 9a 9b	9 years	 2 years 20 years
10. Opportunity Cost of Capital	Baseline 10a 10b	28.8%	 10% 50%
11. Proportion of Cowpea Consumed in 'Period 1'	Baseline 11a 11b	70%	 60% 80%
12. Adoption Levels of Improved Varieties	Baseline 12a 12b 12c	3.58%	 7.170% 17.92% 35.80&
13. Yield Advantage of Improved Varieties	Baseline 13a 13b	40%	 0% 20%
14. Operation Cowpea	Baseline 14a	Value of green pods from improved varieties & impact of Operation Cowpea included	 Value of green pods from improved varieties & impact of Operation Cowpea excluded

Measure	Test Number	Baseline Value	Variation Value
15. Agronomy and Storage Program Alone	Baseline 15a 15b	Impact of both storage and breeding included	 Benefits of Storage Only Benefits of Breeding Only
16. Extension Cost	Baseline 16a 16b 16c 16d	0	 20 000 50 000 100 000 200 000

MOVING FROM PROVIDING FIELD SCALE IMPACTS TO HUMAN WELFARE LEVEL IMPACTS

The results of impact assessment studies are most useful when the researchers can move beyond standardized calculations and identify the impact on many levels from human welfare to the economic system. The following matrix, consistent with the discussion of the USAID impact assessment conference held in September 2002, provides an overview or framework for analyzing and reporting these impacts. In the results section the matrix will be presented with specific results from this analysis.

Table 5 Example of a matrix summarizing the impact of the metallic drum cowpea storage technology in Senegal

Impact Level	Scale	Impact Example	Data Needs: Minimum	Data Needs: Optimal	Model	Example Indicators
Human Welfare Human consequences of enhanced agricultural performance	Country	Reduction in illness/death due to use of storage pesticides	Present level of use of storage pesticides ➢ *Percent of stored cowpea under insecticide treatment:* ______________________	Number of storage pesticide related injuries/deaths Type and severity of pesticide related injuries/deaths Medical treatment costs for pesticide related injuries/death Number of worker days lost due to storage pesticide related injuries	Descriptive Statistics	Reduction in storage pesticides related to sickness, injuries and deaths
		Increased level of food security in rural households	Present level of cowpea grain loss during storage ➢ *Percent of cowpea grain loss:* ________________ Previous level of cowpea grain loss during storage ➢ *Percent of cowpea grain loss:* _______________ Value of cowpea grain loss during storage Change in household income by household type (including gender)	Participation rates and use levels of storage technology by household type (including gender)		

Impact Level	**Scale**	**Impact Example**	**Data Needs**		**Model**	**Example Indicators**
			Minimum	**Optimal**		
Economic System(s) Economic value of improved storage technology	Country Region: Senegal's North-Central Peanut Basin	Increased level of income from cowpeas to rural households	Cost of using storage technology ➢ *Unit cost of storage in new technology:* ______________ Cost of using alternative storage technologies ➢ *Unit cost of alternative storage technologies:* *Alt:* _________ *Cost:*____ *Alt:* _________ *Cost:*____ *Alt:* _________ *Cost:*____	Discount rates Research and Extension Costs	Economic Surplus Net producer and consumer benefits measured as economic surplus	Decreased cowpea and storage costs Increased income per rural household
Markets Local market structure and characteristics	Country Region: Senegal's North-Central Peanut Basin	Total quantity of cowpea grain available for consumption	Total Supply of cowpea grain available in key market regions: ➢ *Estimated volume in markets:* __________________________ ➢ *Cowpea supply elasticity:*____ Total consumption of cowpea grain in key market regions ➢ *Estimated volume in markets:* __________________________ ➢ *Cowpea demand elasticity:*___	Population projections Rural household income projections by type Marketing changes with use of new storage technology	Part of Economic Surplus Calculation	Commodity Prices Value of Production Increased year-round availability of cowpea grain

IMPACT LEVEL	SCALE	IMPACT EXAMPLE	DATA NEEDS		MODEL	EXAMPLE INDICATORS
			MINIMUM	OPTIMAL		
PRODUCTION SYSTEMS Cowpea production ~ includes consideration of grain storage processes	Region: Senegal's North-Central Peanut Basin	Volume of cowpea saved through the use of new storage technology	Participation rates in use of new technology ➢ *Percent of cowpea stored with technology: ______________* ➢ *Percent of households using technology: _____________* Value of 'saved' cowpea ➢ *Estimated value of storage losses prevented through use of technology: _______________*	Districts and demographics variability in technology adoption Range of geographic region in which this technology has been adopted Variability by household in access to credit, input and output markets	Part of Economic Surplus Calculation	Number of technologies adopted Level of adoption by farm type (including gender) Share of cowpeas under new storage technology

RESULTS

In the previous section, the methodology and dataset used to run an economic surplus model was described. Using this information, estimates of consumer and producer surplus impacts can be made, and an estimate of the returns from the investment in the storage and varietal technologies made. This section commences with a general description of the characteristics of the villages, households, and individuals who were surveyed. The principal assumptions and limitations of this study are then described. Finally, the results of the baseline and sensitivity analyses are discussed.

CHARACTERISTICS OF SURVEYED VILLAGES

RESPONDENTS

Village level data was collected through interviewees with the 'Chef du village' in each of the selected communities. In each community, this individual was male and in most instances appeared to be older than the average community member. Although questions were directed to the community leader, other individuals from the community were frequently present for this interview and would provide assistance to the leader in recalling details required for completion of the survey (i.e. agricultural production by community members). In all instances the community members who provided feedback were men; although in some instances women were present, in general they did not actively take part in these discussions.

In all instances, the community leader was quite welcoming and willing to help in any way possible; with one exception, each of the village surveys were generally completed without great difficulty. In one former mini-kit community, however, the health of the community leader prevented him from assisting with the village survey. In this case, effort was made to obtain information from other members of his family; unfortunately, however, those present at the time were able to provide only a limited amount of information. As with the other communities, the information collected from this village was recorded, and later translated and entered into a database for analysis.

VILLAGE

Characteristics of the villages included in the sample are summarized in Appendix I (Table 11 and Table 12). Details of the community location, population, agricultural activity, and proximity to relevant markets are provided.

The process of village selection was previously described in the methodology selection. As a result of this process, eight (8) communities in the Louga region, and five (5) in each of the Diourbel and Thies regions were selected; this represents a sampling distribution of 44.4%, 27.8% and 27.8% from each of regions respectively. On average, the surveyed communities were home to 62 compounds, and had a population of 596 people. It must be noted, however, that while community records were generally complete concerning the number of compounds, information about the village population as a whole, and specifically the relative number of men, women, and children was quite variable. In three cases, no village population was obtained, and in several others, although community leaders were quite willing to estimate the relative breakdown of their population, this offer was declined and only information in the community census book recorded.

Most communities reported that the ethnic majority of their population was Wolof (77.7% of surveyed communities); other surveyed villages reported ethnic majorities of Sérèr (11.1%), Poular (5.5%), and Maure (5.5%). Interestingly however, the relative proportion of ethnic groups in Senegal are: Wolof 43.3%, Pular 23.8%, Sérèr 14.7%, Jola 3.7%, Mandinka 3%, Soninke 1.1%, European and Lebanese1%, and other 9.4% (CIA, 2004). Although the surveyed sample is more heavily representative of the Wolof peoples than is the average Senegalese population, as the geographic area of interest is predominately Wolof this outcome is not surprising. As such, overall it is felt that the random sampling process used was appropriate for the needs of this research.

DEMOGRAPHICS CHARACTERISTICS OF INDIVIDUAL RESPONDENTS

RESPONDENT CHARACTERISTICS

A total of 86 individual interviews were conducted. Demographic characteristics of those who participated in these interviews are summarized below.

GENDER

Of the 86 individual interviews conducted, 4 (4.6%) were conducted with females and 82 (95.3%) with males. This gender imbalance among respondents was due, in large part, to both the research design and the household decision making structure. As described previously in the 'Methodology' section, each concession in a community was assigned a number, and numbers were randomly drawn to select those who would be interviewed. The list of concessions was provided by the 'Chef du Village' and in most cases was the list used for local census information and/or tax collection. In either/both instance, the list against which drawn numbers was compared against, however, cited only the name of the 'Chef de Concession'. As this position is not held by females, it was only in instances where either that individual had passed away and his widow was present, or when the Concession Head was not present and his wife was willing to be interviewed that there was an opportunity to interview females. This gender imbalance differs from that experienced during the collection of data for the 1996 study by Lowenberg-DeBoer and Faye (1996). In this earlier study, a majority of individual respondents were female.

AGE

The average of those who participated in individual interviews was 56.9 years; the range of respondent ages was between 18 and 95 years. Among these, the average age of males (56.8 years of age) was slightly lower than the average age of female respondents (59.5 years of age). These values are slightly higher than averages reported for Senegal's population where males are reported to have a mean age of 54.9 years and females a mean age of 58.2 years (CIA, 2004). All participants answered this question.

EDUCATION

Respondents were asked to indicate the level and number of years of education that they have attained. Of the 86 individual interview respondents, 12 (14.0%) indicated that they had some formal education. Among these 1 had attended secondary school for four (4) years, and the remaining 11 had attended primary school for an average of 5.7 years. Other respondents (58.1%) indicated that they had obtained some education through the (informal) Coranic system, or had no education (17.4%). The remaining respondents (10.5%) indicated some from of training (i.e. historian), or provided no response.

MARITAL STATUS

All but one respondent replied to the question concerning their marital status. A large majority of respondents (91.9%) reported that they were married. The remainder of respondents were Single (4.6%), Widowed (2.3%), or Divorced (1.2%). Not surprisingly, each of the individuals who were Single were male and between the ages of 18 and 30, and those who were Widowed were females between 65 to 70 years of age.

CONTACT WITH EXTERNAL ORGANIZATIONS

Participants were asked whether or not they had had any contact with external organizations concerning their agricultural activities. For those who indicated that they had, they were asked to identify the organization. A total of nine individuals (10.4%) reported that they were in contact with some organization. Among these, three indicated they had been in contact with research organizations, two with DRDR (Direction Regional de Developement Rurale), one with FIDA (Fonds International de Dévélopement Agricole), and the remaining two with NGOs. These results are somewhat surprising given both the level of NGO activity in Senegal's Peanut Basin, and the number of former mini-kit communities which were included in this study. It may be, however, that individuals did not view efforts directed toward the community as being contact that they, individually, had experienced with these external support organizations.

HOUSEHOLD CHARACTERISTICS

Size

Respondents were asked to provide details concerning the composition of their concession membership. It was reported that each concession had an average of 13.41 members; among these, there was an average of 3.95 men, 3.62 women, 3.13 male children, and 2.71 female children.

Economic Activity

Respondents were asked to list their economic activity of primary and secondary importance. All interviewed households reported that agriculture was among the top two areas of importance; a large majority (93.5%) indicated that agricultural activity was their primary occupation, while the remainder of these individuals indicated that it was of secondary importance. Those who had alternative primary occupations were most usually involved in some form of commercial activity (3.5%).

Secondary occupations of households were considerably more varied. Over thirty percent (30.2%) reported that their secondary activity was animal husbandry, while 25.6% reported involvement in commercial activities to be of secondary importance. A notable percentage (20.9%) of individuals pursued various 'Other' activities, such as bricklaying, masonry, tailoring, religious leadership, or seasonal work to be of secondary economic importance. Several individuals did not report a second area of activity, as all of their efforts were focused in the agricultural sector. Overall these figures indicate that economic activity of those interviewed was more focused in the agricultural sector than is the Senegalese average; the CIA Handbook (2004) reports that 70% of Senegal's population is employed in the agriculture sector. As the focus of this research in agriculturally productive rural areas, however, this result is not surprising.

ASSUMPTIONS AND LIMITATIONS

As with most survey research, two main types of error must be considered: respondent error and administrative error. Although attempts were made to limit both types of error, both are still present to some degree in this research.

An important type of respondent error that may have occurred in this study is response bias. This limitation can be caused by a number of respondent actions including unconscious misrepresentation and deliberate falsification of responses. Unconscious misrepresentation can occur when a subject unintentionally provides an incorrect answer to a survey question; it is possible, for example that a respondent may have over/under estimated their production yields or their storage allocations. Conversely, deliberate falsification of responses can occur when a subject intentionally provides incorrect information. While there are several factors leading to this type of error, most frequently deliberate falsification is done out of a desire to make respondent appear 'better' than their peers, or to purposely skew results. While the village and individual interview process provided no suggestion of either factors motivated responses, (and as such, it is not anticipated that either of these factors influenced survey results), it is possible that each of these errors could affect the study findings.

In this study, the design of the survey instrument should minimize response bias. Although factual information is likely to generate unintentional errors, the administration of the survey by skilled interviewers helped to reduce the number of 'nonsensical' responses which can occur when respondents don't fully understand what is being asked of them. Use of interviewers who were familiar with the topic, as well as skilled at interviewing, allowed the flexibility for questions to be repeated and, when necessary, rephrased until respondents had an accurate understanding of the question. Further, a number of 'checkpoints' were included in the survey, at which points the interviewers were instructed to compare results of various questions for consistency. Deliberate falsification, while far more difficult to guard against, was minimized by the confidentiality afforded to the survey responses. There would be absolutely no benefit to a respondent to deliberately report incorrect information. By assuring respondents that the information they provided would remain confidential and used as pooled data, it is hoped that subjects would be as truthful and accurate as possible in their responses.

Administrative error is a second type of error to which quantitative research studies are prone. This can occur as a result of data processing and/or sample selection errors. The criteria for sample selection was previously discussed in the Methodology section 'Sample Selection'. It is expected that those organizations who did not meet the stated criteria for each group were excluded from the study. Given the relatively small number of villages which were visited, and the care with which they were selected, it is not anticipated that communities which did not meet the criteria for selection within each sample category were included.

One final issue that may limit the validity of the findings of this research is the knowledge level of the respondents themselves. As described in the Methodology section, proper completion of the surveys required someone who was familiar with all aspects related to the village or household's cowpea production and storage. In some instances, however, although generally familiar with cowpea production, the respondent was not (or no longer) directly him or herself involved with this process; the information reported by such subjects may not be as accurate as if a member of the village or concession who was actively involved with cowpea production had participated. Further, some of the terms used in the study were unfamiliar to respondents. In particular, several participants had difficulty in understanding and relating their production area to hectares, and in understanding questions which required an understanding of the concept of relative proportions. In such circumstances, careful explanation of the concepts, including drawings in the sand, were an important component of ensuring the best responses. Again, although effort was made to eliminate error or bias generated through such processes, it is impossible to determine the degree to which this potential limitation impacted the findings of this research.

STORAGE TECHNOLOGY

GENERAL DISCUSSION OF COWPEA GRAIN STORAGE TECHNIQUES

A summary of individual interview results concerning use of various storage technologies is presented in Table 5. Respondents who used metallic drums also frequently reported using bidons if their harvest in a particular season was higher than anticipated. Although in some instances individuals who added phostoxin to metallic drums would also add it to bidons, interestingly, individuals who used metallic drums without phostoxin would frequently add phostoxin to any grain storage in bidons. This result suggests that although bidons are perceived to be a good substitute for metallic drums, that they are not considered by all respondents to be an equally reliable storage technology. Some respondents (6) reported that they did not use a storage technology for some or all of their production as it was either (1) harvested early and sold as green pods, or (2) used as forage for animals.

Using results of individual interviews, Table 5 summarizes the reported use of storage technologies. An expanded presentation of these results is available in Table 15 of the Appendix.

Table 6 Characteristics of storage technology use

Technology [1]	# Users (2003) [2,3]	Weighted Average Quantity Stored (kg, 2003)[7]	Proportion Users	Proportion Total Production	Weighted Average Min Storage Pd. (months)[7]	Weighted Average Max Storage Period (months)[7]
Metallic Drum [6]	62	486.77	68.8%	83.3%	5.23	12.89
Single Bag [4,6]	7	206.28	7.8%	4%	4.21	9.86
Double Bag + Phostoxin	6	186	6.7	2.6	2.2	4.4
Bidon [4,6]	13	225.8	14.5%	7.8%	5.82	11
Other [6]	2	402	1.1%	1.15%	3	5.5

[1] Several other options of storage technology were provided to subjects, but which no respondent reported using. Among the more notable of these are Double Bag (only), Triple Bagging techniques, and the use of Jars.
[2] As several respondents reported using more than one storage technology, the number of users of technologies does not sum to the total number of respondents.
[3] Responses concerning the type of storage technology used was not received from four subjects concerning the type of storage technology they used.
[4] Some subjects who reported using this technique had no harvest in the field year in question (2003).
[5] Only one of the four subjects who reported using this technology had any harvest in the field year in question (2003).
[6] Technologies include use of technology only, use of the technology with sand, and use of the technology with phostoxin
[7] Averages weighted by the number of users

USE OF STORAGE INSECTICIDES

Phostoxin is still, far and away, the most commonly used storage insecticide. The results of the individual interviews suggest that this insecticide is added to 73% of grain stored in metallic drums. Interestingly, the use of Phostoxin has been extended to be included in other storage technologies. Survey results indicate that 12.3% of farmers report adding phostoxin to grain stored in single or double bags, and 7.8% of farmers report adding it to grain stored in bidons. Interviews revealed that a large part of the draw to this insecticide is the price and its relative ease of use. Phostoxin costs approximately 100 FCFA/container (15 capsules). Capsules need only to be dropped in the drum and the drum closed. Another perceived advantage is that additional Phostoxin can later be added should the drum be opened part-way through the storage period. When compared with other storage insecticide options, this method is considerably easier and safer.

It is interesting to note that this level of phostoxin use is considerably higher than the level previously observed by Lowenberg-DeBoer and Faye (1996), _**__. As it is well documented that no storage insecticide is needed when using drum storage technology (Murdock *et al*. 2003) it is somewhat surprising that the farmers are using this as an apparent insurance policy. Further, it is unclear as to what may have motivated such a significant increase in the use of this chemical in such a (relatively) short time. Interestingly, a similarly noticeable increase in the use of phostoxin in cowpea storage was reported by an IER (what does this stand for?) technician conducting a survey in Mali. Here it was reported that "[p]hostoxin is definitely more available that 5-10 years ago and that is the reason for some of the producers to adopt that conservation technique." He goes on to report that "…some sources do mention the outspead of those [phostoxin] of poor quality or imitations of that product in rural markets". In this example, phostoxin (and other chemical) had in 2000 become regulated by the Malian Comité Sahélien des Pesticides. Although unsubstantiated, one might reasonably hypothesize that in this case enhanced regulation may have eased citizen concerns about the safety of this chemical and indirectly contributed to its increased use and/or production. It is presently unknown if any such regulatory changes have occurred in Senegal, if there has been a shift in understanding of the need for use of a storage chemical, or if some other change, such as an increase in availability, has occurred; further study is required to identify the specific cause(s)of this trend change. For the purpose of the present analysis however, assuming the storage technology is being properly implemented, addition of this chemical, although not required, should not affect the observed rates of storage loss. Further, as the cost of this chemical is relatively low, its use will not significantly diminish the value of this technology to producers. A test of this impact is not explicitly conducted, however, in later discussion of the sensitivity analysis results it is revealed that even relatively large differences in the per kg cost of using the 'new' technology does not substantially alter the calculated annualized value of the technology (Test 7). As such, inclusion (or not) of this small percentage of the total storage cost will not affect the result of this analysis in any meaningful way.

Beyond Phostoxin, there was reported use of only a few other storage insecticides. One village interview reported that individuals in that community used leaves of the neem tree[2] when storing grain in single (polyethylene or polypropylene) bags. One individual respondent in the individual interviews reported that he used leaves of Ndiandame (*Boscia Senegalensis*) in his granary to protect the grain "with the least abuse of the cowpea"

METALLIC DRUM STORAGE TECHNOLOGY

In enquiring about the storage techniques used by individuals, effort was made to gain some insight into the reasoning and motivation behind respondent choices. To this end, as part of the individual interviews, respondents were asked why they chose the technique that they used, specific reasons why they don't use other common storage methods, how they learned about their chosen technique, and what (if any) problems they have encountered with their chosen technique.

A summary of the results of these discussions concerning the metallic drum storage technology is presented in Table 6. The following discussion elaborates upon these findings.

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[2] Neem is an evergreen of the tropics and sub-tropics. It belongs to the family Meliaceae and is becoming increasingly popular for its insect repellent traits (http://www.neemfoundation.org/tree.htm)

WHY USE OF METALLIC DRUM STORAGE TECHNOLOGY

A total of 56 subjects provided some response as to why they use the metallic drum storage technology. Among these, by far the most commonly cited reason for the choice was the grain preservation abilities that the drum afforded. This reason was cited by 87.5% of respondents. Other reasons that subjects reported for using the metallic drums were: lower cost (10.7%), and that they were 'cleaner' (7.1%), 'neater' (1.7%) and 'easier to use' (1.7%) than other storage options. Availability of drums (1.7%), and the fact that the drums themselves do not require any specific storage (3.6%) were also cited as reasons why this method was chosen. A summary of these results is presented in Table 6.

WHY NOT USE METALLIC DRUM STORAGE TECHNOLOGY

Twenty-one respondents who use a cowpea grain storage method other than a metallic drum provided an explanation for their choice. In a majority of cases (57.1%) the cost of the drum was cited as the primary constraint to its use. Also important was the capacity of the drum with 19% of respondents reporting that their production levels were insufficient to 'bother' using this technology. Interestingly, although the grain preservation abilities of the drum were the primary motivation for individuals to use it, 23.5% of respondents indicated they did not use metallic drum storage because of the risk of infestation of grain stored in drums. Finally, in other cases, subjects reported that they sell their grain almost immediately after harvest and thus have no need for this storage technique (9.5%). A summary of these results is included in Table 6.

Table 7 Metallic drum storage techniques: Summary of findings concerning individual use characteristics

Reason	Frequency (%) [1]
Why Use Metallic Drum for Cowpea Grain Storage	
Good preservation/ Good Conservation / No infestation / More effective	87.5
Less Costly	10.7
Cleaner	7.1
Drums do not require cover	3.6
Availability	1.7
Easy to use	1.7
Neater	1.7
Why Metallic Drum not used for Cowpea Grain Storage	
Too expensive	57.1
Not enough product	19
Risk of Infestation	14.3
Less Effective	4.8

Preservation difficult without sand	4.8
No need - sell (almost) immediately	4.8
How Learned of Storing Cowpea Grain in Metallic Drums	
From others in Community / In the village / Watching Others	44
From (various members of) Family	17.5
Own initiative / Experimentation	15.2
From the Merchants	12.2
Through Educational Rural Radio	1.7
From Government or NGO agencies	
DRDR (Direction Regional de Developement Rurale)	1.7
ISRA	1.7
Municipal Administrator	1.7
SODEVA (Société du Developement et Vulgarization Agricole)	1.7
From Market Vendors	1.7

[1] The frequency with which reasons were provided will not necessarily sum to 100% as multiple reasons were provided by some subjects.

HOW LEARNED OF METALLIC DRUM STORAGE TECHNOLOGY

Word-of-mouth from other community members, and family members, were the source of information concerning the drum storage technique for a majority of respondents (45.7% and 17.5% respectively). A number of individuals also reported that they came to use metallic drums through their own initiative and experimentation (15.2%). Interestingly, among these, one respondent noted that he used drum storage for peanut preservation and had decided to apply the technique to cowpea grain storage. The marketplace also was a source of information for storage techniques with 12.2% of metallic drum users reporting learning of the technique from the Bana Bana, and an additional 1.7% reporting that market vendors were their source of information. Various government and non-government agencies were cited as the source of metallic drum storage knowledge by 6.8% of individuals. In some cases, however, respondents were unable to recall how they came to use the technology (3.4%). A summary of these results is also included in Table 6.

Table 8 Problems encountered and solutions found by users of the metallic drum storage technology

PROBLEM	SOLUTION	FREQUENCY PROBLEM REPORTED BY USERS OF TECHNOLOGY (%) [1]
Expense of Drum	None	3.5

Drum Rust Through	Short Term: Shelter Drum Long Term: None	3.5
Drum does not 'tolerate' frequent / repeated opening	Hermetically sealed and leave closed until grain is needed	3.5
Burning of Grain	Place drum in cool place	1.7
Difficulty in Filling	Use Funnel to Fill	1.7
If grains are not dry there can be considerable damage	Ensure grains are completely dry before filling	1.7
Infestation	Prevent pocket of air in drum by filling totally, or treat with an insecticide	1.7
No Problem		85.9
[1] The frequency with which problems were listed will not necessarily sum to 100% as multiple problems were cited by some subjects.		

PROBLEMS NOTED AND SOLUTIONS FOUND

A summary of the primary problems encountered through the use of metallic drums, and the solutions (if any) found to these problems is presented in Table 7. Overall, a majority of subjects reported that they have not encountered any problems using the drum storage technique (85.9%). Among those who did report challenges using the drums, the most commonly cited problem was again said to be the cost of acquiring the drums. Also without a ready solution was the challenge created by drums rusting through and the resulting damage to grains from both the rust and drum infestation. It should be noted, however, that the drum storage technique promoted by the Bean/Cowpea CRSP suggests that drums made of galvanized steel be used in order to prevent this problem. Other challenges, such as difficulty in filling drums, and the burning of grain stored in the drums, were noted by single respondents, but respondents reported finding at least partial solutions to each of these problems.

CHARACTERISTICS OF METALLIC DRUM STORAGE

Individual interview respondents were queried as to the anticipated useful life of their drums. Responses to this question were interesting, as a few respondents reported that the drum useful life was less than the number of years that they, themselves, had been using their own drums. When this fact was pointed out, only in one instance did a respondent make an adjustment to his prediction of the drum's useful life. Overall, the average useful life of each metallic drum was reported to be 9.35 years. As previously described, however, there was a large variation in the reported useful life of metallic drums (2 to 20 years); the impact of this variable prediction in useful life was evaluated through the sensitivity tests and is reported in the results section.

Other details concerning drum storage were also gathered during these interviews. It was determined that, on average, cowpea producers who use metallic drum storage own 3.28 drums, while the range of drums being used varied between 1 to 15 drums. Further, while drums which are presently used were purchased between 1994-2004, on average, the drums were relatively new and were purchased in 2000. Two respondents reported using 'little' metallic drums rather than the larger variety. These containers were significantly smaller than what is normally used and looked to be similar in shape and dimension to what is used in North America for large purchases of cooking oil. (~10L). Interestingly, neither of these respondents reported adding a storage insecticide to their drums. Finally, as drums are also used for storage of other products (i.e. peanuts), the availability and thus the price of drums was described by several respondents to fluctuate inversely with the peanut crop.

LABOR USED IN METALLIC DRUM STORAGE PROCESS

Individual interview respondents were asked to report the number of individuals (men, women, children) who assisted in the cowpea storage process. For those that use metallic drums, the average concession reported that it used 1.73 days of man labor, 2.21 days of women labor, and 0.472 days of child labor in the storage process. While the use of labor of adult males and females does seem reasonable, the reported use of child labor is likely below that which is actually employed. Possibly in part due to attention of the international community to issues of child labor in Senegal, in several instances, respondents appeared to be reluctant to include mention of the work of children in discussions concerning household labor. As the International Labor Office reports that a significant portion of children in Senegal are 'economically active'[3], it is likely that the contribution of children to the cowpea storage process has been under-reported.

LEVEL OF ADOPTION OF METALLIC DRUM STORAGE

In the 1996 study by Lowenberg-DeBoer and Faye of the impact of the metal drum storage technology in Senegal, it was reported that the metallic drum method was used in all but one village. Results of this investigation, however, suggest that the use of this technology may be slightly waning. Responses from 17 communities were collected concerning the use of storage technology. Among these 17 communities, 4 reported that they do not use the drum storage technology. Among repeated villages, a comparison of metallic drum use over time indicates that all but one village that reported 100% use of this technology in 1996, continued to use only this technology. Villages who reported less than 100% use of the metallic drum storage in 1996, however, indicated a decrease in their use of this technology. Interesting also, is the fact that, according to village surveys, among new randomly selected non-minikit villages (n=8), 3 (37.5%) reported no use of the metallic drum storage technology. As this number is substantially higher than that observed in the previous study, this observation warrants further consideration. At the outset one may interpret this result as an indication that there is a decrease in the use of this technology. Alternatively, however, in the instance of the village survey, as responses are provided by the community leader who may, or may not, himself be involved in cowpea production (and thus will have variable first-hand knowledge of community practices), the possibility exists that these results may be influenced by the respondent's perception of the purpose of this research. In this repetition, effort was made to not lead respondents in this sense; respondents were told only of the general purpose to collect information about cowpea storage

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3. In 1995, there were 327,000 economically active children, 160,000 girls and 167,000 boys between the ages of 10-14 years, representing 31.36% of this age group. (ILO, International Labor Office - Bureau of Statistics, Economically Active Population 1950-2010, STAT Working Paper, ILO 1997)

technologies, and not of interest in any technology in particular. As a final alternative, these differing results between time periods may simply reflect a lack of awareness of community leaders of cowpea storage practices. Table 15 compares responses about the use of storage technologies obtained from the village survey with those collected through individual interviews; quite clearly there are substantial differences in these results. While it is possible that the individuals who were randomly selected for interviews represent outliers in terms of their storage practices, the lack of mention of commonly used storage methods in several communities, draws into question the validity of responses obtained though village surveys on this issue. Notably however, in instances where the community leader was, himself, a cowpea farmer, the consistency between the village and individual responses was much greater.

COWPEA VARIETIES

GENERAL DISCUSSION OF COWPEA VARIETIES

The use of cowpea varieties varied among villages. In some villages, a majority of the production was dedicated to one particular variety, while in other communities production was divided among three or more varieties. Using the results from the individual interviews, Table 8 summarizes the relative proportion of variety production by each community 'type'. An expanded presentation of these results is available in Table 17, in Appendix I. In reviewing these results it is interesting to note the relative prevalence of the varieties 58-57, BNG, and Ndiaga Aw in almost every community.

Table 9 Summary of community production by cowpea variety

VILLAGE	58-57	BNG	NDIAGA AW	NDIASSIW	OTHER [2]	ISRA/CRSP IMPROVED VARIETIES		
						CB5	MELAKH	MOURIDE
Average - All	14.98%	16.29%	62.97%	1.47%	0.17%	0.24%	3.39%	0.49%
Average - Former Mini-Kit	7.42%	12.81%	72.30%	1.81%	0.50%	0.71%	3.00%	1.43%
Average - Randomly Selected	18.86%	18.08%	58.17%	1.30%	0.00%	0.00%	3.58%	0.00%

Notes:
[1] Data is from individual interview results
[2] 'Other' varieties include B819, M'Bay Ngagne

USE OF IMPROVED VARIETIES

It had previously been anticipated (Lowenberg-DeBoer and Faye, 1996) that the improved varieties Melakh and Mouride would eventually replace CB5 for production of green pods. As it was reported that CB5 was used in only one community, for the most part, that hypothesis has been supported by the findings of this research. The cowpea production characteristics in the community in which CB5 was reported are however, interesting and unexpected. In the 1996 impact assessment Gatt Ngaraf2 reported that 1.7% of the total quantity of cowpea seed used in their village was of each of the Melakh, Mouride, and Diongama varieties. In returning to this village for the present study, however, individuals who were interviewed in this community reported that there was no use of Melakh, Mouride or Diogama, but instead that 20.3% of their production is of CB5. Although an isolated observation, this result suggests that the original hypothesis concerning CB5 replacement with other improved varieties may not always hold true.[4]

IMPROVED VARIETIES: COMPARING VILLAGE AND INDIVIDUAL SURVEY RESULTS

Significant differences exist in the stated production of these varieties between the results of the individual and village level surveys. Individual interviews indicate that these varieties were grown in 44.4% of communities; village level surveys, however, claimed only 27.8% of communities used improved grain. Interestingly also, it was not always the same communities which identified use of these varieties in the village surveys as in the individual surveys. This latter result underlines the need for verification of village-level and individual survey findings. In instances such as this, where conflict exists in the results, use of the individual survey results is recommended. Village-level surveys, while useful for gaining an appreciation for the 'overall picture' of the community, may not be as reliable for this sort of quantitative information. In this study, village leaders were themselves only infrequently involved with cowpea production and as such, although they may have a general awareness of such issues, they would not be as familiar with the production and storage practice requirements of this crop as would actual producers.

ECONOMIC IMPACT ASSESSMENT

Through use of the sensitivity analysis (discussed later), it is clearly demonstrated that the impact of Operation Cowpea completely dominates the reported economic returns. Due to the magnitude of the impact of this program, when it is included in the analysis, regardless of the magnitude of the scenario shock, there is relatively little variation in the IRR. Indeed, in examining results of each of the other sensitivity analyses, the IRR varies only within the limited range of 224.1521% to 224.4617%. This outcome is due to the manner in which the IRR value is calculated; as the value of this measure is quite high, benefits and costs reported in the initial observations (~5) will drive the calculation of this value and cause later observations have relatively little impact on the generated IRR. By comparison, there is more variation in the observed NPV and AV values. Since these values move together, this discussion will focus upon only one measure. The annualized value is the value of an annuity that could be provided over the planning period if the NPV of a program could be invested in long term government bonds. Due to the relative ease of interpreting this measure and changes in its relative magnitude, the discussion here focuses on annualized values. Table 9 summarizes the results of the baseline analysis and sensitivity tests.

BASELINE ANALYSIS

Three summary measures were used to evaluate the benefits derived from investment in development and extension efforts of the metallic drum storage technology; Internal Rate of

[4]Alternatively, and perhaps more likely, this result could be due to a misunderstanding on behalf of the farmers of the varieties which they are actually growing.

Return (IRR), Net Present Value (NPV), and Annualized Value (AV). The baseline scenario was found to have an IRR of 224.36%, a NPV of $33,697,275.84 USD and an annualized value of $1,923,052.74 in year 2000 US dollars (Table 9). Due to the benefits generated though Operation Cowpea early in the planning period, the IRR calculated in this analysis is quite high. Interestingly, this value is much higher than even that reported by Schwartz *et al.*1993, (92%) in their evaluation of the economic impact of this program. This divergence is due to the differential treatment of training costs which, as previously described, are excluded in the calculation of costs.

The annualized benefit calculated for the baseline analysis indicates that $1.2 million USD annuity could be provided by the benefits generated from this project. As the total annualized research costs vary between $83,409.83 USD (1996) to $375,742.54 USD (1985), the annualized benefit would easily be sufficient to cover the costs of the ISRA/CRSP cowpea program.

SENSITIVITY TESTS

Results of the sensitivity tests preformed on this analysis are presented and described below. In an effort to demonstrate similarities between some of the obtained results, in some instances, discussion of related tests are drawn within common headings.

Table 10 Summary of results from baseline analysis and sensitivity tests

MEASURE	TEST NUMBER	IRR (%)	NPV (FCFA)	ANNUAL (FCFA)	CHANGE FROM BASELINE AV (%)
Baseline		224.3616	32,145,755.20	1,834,509.80	
1. Estimated Adoption Level	1a	224.4217	30,027,001.36	1,713,595.71	-6.5911
2. Demand Elasticity	2a 2b	224.4235 224.4220	32,863,659.94 31,708,096.22	1,875,479.54 1,810,441.65	2.2333 -1.3120
3. Supply Elasticity	3a 3b	224.4226 224.4225	32,225,234.23 32,181,940.14	1,839,045.55 1,836,574.82	0.2472 0.1126
4. Rate of Storage Loss - Old Technology	4a 4b 4c	224.3807 224.4011 224.4660	22,645,495.01 27,018,192.79 45,046,111.70	1,292,344.27 1,541,887.54 2,570,713.70	-29.5537 -15.9510 40.1308
5. Rate of Storage Loss - New Technology	5a	224.4220	32,057,804.53	1,829,490.58	-0.2736
6. Storage Costs - Traditional Technology, Base Drum Cost	6a 6b	224.4138 224.4065	31,290,571.94 30,523,654.83	1,829,490.58 1,758,705.78	-2.6603 -5.0461
7. Storage Costs - New Technology, Base Drum Cost	7a 7b	224.4296 224.4354	32,880,207.56 33,449,476.31	1,876,423.89 1,908,911.20	2.2848 4.0557
8. Storage Costs - Traditional Technology, Drum Useful Life	8a 8b	224.4293 224.4203	32,883,781.01 31,957,866.82	1,876,627.82 1,823,787.29	2.2959 -0.5845
9. Storage Costs - New Technology, Drum Useful Life	9a 9b	224.4057 224.4252	30,533,012.88 32,453,709.55	1,742,473.03 1,852,084.29	-5.0170 0.9580
10. Opportunity Cost of Capital	10a 10b	224.4189 224.4275	31,347,410.07 33,343,899.77	1,788,949.45 1,902,886.10	-2.4835 3.7272
11. Proportion of Cowpea Consumed in 'Period 1'	11a 11b	224.4364 224.4088	35,392,206.39 29,019,797.63	2,019,779.88 1,656,116.11	10.0992 -9.7243
12. Adoption Levels of Improved Varieties	12a 12b 12c	224.4226 224.4226 224.4227	40,636,804.36 64,365,152.20 101,355,810.18	2,319,081.18 3,673,222.23 5,784,223.32	26.4142 100.2291 215.3008
13. Yield Advantage of Improved Varieties	13a 13b	224.4225 224.4225	27,670,352.70 29,742,735.98	1,579,105.32 1,697,373.11	-13.9222 -7.4754
14. Operation Cowpea	14a	16.4452	7,492,474.41	427,584.22	-76.6922
15. Agronomy and Storage Program Alone	15a 15b	15.3863 12.8028	6,981,346.57 7,986,891.11	398,414.93 455,799.84	-78.2822 -75.1541
16. Extension Cost	16a 16b 16c 16d	224.3958 224.3556 224.2886 224.1544	31,932,182.73 33,537,159.32 30,878,786,98 29,562,042.30	1,822,321.54 1,799,778.15 1,762,205.83 1,687,061.20	-0.6644 -1.8932 -3.9413 -8.0375

Estimated Adoption Level

As previously described, in some instances issues were addressed on both the individual and village surveys; the results from similar questions, however, often gave very different results. This sensitivity test, which compares individual and village level responses concerning the level of adoption of the metallic drum storage technology, is an important indicator of the impact of such response differences. For this parameter, the village survey which reported a 63.9% adoption of the new storage technology, resulted in a 6.2% decrease in the estimated annualized value as compared to the baseline analysis which assumed an 83.3% technology adoption. As the magnitude of this AV percent change is relatively small compared to the difference in the survey estimates, for this parameter the choice of the individual survey outcome over that of the village survey does not significantly impact upon the final analysis outcome.

Supply and Demand Elasticities

Sensitivity analysis of the demand and supply elasticities suggest that this analysis is robust in response to changes in this variable. For both of these measures, even rather significant changes in their values resulted in a small change (less than 0.25% supply, and less 2.25% demand) in the calculated annualized value of return as compared with that generated in the baseline analysis. As previously discussed, to date there is no known empirically generated estimate of these elasticities. Given the relatively insignificant impact choice of this measure has on the final analysis, however, this lack of information does not appear to pose a serious limitation on the results of this study.

Rate of Storage Loss

Examination of the impact of changes in the estimated storage loss indicate that the value of the AV is more sensitive to this parameter than to many of the others. Rate of storage loss experienced while using the old technology varied from 25% (baseline), to 0.5% , 12.5%, and 50%; these estimated loss levels result in a -29.55%, -15.95%, and a 40.13% change respectively in the AV from the baseline analysis. As would be anticipated the higher the estimated loss level from the traditional technology, the greater the difference between the traditional and new technology loss levels and the greater the potential impact of the new technology. Thus, as the traditional technology estimated loss levels are increased, there is an increase in the annualized value of this investment.

In evaluating the new technology, as the individual interviews reported a range of loss from use of this technology is quite narrow (0% to 1%), only a limited sensitivity analysis was preformed on this parameter. The baseline analysis assumed a 0.6% production loss while the maximum loss of 1% was also evaluated. Not surprisingly, this small change in estimated loss (0.4%), resulted in a relatively unimportant (-0.27%) change from the baseline AV estimate. The direction of this AV shift relative to the baseline is expected.

Consideration of the combined impact of these parameters suggests that estimates of these measures are relatively influential in AV estimation. Further, in consideration of the impact of this parameter compared to other parameters (i.e. supply and demand elasticities, opportunity cost of capital), it appears that this measure is relatively (more) important. This result emphasizes the necessity of performing a careful study and estimate of this parameter prior to conducting such an analysis.

Storage Costs

Storage cost assumptions have a modest impact on the annualized value generated for this project. For both the old and the new technologies, adjustments to the base price of the metallic drum impact the AV in the direction that would be expected. A lower cost of 'traditional' technology drums reduces the potential benefit of the new technology and results in a decrease in the AV relative to the baseline level. A lower cost of drums for the 'new' technology, however, increases the potential benefits which might be obtained through use of the new technology and, as such, improves the estimated AV compared to the baseline. The reverse affect is experienced in each scenario with higher base drum cost estimates.

The anticipated useful life of the metallic drums has a similar and expected impact upon the AV relative to the baseline scenario. Extending the useful life of the drums results in a decrease in the annual cost of the drum. For the traditional technology, a decreased average cost decreases the relative benefit which might be experienced with the new technology, and as such decreases the annualized value relative to the baseline. For the new technology, the reverse is true; a longer useful life will result in a decreased annual average storage cost; this decreased cost, in turn, increases the potential benefits that this technology might provide and as such improves the estimated annualized value relative to the baseline scenario.

Opportunity Cost of Capital

As described previously in the methodology section, due to data availability limitations estimates of the opportunity cost of capital were made via a proxy measure which considered relative cowpea prices at different annual time points. As this measure has noted limitations, and as the data upon which the proxy estimate was made could not be updated, it was acknowledged that there may be some shortcomings in this estimate. Through this analysis, opportunity costs of capital of 10% and 50% were evaluated relative to the baseline estimate of 28.8%. Somewhat surprisingly, this analysis revealed that the impact of these significant changes in opportunity cost of capital have a relatively small impact upon the annualized value relative to the baseline analysis. When the farm opportunity cost of capital is 50% annually, annualized benefits rise compared to the baseline (3.73%). When the farm opportunity cost of capital is 10%, annual benefits drop (-2.48%).

Proportion of Cowpea Stored in 'Period 1'

The household decision to sell or consume cowpea in the first period has only a small impact upon the estimated benefits. As would be expected, when a smaller amount of cowpea is consumed in the first period (and it is stored and marketed in the second period), the annualized value of benefits improve relative to the baseline analysis.

Adoption Levels of Improved Varieties

The results indicate that benefits from either the breeding program or the storage research could have more than paid for the investment in the cowpea program in Senegal. When the analysis is done with only the storage benefits the IRR is greater than 15% (15.4%) and the annualized value $398,414.93 When only the benefits from the breeding program are included, the IRR is 12.8% and the annualized value is $455,799.84. In both cases the IRRs are substantially greater than the cost of capital to the U.S. government and the annualized value greater than the average real research cost.

It should be noted that the sum of the storage and breeding program NPVs does not equal the NPV from scenario 14a (Drop Operation Cowpea) because all the research costs are deducted in both the storage and breeding analyses.

Operation Cowpea

If the benefits and costs of Operation Cowpea in 1986 and 1987 are dropped from the analysis, the IRR falls to 16.4%, and the annualized value of $427,584. A 16.4% IRR is still substantially greater than the 4.78% annual cost of capital to the U.S. government which was the primary investor (donor). The annualized NPV of the project is still more than twice the average $200,000 real annual expenditure by both Bean/Cowpea CRSP and ISRA.

Agronomy and Storage Program Alone

Results of this sensitivity test indicate that the benefits of either the agronomy program or the storage initiatives alone, and in isolation of other adjustments to the baseline scenario, would be insufficient to justify the investment in cowpea research in Senegal. In considering the benefits of the storage program alone, an annualized value of $398,415 was realized; consideration of the breeding program benefits alone results in an annualized benefit of $571,326. These values reflect IRR of 15.38% and 13.71% respectively.

Annual Extension Cost

The impact of an increase in extension expenditures has a relatively significant and expected impact upon the annualized value of the research. As could be anticipated, an increase in the extension cost results in a decrease in the annualized value relative to the baseline analysis; as these extension costs are simply added to the real cost of the investment in the project, there is a direct and proportional relationship between the amount dedicated to extension work and the decrease AV. Although not examined here, it is worth noting that the AV impact of an annual investment in the extension of these technologies will vary dependant upon when the investment was made. Thus, if it were not possible to fund extension efforts throughout the duration of a project, a greater AV would be generated through dedicating this expenditure earlier rather than later in the planning period.

WELFARE IMPACTS

In order to move beyond standardized calculations and identify the impact on many levels from human welfare to the economic system, the matrix noted earlier is presented with key findings from this analysis. In this case of the dissemination and adoption of a new storage technology and new varieties, it is possible to examine the impact at the levels of the cowpea production system, cowpea markets, the regional economic system, and finally human welfare. As many of the potential impacts are difficult to quantify, this method of analysis incorporates both qualitative and quantitative descriptions of impact.

The impact of the ISRA/CRSP program is evident on many levels. It is interesting to note that the estimated average annual reduction in grain loss due to the new technology is 7867 metric tons, which translates into a value of saved grain of 1,947,111,646 FCFA or $32.80 per household per year. It is also interesting to note the improvement in household welfare is a result of households storing more grain, and selling in Period 2 when prices are relatively higher.

Finally, it is important to recognize deviations between the assumptions employed in performing impact assessments, and the reality of the circumstances which are being modeled. In Fuglie (1995), for example, it is explicitly stated that farmers base their storage decisions on their expectations about price movements and storage costs over the course of the storage periods. During the individual interviews, however, in several instances it was revealed that storage decisions were instead frequently based upon personal circumstances. A notable example of this was the case of a farmer who in the previous cropping season had to sell his entire stored stock to cover the funeral expenses for his brother. As such, interpretation of the economic impact of these storage and varietal improvements reflect the potential benefit which might be experienced under this limited and defined set of conditions. Deviations from these conditions, beyond those considered in the sensitivity analysis, are both possible and probable in the case of venerable small landholders.

Table 11 Matrix summarizing the impact of the metallic drum cowpea storage technology in Senegal

IMPACT LEVEL	SCALE	DATA NEEDS		MODEL
		MINIMUM	OPTIMAL	
HUMAN WELFARE Human consequences of enhanced agricultural performance	Country	Present level of use of storage pesticides ➢ *Percent of stored cowpea under insecticide treatment: 85.1% and increasing* Present level of cowpea grain loss during storage ➢ *Percent of cowpea grain loss: 0.6% using new technology* Previous level of cowpea grain loss during storage ➢ *Percent of cowpea grain loss: ~25% using traditional technology* Value of cowpea grain loss during storage ➢ *Average (10 year) price of cowpea grain = 254 FCFA/kg* ➢ *Estimated avg. annual reduction in grain loss due to new technology = 7867 mt* ➢ *Average annual value 'saved' cowpea grain = 1,947,111,646 FCFA or $3,892,121.55 USD* Change in household income by household type (including gender) ➢ *Value of Saved Grain/Household = 16,399.5 FCFA or $32.80 USD* ➢ *Due to storage, economic surplus of $6,981,350 USD was generated for the region.* ➢ *Sample insufficient to separately evaluate household income changes by gender. (See comments under 'optimal data needs.)*	Number of storage pesticide related injuries/deaths ➢ *Attempted to collect this information through in-country survey* ➢ *No pesticide related injuries/deaths reported (accidents with farm equipment and animals noted)* ➢ *Possible that pesticide injuries are not recognized as such, and thus are unidentified* Type and severity of pesticide related injuries/deaths ➢ *Information not available* Medical treatment costs for pesticide related injuries/death ➢ *Information not available* Number of worker days lost due to storage pesticide related injuries ➢ *Information not available* Participation rates and use levels of storage technology by household type (including gender) ➢ *Only 4.6% of respondents were women.* ➢ *No noticeable difference on the basis of gender in the use of storage technologies.*	Descriptive Statistics

<table>
<tr><th rowspan="2">IMPACT LEVEL</th><th rowspan="2">SCALE</th><th colspan="2">DATA NEEDS</th><th rowspan="2">MODEL</th></tr>
<tr><th>MINIMUM</th><th>OPTIMAL</th></tr>
<tr><td>ECONOMIC SYSTEM(S)

Economic value of improved storage technology</td><td>Country

Region: Senegal's North-Central Peanut Basin</td><td>Cost of using storage technology
➢ Unit cost of storage in new technology: 21.83 FCFA/kg

Cost of using alternative storage technologies
➢ Unit cost of alternative storage technologies:
Alt: Single Sac Cost: 9.54 FCFA/kg
Alt: Double Sac Cost: 10.75 FCFA/kg
Alt: Bidon Cost: 14.33 FCFA/kg
Note: These estimates do not account for higher relative grain loss levels in using these alternative technologies.</td><td>Discount rates
➢ Opportunity Cost of Capital estimated to be 28.8% for farmers
➢ 4.78% for U.S. Government

Research and Extension Costs
➢ Major research and extension costs for organizations contributing to this program were available and included in this analysis.
➢ Information sources provided in the methodology section; expenditures are listed in Table 25. Average real expenditure 1982-1998 ~ $200,000/year</td><td>Economic Surplus

Net producer and consumer benefits measured as economic surplus</td></tr>
<tr><td>MARKETS

Local market structure and characteristics</td><td>Country

Region: Senegal's North-Central Peanut Basin</td><td>Total Supply of cowpea grain available in key market regions:
➢ Avg. production in primary cowpea production area over past 10 years = 38, 706 tonnes/year.
➢ Households sell 47.9% of production
➢ Average grain on market = 18,540 tonnes/year
➢ Cowpea supply elasticity: 0.8 (est.)

Total consumption of cowpea grain in key market regions
➢ Producing households consume 52.1% of production
➢ Average grain on market = 18,540 tonnes/year
➢ Cowpea demand elasticity: 0.5 (est.)</td><td>Population projections
➢ Not required for the present analysis

Rural household income projections by type:
➢ Economic surplus increases with higher adoption levels of the new technology (Sensitivity Test 1)

Marketing changes with use of new storage technology
➢ Households choose to store more grain due to the availability and affordability of improved storage technology
➢ Sensitivity analysis (Test 11) found that an increase in economic surplus is generated through delayed grain consumption</td><td>Part of Economic Surplus calculation</td></tr>
</table>

IMPACT LEVEL	SCALE	DATA NEEDS		MODEL
		MINIMUM	OPTIMAL	
Production Systems Cowpea production ~ includes consideration of grain storage processes	Region: Senegal's North-Central Peanut Basin	Participation rates in use of new technology ➢ Percent of cowpea stored with technology: 83.3% ➢ Percent of households using technology: 68.8% Value of 'saved' cowpea ➢ Net present value (NPV) of the economic surplus generated through the storage program alone is: $6,981,350 (Test 15a)	Districts and demographics variability in technology adoption ➢ Storage technology widely used in the major cowpea production area ➢ No geographic or demographic difference in the technology adoption within the region. Range of geographic region in which this technology has been adopted ➢ Technology well adopted within Senegal's North-Central Peanut Basin (primary cowpea production area) Variability by household in access to credit, input and output markets ➢ Results suggest access to credit for households is extremely limited ➢ 1.16% of respondents reported knowledge of credit available to men; 2.32% of respondents reported knowledge of credit available to women. ➢ Credit, when available, is provided through NGO's with no/low interest	Part of Economic Surplus calculation

Conclusion

This analysis sought to assess the economic impact of the ISRP/CRSP collaboration on cowpea related programs. Outcomes of initiatives related to Operation Cowpea, and the dissemination and adoption of a hermetic drum storage technology, and two improved cowpea varieties, Melakh and Mouride, are the focus of this research. By all measures, this collaboration has been successful; in general, the technologies developed through this partnership have become widely adopted and have generated significant economic benefit. The following discussion summarizes the results from each of the major areas of collaboration which were explored herein.

Operation Cowpea

The impact of Operation Cowpea was previously assessed by Schwartz *et al.,* 1993. This earlier investigation, which included data through 1986, found that if green pod benefits were included Operation Cowpea yielded had an internal rate of return of 92%. The quantitative results of this research were incorporated into the present investigation.

Storage Technology

As more than a decade has passed since the introduction of the metallic drum storage technology, a key point of interest of this investigation was to determine the present state of adoption of this technology. Through an adoption study, it was determined that the hermetic metallic drum has continued to be widely used for the storage of cowpea grain. This survey found that 68.8% of households use these drums for preserving 83.3% of stored cowpea production.

Results of an earlier adoption study conducted in June 1996 (Lowenberg-Deboer and Faye, 1996) found that the metallic drum storage technology was used by more than 80% of households in the northern peanut basin and that this technology was used to preserve approximately 95% of stored production. A comparison of the results of these two studies, would thus suggest that use of this technology is starting to decline. Although interviews indicate that farmers still feel that use of the metallic drum technology is the best storage technique for use over the long run, the initial cash outlay to purchase a drum is prohibitive for many. As an alternative, several households reported opting instead to buy the relatively inexpensive polyethylene or polypropylene sacs in which rice is imported. Thus, although the closed-top metallic drum continues to be the storage technique of choice, due to budgetary constraints, the use of this technology appears to be declining.

Improved Cowpea Varieties

Individual interviews with cowpea farmers indicate that the improved cowpea varieties, Melakh and Mouride, are valued by farmers for their relatively short growth cycles, good yields, and their amenability to consumption as green pods. Due to the relatively depleted level of food stores prior to harvest, the availability of these varieties two(+) weeks before traditional varieties helps to ease food shortages during this hungry period. Households can choose to consume or to sell these varieties as green pods; when marketed along a roadside to passing travellers, they can be an important source of household income (Faye, 1995). Due to their taste relative to other cowpea varieties, most often households prefer not to use these varieties as dry grain; rather, in many cases, only a small portion of production which is kept aside for seed, is allowed to mature.

In using a weighted average to appropriately account for mini-kit and non-mini-kit production, it was determined through this adoption survey that Melakh, Mouride, and CB5 respectively account for 3.58%, 0.006%, and 0.003% of production. This production pattern was found, however, to vary dependant upon the >type= of village. Melakh is grown in similar proportions in Mini-Kit and non Mini-Kit communities; respectfully, Melakh accounts for 3.0% and 3.58% of production in these community types. In a comparison with previous survey results, it appears that the adoption of Mouride is increasing in mini-kit communties but is decreasing in other randomly sampled villages. In 1996 1.0% of seed in former Mini-Kit communities and 0.6% of seed in random sample villages was of this variety; this study found adoption of Mouride to be 1.43% and 0.0% respectively in these village types. CB5 was similarly found to be used exclusively in former mini-kit communities. These observations are not surprising; the 1996 adoption survey reported that CB5 accounted for only 0.2% of seed in randomly selected communities and that Mouride had similarly not been adopted at all in non-Mini-Kit villages.

ECONOMIC IMPACT

Estimates of the economic benefits of products of the ISRA/CRSP collaboration indicate a rate of return on investment of 224%. This rate of return is very high when compared to the cost of capital in other countries. For comparison with rates of return in industrialized countries, the average U.S rate of return on long-term government bonds between 1982-2003 was 7.6%. In developing nations, although interest rates are often higher than in industrialized countries, this rate of return is still extraordinary. The present value of the net benefits from the ISRA/CRSP collaboration are over $32 million USD; when annualized, this benefit is approximately $1.8 million USD.

As the impact of Operation Cowpea was both significant, and occurred early in the planning period, the benefits of this program dominate the economic returns estimates. Unfortunately, however, the majority of the benefits of this program were short-lived, and were attributable in some part to the unique circumstances under which this program was launched. To isolate the impact of Operation Cowpea from that of the other influences, a series of sensitivity tests were performed. These tests determined that Operation Cowpea alone provided a return of 16.44%; this rate, although below the 92% rate of return reported by Schwartz *et al.*, (1993) is substantial and is higher than what is sometimes generated by such projects.

Independent analysis of economic impact of the agronomy and breeding programs, similarly indicates above-average rates of return. When examining the results of the storage technology alone, this project was determined to have an internal rate of return (IRR) of 15.4%. The breeding program was similarly successful and generated an IRR of 12.8%. Again, these rates of return are substantially above long-term equity interest rates and reflect the potential returns investment in sound development initiatives can make. Overall, whether examined together or in isolation, the benefits generated through the collaboration of the ISRA/ Bean-Cowpea CRSP, are substantial. Through the products of their partnership, these organizations have proven themselves to be an excellent investment for the U.S. and Senegalese governments.

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APPENDIX I

TABLES

Table 12 Geographic and sampling characteristics of random sample villages and former mini-kit villages

VILLAGE	REGION	DEPARTMENT	ARRONDISSEMENT	SAMPLE SUB-SET	DATE OF VILLAGE VISIT
Doga Dekk Rey	Louga	Linguere	Yang-Yang	New Community	May 31
Melakh	Louga	Linguere	Sagatta	New Community	May 31
Gatt Ngaraf1	Diourbel	Bambey	Ngoye	Repeat Community - Mini-Kit	May 30
Niomre Lo	Louga	Louga	Mbediene	Repeat Community	June 1
Sakal	Louga	Louga	Sakal	New Community - Mini-Kit	June 1
Koure Mbelgor	Louga	Kebemer	Sagatta	New Community	June 2
N'Datt Fall	Louga	Kebemer	Sagatta	Repeat Community -Mini-Kit	June 2
Baghathie	Louga	Kebemer	Darou-Mousty	New Community	June 2
M'Bobene Gouye	Diourbel	Diourbel	Ndindy	Repeated Community	June 3
Fass Thiam Darou Khoudos	Louga	Kebemer	Darou-Mousty	Repeated Community	June 3
N'Diompi	Thies	Tivaouane	Niahkene	Repeated Community	June 4
N'Diassane	Thies	Tivaouane	Pambel	Repeated Community	June 4
Khoudiadiene	Thies	Tivaouane	Pambel	New Community	June 5
Sine Macoumba	Thies	Tivaouane	Merina Dakhar	New Community	June 5
Thilmakha Ndoucoumane	Thies	Tivaouane	Niakhene	New Community - Mini-Kit	June 5
Keur Samba Yacine (Taiba)	Diourbel	Bambey	Baba Garage	New Community	June 7
Taiba Moutoupha	Diourbel	Diourbel	Ndindy	New Community	June 7
Kaire Malick	Diourbel	Bambey	Baby Garage	Repeat Community	June 7

Table 13 Characteristics of random sample and on-farm trial villages

Village	Ethnic Majority	Number of Compounds	Population	Agricultural Crop Activity			Distance to Market [1] (km)	Distance to Insecticide (km)
				Primary	Secondary	Tertiary		
Doga Dekk Rey	Poular	17	940	Millet	Cowpea	Peanut	24	24
Melakh	Wolof	207	1700	Cowpea	Millet	Peanut	11	80
Gatt Ngaraf1	Serere	107	1136	Millet	Peanut	Sorghum	3	3
Niomre Lo	Wolof	132	NA	Peanut	Cowpea	Millet	0	12
Sakal	Wolof	125	NA	Millet	Cowpea	Peanut	0	32
Koure Mbelgor	Wolof	23	232	Peanut	Cowpea	Millet	5	5
N'Datt Fall	Wolof	29	NA	Cowpea	Millet	Peanut	10	10
Baghathie	Wolof	18	109	Millet	Cowpea	Peanut	14	14
M'Bobene Gouye	Wolof	33	213	Millet	Cowpea	Peanut	5	5
Fass Thiam Darou Khoudos	Wolof	9	54	Millet	Cowpea	Peanut	7	30
N'Diompi	Wolof	43	171	Millet	Cowpea	Peanut	5	5
N'Diassane	Maure	163	2232	Millet	Peanut	Cassava	2	10
Khoudiadiene	Serere	16	186	Cassava	Millet	Cowpea	12	10
Sine Macoumba	Wolof	55	18	Millet	Cowpea	Peanut	7	7
Thilmakha Ndoucoumane	Wolof	41	420	Millet	Cowpea	Peanut	2	2

Keur Samba Yacine (Taiba)	Wolof	29	321	Millet	Peanut	Cowpea	5	5
Taiba Moutoupha	Wolof	63	597	Millet	Cowpea	Peanut	0	20
Kaire Malick	Wolof	13	111	Millet	Peanut	Cowpea	5	9
Simple Average/Majority [2]	Wolof (78%)	62.4	596	Millet (72.2%)	Cowpea (61.1%)	Peanut (50%)	6.5	15.7

[1] 'Distance to Market' refers to the closest market for cowpea grain. In instances where '0' is noted indicates that cowpea grain is bought/sold in the community market.
[2] 'Majority' indicates the response provided by the greatest number of respondents; the proportion of respondents who provided that response is indicated in brackets.

Table 14 Characteristics of cowpea production in the random sample and former mini-kit on-farm trial villages

VILLAGE	NUMBER (%) OF CONCESSIONS WHO PRODUCE CP	CROP CHARACTERISTICS NO. COMPOUNDS (% LAND)[1]	CP CULTIVATED TOTAL AREA (CONCESSION AVG) HA	HARVEST TOTAL KG (AVG KG / C)	AVERAGE HARVEST KG / HA
Doga Dekk Rey	17 (100%)	Pure: 17 (100%)	220 (12.94)	12500 (735.3)	56.8
Melakh	207 (100%)	Pure: 207 (100%)	500 (2.42)	80000 (386.5)	160
Gatt Ngaraf1	107(100%)	Association: 107 (99%) Pure: 4 (1%)	198 (1.85) 2 (0.5)	5000 (46.7)	25.3
Niomre Lo	132(100%)	Pure: 132 (100%)	800(1.56)	160000 (1212)	200
Sakal	N.A.	N.A.	N.A.	N.A.	N.A.
Koure Mbelgor	23(100%)	Pure: 23 (100%)	40 (1.74)	25000 (1087)	625
N'Datt Fall	29(100%)	Pure: 29 (100%)	160(5.52)	10000 (345)	62.5
Baghathie	18 (100%)	Pure: 18 (100%)	70 (3.89)	20 000 (1111)	285.7
M'Bobene Gouye	33(100%)	Association: 13 (39%) Pure: 20 (61%)	30(0.023) 47(2.35)	N.A. N.A.	N.A. N.A.
Fass Thiam Darou Khoudos	9 (100%)	Pure: 9 (100%)	25 (2.78)	4 500 (500)	180
N'Diompi	43(100%)	Association: 13 (30%) Pure: 30 (70%)	38.7 (2.97) 90.3(3.01)	200 (15.4) 3000 (100)	5.17 33.22
N'Diassane	60(37%)	Association: 3 (16.6%) Pure: 57 (83.3%)	5 (1.67) 25(0.44)	160 (53.3) 325 (5.70)	32 13
Khoudiadiene	15(93.7%)	Association: 14 (80%) Pure: 12 (20%)	0.4 (0.03) 0.1 (0.008)	500 (35.7) 800 (66.67)	1250 8000
Sine Macoumba	55(100%)	Association: 55 (2%) Pure: 55 (98%)	6 (0.11) 280(5.09)	500 (83.3) 27000 (490.9)	83.3 94.4
Thilmakha Ndoucoumane	41(100%)	Association: 41 (16.7%) Pure: 41 (83.3%)	5(0.12) 125(3.05)	2000 (48.7) 93750 (2286.58)	400 750
Keur Samba Yacine (Taiba)	29(100%)	Association: 29 (5%) Pure: 29 (95%)	5(0.17) 95(3.27)	300 (0.34) 2500 (86.2)	60 26.3

Village	Number (%) of Concessions who produce CP	Crop Characteristics No. Compounds (% land) [1]	CP Cultivated Total Area (Concession Avg) ha	Harvest Total kg (Avg kg / C)	Average Harvest kg / ha
Taiba Moutoupha	63(100%)	Association: 13 (20.6%) Pure: 50 (79.4%)	20 (1.53) 80(1.6)	100 (1.58) 900 (18)	5 11.25
Kaire Malick	13(100%)	Pure: 13 (100%)	3 (0.23)	1000 (76.9)	333.3

[1] As some producers may grow cowpea under conditions of both monocrop and in association with other crops, the total number of concessions who grow cowpea under each strategy will not necessarily sum to the number of concessions in the community who produce cowpea.

These results are from the village surveys.

Table 15 Characteristics of storage technology used in the random sample and former mini-kit on-farm trial villages

Village [1]	Storage Technology	Proportion of Production	Duration of Storage	Use after Storage	Storage Loss
Doga Dekk Rey	Metallic Drum with Phostoxin	100%	6	Sell, Consume, Reserve Seed	0 %
Melakh	Metallic Drum	30%	1	Sell, Consume, Reserve Seed	0%
	Metallic Drum and Phostoxin	20%	24	Sell	0%
	Double Bag and Phostoxin	40%	5	Consumption	0%
	Single Bag and Phostoxin	10%	2	Consumption	10%
Gatt Ngarafl	Metallic Drum	18%	24	Consumption, Sell	0%
	Metallic Drum and Phostoxin	70%	24	Consumption, Sell, Seed	1%
	Triple Bag and Phostoxin	2%	3	N.A.	10%
Niomre Lo	Metallic Drum	100%	9	Consumption, Sell	0%
Sakal	N.A.	N.A.	N.A.	N.A.	N.A.
Koure Mbelgor	Metallic Drum and Phostoxin	100%	1	Consumption, Sell	0%
N'Datt Fall	Metallic Drum and Phostoxin	100%	12	Consumption, Sell	0%
Baghathie	Single Bag	20%	7	Consumption, Sell	N.A.
	Single Bag and Phostoxin	80%	7	Consumption, Sell	30%
M'Bobene Gouye	Metallic Drum and Phostoxin	100%	12	Consumption, Sell	0%
Fass Thiam Darou Khoudos	Metallic Drum	40%	12	Consumption, Sell	0%
	Double Bag and Phostoxin	60%	6	Consumption, Sell	10%
N'Diompi	Metallic Drum and Insecticide	100%	8	Consumption, Sell	0%

VILLAGE [1]	STORAGE TECHNOLOGY	PROPORTION OF PRODUCTION	DURATION OF STORAGE	USE AFTER STORAGE	STORAGE LOSS
N'Diassane	Single Bag Vrac	15% 85%	6	Consumption, Sell	0% (if < 6 months)
Khoudiadiene	Single Bag and Phostoxin Bidon and Phostoxin	80% 20%	7 7	Consumption, Sell Consumption, Sell	0% 0%
Sine Macoumba	Metallic Drum Metallic Drum and Phostoxin	10% 90%	10 10	Consumption, Sell Consumption, Sell	N.A. 0%
Thilmakha Ndoucoumane	Double Bag and Phostoxin	100%	6	Consumption, Sell	0%
Keur Samba Yacine (Taiba)	Single Bag and Phostoxin Metallic Drum and Phostoxin	50% 50%	6 12	Consumption, Seed, Sell Consumption, Seed, Sell	0% 0%
Taiba Moutoupha	Metallic Drum Single Bag with Leaves of Neem	90% 10%	24	Consumption, Sell	0%
Kaire Malick	Metallic Drum with Phostoxin	100%	6	Sell, Consume, Gifts	0%

[1] These results are from the village survey.

Table 16 Comparison of results concerning storage technology and average yield information from 1996 study and 2004 village and individual interviews

Village	Sample Sub-Set	Storage Information					Average Yield Information		
		Results 1996 Survey (Use of Metallic Drum)	Village		Individual		1996 kg/ha	Village kg/ha	Individual kg/ha
			Storage Technology	Proportion of Production	Technology	Percent Use			
Doga Dekk Rey	New Community	N.A.	Metallic Drum with Phostoxin	100%	Metallic Drum Metallic Drum with Phostoxin Double Bag Double Bag with Phostoxin	6.8% 82.9% 4.1% 6.2%	N.A.	56.8	289.6
Melakh	New Community	N.A.	Metallic Drum Metallic Drum and Phostoxin Double Bag and Phostoxin Single Bag and Phostoxin	30% 20% 40% 10%	Metallic Drum with Phostoxin Double Bag with Phostoxin	77.8% 22%	N.A.	160	362.9
Gatt Ngaraf1	Repeat Community - Mini-Kit	6% of population stored part of production in drums	Metallic Drum Metallic Drum and Phostoxin Triple Bag and Phostoxin	18% 70% 2%	Drum Drum with Sand Bidon Single Bag Single Bag with Phostoxin	28.8% 1.6% 19.2% 14.4% 36.0%	408	25.3	330.9
Niomre Lo	Repeat Community	100%	Metallic Drum	100%	Metallic Drum	100%	200	200	72.0

Sakal	New Community - Mini-Kit	N.A.	N.A.	N.A.	Metallic Drum Metallic Drum with Phostoxin Bidon	41.2% 30.2% 28.5%	N.A.	N.A.	156.7
Koure Mbelgor	New Community	N.A.	Metallic Drum with Phostoxin	100%	Metallic Drum with Phostoxin	100%	N.A.	625	234.5
N'Datt Fall	Repeat Community -Mini-Kit	100%	Metallic Drum and Phostoxin	100%	Metallic Drum with Phostoxin Metallic Drum	92.6% 7.42%	118	62.5	238.9
Baghathie	New Community	N.A.	Single Bag Single Bag and Phostoxin	20% 80%	Single Bag with Phostoxin Double Bag with Phostoxin Bidon Bidon with Phostoxin	56.5% 14.5% 14.5% 14.5%	N.A.	285.7	170.7
M'Bobene Gouye	Repeated Community - Mini-Kit	100%	Metallic Drum and Phostoxin	100%	Metallic Drum Metallic Drum with Phostoxin Single Bag with Phostoxin Bidon	2.5% 79.0% 15.2% 3.3%	133	N.A. N.A.	174.2
Fass Thiam Darou Khoudos	Repeated Community	100%	Metallic Drum Double Bag and Phostoxin	40% 60%	Metallic Drum Metallic Drum with Phostoxin Bidon	21.4% 78.4% 1.9%	500	180	251.9

N'Diompi	Repeated Community	100%	Metallic Drum and Insecticide	100%	Metallic Drum with Phostoxin	100%	150	A: 5.17 P:33.22	193.3
N'Diassane	Repeated Community	40% of population store 40% of production in drums	Single Bag Vrac	15% 85%	Metallic Drum with Phostoxin 1	100%	300	A: 32 P: 13	250.0
Khoudiadiene	New Community	N.A.	Single Bag and Phostoxin Bidon and Phostoxin	80% 20%	Double Bag with Phostoxin2	100%	N.A.	A: 1250 P: 8000	150.0
Sine Macoumba	New Community	N.A.	Metallic Drum Metallic Drum and Phostoxin	10% 90%	Metallic Drum with Phostoxin Bidon with Phostoxin	94.4% 5.6%	N.A.	A: 83.3 P: 94.4	303.9
Thilmakha Ndoucoumane	New Community - Mini-Kit	N.A.	Double Bag and Phostoxin	100%	Metallic Drum with Phostoxin Bidon with Phostoxin Single Sac with Phostoxin	67.6% 27.9% 4.5%	N.A.	A: 400 P:750	146.4
Keur Samba Yacine (Taiba)	New Community	N.A.	Single Bag and Phostoxin Metallic Drum and Phostoxin	50% 50%	Metallic Drum Metallic Drum with Phostoxin	13.1% 86.9%	N.A.	A: 60 P: 26.3	158.8
Taiba Moutoupha	New Community	N.A.	Metallic Drum Single Bag with Leaves of Neem	90% 10%	Metallic Drum Metallic Drum with Phostoxin In pile mixed with straw	7.4% 7.4% 85.2%	N.A.	A: 5 P: 11.25	103.0

Kaire Malick	Repeat Community	100%	Metallic Drum with Phostoxin	100%	Metallic Drum with Phostoxin Metallic Drum with Sand Bidon with Sand	54.5% 34.6% 10.9%	200	333.3	54.0

A = Association; P = Pure

1. Note: Some individuals also noted use of Single and Double bags (without Phostoxin), and Metallic Drum with Sand. These individuals, however, did not have any harvest in recent years and as these results do not reflect use of these storage technology.

2. Note: Some individuals also noted use of Little Granaries, and Metallic Drums with Sand. These individuals, however, did not have any harvest in recent years and as these results do not reflect use of these storage technology.

Table 17 Characteristics of Storage Technology Use

Technology [1]	# Users (2003) [2,3]	Average Quantity Stored (2003)	Proportion Users (%)	Proportion Total Production (%)	Average Min Storage Pd. (months)	Average Max Storage Period (months)
Metallic Drum	17	234.5	18.9	10.0	6.3	15.4
Metallic Drum + Phostoxin	41	629.6	45.5	73.0	5.1	12.4
Metallic Drum + Sand	4	95	4.4	0.3[5]	2	7.3
Single Bag	1	** [4]	1.1	**	2	4
Single Bag + Phostoxin	5	258	5.6	3.6	3.1	5.8
Single Bag + Sand	1	150	1.1	0.4	12	36
Double Bag + Phostoxin	6	186	6.7	2.6	2.2	4.4
Bidon	5	161.2	5.6	1.8	4.9	10.2
Bidon + Phostoxin	7	300	7.8	5.9	6.6	12.3
Bidon + Sand	1	30	1.1	0.1	5	6
Granary + Leaves	1	** [4]	1.1	**	5	8
Vrac (Pile in Straw)	1	800	1.1	2.3	1	3

[1] Several other options of storage technology were provided to subjects, but which no respondent reported using. Among the more notable of these are Double Bag (only), Triple Bagging techniques, and the use of Jars.
[2] As several respondents reported using more than one storage technology, the number of users of technologies does not sum to the total number of respondents.
[3] Responses concerning the type of storage technology used was not received from four subjects concerning the type of storage technology they used.
[4] Although subjects reported using this technology, none had any harvest in the field year in question (2003).
[5] Only one of the four subjects who reported using this technology had any harvest in the field year in question (2003).

Table 18 Percent of village production by variety

Village[1]	58-57	BNG	Ndiaga Aw	Ndiassiw	Other [2]	Improved Varieties		
						CB5	Melakh	Mouride
Doga Dekk Rey	60.97%	1.62%	37.40%	-	-	-	-	-
Melakh	61.11%	**	38.90%	-	-	**	**	-
Gatt Ngarafl*	-	45.56%	1.68%	32.37%	**	20.38%	-	-
Niomre Lo	42.98%	7.86%	48.74%	-	-	-	0.42%	-
Sakal*	19.67%	6.34%	57.11%	5.08%	-	-	11.80%	-
Koure Mbelgor	-	16.67%	81.16%	2.17%	-	-	-	-
N'Datt Fall*	0.37%	0.56%	99.07%	-	-	-	-	-
Baghathie	13.27	4.42%	73.45%	-	-	-	8.85%	-
M'Bobene Gouye	-	51.52%	-	-	-	-	48.48%	-
Fass Thiam Darou Khoudos	15.33%	-	84.67%	-	-	-	-	-
N'Diompi	6.31%	6.64%	87.04%	-	-	-	-	-
N'Diassane	20.0%	40.0%	40.0%	**	-	-	-	-
Khoudiadiene	-	33.33%	-	66.67%	-	-	-	-
Sine Macoumba	-	32.07%	65.66%	0.38%	-	-	1.89%	-
Thilmakha Ndoucoumane*	12.27%	26.78%	52.00%	-	1.34%	-	3.79%	3.79%
Keur Samba Yacine (Taiba)	-	55.14%	34.16%	10.70%	-	-	-	-
Taiba Moutoupha	-	100.0%	**	**	-	-	-	-

Kaire Malick	-	20.0%	64.0%	**	-	-	16.0%	-
Average - All	14.98%	16.29%	62.97%	1.47%	0.17%	0.24%	3.39%	0.49%
Average - Former Mini-Kit	7.42%	12.81%	72.30%	1.81%	0.50%	0.71%	3.00%	1.43%
Average - Randomly Selected	18.86%	18.08%	58.17%	1.30%	0.00%	0.00%	3.58%	0.00%
Weighted Average[4]	18.812%	18.058%	58.229%	1.302%	0.002%	0.003%	3.578%	0.006%
T-test [3]	2.306 (p<0.500)	2.145 (p<0892)	2.160 (p<0.335)	2.776 (p<0486)	N.A.	N.A.	2.571 (p<0.954)	N.A.

Notes:

1 Data is from individual interview results

2 'Other' varieties include B819, M'Bay Ngagne

3 T-tests performed were two-sample tests which assumed equal variance. This test evaluated potential difference mean variety production of the former min-kit villages and the randomly selected villages

4 This measure considered the estimated total number of villages in the geographic region of interest (1915), and proportionately weighted the number of mini-kit (8), and non-mini-kit villages (1907)

Legend:

* Mini-Kit Community

** Individuals reported the use of these varieties

\- No production reported of these varieties in these villages

APPENDIX II

VILLAGE SURVEY

ENQUETE SOCIO-ECONOMIQUE DE LA RECHERCHE SUR L'ADOPTION DES TECHNOLOGIES AMELIOREES DE STOCKAGE DU NIEBE AU SENEGAL.

QUESTIONNAIRE DU VILLAGE

A REMPLIR UNE FOIS PAR VILLAGE

1. Information générales

a) Nom de l'observateur ____

b) Nom du village ____

c) Arrondissement ____

d) La pluviométrie moyenne annuelle: ______________________________________

e) Population du village : Hommes __________ Femmes : __________ Enfants : __________

f) Nombre de ménages dans le village __________

g) Nombre de ménages dans le village qui font le niébé __________

h). Quel est le groupe ethnique majoritaire dans le village?
☐Wolof ☐Poular ☐ Sérère ☐ Maure ☐Autre:__________

2. Quelles sont les principales spéculations par ordre d'importance de la superficie semée?

No.	Spéculations	Superficie moyenne emblavée (ha)
1.		
2.		
3.		
4.		
5.		
6.		
7.		

3. Est-ce qu'il y a un marché dans le village? ô Oui ô Non

b) Si oui, commentaires de ce marché.

____

____

____

c) Quelle est sa fréquence? ô Journalier ô Hebdomadaire ô Autres formes (précisez) :___

d) Rayon de fréquentation? __________km

e) Autres commentaires sur le marché – Produits vendus

4.Quelle est la distance du marché le plus proche où on peut vendre du niébé? ____________ km

5. Quelle est la distance à parcourir pour acheter le matériel de stockage et les insecticides pour le traitement phytosanitaire du niébé ?

Matériel ou produits _____________________________________ Distance: ______________km

Matériel ou produits _____________________________________ Distance: ______________km

Matériel ou produits _____________________________________ Distance: ______________km

LA PRODUCTION DU NIEBE

6. Quelles sont les principales variétés du niébé par ordre d'importance de la superficie semée?

No.	Spéculations	Superficie moyenne emblavée (ha)
1.		
2.		
3.		
4.		
5.		

7. Avec quelle autre culture le niébé est-il associé ?

Culture associée avec niébé	Proportion de la superficie réservée au niébé (%) ?

8. Questions relatives à la production du niébé en association et en culture pure.

	Association	Pure
a) Nombre de ménage dans le village qui font le niébé? (voir question 1.e pour consistance)		
b) Superficie moyenne de niébé / ménage?		
c) La quantité de semence moyenne pour semer un hectare?		
d) La proportion (%) des champs de niébé traités avec de l'insecticide?		
e) La quantité moyenne du niébé récoltée par ménage? (précisez l'unité)		

9. Quelles sont les principales contraintes liées á l'utilisation des variétés améliorées?

____

____

____

10. Les techniques de stockage du niébé

Technologies de stockage	Proportion des producteur de niébé qui utilisent (%)	Proportion de la production traitée (%)	Types d'insecticide	Durée du stockage	Utilisation du niébé après stockage	Perte de stockage (% ou quantité)
Fût métallique (seulement)						
Cendre						
Triple ensachage (seulement)						
Double ensachage (seulement)						
Un sac (seulement)						
Triple ensachage + Insecticide						
Double ensachage + Insecticide						
Un sac + Insecticide						
Séchage solaire en plastique + Triple ensachage						
Séchage solaire en plastique + Fût métallique						
Fût métallique et insecticide						
Autres:						

11.a) Les techniques de stockage différent elles selon les variétés du niébé? ☐Oui ☐Non

b) Si oui, citez les variétés destinées à la vente et celles destinées à la consommation.

Variétés	Vente	Consommation	Type de stockage

11. Est-ce qu'il y a eu des incidents liés à la conduite des activités agricoles? (blessures ou mort)

____

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APPENDIX III

INDIVIDUAL SURVEY

ENQUETE SOCIO-ECONOMIQUE DE LA RECHERCHE SUR L'ADOPTION DES TECHNOLOGIES AMELIOREES DE STOCKAGE DU NIEBE AU SENEGAL

QUESTIONNAIRE INDIVIDUEL

I - L'INFORMATION GENERALE DU VILLAGE

1. Information à compléter avant le début de l'interview

a) Nom de l'enquêteur ____

b) Nom du village ____

c) Arrondissement ____

II - L'INFORMATION GENERALE DU REPONDANT

2. Nom: ____________________ **3. Genre**: H____ F_____ **4. Age**: __________

5. Statut matrimonial du répondant:
Î Marié Î Divorcé Î Célibataire Î Veuf(ve) Î Autre: ________________

6. Nombre actifs/genre dans le ménage: Adultes: H____ F____ Enfants: G ____ F ____

7. Bénéficiez-vous d'un encadrement pour vos activités agricoles? Î Oui Î Non
b) Si oui, par qui ?
Î Recherche Î ANCAR Î DRDR Î ONGs ÎAutres (précisez) _________

8. Nombre d'années d'expérience dans la production du niébé: ___________

9. Niveau d'éducation et nombre des ans:
Î Aucun Î Primaire _____ Î Secondaire _____ Î Universitaire _____
Î Formation _____ Î Autre: ______________________________

10. Membre d'une association villageoise: Î Oui Î Non
b) Si oui, lesquels? ____

11. Activités principales de l'individu enquêté:
ÎAgriculture ÎCommerce ÎTransformation agricole ÎÉlevage ÎAutres:__________

12. Activités secondaires de l'individu enquêté:
ÎAgriculture ÎCommerce ÎTransformation agricole ÎÉlevage ÎAutres:__________

III - QUESTIONS SUR LES VARIETES AMELIOREES DU NIEBE

13. Superficie totale emblavée en niébé en 2003: _______ ha.

14. Production totale de niébé en 2003: ________ kg

15. Question sur les variétés

	Variétés 1	Variétés 2	Variétés 3	Variétés 4
Nom de la Variété				
Semer en en pure ou en association (préciser culture associée)				
Première année où la variété a été semée?				
Source de semence en 2003?				
Superficies en 2003 (ha)?				
Quantité de niébé semée en 2003?				
Densité en 2003 (en cm où unité locale)				
Combien de traitements phytosanitaire ont été faits en 2003				
Quantité récoltée en 2003 (précisez l'unité)				

16. Quels sont les avantages et les inconvénients des Variétés

Variétés	Avantages	Inconvénients
Variété 1 :		
Variété 2 :		
Variété 3 :		
Variété 4 :		

IV - QUESTIONS SUR LES NOUVELLES METHODES DE STOCKAGE

17. Quelles méthodes de stockage avez-vous utilisé pour la récolte en 2003?

Types de stockage	Pourquoi vous utilisez cette méthode	Pourquoi vous n'utilisez pas cette méthode	Comment avez-vous connu cette méthode
Fût Métallique (Seulement)			
Double Ensachage (Seulement)			
Triple Ensachage (Seulement)			
Grenier (Seulement)			
Sac Simple (Seulement)			
Bidon (Seulement)			
Canari (Seulement)			
Séchoir Solaire + Fût Métallique			
Séchoir Solaire + Triple Ensachage			
Fût Métallique + Sable (%_____)			
Cendre			
Insecticide pour le stockage spécifier:________			
Autres spécifier: __________			

18. Avez-vous rencontré des difficultés avec la méthode de stockage utilisée? ꞁOui ꞁNon
b) Si oui, citez-les et les solutions trouvées:

Type de stockage	Problèmes notés	Solutions trouvées

19. Question sur les étapes du stockage de niébé :

Etapes suivies	Comment	Durée	Matériel utilisé

20. Les questions sur le matériel de stockage et la main d'œuvre nécessaire pour chaque type de stockage. (Coût des sacs, plastique, insecticide, etc.)

<table>
<tr><th rowspan="3">Technologies de stockage</th><th colspan="5">Matériel pour stockage</th><th colspan="6">Quantité Main d'œuvre (jour)</th></tr>
<tr><th rowspan="2">Nombre utilise</th><th rowspan="2">Année D'acqui sition</th><th rowspan="2">Prix Unitaire au moment de l'achat</th><th rowspan="2">Prix actuel (2004)</th><th rowspan="2">Durée de vie utile</th><th colspan="2">Hommes</th><th colspan="2">Femmes</th><th colspan="2">Enfants</th></tr>
<tr><th>No.</th><th>Coût</th><th>No.</th><th>Coût</th><th>No.</th><th>Coût</th></tr>
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</table>

21. Les techniques de stockage du niébé

Technologies de stockage	Proportion de la production stockée (%)	Utilisation après stockage	Perte de stockage (% ou quantité)	Causes de pertes de stockage

22. Question sur le stockage du niébé ?

Variétés	Type de stockage	Durée de stockage		Utilisation faite du niébé stocké	Fréquence d'utilisation de ce stock
		Maximum	Minimum		

V - QUESTIONS SUR LA COMMERCIALISATION DU NIEBE

23. Avez-vous vendu du niébé en 2003? ꙰**Oui** ꙰ **Non**

b) Si oui, citez les variétés vendues en 2003.

Variétés	**Marché**	**Prix (CFA / kg) et date**	**Quantité Vendue (kg)**	**Moyen Transport (notez coût si pertinent)**

24. Mode d'acquisition du matériel de stockage *(Par exemple, utiliser des économies où faire un emprunt.)*________________________________

____

____

____

____

25. Existe t-il un système de prêt relatif à l'acquisition du matériel de stockage pour les hommes? ☐ **Oui** ☐ **Non**

b) Si oui, avez-vous une idée sur les détails? ***(Par exemple:où, intérêt, plan de remboursement)***

___

___

___

26. Existe t-il un système de prêt relatif à l'acquisition du matériel de stockage pour les femmes? ☐ **Oui** ☐ **Non**

b) Si oui, avez-vous une idée sur les détails? ***(Par exemple:où, intérêt, plan de remboursement)***

___

___

___

VI - AUTRES QUESTIONS

27. Qui prend les décisions dans le ménage?

Types de décisions	Femmes mariées	Hommes mariés	Femmes célibataires	Hommes célibataires	Commentaires
Les variétés du niébé emblavées:					
Superficie totale emblavée en niébé					
Le stockage du niébé					
L'achat d'intrant					
Où vendre le niébé					
Quand vendre le niébé					
Quantité de niébé à vendre					

28. Incidences des technologies de stockage utilisées sur la sécurité alimentaire de la famille. *Pour ceux qui utilisent les technologies améliorées de stockage.*

___

___

___

APPENDIX IV

BASELINE SCENARIO CALCULATIONS

Table 19 Parameters Used in Baseline Analysis

Parameters			
D1 Elasticity		-0.5	
D2 Elasticity		-0.5	
Supply Elasticity		0.8	
Storage Loss (%)	Old Technology	25%	
	New Technology	0.60%	
Phi	Old Technology	1.333333333	
	New Technology	1.006036217	
Storage Cost	Old Technology	21400	FCFA/MT
	New Technology	21830	FCFA/MT
	Change in Cost	-430	FCFA/MT
r		0.144	
rho		1.168224299	
Adoption: - year, rate	1986	0.001	
M		0.7083832	
b		707.3832	
Sold / Consumed in First Period		0.7	

Table 20 Fulgie-Muth Model of Storage Benefits

Crop Season	Adoption	Average Alpha	Average Beta	P1 FCFA	P2 FCFA	QT MT	Q1 MT	QS MT	Q2 MT
1980	0.000	0.000	0.000	30096	35706	20889	14622.3	6266.7	4700.0
1981	0.000	0.000	0.000	39216	46526	25800	18060.0	7740.0	5805.0
1982	0.000	0.000	0.000	39216	46526	10889	7622.3	3266.7	2450.0
1983	0.000	0.000	0.000	39216	46526	12858	9000.6	3857.4	2893.1
1984	0.000	0.000	0.000	54720	64920	15795	11056.5	4738.5	3553.9
1985	0.000	0.000	0.000	100320	119020	65966	46176.2	19789.8	14842.4
1986	0.001	0.000	-0.430	100320	119020	54863	38404.1	16458.9	12348.2
1987	0.003	0.001	-1.166	100320	119020	28625	20037.5	8587.5	6446.3
1988	0.007	0.002	-3.149	86640	102790	24405	17083.5	7321.5	5504.2
1989	0.020	0.006	-8.410	91200	108200	266350	186445.0	79905.0	60310.1
1990	0.051	0.017	-21.826	72960	86560	12242	8569.4	3672.6	2799.9
1991	0.123	0.040	-52.825	145920	173120	166679	116675.3	50003.7	39001.6
1992	0.257	0.084	-110.627	36480	43280	16833	11783.1	5049.9	4104.4
1993	0.431	0.141	-185.164	54720	64920	43993	30795.1	13197.9	11285.1
1994	0.573	0.187	-246.185	72960	86560	28980	20286.0	8694.0	7735.0
1995	0.652	0.213	-280.148	91200	108200	41911	29337.7	12573.3	11428.7
1996	0.686	0.225	-295.127	168720	200170	20626	14438.2	6187.8	5677.1
1997	0.700	0.229	-301.048	150480	178530	33131	23191.7	9939.3	9152.4
1998	0.705	0.231	-303.287	278160	330010	40620	28434.0	12186.0	11236.7
1999	0.707	0.231	-304.119	155040	183940	68000	47600.0	20400.0	18820.4
2000	0.708	0.232	-304.426	150480	178530	47290	33103.0	14187.0	13091.0
2001	0.708	0.232	-304.539	296400	351650	31720	22204.0	9516.0	8781.4
2002	0.708	0.232	-304.581	383040	454440	12805	8963.5	3841.5	3545.1
2003	0.708	0.232	-304.596	510720	605920	15000	10500.0	4500.0	4152.8
2004	0.708	0.232	-304.601	299136	354896	34963	24474.1	10488.9	9679.6
2005	0.708	0.232	-304.604	299136	354896	34963	24474.1	10488.9	9679.6
2006	0.708	0.232	-304.604	299136	354896	34963	24474.1	10488.9	9679.6
2007	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2008	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2009	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2010	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6

2011	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2012	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2013	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2014	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2015	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2016	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2017	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2018	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2019	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
2020	0.708	0.232	-304.605	299136	354896	34963	24474.1	10488.9	9679.6
Average 1999-2003				299136	354896	34963	24474.1		
Notation:									
Alpha	Change is storage loss factor with new technology								
Beta	Change in storage cost per unit with new technology								
P1	Average price (per MT) in period October to March (Period 1); estimated as 91.2% of the average annual cowpea grain price								
P2	Estimated price (per MT) in period from April to September (Period 2); estimated as 108.2% of the average annual cowpea grain price.								
QT	Total National Production: Data after technical change. (FAO Stat 2004)								
Q1	Cowpea sold or consumed by farmers from October to March (Period 1). Data after technical change								
Qs	Cowpea put into storage for the second period. Data after technical change								
Q2	Cowpea sold or consumed by farmers from October to March (Period 2). Data after technical change								
Consumer Surplus Calculation for Storage Technology									

Table 21 Consumer Surplus Calculation for Storage Technology

Crop Season	dP1	dQ1	dP2	dQ2	dQT	CS1	CS2	PS
1980	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1981	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1982	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1983	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1984	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1985	0.000	0.000	0.000	0.000	0.0000	0	0.0	0.0
1986	0.000	0.000	-46.925	0.000	0.0000	4.92E+04	5.79E+05	-7.03E+04
1987	0.000	0.000	-127.250	0.001	0.0000	6.96E+04	8.20E+05	-9.95E+04
1988	0.000	0.000	-302.423	0.001	-0.0001	1.28E+05	1.66E+06	-1.83E+05
1989	0.000	0.000	-844.582	0.004	-0.0002	4.07E+06	5.08E+07	-5.81E+06
1990	-0.001	0.000	-1811.314	0.010	-0.0004	3.38E+05	5.05E+06	-4.83E+05
1991	-0.002	0.001	-8086.088	0.023	-0.0015	3.16E+07	3.12E+08	-4.52E+07
1992	-0.001	0.000	-5322.078	0.061	-0.0005	2.54E+05	2.12E+07	-3.62E+05
1993	-0.004	0.002	-12179.062	0.094	-0.0029	6.19E+06	1.31E+08	-8.87E+06
1994	-0.007	0.003	-20561.884	0.119	-0.0055	1.02E+07	1.50E+08	-1.46E+07
1995	-0.009	0.005	-28372.977	0.131	-0.0074	2.47E+07	3.03E+08	-3.55E+07
1996	-0.012	0.006	-52090.785	0.130	-0.0099	2.99E+07	2.76E+08	-4.31E+07
1997	-0.012	0.006	-47820.394	0.134	-0.0098	4.26E+07	4.08E+08	-6.13E+07
1998	-0.014	0.007	-85746.967	0.130	-0.0111	1.10E+08	9.01E+08	-1.58E+08
1999	-0.012	0.006	-49658.659	0.135	-0.0100	9.18E+07	8.72E+08	-1.32E+08
2000	-0.012	0.006	-48362.557	0.135	-0.0099	6.16E+07	5.90E+08	-8.86E+07
2001	-0.014	0.007	-91494.309	0.130	-0.0113	9.24E+07	7.51E+08	-1.33E+08
2002	-0.014	0.007	-117109.206	0.129	-0.0116	4.96E+07	3.88E+08	-7.15E+07
2003	-0.015	0.007	-154846.704	0.128	-0.0119	7.92E+07	6.02E+08	-1.14E+08
2004	-0.014	0.007	-92321.888	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2005	-0.014	0.007	-92322.524	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2006	-0.014	0.007	-92322.758	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2007	-0.014	0.007	-92322.844	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2008	-0.014	0.007	-92322.876	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2009	-0.014	0.007	-92322.888	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2010	-0.014	0.007	-92322.892	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08

2011	-0.014	0.007	-92322.893	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2012	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2013	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2014	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2015	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2016	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2017	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2018	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2019	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
2020	-0.014	0.007	-92322.894	0.130	-0.0113	1.03E+08	8.36E+08	-1.48E+08
Notes:								
dP1	Proportional change in Period 1 price = dP1/P1 evaluated at prices after technical change							
dQ1	Proportional change in Period 1 consumption and sales by producers evaluated at quantities observed after technical change							
dP2	Change in Period 2 price evaluated at prices after technical change (P2*dP2*=dP2)							
dQ2	Proportional change in Period 2 consumption and sales by producers evaluated at quantities after technical change.							
dQT	Proportional change in total consumption and sales by producers evaluated at quantities after technical change							
CS1	Change in consumer surplus in Period 1 due to technical change in storage							
CS2	Change in consumer surplus in Period 2 due to technical change in storage							
PS	Change in producer surplus due to technical change in storage; occurs only in Period 1.							

Table 22 Other Benefits – Operation Cowpea, green-pod production with CB5, Melakh and Mouride adoption

Melakh & Mouride Adoption Parameters	
First Year	1992
Observed Adoption Rate	0.0188
Observation Year	2003
Plateau	0.03584
B	54268.90292
Yeild Advantage	0.4
Green Pod Price	565

Table 23 Other Benefits – Operation Cowpea, green-pod production with CB5, Melakh and Mouride

Crop Season	Cowpea Area[1]	Cowpea Yeild[1, 5]	Average Cowpea Price	Senegal CPI[3]	Schwartz et al. Scenario 2[3]
1980	50000	417.80	33	37.95	
1981	59183	435.90	43	40.19	
1982	45886	237.30	43	47.18	
1983	39433	326.10	43	52.66	
1984	52498	300.90	60	58.86	
1985	120716	546.50	110	66.52	8022272
1986	117607	466.50	110	70.63	6355491
1987	71480	400.50	110	67.71	
1988	70687	345.30	95	66.47	
1989	64809	406.66	100	66.77	
1990	45334	270.00	80	66.98	
1991	50744	328.70	160	65.81	
1992	73653	228.50	40	65.74	
1993	118432	371.50	60	65.35	
1994	91504	316.70	80	86.46	
1995	97479	429.90	100	93.26	
1996	88623	232.70	185	95.82	
1997	88000	376.50	165	97.33	
1998	123365	329.30	305	98.46	
1999	170000	400.00	170	99.27	
2000	146464	322.90	165	100.00	
2001	90685	349.80	325	103.07	
2002	1325966	96.60	420	105.37	
2003	120000	125.00	560	105.34	
2004	370623	258.86	328	105.34	
2005	370623	258.86	328	105.34	
2006	370623	258.86	328	105.34	
2007	370623	258.86	328	105.34	
2008	370623	258.86	328	105.34	
2009	370623	258.86	328	105.34	
2010	370623	258.86	328	105.34	

2011	370623	258.86	328	105.34	
2012	370623	258.86	328	105.34	
2013	370623	258.86	328	105.34	
2014	370623	258.86	328	105.34	
2015	370623	258.86	328	105.34	
2016	370623	258.86	328	105.34	
2017	370623	258.86	328	105.34	
2018	370623	258.86	328	105.34	
2019	370623	258.86	328	105.34	
2020	370623	258.86	328	105.34	

Notes:
[1] Data from FAO Stat 2004
[2] Data from 1980-1993 replicated from Lowenberg-DeBoer and Faye (1997); 1994-2003 provided by ISRA Socio-economic group
[3] Senegal CPI: International Financial Statistics (Online): 1980- 2003. Base Year = 2000
[4] Est. green pod price: Price per pound of equivalent amount of dry cowpea. Ratio of green pods to dry grain is assumed to be 1:8.
[5] Cowpea Yield: Calculated as annual production divided by annual area
[6] Data from Schwartz et al. (1993). p. 168.

Table 24 Other Benefits (continued) – Operation Cowpea, green-pod production with CB5, Melakh and Mouride

Crop Season	Estimated Green Pod Price FCFA/kg[4]	Value of CB5 Adoption	Net Melakh and Mouride Value	Estimated Yield kg/ha	Value FCFA	CB5 adoption area
1980	NA	NA	0.0000	NA	0	
1981	NA	NA	0.0000	NA	0	
1982	NA	NA	0.0000	NA	0	
1983	NA	NA	0.0000	NA	0	
1984	NA	NA	0.0000	NA	0	
1985	NA	NA	0.0000	NA	0	
1986	NA	NA	0.0000	NA	0	
1987	363.1683	14495273	0.0000	NA	0	0.0020
1988	356.5175	12766352	0.0000	NA	0	0.0020
1989	358.1265	13605968	0.0000	NA	0	0.0020
1990	359.2529	6836211	0.0000	NA	0	0.0020
1991	352.9775	6437557	0.0000	NA	0	0.0020
1992	352.6021	10522004	0.0043	319.900	3.221E+07	0.0020
1993	350.5103	25563443	0.0027	520.100	5.025E+07	0.0020
1994	463.7355	22240787	0.0035	443.380	5.643E+07	0.0020
1995	500.2079	33542402	0.0033	601.860	8.122E+07	0.0020
1996	513.9387	13567123	0.0000	325.780	3.315E+08	0.0020
1997	522.0377	23658745	0.0001	527.100	1.794E+06	0.0020
1998	528.0985	18126352	0.0003	461.020	4.476E+08	0.0020
1999	532.4430	49292254	0.0007	560.000	2.723E+07	0.0020
2000	536.3585	35125479	0.0019	452.060	5.046E+07	0.0020
2001	552.8247	14453932	0.0047	489.720	6.433E+07	0.0020
2002	565.1609	37186832	0.0103	135.240	4.261E+08	0.0020
2003	565.0000	150000	0.0188	175.000	5.431E+07	0.0020
2004	565.0000	45475309	0.0269	362.404	1.146E+09	0.0020
2005	565.0000	45475309	0.0319	362.404	1.361E+09	0.0020
2006	565.0000	35186271	0.0343	362.404	1.462E+09	0.0020
2007	565.0000	13307515	0.0353	362.404	1.503E+09	0.0015
2008	565.0000	4946622	0.0356	362.404	1.519E+09	0.0006
2009	565.0000	1826770	0.0358	362.404	1.525E+09	0.0002

2010	565.0000	672985	0.0358	362.404	1.527E+09	0.0001
2011	565.0000	247707	0.0358	362.404	1.528E+09	0.0000
2012	565.0000	91144	0.0358	362.404	1.528E+09	0.0000
2013	565.0000	33532	0.0358	362.404	1.528E+09	0.0000
2014	565.0000	12336	0.0358	362.404	1.528E+09	0.0000
2015	565.0000	4538	0.0358	362.404	1.528E+09	0.0000
2016	565.0000	1670	0.0358	362.404	1.528E+09	0.0000
2017	565.0000	614	0.0358	362.404	1.528E+09	0.0000
2018	565.0000	226	0.0358	362.404	1.528E+09	0.0000
2019	565.0000	83	0.0358	362.404	1.528E+09	0.0000
2020	565.0000	31	0.0358	362.404	1.528E+09	0.0000

Notes:

[1] Data from FAO Stat 2004

[2] Data from 1980-1993 replicated from Lowenberg-DeBoer and Faye (1997); 1994-2003 provided by ISRA Socio-economic group

[3] Senegal CPI: International Financial Statistics (Online): 1980- 2003. Base Year = 2000

[4] Est. green pod price: Price per pound of equivalent amount of dry cowpea. Ratio of green pods to dry grain is assumed to be 1:8.

[5] Cowpea Yield: Calculated as annual production divided by annual area

[6] Data from Schwartz et al. (1993). p. 168.

Table 25 Sum of Storage and Varietal Benefits

Crop Season	Storage Benefit FCFA	Exchange Rate[2] FCFA / $	Schwartz et al. [1]	Nominal Storage & Varietal Benefit USD
1980	0	211.28		0
1981	0	271.73		0
1982	0	328.61		0
1983	0	381.07		0
1984	0	436.96		0
1985	0	449.26	8022272	8022272
1986	558297.7877	346.31	6355491	6357103.133
1987	790226.941	300.54		2629.356968
1988	1608371.033	297.85		48261.61947
1989	49093872.73	319.01		196545.0627
1990	4900061.425	272.27		43105.27357
1991	298076234.3	282.11		1079415.09
1992	21063721.25	264.669		241044.5288
1993	128320405.6	283.16		720913.2036
1994	145179751.8	555.21		403175.7277
1995	292221510.5	499.15		815354.4774
1996	263320745.4	511.55		1189383.404
1997	389630451.5	583.67		711161.3962
1998	852515115.3	589.95		2234489.468
1999	831097224.9	615.7		1474127.358
2000	563146038.8	711.98		911170.6176
2001	710372897.8	733.04		1076549.465
2002	366502706.6	696.99		1190515.908
2003	566919742.8	581.2		1069128.188
2004	790053305.9	667.782		2967438.423
2005	790059361.1	667.782		3289661.534
2006	790061588.7	667.782		3425492.901
2007	790062408.2	667.782		3454172.057
2008	790062709.7	667.782		3465131.681
2009	790062820.6	667.782		3469221.244

2010	790062861.4	667.782		3470733.647
2011	790062876.4	667.782		3471291.11
2012	790062881.9	667.782		3471496.336
2013	790062883.9	667.782		3471571.854
2014	790062884.7	667.782		3471599.638
2015	790062884.9	667.782		3471609.86
2016	790062885	667.782		3471613.62
2017	790062885.1	667.782		3471615.003
2018	790062885.1	667.782		3471615.512
2019	790062885.1	667.782		3471615.699
2020	790062885.1	667.782		3471615.768

Notes:
[1] Data from Schwartz et al. (1993). p. 168.
[2] Exchange Rates - Official Rates FCFA per US Dollar (Period Average). Source IFS 1980-2003.

Table 26 Research and extension cost for the drum storage and varietal development (Melakh, Mouride)

Crop Season	B-C Research HC Budget[1] US$	B-C Research US for HC[1] US$	B-C Training[1] US$	B-C Research Cost US$	ISRA Cost[2] US$	Total Research Cost US$	Total Extension[4] FCFA	Total Extension[2] US$
1980	0.00	0.00	0.00	0.00	0.00	0	0	0
1981	0.00	0.00	0.00	0.00	0.00	0	0	0
1982	35173.94	NA	NA	35173.94	105042.02	140216	0	0
1983	117499.20	NA	NA	117499.20	105042.02	222541	0	0
1984	75078.11	NA	NA	75078.11	105042.02	180120	0	0
1985	156888.11	NA	NA	156888.11	105042.02	261930	0	1000000
1986	92301.95	11800.00	11800.00	92301.95	97839.27	190141	0	600000
1987	31050.25	58782.02	30195.77	59636.50	106981.34	166618	0	0
1988	43259.75	31466.82	24485.00	50241.57	110305.43	160547	0	0
1989	58450.00	40289.64	32219.23	66520.41	87583.20	154104	0	0
1990	62015.88	41408.45	24761.64	78662.69	75951.50	154614	0	0
1991	71004.00	17464.66	6546.50	81922.16	74545.88	156468	0	0
1992	44833.00	66976.25	35638.07	76171.18	112779.77	188951	0	0
1993	64311.00	40269.48	15224.00	89356.48	85687.03	175044	0	0
1994	53051.00	21743.98	14420.00	60374.98	41429.73	101805	0	0
1995	65313.00	34707.28	27888.00	72132.28	45405.43	117538	0	0
1996	37923.00	32000.00	32000.00	37923.00	40357.12	78280	0	0
1997	81972.00	0.00	0.00	81972.00	0.00	81972	0	0
1998	94903.00	0.00	0.00	94903.00	0.00	94903	0	0
1999	0.00	0.00	0.00	0.00	0.00	0	0	0
2000	0.00	0.00	0.00	0.00	0.00	0	0	0
2001	0.00	0.00	0.00	0.00	0.00	0	0	0
2002	0.00	0.00	0.00	0.00	0.00	0	0	0
2003	0.00	0.00	0.00	0.00	0.00	0	0	0
2004	0.00	0.00	0.00	0.00	0.00	0	0	0
2005	0.00	0.00	0.00	0.00	0.00	0	0	0
2006	0.00	0.00	0.00	0.00	0.00	0	0	0
2007	0.00	0.00	0.00	0.00	0.00	0	0	0

Crop Season	B-C Research HC Budget[1] US$	B-C Research US for HC[1] US$	B-C Training[1] US$	B-C Research Cost US$	ISRA Cost[2] US$	Total Research Cost US$	Total Extension[4] FCFA	Total Extension[2] US$
2008	0.00	0.00	0.00	0.00	0.00	0	0	0
2009	0.00	0.00	0.00	0.00	0.00	0	0	0
2010	0.00	0.00	0.00	0.00	0.00	0	0	0
2011	0.00	0.00	0.00	0.00	0.00	0	0	0
2012	0.00	0.00	0.00	0.00	0.00	0	0	0
2013	0.00	0.00	0.00	0.00	0.00	0	0	0
2014	0.00	0.00	0.00	0.00	0.00	0	0	0
2015	0.00	0.00	0.00	0.00	0.00	0	0	0
2016	0.00	0.00	0.00	0.00	0.00	0	0	0
2017	0.00	0.00	0.00	0.00	0.00	0	0	0
2018	0.00	0.00	0.00	0.00	0.00	0	0	0
2019	0.00	0.00	0.00	0.00	0.00	0	0	0
2020	0.00	0.00	0.00	0.00	0.00	0	0	0

Notes:
[1] Bean-Cowpea CRSP expenditures from the CRSP accounting office at MSU
[2] ISRA expenditures from the accounting office at the Bambey station.
[3] Extension costs for Operation Cowpea from Swartz et al. 1993.
[4] Extension cost from 1980-1986 are unknown

Table 27 Estimation of real benefits and cost, IRR, NPV

Fiscal Year	US GDP Deflator 2000 = 100	Real Gross Benefit US	Real Research Cost US$	Real Extension Cost US$	Real Net Benefit US$
1979	49.55				
1980	54.04	0.00	0.00	0.00	0.00
1981	59.12	0.00	0.00	0.00	0.00
1982	62.73	0.00	223522.96	0.00	-223522.96
1983	65.21	0.00	341268.54	0.00	-341268.54
1984	67.65	0.00	266252.96	0.00	-266252.96
1985	69.71	11508064.84	375742.54	1434514.42	9697807.88
1986	71.25	8922250.01	266864.87	842105.26	7813279.88
1987	73.2	3592.02	227620.00	0.00	-224027.99
1988	75.69	63762.21	212111.25	0.00	-148349.04
1989	78.56	250184.65	196160.41	0.00	54024.25
1990	81.59	52831.56	189501.39	0.00	-136669.83
1991	84.44	1278321.99	185300.85	0.00	1093021.14
1992	86.39	279019.02	218718.55	0.00	60300.47
1993	88.38	815697.22	198057.83	0.00	617639.39
1994	90.26	446682.61	112790.50	0.00	333892.11
1995	92.11	885196.48	127605.81	0.00	757590.67
1996	93.85	1267323.82	83409.83	0.00	1183913.99
1997	95.41	745374.07	85915.52	0.00	659458.54
1998	96.47	2316253.21	98375.66	0.00	2217877.55
1999	97.87	1506209.62	0.00	0.00	1506209.62
2000	100	911170.62	0.00	0.00	911170.62
2001	102.37	1051625.93	0.00	0.00	1051625.93
2002	103.95	1145277.45	0.00	0.00	1145277.45
2003	105.67	1011761.32	0.00	0.00	1011761.32
2004	105.67	2808212.76	0.00	0.00	2808212.76
2005	105.67	3113146.15	0.00	0.00	3113146.15
2006	105.67	3241689.13	0.00	0.00	3241689.13
2007	105.67	3268829.43	0.00	0.00	3268829.43
2008	105.67	3279200.99	0.00	0.00	3279200.99

Fiscal Year	US GDP Deflator 2000 = 100	Real Gross Benefit US	Real Research Cost US$	Real Extension Cost US$	Real Net Benefit US$
2009	105.67	3283071.11	0.00	0.00	3283071.11
2010	105.67	3284502.36	0.00	0.00	3284502.36
2011	105.67	3285029.91	0.00	0.00	3285029.91
2012	105.67	3285224.13	0.00	0.00	3285224.13
2013	105.67	3285295.59	0.00	0.00	3285295.59
2014	105.67	3285321.89	0.00	0.00	3285321.89
2015	105.67	3285331.56	0.00	0.00	3285331.56
2016	105.67	3285335.12	0.00	0.00	3285335.12
2017	105.67	3285336.43	0.00	0.00	3285336.43
2018	105.67	3285336.91	0.00	0.00	3285336.91
2019	105.67	3285337.09	0.00	0.00	3285337.09
2020	105.67	3285337.15	0.00	0.00	3285337.15
Average 1993-2003	10.86622222				
		Real research cost - min	83409.82724		
		Real research cost – max	375742.5417		

Table 28 Yield on long term US government bonds

Year	Nominal Rate[1] %	GDP Deflator Increase[2] %	Real Interest Rate[3] %
1980	11.46	9.061553986	2.398446014
1981	13.91	9.400444115	4.509555885
1982	13	6.106224628	6.893775372
1983	11.11	3.953451299	7.156548701
1984	12.44	3.741757399	8.698242601
1985	10.62	3.045084996	7.574915004
1986	7.68	2.209152202	5.470847798
1987	8.38	2.736842105	5.643157895
1988	8.85	3.401639344	5.448360656
1989	8.5	3.79178227	4.70821773
1990	8.55	3.856924644	4.693075356
1991	7.86	3.493075132	4.366924868
1992	7.01	2.30933207	4.70066793
1993	5.87	2.30350735	3.56649265
1994	7.08	2.127178095	4.952821905
1995	6.58	2.04963439	4.53036561
1996	6.44	1.889045706	4.550954294
1997	6.35	1.662226958	4.687773042
1998	5.26	1.110994655	4.149005345
1999	5.65	1.451228361	4.198771639
2000	6.03	2.176356391	3.853643609
2001	5.02	2.37	2.65
2002	4.61	1.543420924	3.066579076
2003	4.02	1.654641655	2.365358345
Average 1980 – 2003	8.011666667	3.226895778	4.784770889

Notes:
[1] Data from 1980 - 2003 from IFS Database - US Government 10 Year Bond Yield
[2] GDP Deflator Increase = 100 * (GDP Deflator Present Year - GDP Deflator Previous Year) / GDP Deflator Previous Year
[3] Real Interest Rate = Nominal Interest Rate - GDP Deflator Increase

Table 29 Green Pod Prices Along Highway from Thies to St. Louis (1994)

Day	Month	Unit	Product	Quantity	Total Pod Weight	Price per Unit	Price Per kg	Varieties
14	September	basins	Gousse	8	80	1200	120	Melakh, B21
14	September	bowls	Gousse	4	12	400	133.33	Melakh, B21
14	September	bags	Grains	28	56	100	50	Melakh, B21
21	September	basins	Gousse	172	1720	900	90	Melakh, B21, Mouride
21	September	bowls	Gousse	39	117	300	100	Melakh, B21, Mouride
21	September	bags	Grains	142	284	100	50	Melakh, B21
28	September	basins	Gousse	233	2330	600	60	Melakh, Mougne
28	September	bowls	Gousse	46	174	200	52.87	Melakh, Mougne
28	September	bags	Grains	167	334	100	50	Melakh, B21
5	October	basins	Gousse	322	3220	500	50	Baye Ngagne, Mougne
5	October	bowls	Gousse	58	174	150	50	Baye Ngagne, Mougne
5	October	bags	Grains	75	150	100	50	Mame Fama
9	October	basins	Gousse	295	2950	500	50	Baye Ngagne, Mougne
9	October	bowls	Gousse	67	201	150	50	Ndiaga Aw
9	October	bags	Grains	42	84	100	50	Mame Fama
19	October	basins	Gousse	3	30	850	85	Baye Ngagne
19	October	bowls	Gousse	2	6	300	100	Baye Ngagne
Melakh Simple Average				78				
Dry Grain Equivalent				627.74				
Melakh Simple Gousse Average				93				
Dry Grain Equivalent				741.61				
Melakh Weighted Average				70.57				
Dry Grain Equivalent				564.56				
Source: Faye, Mbene, "Rapport d'Activities 1994/95 du Service Socio-Economie", March 1995.								