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The Rate of Return to Agricultural Research in Uganda: The Case of Oilseeds and Maize

by

Rita Laker-Ojok

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Rita Laker-Ojok*

June 1994

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1. INTRODUCTION

The importance of the agricultural sector to overall development has long been recognized. The contributions of the agricultural sector to the process of national structural transformation, as summarized by Daniels et al. (1990, 7), include the following: "(1) providing food; (2) supplying capital especially for the development of the non-farm sector; (3) providing labor for the expansion of non-farm activities; (4) supplying foreign exchange from export earnings in order to facilitate the purchase of critical inputs from abroad; and (5) providing a market for the products of the non-farm sector." In order for the agricultural sector to make these contributions, it is essential that production exceed the subsistence food needs of the producers. Surplus production is the engine of capital accumulation, and it releases agricultural labor to non-agricultural activities.

Agricultural research (broadly defined to include basic, adaptive, and applied research) can lead to the discovery and diffusion of cost saving techniques which enhance the development process and shape the development pattern. The nature of the technical change determines whether a network of consumption, production, and fiscal linkages between the agricultural and non-agricultural sectors will emerge to contribute to overall economic development. Studies around the world have shown that it generally takes a minimum of six to ten years for new technologies to begin to have an impact on agricultural production practices.

The objectives of this rate of return study are as follows: (1) The determination of the rate of return to previous investments by USAID and GOU in soybean, sunflower, and maize research in Uganda. (2) Determination of the potential returns to future investment in research on each of the major oilseeds in Uganda (soybean, sunflower, groundnut, and sesame). This analysis will systematically consider the impact of other aspects of the technology transfer system (extension, input markets, and product markets), as well as key fiscal policies, on returns to oilseeds research.

This paper is intended to address primarily the first objective of determining the ex-post ROR to maize, sunflower, and soybean research, but will, to a more limited extent, also discuss the anticipated returns to ongoing research in these three commodity programs and outputs expected within the next four years.

2. MAIZE AND OILSEED AGRICULTURE AND RESEARCH

2.1. The Role of Agriculture in Uganda

Uganda faces an important challenge in trying to organize agricultural research and support services to its smallholder producers. Uganda has undergone a dramatic reversal of the agricultural and structural transformation process achieved in the 1960s, as a result of the macro-economic policies and political climate of the 1972-86 period. When Uganda opened up again to the international community after the fall of Amin, the economy was on the verge of total collapse. The decline of the Amin years was exacerbated by the poor macro-policies and internal unrest of the early 80s. By 1986, Uganda had suffered a near total collapse of agricultural research, seed multiplication, output markets, input distribution networks, and extension services.

Domestic markets were disrupted by rapidly declining income levels and underfinanced attempts to create a Produce Marketing Board with monopoly control over maize, beans, groundnuts, soybeans, and sesame. By 1985 per capita incomes had fallen to only 59% of 1971 levels. The situation was much worse in the formal sector, where wages fell to 9% of 1971 levels. Civil servants were unable to meet essential expenses with their salary, and resorted increasingly to moonlighting and petty corruption. Performance standards declined drastically in every department. Exports collapsed, leading to a crisis in rural income generation. Cotton production fell to 2.8% of peak production levels due to gross mismanagement of the cotton cooperatives, which held a monopoly on cotton processing and marketing. Even coffee production fell to 74.2% of its former level.

As a result, the Ugandan farmer today is producing at essentially the same level of productivity as twenty years ago. Virtually no new agricultural methods or technologies have been introduced since the late 1960s. Far worse, many labor-reducing or productivity-enhancing technologies have fallen into disuse in recent years, leaving Ugandan yields much lower than those of other developing countries with similar climatic conditions. National fertilizer consumption has fallen from an estimated average of 1.4 kg/ha in the 1960s to 0.2 kg/ha at the present time, making it among the lowest in the world. Total annual expenditure on agricultural inputs (fertilizers, implements, and agricultural chemicals) is estimated at only $10-$15 per smallholder household. Farmers in those areas of Eastern and Northern Uganda where animal traction had been well established for nearly 50 years have suffered a massive loss of animals due to political insecurity. Suddenly they are forced back into hand hoe cultivation with all of its resulting labor constraints. Staple food production continues to be dependent upon traditional varieties produced from farmers' own retained seed year after year. What results is a vicious cycle of low input/low productivity agriculture which is very difficult to break out of.

Currently, Uganda stands close to the starting point of the agricultural transformation process. The Ugandan economy is heavily dependent upon an agricultural sector that has largely reverted to subsistence production. Agriculture constitutes by far the dominant sector in the economy. Eighty-nine percent of the 1991 population of 16,582,700 are rural. Virtually all rural residents have some access to land use rights for cultivation. There are approximately 2.5 million smallholder farm households in Uganda and 80% of them have under 4 ha of farmland.

In 1990 agriculture constituted 53.3% of Uganda's Gross Domestic Product. Thirty percent of GDP is produced by agriculture in the non-monetary sector consisting of subsistence crops grown for home consumption. Even though agricultural production for the cash economy constituted only 23.6% of GDP in 1990, it accounted for 95% of Uganda's export earnings and over 40% of government revenues.

The future of agricultural research and the potential for agricultural transformation in Uganda are much brighter now. A structural re-organization is under way which, if successful, will greatly strengthen the agricultural sector. This re-organization includes market liberalization in both the input and export markets, rehabilitation of the seed multiplication scheme with particular emphasis on making the scheme self-accountable, and creation of the National Agricultural Research Organization which will be an independent parastatal organization capable of offering more competitive incentives to researchers and demanding greater productivity and accountability.

Since the inauguration of the Economic Recovery Program in May 1987, many positive steps have been taken to reverse the economic decline. Farmers (especially in the South and Southwest) have responded to improved security, political stability, and price incentives by utilizing previously underemployed labor and land resources. Donor assistance to rehabilitate infrastructure and provide credit and inputs have also helped to encourage production increases. The relative freedom from policy-induced distortion in food markets has resulted in consumer demand being reflected in market prices. Tight fiscal management has finally brought relief from the skyrocketing inflation. Foreign exchange markets have been deregulated to allow exchange rates to respond to open-market forces.

While official statistics report that food production per capita fell from its 1975 peak of over 1.4 tons per person to less than 0.9 tons in 1980 and has not yet regained its peak per capita level, Uganda is still 98.6% self-sufficient in food. The one notable exception is in the area of edible oils.

In the 1960s and early 1970s, Uganda was self-sufficient in edible oils. Substantial quantities of these cottonseed-based oils were exported to Kenya and Tanzania. A major factor which contributed to the collapse of the oil industry was the 1972 expulsion of the Asians who owned the national crushing capacity, and the subsequent nationalization of that industrial capacity. This was further exacerbated by the breakdown of the cotton marketing structures under the cooperative monopoly. Lack of operating capital, poor price incentives, and grossly inefficient management led to serious shortages of raw materials for crushing. Commercial edible oil production fell to negligible levels by the mid-70s, and have only recently begun to rise as a result of efforts to develop sunflower as an alternative oil source. Uganda is still highly dependent on commercial cooking oil imports and American PL480 commodity aid.

The challenge facing Uganda is to provide the necessary support services to turn Uganda's widely dispersed, extremely small-scale, largely subsistence agriculture into an engine of economic development after 20 years of political strife and bad macro-economic policies. If small farmers in Uganda are to be able to improve their standard of living, to generate a larger surplus with which to feed a growing urban population, and to contribute to foreign exchange earning through diversified exports, agricultural productivity must be increased.

2.2. Agricultural Research History

Uganda has had a long but checkered history in agricultural research. As early as 1908 the Botanical Gardens in Entebbe began the work of collecting relevant germplasm samples and testing potentially valuable, non-native, tropical crops for possible introduction. The first experiment station was opened in 1922, and the Research Division of the Department of Agriculture was founded in 1937. In 1949 the Cotton Research Corporation opened a regional research station at Namulonge in recognition of Uganda's cotton production potential. By independence in 1962, Uganda had a well-integrated system of two major research stations, two agricultural training colleges, a university farm, nine sub-stations, and 46 District Varietal Trial Centers.

Between 1950 and 1972, the majority of the research effort was focussed on Uganda's principal cash crops of coffee and cotton. A limited amount of work was also done on some 21 other food and cash crops (including sesame and soybeans). This surprising array of research efforts is the result of the wide range of ecological conditions and cultural food preferences in Uganda which puts pressure on the research structures to become overextended.

Achievement of dramatic production increases through research is complicated by Uganda's highly diversified agricultural system. Staple food crops in Uganda are highly varied and regionally concentrated. They include, in order of importance, cooking bananas (matoke), cassava, sweet potatoes, beans, millet, maize, and sorghum. These crops together accounted for 93% of the land planted in food crops in 1988 (Ministry of Agriculture 1990). There is, therefore, no one leverage point where a major breakthrough can lead to broad transformation. This is in contrast to economies where most consumers depend on a single staple.

In the period from 1971 to 1980 the research programs in Uganda declined due to the uncertainties associated with the Amin regime and to the government's failure to provide adequate levels of support. Facilities, equipment, vehicles, and machinery deteriorated. For example, Kawanda Composite B (a variation on the existing improved maize variety) was judged ready for release by 1977 but by that time facilities for multiplication were inadequate. The breeder seed was not properly stored and was lost as a result.

Staff turnover was high. Vacant research posts were filled, but new staff lacked adequate training and research experience. Ugandan researchers were isolated from the world scientific community by the lack of resources for training, travel, and written materials. Despite the lack of financial resources, by 1981 the number of senior staff had increased to 119. However, of these only 21 were at the M.S. level or above (IDRC 1982).

The break-up of the East African Community in 1977 further jeopardized agricultural research in Uganda. The best research facilities in East Africa had been established in Nairobi, Kenya under the East African Community. Not only did the loss of collaborative opportunities demoralize Ugandan breeders, but they suddenly had no access to such necessary facilities as cold storage, computer services, and multiplication facilities. Many of the accession lines of maize and soybeans which had been evaluated over the years were only kept in the Kenyan stores. As a result, valuable breeding materials were lost and others became irreparably damaged as a result of the break-up of the community. The Ugandan research program was virtually paralyzed.

Maize and soybean seed production declined dramatically from 1975 to 1982. The situation worsened during and after the 1979 liberation war when all stores, equipment, and records were looted. Research activities were at a standstill and no new breeder seed could be provided to the seed project. The Seed Project continued to multiply a limited quantity of certified seed but seed quality deteriorated rapidly as inspection and other quality control activities were suspended. Continued political instability led to further destruction and eventual abandonment of Kawanda Research Station in 1985.

In 1983 USAID signed an agreement with Uganda to assist the Government of Uganda to rehabilitate, retrain, and redirect Uganda's agricultural manpower and institutional capability in food crop production under the auspices of the Manpower for Agricultural Development project (MFAD). Maize, sunflower, and soybeans were selected as the primary focus of the research activities. Direct investments in research were delayed due to the political instability of the mid-80s. In 1986, after the massive disruptions of the civil war, research activities on all three of these crops were moved to Namulonge Research Station just outside of Kampala, in line with the government's intention to concentrate annual food crop research at Namulonge, where adequate land was available and security could be assured. MFAD concentrated initially on training and the physical rehabilitation of research facilities. In 1988 Dr. C. Simkins was appointed as the long-term technical advisor to the maize and soybean programs, and local currency support for research activities began. In 1989 Dr. Robert Buker arrived as the technical advisor on sunflower. Since 1988 on-station research has been closely linked with on-farm testing to assure that recommended varieties and management practices are acceptable within the relevant farming systems and make a real contribution to producer incomes and food security.

The level of investment directly related to maize, sunflower, and soybean research has been very low.[1] The total investment of just over $2 million includes complementary activities outside of the Namulonge Experiment Station. For example, the lack of indigenous rhizobia to promote soybean nodulation and nitrogen fixation was identified by a consultant as a major constraint to

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[1] Total expenditures including technical consultants, on-station and on-farm research, and technology diffusion support activities between 1987 and 1993 are summarized in appendix 1.

soy production in Uganda. The program to identify appropriate strains, establish production capacity at Makerere University, and promote its use at the farm level has been quite successful. Its full costs are contained in the above estimates.

Table 1. Achievements

Varieties Released Maize = Longe 1 Soybeans = Nam 1 Sunflower = Sunfola	Yield Increases Maize = 15-25% Soybeans = 5-10% Sunflower = 10-20%
On-Farm Trials 1988-92: Maize = 833 Soybeans = 892 Sunflower = 422 Total = 2,147 in 7 districts	Rhizobium production improves yield 25-45%. During 1990-91 sold enough to inoculate 367 ha of soy; can produce enough for 2,000 ha/yr in the future.
CAAS project distributed > 16 tons improved sunflower seed in 1992.	By 1990-92 EIL sold 44 manual presses. EIL distributed 5.7 tons of seed in 1992.
Varieties in the pipeline are expected to be released in 1993/94.	Credit was supplied to processors out of PL480 funds.

A separate project funded by USAID and implemented by Experiment in International Living (EIL) was designed to promote the development and adoption of appropriate technology for village-level pressing of oilseeds. This effort has been important in providing an immediate incentive for producers to adopt the newly-available, high-oil-content variety. In addition, the research staff took upon themselves the multiplication of seed both for use in a massive on-farm trials/demonstration effort and for sale to members of the South Bukedi Cooperative Union in order to promote higher capacity utilization of the Union's crushing plant. Every effort was made to jump-start the process of getting new varieties directly into the hands of farmers.

Lastly, the sector was assisted by the Cooperative Agriculture and Agri-Business Support Project (CAAS). This project made credit available to the Uganda Central Cooperative Union and to other Cooperative Unions and societies for a variety of efforts including the promotion of the edible oils sector. While its contribution is recognized, the fact that it was financed by PL480 edible oil food aid monetization and was made largely in the form of diversified loans that finance a wide range of cooperative activities makes it difficult to make the necessary cost allocation specifically to the edible oils sector. These expenditures reflect a well-integrated approach to the development of the maize and edible oils subsectors.

2.3. Maize Agriculture and Research

While maize is one of the major staple crops in Uganda, maize area averages only about 340,000 ha per year, or less than 8% of the total area under cultivation. Maize was grown primarily as a subsistence food crop up to the 1970s. Throughout the 1970s the importance of maize as a cash crop grew as marketing systems for cotton collapsed under poor cooperative management. This coincided with increasing urbanization and falling incomes. As a fast cooking, easily storable, low cost staple, maize meal met an important demand for urban and institutional consumption. This trend towards maize production for sale was further enhanced by the barter trade agreements of the mid to late 1980s. The fact that in the absence of markets, maize can still be used to meet domestic subsistence needs has given maize a distinct advantage over cotton as a cash crop, especially given the market failures of recent years. At present probably 60% of current maize production is sold on the market.

In Uganda maize is produced with very few improved inputs and yield is generally below 1.5 tons/ha (national average is as low as 900 kg/ha). Yields are restricted by nitrogen and phosphorus deficiencies in the soil and by the prevalence of maize streak virus which can reduce yields by up to 80%. Producers continue to grow more than subsistence needs even if prices are low in order to generate cash for essential consumer items. Hence, in a normal year they usually have at least a modest market surplus.

Prior to 1987, Uganda had released only three maize varieties. These included White Star and Western Queen, which were released in 1960, and Kawanda Composite A, released in 1971. White Star and Western Queen were recommended for the northern and western areas of Uganda respectively. While White Star is still recommended for Northern Uganda because of its early maturity (115 days), seed has not been produced commercially for many years. Western Queen has apparently been discontinued (Sprague 1987).

Kawanda Composite A (KWCA) has dominated the improved seed multiplication program since its release. KWCA was recommended specifically for commercial production during the long rains because it is late maturing (133 days) and requires early planting. The degeneration of the variety due to the lack of maintenance breeding and breeder seed production has led to great heterogeneity at farm level. Complaints include high susceptibility to streak virus and blight diseases, excessive plant and cob height and severe lodging problems.

Serious effort to reassemble a new stock of maize germplasm began in 1987. In addition to local varieties which were collected from all over Uganda, materials were also obtained from international institutions such as IITA and CIMMYT, and from other national programs. The objective of maize research since 1987 has been to modify Kawanda Composite to reduce its maturity period, incorporate resistance to streak virus, and lower plant and ear height in order to reduce the threat of lodging. To accomplish this, KWCA materials which had been sent to IITA in the early 1980s for incorporation of resistance to maize streak were retrieved. (This was indeed fortunate since all of the original breeder materials had been lost in the chaos of the mid-1980s.) These various resistant materials were tested at Namulonge, and KWCA-SR was selected in 1988 as the best performer. In 1989 this material was crossed with a very short, streak resistant population (population 49) to form a new variety. As a result of the crossing and subsequent reselection, plant height was brought down by 69 cm, ear placement by 41 cm and maturity by 14 days. The result is a medium maturity variety (65 days to 50% silk) which is streak resistant and moderately resistant to Northern Corn Blight (Baguma 1991). It yields 4.0 tons/ha on average under good management (including fertilizer) and exhibits at least a 25% yield improvement over traditional varieties even under zero input farmer conditions. Because the initial crossing was done in 1989, the variety was first named Population 89, but this was changed to Longe 1 at the time it was presented to the variety release committee for consideration. Longe 1 was released in September 1991 and is now undergoing multiplication at the Uganda Seed Scheme farm in Masindi. In 1992 three tons of Longe 1 seed were distributed to farmers under the auspices of the on-farm trials program, and an additional ten tons were distributed as part of the rehabilitation efforts supported by CARE.

Despite Longe 1's advantages, it is nevertheless not as high yielding as two other varieties which are currently undergoing testing. These open-pollinated varieties, Gusau and Population 29, yielded 3-4 tons/ha during on-farm trials and 6-7 tons/ha on-station. Unfortunately they are not resistant to Northern Corn Leaf Blight (tolerance is only 25-30% depending on location). Hence Gusau in particular is currently restricted in its use to Kasese District, where the incidence of blight is limited. Because of the yield potential of these varieties, researchers are striving to remedy the susceptibility problem. Gusau is being crossed with Population 42 Eto Illinois to incorporate blight resistance. One hopes that a suitable new variety resulting from the cross of these two varieties will be sufficiently tested to present for release consideration in late 1994. Release will depend on the success of blight resistance incorporation and yield performance.

2.4. Soybean Agriculture and Research

Soybeans were introduced in Uganda between 1908 and 1913. Serious production did not occur until the 1940s when, due to a wartime demand from Britain, cultivation reached 14,000 - 16,000 hectares. In 1950, soybean exports reached a record level of 4,314 tons before undergoing a decline after 1952. In the early 1980s, production was minimal with an average of 5,000-6,000 ha under soybeans annually. Yields averaged less than 1 ton/ha (Hittle 1987). Production has been expanding in response to the demands of the edible oil industry, reaching a record 37,000 ha in 1990 and an estimated 54,000 ha in 1991.

Soybeans are not native to Uganda. The necessary rhizobia to facilitate nodulation and nitrogen fixation are not currently resident in the soil. There is substantial evidence that the introduction of appropriate strains of rhizobium to stimulate nodulation in soybeans can make a significant improvement on yields and probably also has a measurable impact on soil fertility.

While one improved variety had been released in the early 1970s, due to the civil strife of the last 15 years, soybean varieties, breeding lines, and seed increases were lost. Many INTSOY trials were conducted in the 1970s but the results of these trials have either not been reported or reports have disappeared. Only one report, for trials conducted in 1976/77, is currently available.

When the soybean research program was revitalized in 1988, it had two broad objectives. The first was to select or develop soybean varieties of medium maturity (100-120 days) which are high yielding; non shattering; resistant to lodging, major pests, and diseases; free nodulating; with good pod clearance; and which can store well for at least 7 to 8 months. The second is to identify appropriate agronomic practices which will maximize the performance of commercial soybean production in Uganda. Breeding work was given first priority.

One major objective of the soybean research program since 1986 has been to identify varieties which are disease resistant and less susceptible to shattering. As a result of the multi-locational screening program, ICAL 131, an INTSOY variety, was identified as the most promising. ICAL 131 was proposed to the National Variety Release Committee in August 1989 and was given partial release under the name of Nam 1. Further seasons of trials confirmed its performance and it was approved for full release in 1991. It is resistant to bacterial pustule and virus, and it matures in 120 days. A major advantage of the new variety is that, in contrast to Kabanyolo 1, for the existing released variety, shattering is minimal. This greatly reduces the risk of losses in the field. In addition, Nam 1 does not lodge and is higher yielding across locations than Kabanyolo 1. In on-station trials Nam 1 demonstrated a 5-10% yield increment on average over Kabanyolo 1 across many seasons and locations.[2] Responsiveness to inoculation with Bradyrhizobium japonicum has also been well documented.

A major contribution of the USAID supported research effort has been identification of an appropriate strain of rhizobium for Uganda and establishment of a rhizobium production facility at Makerere University. Serious roadblocks still stand in the way of widespread adoption. Farmers need education but at present the majority of the extension staff know nothing about rhizobium technology. The second constraint is the lack of input distribution mechanisms to ensure inoculant viability and timely availability. The inoculant is inexpensive but it must be protected from extreme temperatures and mixed with the seed just prior to planting.

Ongoing breeding work at Namulonge has already identified another variety, L73, which researchers propose to submit to the National Variety Release Committee before the end of 1992. This variety has the advantage of being not only as high yielding as currently released varieties, but also being larger seeded and shatter resistant even if the crop stands in the field. Further crossbreeding to try to incorporate the high yield capacity of certain international

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[2] Researchers see Nam 1 as an alternative for farmers, not a replacement for Kabanyolo 1 which is the existing released variety and which actually performs very well in terms of yields. The very nature of research, which includes disease control and timely harvesting, makes it very difficult to estimate to what extent shatter resistance will actually lead to improved yields under farmer conditions.

varieties with the desired seed color and size is under way. Researchers estimate that a new variety will be considered for release by 1995, and possibly in the hands of farmers for planting in 1997. The expected lag time before release is lengthened by the need for crossbreeding to achieve the seed color and size desired in the Ugandan market.

2.5. Sunflower Agriculture and Research

Although sunflower was widely grown in many parts of Uganda by the 1960s, no significant research had been conducted on this commodity. The Ministry of Agriculture did not even begin collecting national sunflower area and yield estimates until 1989. Interest in sunflower production has risen rapidly in recent years, and the area planted to sunflower has increased from less than 5,000 ha in the early 1980s to over 38,000 ha in 1991.

Prior to 1991, no improved sunflower variety had ever been presented to the release committee for consideration. In most cases farmers were using seed retained from ornamental or confectionery varieties of Russian or Kenyan origin which had been introduced in Uganda in the 1960s and 70s. Oil content of these seeds varied from 10% to 30%. The white seeded varieties have the lowest oil content, followed by the striped and black varieties respectively; all have hard, thick shells. Sunflower varieties with thin seed coats are preferred for crushing because they cause less damage to the screw presses (Buker and Denton N.d.).

In 1988 a National Sunflower Program was launched at Namulonge Research Station. In prior years, Serere had been the center for sunflower research, but germplasm collections were largely lost during the long period of turbulence and political instability. In early 1988, Dr. Charles Simkins was able to replenish the germ plasm stocks with a collection of some 70 varieties obtained from Kenya, mostly hybrids.

In the first season of 1988, Simkins, Hakiiza, and Gahakwa set up sunflower variety trials with the objective of identifying the most promising of the imported hybrids when grown under Ugandan conditions. Results from the trials indicated potential in four hybrids which were recommended for importation. Their average yields on-station were about 2000 kg/ha. Yields of at least 1300 kg/ha and an oil content of 50% were achieved under farmer management. The parent materials for one of these hybrids were obtained, and research on hybrid sunflower production is ongoing at Namulonge. Results suitable for presentation in a release application may be ready before the end of this year, but there are serious questions concerning the ability of the Seed Scheme to handle hybrid seed production.

Despite the potential returns to hybrid development, the research system was under pressure to identify a suitable existing open-pollinated variety for introduction as a short-term solution to the shortage of seed in Uganda. Trials were carried out on a number of Peredovicks of Russian origin and the Australian variety Sunfola, which had been introduced in Uganda in 1988. While both the Peredovicks and Sunfola varied in height and maturity, Sunfola was determined to be the more promising. Reselection efforts were undertaken by Dr. Buker, the MFAD long-term technical consultant in sunflower, with the objective of developing a stable variety that could be cleaned up quickly and placed in the hands of farmers within two years.

During 1989 and 1990, progeny selection and multi-locational on-station trials were conducted at the same time as on-farm trials. In July 1990, more than 1,000 kgs of reselected Sunfola were harvested at Namulonge Research Station and this was distributed by MFAD to its on-farm trial program, the Uganda Seed Project, CAAS project (which was assisting the South Bukedi Cooperative Union) and EIL (which has a project to distribute a hand operated oil mill suitable for isolated villages). A seed multiplication effort was established by the South Bukedi Cooperative Union in Tororo, and as a result 10 tons of Sunfola seed was produced and sold to farmers in Tororo in 1991. In addition, EIL reported that farmers' organizations with which it was associated had planted 2,000 acres.

The re-selected Sunfola was renamed New Sunfola and recommended for release in October 1991. There are indications that it may have a 10-20% yield advantage over local striped varieties, and, more importantly, a 25% higher oil content. Its thin shell and high oil content make it preferred for crushing and it commands at least a 25% price premium on the market. The release does not mark the culmination of the research effort in open-pollinated varieties. Currently the most promising variety in the pipeline is a breeding line called Record 11-1.7 of Tanzanian origin, which realized high yields and a more than 40% oil content in multi-locational trials. Record will be a highly promising open-pollinated variety if its variability in height and maturity can be reduced. It yields about 1,000 kg/ha on farmers' fields compared to Sunfola's 700 kg/ha and it appears to be more resistant to bird damage.

Recurrent selection of the Record variety is under way in order to ultimately achieve uniform characteristics in terms of yields, maturity period, height, head size, disease resistance, and seedling vigor. One hopes that researchers will be ready to present a uniform reselected variety of Record for release in 1994. The recurrent selection method generally takes at least six seasons in order to realize the desired characteristics.

There has been a great deal of interest in the production of edible oil from sunflower since the early 1980s. Most of the early promotion was carried out by religious organizations, especially the Catholic Diocese, who introduced medium-scale oil-press technology as part of their income-generating activities. From the mid-1980s, a number of NGOs also funded procurement of small to medium size oil presses for various individuals and groups. The poor oil content and very hard shell coat of local seed varieties resulted in low profit margins and high maintenance costs, especially with the smaller presses.

Appropriate Technology International (ATI) has had a very highly successful project in Tanzania producing and promoting a manual oil press originally designed by Carl Bielenberg in 1985. This press has undergone numerous design modifications to improve its efficiency and ease of operation. One key factor in the adoption of this press is the availability of high-oil-content, soft-shelled sunflower varieties for crushing. There is a synergistic interaction between variety adoption and investment in manual crushing technology. The importance of high oil content becomes immediately obvious to farmers who use the manual press. The availability of local crushing capacity increases farmers' options for direct consumption or sale of oil on the local market, encouraging sunflower production.

In 1988, the Experiment in International Living began a similar project in Uganda with funds provided by USAID. Initially the Agricultural Processing Machinery Testing and Manufacturing Project (APMP) concentrated on the testing of alternative small oil expellers. The Bielenberg ram press was identified as the most appropriate for use in rural Uganda, primarily due to its low procurement and operating costs. The ram press design was modified, and fabrication by local manufacturers began with EIL assistance. Individuals and groups interested in procuring the presses were required to have at least 25 acres of sunflower planted to qualify for a press on credit. EIL project staff instructed farmers on sunflower production practices and provided high-oil-content seed (originally a Peredovick obtained from the Kagando Hospital Rural Development Project, later Sunfola from Namulonge). Farmers who received free seed were asked to repay with double the amount of seed the following year. Training and follow up on the mechanical operation of the ram press were also provided.

While there have been complaints from some ram press owners about the difficulty of operating the press and the low level of payoffs if one hires manual labor, there is no question that the press-promotion project has had a major influence in disseminating high-oil-content seed and spreading sunflower production throughout the country. The small mechanical expellers and the two large-scale oil mills are all operating at less than capacity due to lack of raw materials. These commercial operations will compete with the ram presses for the available sunflower. Manual-press technology can fill an important niche in isolated areas, but will be viable only if its efficiency and ease of operation can be improved. Fortunately, a new model which is easier to operate and has proven widely acceptable to women was developed in Tanzania. If the efforts to replicate this improvement are successful in Uganda, this will be a major step forward.

During this same time period two new, large-scale, commercial processors have entered the Ugandan market. The first is a cooperatively owned mill built with German donor funds and dedicated in 1988. This mill is located in Tororo and was initially intended to crush cotton seed from the ginneries belonging to the South Bukedi Cooperative Union. Cotton production has lagged far behind expectation and the mill was standing virtually silent. Thanks to the technical assistance of Mr. Russ Read, an ATI engineer posted to the Cooperative Agriculture and Agribusiness Support Project, and the advice and support of Dr. Robert Buker, the MFAD long-term technical consultant in sunflower, the South Bukedi Cooperative Union now considers itself a cotton and sunflower union. Equipment and procedures were modified to accommodate sunflower processing. In 1989, hybrid sunflower seed was imported and made available to local farmers. In the same year, local multiplication of hybrid sunflower was undertaken under the supervision of Dr. Buker and the seed produced was sold to cooperative members on credit.

Dr. Buker also supervised multiplication of both Sunfola and hybrid sunflower seed through two commercial farms near Kampala. Every effort was made to see that seed produced at Namulonge Research Station, as well as by these organizations, got out into the hands of farmers as quickly as possible. Some was distributed through the Experiment in International Living. Some was sold to Mukwano Enterprises, the other large-scale oil mill. This plant was constructed in 1990 and went on line in 1991. Its dynamic, private management has clearly recognized the constraint created by the lack of appropriate seed and has taken on the role of subsector "channel captain." They provide free seed to farmers and have created their own network of buyers who penetrate deep into the rural areas to procure raw materials.

In the 1992 PL480 agreement between USAID and the Government of Uganda, it was agreed that a large proportion of the revenues generated by the sale of surplus, US, edible oil would go to the promotion of the edible-oils industry in Uganda. The full details of how this will be implemented have yet to be determined. As part of this effort the CAAS project is providing a short-term grant for imported seed, the financing of hybrid sunflower seed multiplication by staff from Namulonge Research Station, and multiplication of the open pollinated sunfola seed by large scale outgrowers.

The most important accomplishments of the research component is the release of new open-pollinated varieties of soybeans, sunflower, and maize in 1991. These are the first variety releases in Uganda in over 20 years. Commercial seed multiplication of these varieties by the Uganda Seed Scheme began immediately. Efforts to jump start the process through on-farm trials/demonstrations and seed distribution through EIL, cooperatives, and private sector processors have had a significant impact in promoting the earliest possible adoption of the varieties.

3. EVALUATION METHODS AND RESULTS

3.1. The Rate of Return as a Measure of Project Worth

When a new agricultural technology is adopted, the increased productivity benefits a wide range of actors in society. Producers benefit from lower production costs and increased returns to limiting factors of production (land, labor, or capital). Consumers (including farm households) benefit from increased product availability, improved product quality, and lower prices. The nation benefits from the improved health and productivity of its citizens as well as the broader economic linkages.

The rate of return (ROR) is the measure of project worth most commonly used in the evaluation of investments in agricultural research.[3] The ROR is a single number which summarizes the time pattern and the relative sizes of both the cost and the benefit streams resulting from the project. The ROR is comparable to the rate of bank interest which the investment would have to earn to achieve the same net returns as the research project. Once the ROR has been determined, it can be compared to the prevailing interest rate or some other measure of the opportunity cost of capital to determine the relative attractiveness of the investment. If the ROR exceeds the cost of capital, then the project is considered economically successful (Schwartz, Sterns, and Oehhmke 1990, Daniels et al. 1990).

The ROR is an appropriate measure for investments having costs and benefits which vary over time as long as the costs are incurred primarily in the early stages of the project, and most benefits accrue in the later stages. Because it is expressed as a percentage, it is independent of the level of project capitalization as well as the unit of currency. This facilitates comparison between alternative investments (Gittinger 1982).

Since Schultz (1953) made the first attempt to quantify the rate of return to agricultural research, there has been a steady refinement of the methods used. Measurement of social surplus was popularized by Akino and Hayami (1975), who developed a concise formula to estimate the change in social surplus arising from investments in research. The production function method includes research as a separate variable in the estimation of a production function, allowing calculation of a marginal rate of return. This allows policy makers to discuss the impact or benefits of reallocating research resources from one project to another.

The steps in the basic benefit-cost analysis are as follows:

1) Calculation of gross benefits, both "without-research" and "with-research."

    a) Determination of the area and yield levels for both traditional and improved technologies for the life of the project. When benefits are being projected into the future,

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[3] The advantages and disadvantages of various alternative measures of project worth are discussed in detail by Gittinger (1982).

the estimation of area for the improved technology requires prediction of the expected adoption level for each year of the analysis.

b) Determination of the price at which production should be valued. The purpose of an economic analysis is to measure the total net benefits to the economy as a whole rather than to the individual producer. The price, therefore, should be adjusted for exchange rate distortions, subsidies, and taxes, which are simply a transfer between sectors within the economy, in order to reflect the real economic value of increased production.

2) Calculation of incremental gross benefits. Production benefits which would have been achieved in the absence of the research are netted out as negative incremental benefits because they would have been achieved even without the research.

3) Calculation of incremental ("with research" minus "without research") production costs per year attributable to adoption of the technology.

4) Determination of annual research costs. One major difficulty encountered in evaluating the rate of return to agricultural research is the problem of separating the impact of research from that of complementary investments in extension, institution building, training, promotion, and diffusion. It is necessary to include all relevant investments as costs and report the returns to research and extension jointly.

5) Calculation of the annual incremental net benefit. This is the incremental gross benefit minus the total costs (incremental production costs plus the cost of research, rehabilitation, training, diffusion, and extension).

6) The stream of annual incremental net benefits then needs to be deflated by an appropriate cost of living index to reflect its real value in constant prices. This is especially important in a highly inflationary economy.

7) Calculation of the rate of return. The Internal Rate of Return is the discount rate that equates the present value of the net benefit stream to zero. This rate can then be compared to the interest rate or some other estimate of the cost of capital to determine the profitability of the investment.

8) Lastly, sensitivity analysis is conducted to test the stability of the ROR and the relative importance of its various components (price, yields, adoption). This is one means of incorporating the effects of market imperfections and changing macroeconomic policies into the analysis.

Because the new varieties under consideration were only released in late 1991, the analysis of the ROR to maize, sunflower, and soybeans in Uganda becomes a hybrid between ex-post and ex-ante analysis. The analysis uses known costs and projected benefits. This entails prediction of farmer adoption, market conditions, and potential institutional support for technology transfer.

The resulting rate of return is bound to be highly uncertain. On the basis of his work with this approach in Mali, Henry de Frahan (1990, 341-42) emphasizes the importance of sensitivity analysis:

> The most useful information to come out of an ex-ante evaluation is, by far, a better understanding of the factors that affect the return to research rather than the rate of return figures themselves. Ranking these factors according to their impact on the return to research allows decision-makers to determine the most important constraints to the return to research.

For this reason, the ROR estimates calculated in this analysis are an approximation that tells only part of the true story. Their usefulness lies primarily in the issues they raise regarding the factors necessary to achieve a reasonable payoff to research investment.

3.2. Data Sources

Information for this analysis was obtained through extensive informal interaction with researchers, extension agents, traders, policy makers, processors and producers. Informal reconnaissance surveys, secondary data, and in-depth interviews with key informants at different levels of the sub-sector were conducted. Restrictions on time and resources limited the possibilities for large-scale formal survey confirmation of each of the parameter estimates required.

The data sources for the key parameters in the analysis of all three commodities are similar and will be discussed here jointly to avoid repetition. These parameters are yield, area, adoption/diffusion projections, price, production costs, and research costs.

Given the high degree of uncertainty involved in the projection of benefits, when the available information is equivocal, the procedure was to underestimate the benefits and overestimate the costs. The estimate of benefits is selected from the low end of the possible range and the cost esimate is selected from the upper end of its possible range.

3.2.1. Yield

Yield advantages demonstrated on-station are indicative of the potential of the variety but are not a good predictor of expected yields under farmer conditions. The on-farm trials conducted by the MFAD project were designed to demonstrate to farmers the potential yield gain to be achieved by improved management. They, however, provide poor documentation of the yield increment which can be expected from the new varieties under local management practices.

A survey was undertaken in January of 1992 to try to remedy the lack of yield data. One hundred and sixty-three randomly selected on-farm trial participants from four districts were interviewed. The survey was designed to elicit information about production practices and the yields obtained in 1991 on the farmers' own fields, as distinct from those of the on-farm trials. The purpose of the survey was to test for the acceptability of the technology to farmers as well as to estimate the yield increment achieved under local conditions.

Because the number of farmers who participated in the on-farm trials for Sunfola was extremely limited, farmers from two traditional sunflower producing districts were also interviewed.

For traditional maize varieties, survey data gave an estimate of 924 kg/ha for the existing mix of varieties under cultivation.[4] This estimate agrees quite well with the national maize yield estimate of 900 kg/ha reported by Vanegas and Ngambeki in their Baseline study (1987, 9) but is lower than the figure of 1,500 often quoted by the Ministry of Agriculture. Survey data gave an average yield estimate for the new Longe 1 variety without fertilizer of 1,173 kg/ha but this was a very small sub-sample (18 cases). By comparison, the on-farm trial data (132 cases) gave an average yield for Longe 1 without fertilizer of 1,434 kg/ha but a median closer to 1,200. On the basis of this information it was decided to use 900 kg/ha for traditional varieties and 1,200 kg/ha for Longe 1 as the base case estimate. The impact of raising the estimated yield change is then tested using sensitivity analysis.

For soybeans, the survey data do not show a significant yield increment for the newly released variety over the previous variety when grown without fertilizer and rhizobium. The survey yields for each variety without fertilizer is about 800 kg/ha. This is consistent with data for unfertilized, on-farm trials for 1988-90. On-station yields average about 10% higher across years and locations. Therefore, 5% and 10% increments over traditional yields are used as base case and sensitivity analysis scenarios respectively. This increment may underestimate the yield advantage of Nam 1 over Kabanyolo 1 because it fails to take into account the losses which farmers planting Kabanyolo 1 might expect to incur due to both shattering and disease problems. Unfortunately, no research has been conducted to quantify the extent of such losses under farmer conditions.

Survey yields for all varieties of sunflower in unfertilized fields averaged approximately 600 kg/ha (60 cases). The survey found a substantial increase in yield for Sunfola (1,454 kg/ha). The small sub-sample of farmers growing this variety (only 8 observations) raised serious questions about the validity of the Sunfola yield estimate. On-station trials had failed to demonstrate any significant yield advantage for Sunfola over the widely popular striped variety. Researchers agree that the major advantage of Sunfola is in its higher oil content, not in its yield. As a result,

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[4] The data are far from conclusive. A limited number of surveyed farmers were able to provide the yield estimates. Many of them had participated in the trials prior to the introduction of these three varieties and so were planting other improved seed. Others had either intercropped their fields or harvested the crop when it was green and were unable to provide reliable yield estimates. Some had decided to use fertilizer because of their experience with the on-farm trials. Still others had given up production of either soybeans or sunflower due to marketing difficulties. Analysis of the available data suggests the presence of interaction effects between yield and location, fertilizer and season in addition to the effects of variety alone. This raised questions about the representativeness of our sample when extrapolated on a national basis to non-drought years.

the base case scenario for the sunflower ROR assumes a zero yield increment for Sunfola, but includes the observed price premium for higher oil content.

There is a substantial yield increment with the hybrid sunflower which has been produced and sold by Namulonge. While no on-farm-trial or survey data are available for the hybrids, on-station trials generally produced 2,000 to 3,000 kg/ha. Under these circumstances, the selection of a yield estimate of 1,400 kg/ha for hybrids under farmer conditions was considered reasonable. The hybrids have the same high oil content price advantage as Sunfola.

3.2.2. Area

Total area figures for the without-research scenario for maize and soybeans during 1986-91 are based on national estimates prepared by the Ministry of Agriculture, Animal Industries, and Forestry. No expansion in area is attributed to the research effort. In the absence of evidence about expected production trends, area planted to maize and soybeans is held constant at 1991 levels in the future projections.

Unfortunately, area data for sunflower were only available from the Ministry for 1989-90. Since the new variety was not available until 1990, the lack of area data prior to this year has no effect. The 1991 area estimate is based on preliminary figures from the Ministry supplemented by a survey of District Agricultural Officers in key districts which had not yet submitted their reports.[5] Given the importance of the promotion and seed distribution efforts for sunflower, area is held constant at 1990 levels for the without-research scenario, but is allowed to rise to actual 1991 levels in the with-research scenario. No further expansion of area is projected after 1991.

Sunfola is the first sunflower variety to have been released in Uganda. Fortunately, the heavy investment in Sunfola seed distribution has paid off with a substantial level of adoption even as early as 1992. Reports of seed distribution and anticipated planting levels supplied by EIL, CAAS, and Namulonge were used to estimate adoption levels for 1990-92.

3.2.3. Adoption/Diffusion Projections

Estimated areas, yields, prices, extension costs, and maintenance breeding expenditures are held at a constant level for the entire projected life of the analysis. This is obviously an unrealistic assumption since these values will vary over time. This is a standard procedure in cases where evidence necessary for more accurate projections does not exist. Clearly external factors will affect the future level of these parameters and alter the realized ROR to research. The results of the analysis, therefore, are indicative at best and should be interpreted accordingly.

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[5] For this reason, these figures may not match well with the official statistics that will eventually be reported.

The projection of variety adoption is one of the most uncertain aspects of the benefit-cost analysis. The new maize and soybeans varieties have only been available to on-farm trial participants. No current adoption data exist on which to base future projections. Both maize and soybeans were extensively multiplied by seed multiplication during the 1970s. The data on seed sales and likely seed retention rates by farmers are used as a guide to future adoption of the new varieties. A log function with the standard "s" shaped adoption curve was fitted to the 1970-79 adoption figures for maize and soybeans using Ordinary Least Squares regression analysis. The value of the equation parameters (y intercept, as well as a and b which determine the nature of the curvature) were determined using alternative estimates of the adoption ceiling. The curve with the best fit or highest explanatory power (as reflected in the R^2) was selected. For details of this estimation process see appendix 2. These parameters were used to project adoption levels for the post-1992 period. Because of its limited yield advantage over Kabanyolo 1, Nam 1 is expected to only constitute half of the improved seed. This effectively cuts the adoption ceiling in half.

The time series data on sunflower area and seed sales are very limited. The area estimates derived from seed distribution information supplied by EIL and CAAS were used to calculate a diffusion curve in the same manner as explained above. Given the limited timeframe, however, sensitivity analysis is necessary to test the ROR for stability under alternative projected diffusion paths. Further details concerning the sensitivity analysis of the adoption equations for sunflower can be found in appendix 1.

3.2.4. Price

Ugandan markets for maize, soybeans, and sunflower are free of policy-induced distortions. Price is set on the open market in response to supply and demand. There are no fixed prices for food crops and no government subsidies to either producers or consumers. The increase in total production of these commodities is expected to be relatively small. Given anticipated population growth, the increased production is unlikely to affect future prices.

Average domestic farm gate prices are used to value the production of improved varieties of soybeans and sunflower. After 1991 price is held constant at the 1991 domestic price level. Because soybeans and sunflower are not imported or exported in any significant quantities,[6] no adjustment for either import or export parity pricing is required. In the case of sunflower, however, there is an observed price premium for the new varieties. In the absence of simple measurement techniques, processors rely on seed variety as an indicator of oil content. Sunfola and the hybrid varieties have an average oil content of 40% compared to 10%-30% for the traditional varieties.

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[6] Soybeans were exported by the Produce Marketing Board in 1987-88. These barter trade deals were negotiated primarily for political reasons and were not profitable (Carl Bro 1992).

The case of maize is somewhat different. While Uganda cannot profitably export maize outside the region because of the high costs of shipping, it is in an excellent position to sell maize on the regional level. Large quantities of maize have been sold to various international organizations in recent years.[7] This maize is sold to FOT Kampala at the import parity price for delivery to Sudan, Somalia, Ethiopia, and Rwanda. The base case scenario values maize production increases at the 1990-91 FOT price offered by the World Food Program (converted at the real exchange rate) less the estimated cost of marketing and transportation from farm gate.[8] A possible alternative market for maize would be direct export to neighboring countries. Sensitivity analysis tests the impact of valuing increased production at the Kenyan import parity price for maize[9] and at the domestic farm gate price.

3.2.5. Production Costs

The technologies being evaluated in this report are simple, basic inputs entailing few additional production costs. The assumption that the majority of farmers in Uganda do not use fertilizer is reflected in the choice of yield level for our analysis. For this reason, it is assumed that the additional cost of fertilizer or chemicals is zero. The extra labor required by the new varieties is limited to the additional harvesting and post-harvesting effort necessitated by the higher yield.[10]

Most farmers in Uganda buy commercial seed only once every 4-5 years. Since the new varieties are also open-pollinated, there is no reason to believe that there will be any increased seed cost from replacing the old varieties with the new ones. Increases in input costs are limited to the cost of rhizobium inoculation for soybeans and annual seed purchase for adopters of hybrid sunflower varieties. Rhizobium is costed at its 1991 production cost.[11] In the absence of

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[7] Maize exports equalled over 9% of national production in 1991. Customs data for Uganda are very poor, generally underestimating actual levels of international trade. For example, maize exports in 1991 are reported by the Dept. of Customs and Excise to have totalled 33,070 mt. This contrasts to the 48,427 mt. which was exported by the World Food Program alone that year.

[8] Calculations are based on information provided in Carl Bro 1992.

[9] Calculation of the CIF Nairobi price is based on price and transportation costs reported in the *Maize Subector Study* conducted by the Kenyan government in 1987. Adjustment to Uganda farm gate based on Ugandan marketing and transportation cost estimates from Carl Bro 1992.

[10] Technically, the way to solve this problem is to use a field price for the commodity, ie. the farm gate price less the cost of harvesting, transportation from the field and post-harvest processing. The scarcity of data made it impossible to calculate such a per-kg field price. The additional labor costs are expected to be minimal, however, and are unlikely to affect the analysis to any substantial degree.

[11] Personal communication with Dr. Robert Buker, long-term technical advisor for sunflower, Namulonge Research Station, and Mr. Charles Nkwinne, rhizobium production unit, Makerere University.

information on the expected cost of locally produced hybrids, hybrid sunflower is costed at its 1991 import-parity price.

3.2.6. Rehabilitation, Research, Promotion, and Extension Costs

The essence of an economic analysis, as opposed to a financial analysis, is that all costs and benefits are viewed from the perspective of the society as a whole rather than a single organization or individual. For this reason, expenditures such as taxes which would be a cost to the organization which had to pay them are not included because they are simply a transfer from that organization to the government, not a cost to the society as a whole. The value added by the production increases the general wealth in the society even though the producing organization does not itself benefit from the taxed component directly. In a similar manner, subsidies are also an internal transfer.

The most significant adjustment from a financial to an economic analysis is the correction for exchange rate distortion. In the early to mid-1980s Uganda had an over-valued exchange rate. During the time period under consideration the percentage gap (the percent by which the open-market rate exceeds the official exchange rate) rose from 149.2% in 1985 to a 1987 peak of 409%. In August 1990, the open-market exchange system was legalized and foreign exchange bureaux were created. By 1992 the percentage gap had fallen to 22%, and the government intends to gradually merge the official rate with the open-market rate.

If the hard currency investments in research, rehabilitation, promotion, and extension were converted to Ugandan shillings at the official exchange rate they would under-represent the real value of the expenditure. For this reason, all hard currency investments are valued at a shadow exchange rate which reflects their scarcity value. An estimate of the open-market exchange rate, obtained from the Bank of Uganda, is used to value hard currency costs prior to 1990. While it may be argued that a black market exchange rate overstates the level of exchange rate distortion due to risk factors, this is the best information available.[12] After 1990 the bureau rate is used to value all hard currency investments.

Another difficulty is that project accounting systems do not categorize expenditures by their expected impact. Identifying project expenditures which contributed to research impact, as opposed to general manpower development, is difficult in such a broadly defined project. The researcher worked together with the project management to decide which expenditures to include.

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[12] The level of risk premium is probably very small, given the openness with which the black market functioned during this time period. At various times during this period there was an official two-tiered exchange system (window one and window two). Even when the two-tiered system was not functioning, the open market rate was well known. Referred to as the "door rate," it was published on the front page of many newspapers each week. No serious attempts were actually made to enforce the official rate or penalize those who traded on the black market. In fact, black market exchanges were actually made right on the premises of most major banking institutions.

The ROR analysis demonstrates the impact of expanding the definition of "research costs." On the first level, only those costs directly associated with the research which led to the development of the released varieties, or which contributed directly to their testing or promotion, were included. This included (1) the government of Uganda investments in the three commodity programs, (2) the cost of technical consultants connected to the research effort, (3) local currency USAID contributions to on-station research costs, (4) the cost of on-farm trials, (5) the promotional activities associated with the development of manual oil pressing and distribution of sunflower seed, and (6) the cost of rhizobium development, production, and promotion. Future costs were estimated using current program budget projections.

At the second level, the additional expenditures in training of scientific talent connected to each of the commodity programs, and the physical rehabilitation of the research facilities and equipment were added. Investments for training were charged against the commodity program only if the individual was connected to that program at some time. Similarly, a rather arbitrary decision was made to allocate half of the physical rehabilitation costs for Namulonge research station[13] to these three commodities and to divide this investment equally between them.[14] The costs also include a related proportion of the management and indirect costs of the implementing institution. The addition of training and rehabilitation investments meant a considerable front loading of costs compared to the direct research investments. Physical rehabilitation began as early as 1985 and training was in full swing by 1987, whereas technical consultants and local currency funding of direct research costs did not begin until late 1988.

The third level of costing includes an estimate of the expected future investment in extension services to promote adoption of these newly released varieties. The costs of direct extension agent involvement in the on-farm trials/demonstration program had already been included as a direct cost in level one. Once these varieties become part of the normal seed multiplication and diffusion system, the broader extension system will be expected to play a broader promotional role.

Detailed information about the level of investment in extension services is difficult to obtain, but the World Bank reports that in 1990 the Government of Uganda employed 3,185 agricultural extension agents at a total annual cost of just $350 per agent including supervision, materials, and Ministry overhead costs. In the current analysis it is assumed that extension agents dedicate effort to commodity production promotion in proportion to the relative importance of that com-

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[13] Identifying the costs of physical rehabilitation, equipment, and supplies for Namulonge research station was itself a difficult exercise given that expenditures for Namulonge were not separated in the accounts from those for Serere Research Station, the Faculty of Agriculture and Forestry building on campus, the University farm, and minor work on various other substations. This raises the important issue of designing financial accounting/reporting procedures with impact assessment in mind.

[14] This seemed a reasonable if conservative decision given that Namulonge Research Station is also the home of other important commodity programs such as cassava, rice, groundnuts, sesame, cowpeas, and animal traction.

modity in the local farming system.[15] Based on this assumption, total annual extension cost was apportioned to the commodities of interest in proportion to the percent of total cultivated land area devoted to each commodity. In the absence of any information about future trends, extension costs were held constant for the duration of the projected analysis period. Even recognizing the uncertainty of this cost projection, it still seems important in principle to include it as an acknowledgment that the government is likely to continue to invest in extension.

3.2.7. Inflation

The last step in the calculation of the net annual benefits from research is the transformation of the nominal value of the net benefit stream into a real value. This process is necessary to control for the effects of inflation. In Uganda, the rate of inflation peaked at over 200% in 1987. In addition, there was a major currency reform in May of 1988. New currency was printed and exchanged for the old at the rate of 1 new shilling for 100 old shillings after a tax of 30% of the value of the old currency had first been deducted. The value of the net benefit stream is deflated by converting all nominal values to constant 1989 prices using the New Consumer Price Index for Kampala.[16] While this is not an ideal measure, no rural price index is available. All post-1992 prices are held constant and therefore continue to be deflated by the estimated 1992 CPI.

3.3. Results of the ROR Analysis

3.3.1. Maize

If one were to take a literal definition of ex-post rate of return, the benefit stream from research should include only those benefits which have been achieved at the time of the analysis. Since Longe 1, the new maize variety, was only released in late 1991, the area currently planted to the new variety is limited to that planted by the on-farm trial participants since 1991. This amounts to less than 90 hectares. With such limited current benefits, and the fact that the internal rate of return calculation procedure discounts benefits in 1992 more than it does costs in 1985, it is not surprising that the 1992 ROR is a negative 100%. The interesting question is not what the rate of return is in 1992, but rather what it might be over five, ten, or fifteen years.

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[15] While reasonable on the surface, the validity of this assumption is difficult to gauge. Out of 281 farm households who had not participated in the on farm trials, only 26% report having ever been advised about maize production by an extension agent. The proportions for soybeans and sunflower were 12% and 17% respectively. The higher than expected proportion who had been advised about sunflower is no doubt biased by the fact that sunflower is rapidly expanding commodity in two of the Districts. The proportion of total area under sunflower cultivation is therefore higher in the sampled Districts than in the country as a whole.

[16] The New Consumer Price Index (September 1989 = 100) was spliced with the old Kampala Cost of Living Index, Low-Income Group, using calendar year 1988 as the overlap period. The consumption basket used for the two indices is different but the level of accuracy achieved in this manner should be adequate for our purposes and there are no better alternatives.

The results of the ROR analyses for maize for these three time periods are reported in table 2. For nearly every scenario, the ROR is negative if benefits end in 1996 (table 2, column 1). The gradual pace of adoption and heavy front loading of project costs means that more than 5 years will be required for the value of the returns to equal the cost of the investment that has been made. One exception to the negative ROR through 1996 is the scenario which includes only the direct costs of research. The benefits from increased maize production more than equal the value of the direct research investment five years after the release of the variety. In fact the equivalent of a 9% interest rate of return on investment is achieved.

Kawanda Composite, the improved maize variety which has dominated the seed multiplication effort was released more than twenty years ago. Despite the lack of maintenance breeding and the collapse of the seed multiplication system in the early to mid-1980s, it is estimated that 43% of all maize producers grow this variety. Given this history, a projection of benefits from research for ten to fifteen years does not seem unreasonable.

Table 2. The Rate of Return to Maize Research in Uganda

SCENARIO ANALYZED		Projected Life of the Benefit Stream		
		1985-1996	1985-2001	1985-2006
1.	Research costs only.	9.6%	43.6%	50.6%
2.	Research, rehabilitation, and training costs.	-6.9%	26.7%	35.1%
3.	Research, rehabilitation, training, and extension costs.	-22.8%	23.5%	33.2%
4.	All costs, yield increased to 1,400 kg/ha.	-6.9%	31.1%	39.4%
5.	All costs, yield cut to 1,080 kg/ha.	-42.6%	16.0%	27.3%
6.	All costs, adoption ceiling cut to 43%.	-33.4%	19.3%	29.8%
7.	All costs, price increased to Nairobi import parity.	-18.2%	25.6%	34.9%
8.	All costs, price reduced to level of domestic maize price. (Assumes no maize export market.)	-43.0%	15.9%	27.3%
9.	Hyami and Ruttan approach to estimating the combined benefits to producers and consumers from maize research. All costs. No export market. Domestic price.	-56.6%	20.1%	35.6%
10.	All costs, yields for both traditional and improved varieties increased to levels estimated by researchers.	11.9%	41.8%	48.3%
11.	Ex-ante. All costs, introduction of Gusau in 1996.	-13.9%	39.1%	47.3%
12.	Ex-ante. All costs, at high yield levels.	14.8%	51.1%	57.5%

In contrast to the negative RORs through 1996, all of the ROR estimates for scenarios in which the benefits persist until 2006 (column 3) are positive. Given the current tightness in the Ugandan economy, a real opportunity cost of capital in the range of 10%-15% is a reasonable estimate for comparison.[17] The projected ROR of 25% to 50% from investment in maize research indicates worthwhile investment.

Scenarios 1 to 3 illustrate the impact on the ROR of incorporating increasing levels of the supporting institutional costs into our analysis. When the investment in research station rehabilitation and manpower training are added to the direct costs of research (including on-farm trials), the 1985-2006 ROR falls from 50% to 35% (column 3). This is a significant drop, but is to be expected given the heavy front loading of these expenditures as well as their high foreign exchange content. The addition of extension costs has little impact; a drop of less than 2 percentage points. Not only are these future costs, and therefore discounted, but the overall level of government investment in extension is very low, and the proportion which can be attributed fairly to maize is even smaller. For the purposes of the sensitivity analysis, scenario 3, which includes all of these costs, was taken as the base case for comparison.

Scenarios 4 and 5 examine the impact of improved variety yields. If Longe 1 achieves yields of 1,400 kg/ha, an increase of 55%, the ROR rises to nearly 40%. The other end of the spectrum is represented by scenario 5, in which the yield increment from adoption is cut by 10% (to 1,080 kg/ha). Again, the changes in estimated ROR are as expected and even scenario 5 gives an acceptable return on investment.

Scenario 6 looks at the impact of changing the adoption ceiling. The projected adoption ceiling was 59%, based on adoption rates for Kawanda Composite in the 1970s; however, this adoption level had never actually been attained. If the adoption ceiling were 43% (the estimated current proportion of maize held by Kawanda Composite), then the ROR falls to 24.8%. This is still an acceptable ROR.

Scenario 7 illustrates the impact of valuing the increased production at the Nairobi import-parity price, which represents a 15% increase in price over the WFP export-parity, farm-gate price. This change has surprisingly little impact, resulting in only a 1.7 percentage point increment in the ROR over the base case.

Scenario 8 values the increased production at the 1991 domestic market price, approximately one-half of the Nairobi import-parity price. The ROR falls by 6 percentage points from the base case to 27%. This still indicates returns in excess of opportunity costs and consequently is a worthwhile investment.

The analysis so far has assumed that as a result of the export market opportunities, the increase in production resulting from the use of new technology has no impact on the price of the commodity. In a closed economy, where the increase in production is significant, this assumption would not hold. In that case, the calculation of benefits which has been used so far

[17] The interest rate for borrowed investment capital is currently running at over 40% per annum, but with inflation at 30% or higher. This leaves a real interest rate in the range of 10%-12%. The interest to be earned from holding funds in a savings deposit is still highly negative.

would over-estimate the benefits to producers while failing to consider the benefits to consumers. In such a case, change in producers' surplus and the consumer's surplus should be considered. Often the benefit of reduced prices is assumed to accrue only to the urban population. This is not necessarily the case.[18]

The benefits to consumers and producers are captured using the Akino/Hyami (1975) approach to measuring economic surplus.[19]   Scenario 9 uses the domestic producer price, but incorporation of the benefits to consumers from falling maize prices in a closed economy increases the estimated ROR to levels very similar to those for the base case scenario. The calculation procedure followed in this method is illustrated in appendix 3.

Scenario 10 uses researchers' estimates of the yield for both traditional varieties and Longe 1 under good management and weather conditions. This change resulted in a nearly 15 percentage point increase in the projected ROR. It is unlikely that these yield levels can be achieved on farm fields unless there is a substantial improvement in farm level management such as monocropping, increased plant population, early planting and clean weeding. The results from this scenario may be indicative of the potential returns if extension advice can encourage farmers to improve management practices.

The last two scenarios attempt to address the question of the impact of success in research efforts currently under way. Scenario 11 measures the expected impact of release of varieties currently in the pipeline. On the basis of extended discussions with the members of the maize research team, it is estimated that blight resistant strains of Gusau and Population 29, higher-yielding varieties already tested in on-farm trials, will be ready for release in 1995, gradually replacing Longe 1 over the 1995-2000 period. This is not expected to change the overall adoption ceiling for improved varieties, but only to increase the yield increment from adoption. Since Gusau and Population 29 are still open-pollinated varieties, no additional production costs were anticipated. Scenario 12 assumes a yield of 4 t/ha and is indicative of the additional gains to be obtained from adoption of chemical weed control, pest management or fertilizer, and hybrid varieties from the IARC system. The high RORs for these scenarios (47.3% and 57.5% respectively) demonstrate the substantial increase in ROR anticipated from future technological developments and the importance of maintaining research effectiveness.

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[18] Where many small producers are actually food deficit households and would therefore benefit from a reduction in price of the basic staple commodity, lower prices can be an important benefit for rural residents as well as urban dwellers.

[19] This approach is also referred to as the index number approach. The index number approach, first pioneered by Griliches (1958) is based on Marshall's economic surplus paradigm. Agricultural research results in rising productivity, hence a downward shift in the aggregate supply function. The benefits of such a supply shift are quantified as the area between the original supply function and the new supply function and below the demand function. The relative gains by producers and consumers depend upon the price elasticities of demand and supply. For purposes of this analysis estimates of the price elasticity of supply and demand for maize in Uganda were taken from Vanegas (1990).

3.3.2. Soybeans

Table 3 presents the results for the soybean ROR analysis under a variety of assumptions. In general, the returns to research in soybeans are far less satisfactory than for maize. Table 3 indicates that if benefits end in 1996 (column 1), the returns to investment are negative for all scenarios. Even if benefits are extended until 2001, the returns will be negative unless new varieties currently in the pipeline can be perfected and released and the institutional constraints to rhizobium dissemination can be overcome (scenario 6). If current benefits (scenarios 1-5) continue to the year 2006, the returns are probably less than the real opportunity cost of capital.

A number of factors contribute to the lower returns to soybean investment. First, the direct cost of research on soybeans was higher than for maize because of the investment in rhizobium production and in its promotion. Secondly, researchers have been unable to identify a variety that significantly increases yield while meeting the demand characteristics of the local market.[20] The smaller size of Nam 1 makes it less acceptable to some consumers. Third, while edible oil can be extracted from soybeans using technology available in Uganda, the demand for soybean cake for livestock feed is very limited.[21] Low per capita incomes constrain the demand for meat and dairy products and hence the demand for feed ingredients. The potential expansion of soybean production in Uganda will be limited by demand constraints.

[20] In addition to its use in livestock feeds, soybeans are roasted as a snack food, or ground into a high-protein baby food supplement. These applications requires large, uniform light colored soybeans. The highest yielding soybean varieties available from the IARC system are small and dark colored.

[21] In developed countries, 60% of the value of soybeans is derived from the cake rather than the oil. It is the combined demand for the two end products which has contributed to the very rapid expansion in world soybean production in the past two decades. In the absence of a demand for cake, sunflower is more suitable for oil extraction because of its higher oil content.

Table 3. The Rate of Return to Soybean Research in Uganda

	SCENARIO ANALYZED	1985-1996	1985-2001	1985-2006
1.	Research costs only—with no rhizobium benefits.	-100%	-4.6%	6.3%
2.	Research costs only, but adding benefits from rhizobium.	-100%	-0.4%	9.6%
3.	Research, rehabilitation, and training costs, without rhizobium benefits.	-100%	-7.4%	3.2%
4.	Research, rehabilitation, training, and extension costs, assuming only 5% yield increment and no benefits from rhizobium.	-100%	0.0%	-6.0%
5.	All costs, assuming 10% yield increment and including benefits from rhizobium.	-100%	-5.6%	4.8%
6.	Ex-ante analysis including all costs, assuming release of higher yielding variety in 1994, which is more rhizobium-responsive and increases adoption ceiling to 70%.	-35.7%	12.9%	19.9%

Scenario 6 includes both release of a new variety and full utilization of existing rhizobium production capacity.[22] The results indicate that if a stable cross which incorporates higher yield with the desired size and color characteristics can be developed, and rhizobium distribution problems can be overcome, a reasonable ROR might be achieved as long as benefits continue through 2001.

3.3.3. Sunflower

[22] A 25-fold increase in rhizobium production capacity would be required to be able to inoculate all of the improved soybeans. Such a drastic expansion of the production and distribution system would require a substantial new round of investment and the institutional constraints appear formidable at this time.

The ROR analysis for sunflower research gives the highest returns of the three commodities (table 4). Scenarios 1 through 3 show the expected decline in ROR as more of the indirect costs are added to the analysis, but even with all costs included and the benefits from hybrids excluded as in scenario 4, the research shows an ROR exceeding 27% in 1996.

Scenario 5 adds the potential benefits from hybrids that have been developed. This scenario assumes that either the research station will continue to carry out hybrid sunflower seed multiplication at current levels or that the national seed scheme will produce a comparable quantity of hybrid seed. Seed multiplication should not be the responsibility of researchers. Unfortunately there is little indication that the Uganda seed scheme is going to be capable of handling the care and exacting management required for hybrid sunflower production.

Table 4. The Rate of Return to Sunflower Research in Uganda

SCENARIO ANALYZED	1985-1996	1985-2001	1985-2006
1. Research costs only.	62.1%	65.5%	65.8%
2. Research, rehabilitation, and training costs.	31.4%	37.7%	38.6%
3. Research, rehabilitation, training, and extension costs.	31.2%	37.5%	38.4%
4. Research, rehabilitation, training, and extension costs, excluding benefits from hybrid sunflower.	27.4%	34.5%	35.6%
5. Research, rehabilitation, training, and extension costs, assuming hybrids have a price advantage but no yield increase.	27.7%	34.5%	35.8%
6. Research, rehabilitation, training, and extension costs. Adoption cut to 30%. No area increase due to promotion efforts. No yield increase from hybrids.	-14.3%	5.8%	10.3%
7. Ex-ante analysis. Includes higher yielding open-pollinated in 1994 and solution of hybrid production constraints allowing expansion of hybrid area to displace open-pollinated up to adoption ceiling of 34%.	44.8%	51.0%	51.6%
8. Ex-ante analysis. Includes higher yielding open-pollinated in 1994, expansion of hybrid area up to an adoption ceiling of 34% and total expansion of improved varieties up to an 80% ceiling.	45.8%	52.3%	53.1%

Scenario 5 is included because data on the yields of the new Ugandan hybrids under farmer conditions are very limited. There are indications that sunflower yields can be highly variable.

Sunflower has a dormancy period just after harvest. If seed from one season is distributed and planted too soon after harvest, germination can be exceedingly poor. On

-station trials have also demonstrated that old seed and/or poor storage can lead to reduced seedling vigor even when acceptable germination levels are obtained. The result is a poor stand and a drastic drop in yields. These factors highlight the importance of institutional factors in the seed multiplication and distribution system since seed quality may not be readily apparent to even the most discerning of farmers.

Earlier diffusion of the new sunflower varieties, as a result of promotion and distribution efforts, contributed to the high ROR.[23] By 1992 nearly 11% of the national sunflower area was already being planted to the high oil content improved seed. This is expected to rise to 35% in 1993 with expanded sunfola seed multiplication financed by USAID. In addition to speeding adoption, the promotional effort has encouraged a 20% expansion of the total area under sunflower.[24] Adoption of new varieties is enhanced by the price premium for the high oil content seed.[25]

The ROR for sunflower needs to be interpreted within the broader context of the edible oils subsector. The edible oils processors in Uganda complain bitterly of a lack of raw materials. At the same time farmers paradoxically complain of a lack of markets for their sunflower. How can this be? The answer is that throughput is constrained by lack of materials resulting in a serious underutilization of production capacity and high unit costs of production for oil. Processors cannot simply raise prices to cover their costs of production because of the inflow of inexpensive Kenyan oil, as discussed previously. High costs of processing can, therefore, only be passed back to the farmers in the form of low farm gate prices offered for oilseeds. If yields remain low, the returns to oilseed production will be unattractive compared to alternative crops and raw material availability will continue to be a constraint. This vicious cycle is illustrated in figure 1.

Research to improve yields on sunflower is one potentially important way to break out of the low capacity utilization cycle. By improving gross margins to farmers it is possible to increase their interest in sunflower production. Since the crushing industry is highly competitive, it is

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[23] With maize and soybeans, extensive seed distribution was dependent upon seed multiplication by the national seed scheme. Multiplication was only begun after the 1991 variety release.

[24] It is assumed that without research and promotion the area under sunflower production would have remained constant at 1990 levels instead of increasing to the estimated 1991 figure.

[25] Price differentials by grade are not yet universal. Small mills and NGOs sometimes pay a uniform price regardless of quality. In isolated areas traders may refuse to pass the price premium for high oil content back to the farmers if competition is not very stiff. If price differentials fail to reach down to the producer level, the incentives for adoption will be muted and the benefits to research may be lower.

very likely that improvements in profit margins resulting from higher capacity utilization will be passed back to farmers in the form of price increases thus reinforcing the possibility of an upward spiral in raw material availability. This is illustrated in figure 2. While raising yields through agricultural research is only one way to break the vicious cycle, it may well be one of the easiest ways to intervene positively in the subsector given the inherent difficulties Uganda has experienced in enforcing protectionist taxation measures.

Figure 1. The Vicious Cycle of Low Production in the Edible Oils Subsector

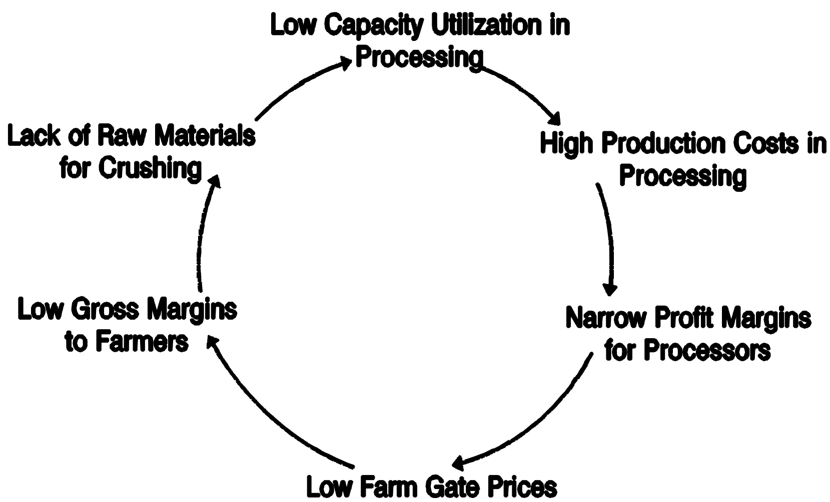
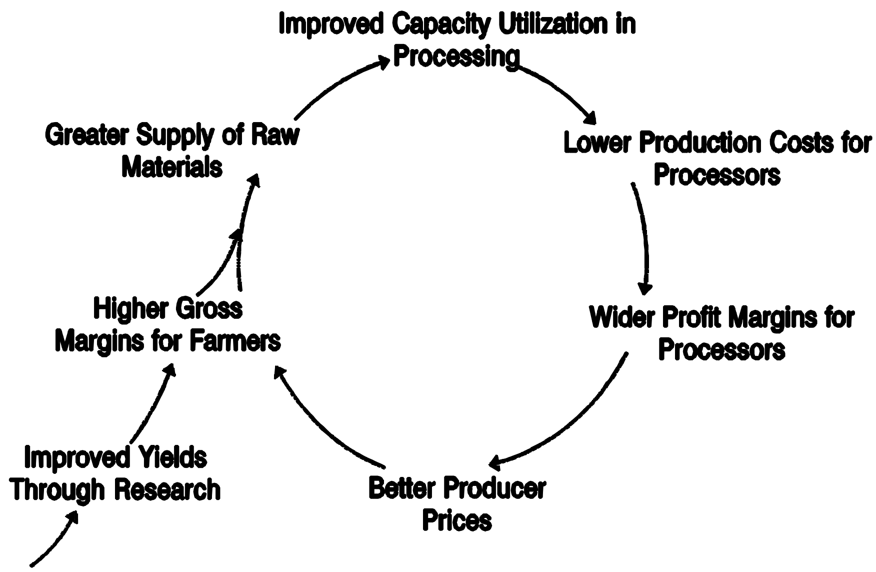


Figure 2. The Potential Upward Spiral of Improved Production in Edible Oils Subsector as a Result of Agricultural Research



What are the implications for the interpretation of the ROR analysis? First it raises questions about the stability of current sunflower production levels. If after several seasons farmers decide that sunflower production is less profitable that expected, or if the current wave of market liberalization spreads to the cotton sector improving gross margins and marketing services for cotton, the benefits to sunflower research could taper off very rapidly. There are already indications that farmers are less than satisfied with sunflower yields. Scenarios 1 through 5 may overestimate the returns to sunflower research because they fail to anticipate the decline in sunflower acreage which may resulting from these other dynamics in the subsector. Scenario 6 was designed to test for the impact of reducing the adoption rate to 30%, eliminating the increase in sunflower area which was observed in response to the sunflower promotion efforts which have accompanied the research in recent years. In addition, this scenario assumes that hybrid production is limited to 1992 levels due to seed production constraints and that hybrids have no yield advantage over the open pollinated varieties.

With this very pessimistic set of assumptions, the projected ROR for sunflower falls dramatically. The ROR estimate is now just marginally acceptable if extended to the year 2006, and it is actually negative if cut off in 1996. The clear message is that research has to find a higher yielding sunflower variety in the near future if the progress achieved so far is to be sustained. Every indication is that hybrids are essential in order to achieve the yields necessary for the sector to be competitive. This requires a solution to the institutional problem of seed multiplication. The high returns projected for the ex-ante scenarios (scenarios 8 and 9) form a sharp contrast to this pessimistic scenario and indicate the potentially high payoff to solving the existing constraints in marketing and hybrid seed production. Whether Ugandan farmers will decide to abandon sunflower production for more profitable alternative commodities or embrace it as an alternative cash crop with an established place in the farming system will depend greatly upon the success of future agricultural research.

While this is not the place for a detailed analysis of the marketing structures for sunflower, the importance of the issue should not be underestimated. Further analysis of the edible oils subsector which explores these factors in depth is being carried out under phase two of this research effort.

3.3.4. Combined Returns to Maize, Soybeans, and Sunflower Research

Table 5 presents the results of a joint ROR analysis for maize, soybeans, and sunflower. This analysis includes all research, rehabilitation, training and extension costs for all three commodities. The benefits from the new open-pollinated varieties of maize and unflower are high enough that they outweigh the low returns to soybean research. The ROR in scenario 1, which includes the base case benefits from all three commodities, is nearly 30%. Even in scenario 2, which excludes benefits from sunflower hybrids and rhizobium and does not assume any yield increment from the new soybean variety, the ROR is quite acceptable in 2006 and marginally so in 2001.

Table 5. The Combined Rate of Return to Maize, Soybeans, and Sunflower Research in Uganda

ANALYSIS CONTENT	1985-1996	1985-2001	1985-2006
1. All costs, benefits from open-pollinated varieties, hybrid sunflower, and rhizobium.	6.3%	24.0%	29.8%
2. All costs, but benefits from only open-pollinated varieties. Assumes no increased yield from Nam 1 soybean variety.	-27.5%	12.4%	22.7%
3. Same as scenario 2, but assumes no export market for maize (valued at the domestic price) and sunflower adoption ceiling cut to 30% due to failure to solve marketing problems.	-53.8%	4.4%	16.8%
4. Ex-ante. All costs and benefits, including new maize variety in 1996, new soybean in 1995, new sunflower in 1994, and solution of supply problem for hybrid sunflower and rhizobium.	15.1%	36.8%	42.3%

The potential importance of marketing constraints is demonstrated by scenario 3. In this scenario it is assumed that there is no export market for maize and increased maize production is valued at the domestic price. This scenario also assumes that adoption of the improved open pollinated variety of sunflower is depressed due to lack of farm-level profits. These two alterations in the assumptions result in a joint ROR which is only marginally acceptable in the year 2006.

The significant potential contribution from varieties in the pipeline and the solution of institutional constraints in rhizobium and hybrid sunflower production/distribution is demonstrated by the 12 percentage point increment in the ROR in scenario 4.

4. UNCAPTURED BENEFITS

Not all the positive impacts of agricultural research are easily captured by a straight ROR analysis which focusses primarily on benefits from increased production. This is certainly true in the case of Uganda. Agricultural research on maize, soybeans, and sunflower has important gender implications for the Ugandan farming system and the distribution of income within the household. All three commodities are less firmly situated within the male sphere of influence than are the more traditional cash crops such as coffee, cotton, tea, and tobacco. Women participate fully in the production and marketing of maize, soybeans, and sunflower. In addition, NGO and micro-projects hoping to enhance women's income-generating capacity have frequently focussed on provision of intermediate technology and technical advice to women's groups to help them enter into both production and processing for the edible oils sector. This research effort will look more closely at this issue as part of the subsector study of phase two.

Another benefit which is difficult to quantify is the extent to which research investments have not only led to an immediate research output, but have strengthened the human capital base and institutional capacity of the country. Institutional and human capital development are investments which have positive payoffs far into the future and across a broad spectrum of commodities and research efforts. The increase in knowledge and skills not only enables the replacement of external research advisors with nationals, but results in an increased earning capacity for the scientists involved.[26] To the extent that investments in technical advice, training, and rehabilitation are included in the costing of the research investment, they result in a very conservative estimate of the returns to research. The history of research in Uganda also illustrates very well the impossibility of turning research off and on. It takes only a short lapse in research support to result in massive losses in human and physical capital which will require painful and expensive new investments to overturn.

Lastly, decision regarding the prioritization of research efforts between different commodities will have serious regional equity implications. This is especially true for sunflower. While sunflower is a relatively new crop, farmers in Northern Uganda have shown keen interest in expanding sunflower production in order to diversify their sources of income. Given the historical concentration of economic activities and development in the south, efforts to increase incomes in the northern region are of particular interest. It is unfortunate indeed that the on-farm research in sunflower production sponsored by USAID coincided with the political insecurity in Northern Uganda during the 1986-1991 period, making it very difficult to judge the acceptability of the newly developed technology in the area most likely to benefit from it in the long-run. The importance that the Ugandan government places on economic development for this region is clearly demonstrated by the recent efforts to initiate a major reconstruction project

[26] One possible way to try to quantify the benefits accrued from training would be to estimate this enhanced income stream. Unfortunately, given the current low salary structures in the public service, the use of official salary scales would grossly underestimate the value of this training which is more likely to accrue in more informal forms (such as consultancy fees, travel opportunities, and other perks involved in working for donor-funded projects, promotion outside of the public sector, and private business earnings).

for the North, financed by the World Bank. The perception of visible government concern for the development of the North could even have implications for future political stability in Uganda.

5. CONCLUSIONS AND OUTSTANDING ISSUES

5.1. Positive Returns to Agricultural Research in Uganda

The ROR analysis has clearly demonstrated that even in Uganda, with its history of political instability, the potential returns to agricultural research are well within the acceptable range. While the returns to soybean research were marginal to negative due primarily to demand and institutional constraints, they were more than outweighed by the positive returns to maize and sunflower research. This proved true even when the high costs of physical rehabilitation, training, and extension were included and benefits were limited to the open-pollinated varieties of maize and sunflower which exhibit the fewest institutional constraints to diffusion.

5.2. Productivity and Sustainability of the Research System

Despite the high potential ROR to investments in agricultural research, Uganda is still plagued by various constraints that inhibit adoption of new technology and the achievement of significant future research results. Foremost among these constraints are macro-level factors which raise questions about the productivity and sustainability of the research system. External economic shocks such as the drastic fall in international coffee prices threaten to undermine the government's ability to invest in agricultural research no matter how potentially profitable such investments may be. Although Uganda is trying very hard to reduce its dependence on coffee exports by diversifying its export base, the fall in prices has resulted in severe foreign exchange shortages and has further limited the already narrow tax base. These constraints have a direct impact on agriculture by constraining the budget allocation to agricultural support services. Uganda's taxation level is very low, at only 8.5% of GDP. The demands on this limited resource base are intense and as belt-tightening measures have intensified under structural adjustment the allocation to agriculture has declined steadily in the past decade, falling from 12% of the budget in 1980/81 to a mere 4% in 1990/91. Uganda's central government expenditure on agriculture averaged just $3.4 per capita over the 1982-87 period, well below the $21 per capita average for a series of 10 sub-Saharan African countries during the same period.[27] Total government expenditure on agriculture in 1990 was only 0.5% of GDP.

The lack of finances for agricultural research has resulted in extremely low remuneration for agricultural researchers. In 1989/90 senior researchers received 10,500/= USh per month in salaries and allowances (less than $250 per year). This is less than half of the average Kampala household expenditure on food alone for that same period.[28] Obviously, salaries fall far short of

[27] The ten countries include Botswana, Mauritius, Swaziland, Zimbabwe, Egypt, Kenya, Malawi, Togo, Ethiopia, Madagascar (World Bank 1988, p.79).

[28] The average monthly household expenditure in Kampala for food exceeded 29,000/= USh in 1989/90, constituting 48.9% of total household expenditure (Ministry of Planning and Economic Development 1991, p. 1.01).

a living wage. Scientists are forced to devote considerable time and energy to simply staying alive. Motivation and productivity decline. Under such conditions, incentive allowances paid to researchers working on USAID-funded projects have a tremendous motivating influence.

With the proposed creation of a new, semi-autonomous, National Agricultural Research Organization, there are hopes that the entire system of rewards and incentives can be restructured independently of the overall civil service in order to promote research productivity. Payment of a living wage, and tying promotion to productivity are key in this restructuring effort. If successfully implemented, such improved incentive structures should have a significant impact on researcher morale as well as future research impact.

Perhaps even more corrosive to research productivity than low salaries has been the uncertainty and lack of control over operating funds. Budget by crises has been the order of the day. Researchers who are entirely government funded have no idea from one month to the next whether funds will be available to carry out their work. For example, funds to all the research stations were cut by 70% in the last quarter of the 1992/93 financial year. Research stations barely had enough money to pay salaries. If it had not been for local currency funds provided through the MFAD project, an entire season of trials would have been lost in the field. It is very difficult for researchers to develop a sense of commitment and professionalism under such conditions. Continued funding is absolutely essential to maintain the achievements that have been obtained and to allow the newly trained scientists to produce to the level of which they are capable.

In the face of such severe macro-level constraints, the Ugandan government and donors alike are faced with the challenge to identify cost-effective means to create a productive and sustainable agricultural research system without mortgaging the future of unborn generations of Ugandans.

APPENDICES

Appendix 1. Research Expenditures

Table 6. Research Expenditures 1986-1992[a]

MAIZE	
USAID Support	$ 335,000
Uganda Government	$ 196,500
Total	$ 531,500
SOYBEANS	
USAID Support	$ 407,500
Other BNF	$ 60,500
Uganda Government	$ 118,500
Total	$ 586,500
SUNFLOWER	
USAID Support (with EIL)	$ 854,500
Uganda Government	$ 92,000
Total	$ 946,500
GRAND TOTAL	$2,064,500

This table presents only the directly attributable research and diffusion costs. In addition, the MFAD project also invested a great deal in physical rehabilitation of the Makerere University Faculty of Agriculture and several research stations as well as both long- and short-term training of scientists. The share of these investments in overall research capacity and institution building which has had an impact on the success of the research in maize, sunflower and soybeans is included in many of the scenarios presented in the rate of return analysis but is not included in the expenditure estimate in the table above.

[a] Taken from Laker-Ojok 1992.

Appendix 2. The Projection of Adoption Curves Based on Historical Seed Sales Data

The logistic growth function is the formulation commonly used to represent the diffusion path of innovations over time. The logistic function is an `S'-shaped curve characterized as follows:

$$P(t) = K/[1+e^{-(a+bt)}]$$

where `P' represents the cumulative growth in the percent of farmers who adopt the innovation; `K' is the long-run upper limit on diffusion (the adoption ceiling); `b' is the slope of the curve and represents a measure of the rate of acceptance of the new technology; and the intercept 'a' reflects aggregate adoption at the start of the estimation period and positions the curve on the time line. Griliches (1958) used this logistic function to describe the diffusion of hybrid corn in the United States.

The estimation of these three parameters, which define the expected diffusion path is conducted in two steps. First, historical data on the sale of improved seeds from the Uganda Seed Scheme during the 1970s are used to estimate the parameters of the diffusion path which occurred in these commodities in the past. The diffusion parameters are estimated with an ordinary least-squares (OLS) regression, using a logistic function of the form discussed above. Because diffusion was cut off by the political insecurity of the 1980s, total diffusion and the date at which the ceiling would have been achieved are forecasted using the estimated diffusion parameters. The level of `K' (which represents the diffusion ceiling) which results in the best fitting regression equation determines which set of parameters is selected for each commodity.

Secondly, this adoption curve is used to project the percent of area planted to each commodity which will be produced using the newly released varieties for each of the next 15 years. Alternative adoption ceilings are then selected to alter the assumed diffusion path for purposes of the sensitivity analysis.

The following table gives the parameters for the best fitting diffusion path for each of the three commodities.

Table 7. Diffusion Paths

ESTIMATED PARAMETER	MAIZE	SOYBEANS	SUNFLOWER
Ceiling	59%	71%	32%
Origin	2.163	5.722	7.252
Slope	.44	.55	2.07
Adjusted R squared	.94	.93	.99

Appendix 3. Rate of Return Calculations

Table 8. Calculation of the Rate of Return to Maize Research and Extension in Uganda: The Base Case Scenario.
(Including research, extension, rehabilitation and training costs. Valued at World Food Program export parity price.)

Category	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
BENEFITS without Research											
Area local vars. (ha)	322000	322000	307000	345000	430000	401000	420000	420000	420000	420000	420000
Yield local vars. (kg)	900	900	900	900	900	900	900	900	900	900	900
Production (t)	289800	289800	276300	310500	387000	360900	378000	378000	378000	378000	378000
Export price ('000 USh/t)	2	2	7	26	57	46	95	126	126	126	126
Prod. value (mill. USh)	449	449	1976	8070	22090	16601	36001	47627	47627	47627	47627
BENEFITS with Research											
Area, local vars. (ha)	322000	322000	307000	345000	430000	401000	419967	419668	418605	417596	415869
Yield, local vars. (kg)	900	900	900	900	900	900	900	900	900	900	900
Production, local (t)	289800	289800	276300	310500	387000	360900	377970	377701	376744	375836	374282
Export price ('000 USh/t)	2	2	7	26	57	46	95	126	126	126	126
Prod. value (mill. USh)	449	449	1976	8070	22090	16601	35998	47589	47469	47354	47158
Area, improved vars.	0	0	0	0	0	0	33	332	1395	2404	4131
Yield, improved (kg)	0	0	0	0	0	0	1200	1200	1200	1200	1200
Prod., impr vars. (t)	0	0	0	0	0	0	39	399	1674	2885	4957
Export price (mill./t)	2	2	7	26	57	46	95	126	126	126	126
Prod. value (mill. USh)	0	0	0	0	0	0	4	50	211	364	625
Add'l benefit	0	0	0	0	0	0	1	13	53	91	156
COSTS											
Research/ext cost (mill.)	0.2	1.8	6.7	18.8	56.6	97.0	136.7	257.9	146.7	110.3	82.9
NET BENEFIT	(0.2)	(2)	(7)	(19)	(57)	(97)	(136)	(245)	(94)	(19)	73
BENEFIT/DEFLATOR	(11)	(34)	(41)	(39)	(62)	(79)	(87)	(157)	(60)	(12)	47
REAL IRR (%) ====>	33.2%		IF CUT OFF IN 2006								
REAL IRR (%) ====>	23.5%		IF CUT OFF IN 2001								

Table 8 (continued). Calculation of the Rate of Return to Maize Research and Extension in Uganda: The Base Case Scenario

Category	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
BENEFITS without Research											
Area local vars. (ha)	420000	420000	420000	420000	420000	420000	420000	420000	420000	420000	420000
Yield Local vars. (kg)	900	900	900	900	900	900	900	900	900	900	900
Production (t)	378000	378000	378000	378000	378000	378000	378000	378000	378000	378000	378000
Export price ('000 USh/t)	126	126	126	126	126	126	126	126	126	126	126
Prod. value (mill. USh)	47627	47627	47627	47627	47627	47627	47627	47627	47627	47627	47627
BENEFITS with Research											
Area, local vars. (ha)	412938	408031	399996	387315	368415	342523	310864	277120	246032	221009	202967
Yield, local vars. (kg)	900	900	900	900	900	900	900	900	900	900	900
Prod., local vars. (t)	371645	367228	359996	348583	331574	308271	279777	249408	221429	198908	182670
Export price ('000 USh/t)	126	126	126	126	126	126	126	126	126	126	126
Prod. value (mill. USh)	46826	46269	45358	43920	41777	38841	35251	31425	27899	25062	23016
Area, impr. vars. (ha)	7062	11969	20004	32685	51585	77477	109136	142880	173968	198991	217033
Yield, impr. vars. (kg)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Prod., impr vars. (t)	8474	14363	24005	39222	61902	92972	130964	171456	208761	238789	260440
Export price ('000 USh/t)	126	126	126	126	126	126	126	126	126	126	126
Prod. value (mill. USh)	1068	1810	3025	4942	7799	11714	16501	21603	26303	30087	32815
Add'l benefit	267	452	756	1235	1950	2929	4125	5401	6576	7522	8204
COSTS											
Research/ext cost (mill)	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9	82.9
NET BENEFIT	184	370	673	1153	1867	2846	4042	5318	6493	7439	8121
BENEFIT/DEFLATOR	118	236	430	736	1192	1817	2581	3395	4146	4750	518

Table 9. Calculation of the Rate of Return to Maize Research and Extension in Uganda: The Akino/Hayami Method

Category	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total area cultivated ('000 ha)	322	322	307	345	430	401	420	420	420	420	420
Area improved vars. ('000ha)	0	0	0	0	0	0	.033	.082	1.395	2.404	4.131
Proportion impr. vars. (1)	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
Yield local vars. (kg/ha)	900	900	900	900	900	900	900	900	900	900	900
Yield impr. vars. (kg/ha)	900	900	900	900	900	900	1200	1,200	1,200	1,200	1,200
Yield gain	0	0	0	0	0	0	300	300	300	300	300
Yield gain/impr. var yield (2)	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0.25
K-factor (3) = (1) x (2)	0	0	0	0	0	0	0.0000	0.0000	0.0008	0.0014	0.0025
Product price ('000 Ush/t)	2	2	7	26	57	46	75	75	75	75	75
Total production ('000t)	289.8	289.8	276.3	310.5	387.0	360.9	378.0	378.1	379.7	380.9	382.9
Prod. value ('000 mill. USh) (4)	.45	.45	1.9	8.1	22.1	16.6	28.3	28.3	28.5	28.6	28.7
Price elasticity of supply	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Price elasticity of demand	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Benefit 1: Area AOC (3)x(4) Mil	0	0	0	0	0	0	1	1	24	41	71
Benefit 2: Area ABC (mill.)[a]	0	0	0	0	0	0	0	0	0	0	0
Total benefits (mill. USh)	0	0	0	0	0	0	1	1	24	41	71
Total costs (mill. USh)	0.2	2	7	19	57	97	137	258	147	110	83
Total net benefit (mill. USh)	(0.2)	(2)	(7)	(19)	(57)	(97)	(136)	(257)	(123)	(69)	(12)
IRR (%) ====> 35.6%											

Table 9 (continued). Calculation of the Rate of Return to Maize Research and Ext. in Uganda: The Akino/Hayami Method

Category	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total area cultivated ('000 ha)	420	420	420	420	420	420	420	420	420	420	420
Area, improved vars. ('000 ha)	7.06	11.97	20.00	32.68	51.58	77.57	109.1	142.9	174.0	199.0	217.0
Proportion, improved vars. (1)	2%	3%	5%	8%	12%	18%	26%	34%	41%	47%	52%
Yield, local varieties (kg/ha)	900	900	900	900	900	900	900	900	900	900	900
Yield, improved vars. (kg/ha)	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Yield gain	300	300	300	300	300	300	300	300	300	300	300
Yield gain, imp. var. yield (2)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
K-factor (3) = (1) x (2)	.0042	.0071	.0119	.0195	.0307	.0461	.0650	.0850	.1036	.1184	.1292
Product price ('000 USh/t)	75	75	75	75	75	75	75	75	75	75	75
Total production ('000t)	386.5	392.4	402.0	417.2	439.9	470.9	508.9	549.5	586.8	616.8	638.4
Prod. value ('000 mill. USh) (4)	28.9	29.4	30.1	31.3	32.9	35.3	38.2	41.2	44.0	46.3	47.9
Price elasticity of supply	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Price elasticity of demand	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Benefit 1: Area AOC (3)x(4) Mil	122	210	359	609	1,013	1,629	2,480	3,505	4,557	5,479	6,186
Benefit 2: Area ABC (mill.)[a]	1	3	9	26	68	164	351	649	1,028	1,413	1,740
Total benefits (mill. USh)	123	213	368	635	1,081	1,793	2,831	4,154	5,585	6,892	7,926
Total costs (mill. USh)	83	83	83	83	83	83	83	83	83	83	83
Total net benefit (mill. USh)	40	130	285	552	998	1,710	2,748	4,071	5,502	6,809	7,843

[a] [.5x(area AOC)x(3)x(1+Es)^2]/(Es+Ed); Es=price elasticity of supply; Ed= price elasticity of demand.

Table 10. Calculation of the Rate of Return to Soybean Research and Extension in Uganda: The Base Case Scenario

(Includes research, extension, training and rehabilitation costs. Assumes a 10% yield increase from Nam 1 and 25% yield increase from rhyzobium inoculation.)

Category	1985	1986	1987	1988	1989	1990	1991
BENEFITS without Research							
Area in local varieties (ha)	12000	12000	10000	17000	18000	37000	54000
Yield, local varieties (kg)	800	800	800	800	800	800	800
Production (t)	9,600	9,600	8,000	13600	14400	29600	43200
Nominal price local vars. ('000 USh/t)	9	9	28	65	103	134	155
Prod. value ('000,000 USh) (1)	86	86	221	884	1,483	3,966	6,696
BENEFITS with Research							
Area in local varieties (ha)	12000	12000	10000	17000	18000	36990	53965
Yield, local varieties (kg)	800	800	800	800	800	800	800
Production, local varieties (t)	9,600	9,600	8,000	13600	14400	29592	43172
Nominal price, local vars. ('000/t)	9	9	28	65	103	134	155
Prod. value, local vars. (2)	86	86	221	884	1,483	3,965	6,692
Area in improved varieties	0	0	0	0	0	10	35
Yield, improved vars. (kg)	0	0	0	0	0	880	880
Prod., improved vars. (t)	0	0	0	0	0	8	31
Nominal price, improved vars. ('000 USh/t)	9	9	28	65	103	134	155
Prod. value, impr. vars. (3)	0	0	0	0	0	1	5
Area, inoculated with rhyzobium	0	0	0	0	0	100	267
Yield, inoculated (kg)	0	0	0	0	0	1,000	1,000
Prod., inoculated (t)	0	0	0	0	0	100	267
Price, inoculated ('000 USh/t)	9	9	28	65	103	134	155
Prod. value, inoculated (3)	0	0	0	0	0	13	41
Add'l benefit (5)=(4)+(3)+(2)-(1)	0	0	0	0	0	14	42
COSTS							
Additional prod. costs (mill. USh)	0	0	0	0	0	0	1
Research costs (mill. USh)	0.2	2	10	27	71	102	117
Total costs (6) (mill. USh)	0.2	2	10	27	71	103	118
NET BENEFIT (7)=(5)-(6)	(0.2)	(2)	(10)	(27)	(71)	(89)	(76)
REAL NET BENEFIT	(11)	(34)	(61)	(56)	(78)	(73)	(49)
REAL IRR (%) ====> 4.8%			IF CUT OFF AFTER 2006				

Table 10 (continued). Calculation of the Rate of Return to Soybean Research and Extension in Uganda: The Base Case Scenario

Category	1992	1993	1994	1995	1996	1997	1998
BENEFITS without Research							
Area in local varieties (ha)	54000	54000	54000	54000	54000	54000	54000
Yield, local varieties (kg)	800	800	800	800	800	800	800
Production (t)	43200	43200	43200	43200	43200	43200	43200
Nominal price, local varieties ('000 USH/t)	160	160	160	160	160	160	160
Prod. value (mill. USh) (1)	6,912	6,912	6,912	6,912	6,912	6,912	6,912
BENEFITS with Research							
Area in local varieties (ha)	53939	51135	49892	48301	46411	44351	42310
Yield, local varieties (kg)	800	800	800	800	800	800	800
Production, local varieties (t)	43152	40908	39914	38641	37129	35481	33848
Nominal price, local varieties ('000 USh/t)	160	160	160	160	160	160	160
Prod. value, local vars. (2)	6,904	6,545	6,386	6,183	5,941	5,677	5,416
Area in improved varieties	61	2,447	3,586	5,047	6,775	8,630	10417
Yield, improved vars. (kg)	880	880	880	880	880	880	880
Prod., improved vars. (t)	53	2,154	3,156	4,441	5,962	7,595	9,167
Nominal price, impr. vars. ('000 USh/t)	160	160	160	160	160	160	160
Prod. value, impr. vars. (3)	9	345	505	711	954	1,215	1,467
Area inoculated with rhyzobium	334	417	521	652	815	1,019	1,273
Yield, inoculated (kg)	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Prod., inoculated (t)	334	417	521	652	815	1,019	1,273
Price, inoculated ('000 USh/t)	160	160	160	160	160	160	160
Prod. value, inoculated (3)	53	67	83	104	130	163	204
Add'l benefit (5)=(4)+(3)+(2)-(1)	54	45	63	85	113	143	174
COSTS							
Add'l prod. costs (mill. USh)	2	2	3	3	4	5	6
Research costs (mill. USh)	236	239	168	139	139	139	107
Total costs (6) (mill.)	237	241	170	142	142	143	113
NET BENEFIT (7)=(5)-(6)	-183	-196	-108	-56	-30	0	61
REAL NET BENEFIT	-117	-125	-69	-36	-19	0	39

Table 10 (continued). Calculation of the Rate of Return to Soybean Research and Extension in Uganda: The Base Case Scenario

Category	1999	2000	2001	2002	2003	2004	2005	2006
BENEFITS without Research								
Area in local vars. (ha)	54000	54000	54000	54000	54000	54000	54000	54000
Yield local vars. (kg)	800	800	800	800	800	800	800	800
Production (t)	43200	43200	43200	43200	43200	43200	43200	43000
Nominal price, local varieties ('000 USh/t)	160	160	160	160	160	160	160	160
Prod. value (mill. USh)	6,912	6,912	6,912	6,912	6,912	6,912	6,912	6,912
BENEFITS with Research								
Area in local vars. (ha)	40469	38943	37766	36906	36303	35892	35617	35436
Yield local varieties (kg)	800	800	800	800	800	800	800	800
Production local vars. (t)	32375	31155	30213	29525	29042	28713	28494	28349
Nominal price local vars. ('000 USh/t)	160	160	160	160	160	160	160	160
Prod. value, local vars.	5,180	4,985	4,834	4,724	4,647	4,594	4,559	4,536
Area in improved vars.	11940	13067	13748	14494	15097	15508	15783	15964
Yield improved vars. (kg)	880	880	880	880	880	880	880	880
Prod., Impr. vars. (t)	10507	11499	12098	12755	13286	13647	13889	14048
Nominal price, impr. vars. ('000 USh/t)	160	160	160	160	160	160	160	160
Prod. Value, impr. vars.	1,681	1,840	1,936	2,041	2,126	2,184	2,222	2,248
Area with rhyzobium	1,591	1,989	2,487	2,600	2,600	2,600	2,600	2,600
Yield inoculated (kg)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Prod, inoculated (t)	1,591	1,989	2,487	2,600	2,600	2,600	2,600	2,600
Price, inoculated ('000 USh/t)	160	160	160	160	160	160	160	160
Prod. value, inocl'ed	255	318	398	416	416	416	416	416
Add'l benefit	204	231	256	269	276	282	285	288
COSTS								
Add'l prod. costs (mill.)	8	10	12	12	12	12	12	12
Research costs (mill.)	11	11	11	11	11	11	11	11
Total costs (mill.)	19	21	23	24	24	24	24	24

NET BENEFIT	185	210	233	245	253	258	262	264
REAL NET BENEFIT	118	134	148	157	161	165	167	169

Table 11. Calculation of the Rate of Return to Sunflower Research and Extension in Uganda: The Base Case Scenario

(Includes research, extension, training, rehabitation, promotion costs. Higher price due to oil content.)

Category	1985	1986	1987	1988	1989	1990	1991
BENEFITS without Research							
Area in local varieties (ha)	5,000	5,000	5,000	5,000	28800	32000	32000
Yield, local varieties (kg)	600	600	600	600	600	600	600
Production (t)	3,000	3,000	3,000	3,000	17280	19320	23220
Price local vars. ('000 USh/t)	6	6	9	12	25	80	90
Prod. value (mill. USh) (1)	18	18	27	36	432	1,546	2,090
BENEFITS with Research							
Area in local varieties (ha)	5,000	5,000	5,000	5,000	28800	31986	34801
Yield, local varieties (kg)	600	600	600	600	600	600	600
Production, local varieties (t)	3,000	3,000	3,000	3,000	17280	19191	20881
Price local varieties ('000 USh/t)	6	6	9	12	25	80	90
Prod. value, local vars. mill.	18	18	27	36	432	1,535	1,879
Area impr. open-pollinated (ha)	0	0	0	0	0	214	3,274
Yield, improved vars. (kg)	0	0	0	0	0	600	600
Prod., impr. vars. (t)	0	0	0	0	0	129	1,964
Price, impr. vars. ('000 USh/t)	6	6	9	12	25	100	120
Prod. value, impr vars. (mill.)	0	0	0	0	0	13	236
Area in improved hybrid vars (ha)	0	0	0	0	0	0	625
Yield, improved vars. (kg)	1,400	1,400	1,400	1,400	1,400	1,400	1,400
Prod., impr. vars. (t)	0	0	0	0	0	0	875
Nominal price, impr vars. (USh/t)	6	6	9	12	25	100	120
Prod. value, impr vars (mill.)	0	0	0	0	0	0	105
Add'l benefit (mill. USh)	0	0	0	0	0	3	130
COSTS With Research							
Additional prod. costs (mill. USh)	0	0	0	0	0	0	7
Research/extension costs (mill.)	0.2	2	10	32	68	188	271
Total costs (mill. USh) (6)	0.2	2	10	32	68	188	277
NET BENEFIT (7)=(5)-(6)	(0.2)	(2)	(10)	(32)	(68)	(185)	(147)
REAL NET BENEFIT (7)/deflator	(11)	(34)	(59)	(67)	(74)	(152)	(94)
REAL IRR (%) ====> 38.4%			IF CUT OFF IN 2006				

REAL IRR (%) ====>	37.5%	IF CUT OFF IN 2001
REAL IRR (%) ====>	31.2%	IF CUT OFF IN 1996

Table 11 (continued). Calculation of the Rate of Return to Sunflower Research and Extension in Uganda: The Base Case Scenario

Category	1992	1993	1994	1995	1996	1997	1998
BENEFITS without Research							
Area in local varieties (ha)	32000	32000	32000	32000	32000	32000	32000
Yield, local varieties (kg)	600	600	600	600	600	600	600
Production (t)	19200	19200	19200	19200	19200	19200	19200
Nominal price, local vars. ('000 USh/t)	120	120	120	120	120	120	120
Prod. value (mill. USh) (1)	2,304	2,304	2,304	2,304	2,304	2,304	2,304
BENEFITS with Research							
Area in local varieties (ha)	33639	30449	24883	22788	22315	22222	22204
Yield, local varieties (kg)	600	600	600	600	600	600	600
Production, local varieties (t)	20183	18270	14930	13673	13389	13333	13322
Nominal price, local vars. ('000 USh/t)	120	120	120	120	120	120	120
Prod. value, local vars. (mill. USh) (2)	2,422	2,192	1,792	1,641	1,607	1,600	1,599
Area impr. open-pollinated vars.	4,561	7,751	13317	15412	15885	15978	15996
Yield improved vars. (kg)	600	600	600	600	600	600	600
Prod., impr. vars. (t)	2,737	4,650	7,990	9,247	9,531	9,587	9,598
Nominal price, impr. vars. ('000 USh/t)	160	160	160	160	160	160	160
Prod. value impr. vars. (mill.) (3)	438	744	1,278	1,480	1,525	1,534	1,536
Area in improved hybrid vars. (ha)	500	500	500	500	500	500	500
Yield, improved vars. (kg)	1,400	1,400	1,400	1,400	1,400	1,400	1,400
Prod., impr. vars. (t)	700	700	700	700	700	700	700
Nominal price, impr vars. (USh/t)	160	160	160	160	160	160	160
Prod value, impr. vars. (mill.) (4)	112	112	112	112	112	112	112
Add'l benefit (mill. USh)	668	744	878	928	940	942	942
COSTS with Research							
Add'l prod. costs (mill. USh)	5	5	5	5	5	5	5
Research/extension costs (mill.)	275	163	149	59	59	59	8
Total costs (mill. USh) (6)	281	168	154	64	64	64	14
NET BENEFIT (7)=(5)-(6)	387	576	724	864	876	878	929
REAL NET BENEFIT (7)/deflator	247	368	462	552	559	560	593

Table 11 (continued). Calculation of the Rate of Return to Sunflower Research and Extension in Uganda: The Base Case Scenario

Category	1999	2000	2001	2002	2003	2004	2005	2006
BENEFITS without Research								
Area in local vars. (ha)	32000	32000	32000	32000	32000	32000	32000	32000
Yield local vars. (kg)	600	600	600	600	600	600	600	600
Production (t)	19200	19200	19200	19200	19200	19200	19200	19200
Nominal price, local varieties ('000 USh/t)	120	120	120	120	120	120	120	120
Prod. value (mill. USh)	2,304	2,304	2,304	2,304	2,304	2,304	2,304	2,304
BENEFITS with Research								
Area in local vars. (ha)	22201	22200	22200	22200	22200	22200	22200	22200
Yield, local vars. (kg)	600	600	600	600	600	600	600	600
Prod., local vars. (t)	13320	13320	13320	13320	13320	13320	13320	13320
Nom. price, local vars. ('000 USh/t)	120	120	120	120	120	120	120	120
Prod. value, local vars. (mill. USh)	1,598	1,598	1,598	1,598	1,598	1,598	1,598	1,598
Area, impr. open-pollinated vars. (ha)	15999	16000	16000	16000	16000	16000	16000	16000
Yield, impr. vars. (kg)	600	600	600	600	600	600	600	600
Prod., impr. vars. (t)	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Nominal price, impr. vars. ('000 USh/t)	160	160	160	160	160	160	160	160
Prod. value impr vars.	1,536	1,536	1,536	1,536	1,536	1,536	1,536	1,536
Area hybrid vars. (ha)	500	500	500	500	500	500	500	500
Yield hybrid vars. (kg)	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
Prod. hybrid vars. (t)	700	700	700	700	700	700	700	700
Price hybrid vars. USh/t	160	160	160	160	160	160	160	160
Prod. value hybrids (mill.)	112	112	112	112	112	112	112	112
Add'l benefit (mill. USh)	942	942	942	942	942	942	942	942
COSTS with Research								
Add'l prod costs (mill)	5	5	5	5	5	5	5	5
Research/ext costs (mill.)	8	8	8	8	8	8	8	8
Total costs (mill.)	14	14	14	14	14	14	14	14
NET BENEFIT	929	929	929	929	929	929	929	929
REAL NET BENEFIT (7)/Deflator	593	593	593	593	593	593	593	593

Some of these investments have not yet made any direct contribution to these particular commodities. For example, many of the scientists sent for long-term graduate training have yet to return to their home research institution. In addition, there are benefits from these investments which are difficult to capture in our ROR analysis. The fact that a scientist who is sent for training was originally a maize breeder is no guarantee that he or she will work on the maize research program upon completion. The improvement in the human capital base is expected to lead to benefits somewhere within the agricultural sector. Similarly, investments in housing and research facilities may serve additional commodity programs as well as enhancing such intangibles as scientist morale and sense of commitment. If these investments were in simple durables such as equipment, you would normally include a salvage value for the durable item in the benefit stream at the end of the project life in order to reflect their true contribution to the economy. This is extremely difficult to estimate for improvements in human or institutional capital, especially in Uganda, where the salary of a scientist is such a poor reflection of the value of his/her contribution.

These rehabilitation and training costs represent clearly necessary investments. They form part of the standing institutional capital which is essential for research success and must somehow be incorporated into the analysis of the impact of the research portfolio. For this reason, the inclusion of the share of rehabilitation investments which can reasonably be attributed to the maize, sunflower, and soybean programs is valid even though it is recognized that not all the benefits accruing to these investments have been captured in our analysis.

To a large extent both the costs and impact of such promotion are unknown. The Ugandan extension system is in a general state of disarray. Extension agent morale and commitment is exceptionally low as a result of the abysmal terms of service. Effectiveness is limited by the lack of such basics as transportation and demonstration materials. Out of 281 randomly selected farmers from six districts, 43.5% reported having never been advised by an extension agent while another 7.9% had not been advised for over 5 years.

The expected impact of such extension activity is as difficult to predict as its costs. The existing extension system is undergoing a fundamental re-organization the exact nature and impact of which are yet to be determined. It is clear that efforts are focussed on reducing staff numbers and enhancing the efficiency and productivity of individual extension agents. One emphasis is on transmission of more relevant and clearly formulated extension messages. Diffusion of improved varieties is one easily identifiable target. Monitoring and evaluation of the extension system pilot project may in the future provide a better means of measuring extension impact. In this analysis, no particular increases in benefits are specifically attributed to the inclusion of the extension effort.

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