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An Economic Analysis of Research and Technology Transfer of Millet, Sorghum, and Cowpeas in Niger

by

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AN ECONOMIC ANALYSIS OF RESEARCH AND TECHNOLOGY TRANSFER OF MILLET, SORGHUM, AND COWPEAS IN NIGER

by

Valentina Mazzucato* and Samba Ly**

June 1994

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EXECUTIVE SUMMARY

Agriculture is the largest sector of the Nigerien economy. In 1988 it employed some 88% of the country's labor force and accounted for 36% of the gross domestic product (GDP). Millet and sorghum are the two most important crops. They accounted for 85% of total production and 80% of national calorie intake in 1990. Cowpea is the leading cash crop, sold mainly to Nigeria. Millet, sorghum, and cowpea intercropping is Niger's most common agricultural production system. From 1961 to 1990, cowpea yields increased an average 0.2% annually, while millet and sorghum yields decreased. Millet yields fell an average 0.7% per annum and sorghum decreased by 2.7% per annum. Since 1970 Niger has experienced 13 years of deficit cereal production. During six of those the country imported more than 30% of its food requirements.

Production decreases can be largely attributed to decline of total rainfall, increase in variability of rainfall, soil degradation, and increase in population pressure, leading to increased cultivation of marginal lands. Niger has one of the fastest growing populations in the world. Food demand is increasing steadily. While achieving food self-sufficiency is one of the government's highest priorities for the agricultural sector, enlarging the total cultivated area is not a viable, long-term option. Meeting future food demand will require continuous investment in the generation and transfer of productivity-enhancing agricultural technologies. Such investments are costly and compete for scarce public resources.

This study analyzes returns to investments in Niger's research and technology transfer system for millet, sorghum, and cowpea between 1975 and 1991. Sixty-eight percent of the country's public-sector outlays for agricultural research and 58% of its agricultural researchers were devoted to research on these three crops between 1986 and 1990. Most of this research was done by INRAN, the national agricultural research institute of Niger (Institut National de la Recherche Agronomique du Niger).

Millet, Sorghum, and Cowpea Research

Since 1976, USAID has invested more than US $22 million in three millet, sorghum, and cowpea research projects in Niger, all of which were executed by or in association with INRAN. The last USAID project was decertified in 1990 and terminated in June 1992. However, a 1992 World Bank loan has provided on-going funding for INRAN.

INRAN was established in 1975 to replace the colonial French agricultural research institute – Institut de Recherches Agronomiques Tropicales (IRAT). Much of INRAN's early millet, sorghum, and cowpea research was carried over from IRAT. Early emphasis was on plant breeding – the development of dwarf and early maturing varieties, two characteristics suitable for Niger's arid climate. Improved varieties were promoted throughout the country with accompanying agronomic recommendations. Most of these, however, were for high-input, monocropped farming systems, which turned out to be highly inappropriate for the on-farm realities of Niger.

The improved varieties evaluated in this analysis are P3KOLLO, HKP, and CIVT for millet and TN5-78 for cowpeas. Also included are three new sorghum varieties about to be released to farmers: NAD1, SEPON82, and SRN39. All of these varieties have been worked on by INRAN during the period of 1975-1991. The economic analysis has thus been conducted both including and excluding HKP. HKP's inclusion here is disputable because its development began at IRAT, prior to 1975 when INRAN was established. However, much of the extension and seed multiplication work for this variety has been done by INRAN.

On-farm trials carried out between 1985 and 1989 comparing improved varieties with unimproved local varieties, obtained average yield increases of 22% for the improved millet varieties being analyzed. Corresponding cowpea yield differentials ranged between 27% and 46%, depending on the region. Given that average millet and cowpea yields are low to begin with, these percentages amount to low real yields of only 200-550 kg/ha for millet and 50-100 kg/ha for cowpeas.

Adoption of improved millet and cowpea varieties is low in Niger, as indicated by seed distribution figures and a survey of extension personnel. Adoption peaked in 1984 when an estimated 900,000 ha, or 20% of the total cultivated area under millet and cowpea, was sown with improved varieties. During the severe droughts of 1985 and 1988 many farmers reverted to traditional varieties. By 1991, the total area sown with improved varieties had fallen to less than 12%.

Measured Returns to Research Investments

The rate of return was calculated together for research, extension, and seed multiplication, reflecting the close relationship of the three. According to the present analysis, INRAN's genetic-improvement research on millet, sorghum, and cowpea will return between 2% and 21% annually, between 1975 and 2011. These returns are low compared with those obtained in related studies of other countries and commodities. However, they do indicate that research and technology transfer have contributed to increased productivity in Niger's agricultural sector.

The single, most influential variable on the rate of return to research investment is the level of farmer adoption of a new variety. When the rate of adoption was modelled to increase by 25%, the rate of return more than doubled. The importance of adoption underscores the need for both extension and research to monitor adoption of new technologies if an accurate economic evaluation of their programs is to be made. Evaluation mechanisms should therefore be included in the institutional organization of research and technology transfer.

Constraints to Technology Development and Adoption

Niger's climate is harsh and extremely variable; water supplies are particularly scarce and irregular and soil quality is low. Improved crop varieties from other countries can rarely be imported for direct use. The scope for increasing yields through improved varieties alone is particularly limited, given the very real prospect of climate-induced crop failures. Economic losses due to crop failures are magnified considerably when purchased inputs are used in conjunction with new varieties. In Niger, climate greatly influences the pattern of adoption of improved varieties, particularly as periodic droughts require farmers to restock their seeds and mobilize scarce resources to bring drought-stressed land back under cultivation.

Adoption of improved cereal varieties is hindered by a number of factors: the low market price for cereal surplus, deficient infrastructure, unavailability of seeds and inputs, and capital constraints. Also, the extension system has suffered from lack of resources, high mobility of its workers, and various changes of mandate, all of which have slowed its development and limited its farm-level impact.

Niger's seed multiplication system has been a costly operation. Because most varieties could be mass-selected by farmers there was little demand for multiplied seed in years of good rainfall. Following years of severe drought, however, the system was unable to satisfy the peak demand for seed.

In many respects, the research orientation at INRAN was science-driven between 1975 and 1990. Although research focussed on food crops, the issues investigated were set by the scientific community and had little relevance to on-farm production constraints. Most research outputs were thus inappropriate. The research system also lacked resources. Donor funds, particularly from USAID, greatly contributed to INRAN's budget. But donor support to research is only a fraction of that provided to other development activities in the agricultural sector. For example, USAID support to INRAN between 1975 and 1991 was only about 25% of what it invested in the seed multiplication centers. Moreover, during the same period, funding from the Nigerien government accounted for less than 25% of INRAN's total expenses. Total research funding in Niger averaged only 0.30% of the agricultural GDP between 1976 and 1985. This is well below West Africa's regional average of 0.73%, as well as the conservative 1985 target of 0.50% set by the United Nations at the World Food Conference of 1974, and the often-cited World Bank target of 2.0%.

Non-Measured Returns to Research Investments

An evaluation of a young research institution such as INRAN must include the degree to which a viable and relevant research capacity has been institutionalized. Between 1976 and 1980, 44% of the expenditures in the millet, sorghum, and cowpea research programs went for capital investments, both physical and human. Since 1975 INRAN grew from just five to sixty-three Nigerien researchers with a degree level of BSc or higher. INRAN also established a documentation center, computer unit, cartography and cereal-quality laboratories, and various other facilities at substations throughout the country. These investments lay the institutional framework for continuing research in the future.

In recent years INRAN has begun the shift to a demand-driven research agenda allowing for feedback from farmers and consumers. The agronomy department has begun development of time- and location-specific agronomic recommendations. These account for the variety of production conditions and practices throughout the country. The resulting "fiche technique" is now the research output most widely disseminated by the extension service. Also, the rural economics department of INRAN has institutionalized a system of on-farm trials to identify the most urgent production constraints faced by farmers. Additionally, a cereal-quality laboratory has been established to test new varieties for consumer concerns, such as cooking characteristics and taste.

Issues

In Niger, research has been primarily focussed on genetic breeding, which is highly resource intensive. While the present study shows positive returns to investment in this research program, it does raise questions as to whether such an investment should be maintained. Productivity gains based on varietal improvements have been hard won in the difficult production environment of Niger. This is particularly so for millet and sorghum, where thousands of years of natural selection have given rise to a number of good local landraces. It is these landraces that have performed best in Niger's various microclimates and localized production environments. In a country where soil and water are the main productivity constraints, and with a cattle population of 15 million, it seems appropriate for INRAN to focus more of its research efforts on improved crop and resource management and related areas in animal production. A structured consideration of INRAN's research strategy and priorities is in order.

INRAN's limited collaboration with regional and international research institutions has also been highlighted in the course of this study. The institute has placed little emphasis thus far on either networks or cooperative research. INRAN's links with the ICRISAT Sahelian Center at Sadoré in particular do not appear as productive as one might expect from two institutions working on the same topic only 45 km from each other. In light of INRAN's limited financial and human resources, functional linkages to external sources of varietal improvements would allow scarce domestic resources to be reallocated to other research problems particular to Niger.

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AgGDP	Agricultural gross domestic product
APS	Agricultural Production Support project
ARDETEC	Atelier de Recherche et de Développement de Technologies
ARI	Agricultural research intensity
CA	Centrale d'Approvisionnement
CDA	Chef de District Agricole
CEAO	Communauté Economique de l'Afrique de l'Ouest
CERRA	Centre Régional de la Recherche Agronomique
CFA (also FCFA)	Francs de la Communauté Française d'Afrique
CILSS	Comité Permanent Inter-états de la Lutte Contre la Sécheresse dans le Sahel
CIRAD	Centre de Coopération International en Recherche Agronomique pour le Développement
CLRV	Cellule Recherche Vulgarisation
CNCA	Caisse Nationale de Crédit Agricole
CNRA	Centre National de Recherche Agronomique
DDA	Direction Départementale de l'Agriculture
DECOR	Département de Recherches en Economie Rurale
DEP	Division des Etudes et Programmes
DEF	Division Enseignement Formation
DRA	Département de Recherches Agricoles
DRE	Département de Recherches Ecologiques
DRF	Département de Recherches Forestieres
DRVZ	Département de Recherches Vétérinaires et Zootechniques
DSI	Département de la Statistique et de l'Informatique
FAO	Food and Agriculture Organization
FNI	Fond National d'Investissement
GDP	gross domestic product
GNP	gross national product
GON	Government of Niger
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
INTSORMIL	International Sorghum/Millet Research
INRAN	Institut National de la Recherche Agronomique du Niger, formerly Institut National de Recherches Agronomiques du Niger
IRAT	Institut de Recherches Agronomiques Tropicales
IRI	Institut de Radio-Isotopes
IRSH	Institut de Recherche en Sciences Humaines
ISNAR	International Service for National Agricultural Research
MAG/EL	Ministère de l'Agriculture et de l'Elevage
NAAR	Niger Applied Agricultural Research project
NARS	National Agricultural Research System

NCP	Niger Cereals Project
NCR	Niger Cereals Research project
ONAHA	Office National des Aménagements Hydro-agricoles
OPVN	Office des Produits Vivriers du Niger
PNRA	Projet National de la Recherche Agronomique
PRSAA	Projet pour les Services d'Appui à l'Agriculture
SAA	Service d'Arrondissement de l'Agriculture
SONARA	Société Nigérienne de Commercialisation de l'Arachide
TROPSOILS	Tropical Soils Collaborative Research
UNC	Union Nationale des Coopératives
UNCC	Union Nigérienne de Crédit et de Coopération
UNDP	United Nations Development Program
USAID	United States Agency for International Development

Figure 1. The Republic of Niger

1. INTRODUCTION

Agriculture, including livestock, is the largest sector of Niger's economy. In 1988, it employed 88% of the labor force (FAO 1989), accounted for 36% of gross domestic product (GDP) (Ministère du Plan 1991a), and provided virtually all of the country's food requirements in years of good rainfall. By generating employment and income, agriculture supports growth and diversification in other sectors of the Nigerien economy.

The greatest challenge for the agricultural sector in the 1990s is to feed the country's rapidly growing population on the 12% of its land that is arable. Niger had a population of close to eight million inhabitants in 1991, growing at an annual rate of about 3.3%. Most of the country's 150,000 km^2 of potential agricultural land receive only an average 300-400 mm of rain—the bare minimum required for rainfed cultivation. Agriculture has been forced onto increasingly marginal lands by soil degradation, population pressure, and the decline in rainfall over the past two decades. During this period the 300 mm isohyet, demarcating the boundaries of arable land, moved southward 100-150 km (Sivakumar et al. 1992). Further expansion of cultivated area is not a viable, long-term option for increasing agricultural production. Meeting future food demand depends largely on technological innovations to increase productivity while conserving the limited and fragile natural resource base.

Increasing food production therefore requires continuing investment in the generation and transfer of productive agricultural technologies for farmers. Because such investments are costly, they compete for scarce public resources. In light of the global trend of declining public funding for agricultural research, research must produce results beneficial to the population. And it must do so in an efficient and effective manner.

Over 170 evaluations of the return to investments in agricultural research have been conducted in Asia, Latin America, and other developed countries. However, as of 1991 only seven pertained to sub-Saharan Africa. The present study was commissioned by the United States Agency for International Development (USAID) with two objectives: to evaluate the economic returns to agricultural research in Niger and to analyze the principal institutional and organizational factors influencing the development and adoption of agricultural technologies. For the first objective, an ex-post rate of return methodology is used to evaluate past research in terms of the economic benefits to the country's producers and consumers of millet, sorghum, and cowpeas. Between 1975 and 1991, three millet and one cowpea improved varieties were developed, disseminated, and to some degree adopted by farmers in Niger. A further three varieties of sorghum, one of which is a hybrid, have been developed and will be ready for dissemination by 1995. The rate-of-return analysis focusses on these seven varieties.

For the second objective, to identify the most important factors influencing the returns to agricultural research in Niger, a qualitative analysis was conducted on the macroeconomic and agroecological environment. This focussed on the research, extension, and seed multiplication systems. This second objective also addressed a more general issue concerning African national agricultural research systems, namely, the role of a small agricultural research system in a poor country. Niger ranks seventeenth from the bottom worldwide in its per-capita gross national product (GNP) ($290 in 1989 dollars) (World Bank 1989). Compared with other low-income countries, Niger's agricultural research system is small in terms of both researchers and funding (Pardey and Roseboom 1991).

Millet, sorghum, and cowpeas are the focus for this study because of their importance in terms of diet, area cultivated, and use of research resources. These three crops occupy 99% of the area cultivated during the rainy season. Millet and sorghum account for 80% of calorie intake. Because cowpeas are virtually always intercropped, especially with millet and sorghum, all three crops were studied. The time period under investigation is 1975 to 1991, the latest year for which data were available. Research benefits have been projected until 2011. Nineteen seventy-five provides a useful start date as it was the year when the Institut National de Recherches Agronomiques du Niger (INRAN), the institute being studied, was founded.

This study is based on data and information collected during four months of in-country research. Extensive interviews were conducted with extension and research personnel, visits were made to all of the agricultural departments, and other experts in the field were consulted. Although time constraints made a farmer survey impossible, on-farm trial results, as well as our observations from the field have contributed to our knowledge of farm conditions in Niger. National statistics were collected from the Ministère de l'Agriculture et de l'Elevage (MAG/EL), the Ministère du Plan, and the treasury department.

This report is organized as follows: Section two presents the institutional setting for agriculture and briefly describes the macroeconomy. Agricultural policies are reviewed and the agriculture sector, in particular the millet, sorghum, and cowpea subsectors, are presented. Section three provides the organizational setting of research and technology transfer and qualitatively analyzes the principal factors affecting the adoption of new technologies. Section four describes the data and methodology used for the economic analysis of the returns to investment in millet, sorghum, and cowpea research and technology transfer. Section five presents the results of the rate-of-return calculations. Section six summarizes the results of the study and draws implications for research policy in Niger.

2. THE INSTITUTIONAL SETTING FOR AGRICULTURE

2.1. Macroeconomy

Niger is a landlocked country occupying an area of 1.267 million km^2 and sharing its border with six countries. It is subdivided into seven administrative regions (departments), each consisting of a minimum of three and maximum of seven *arrondissements* or districts. Niger can be divided into five agroclimatic zones: saharan, saharo-sahelian, sahelian, sahelo-sudanian, and sudanian (table 1).

Table 1. Agroclimatic Zones of Niger

zone	area	total area	amount of rain
	(million km^2)	*(%)*	*(mm of rain with 90% probability)*
saharan	.8235	65.0	< 200
saharo-sahelian	.1540	12.2	200-300
sahelian	.1534	12.1	300-350
sahelo-sudanian	.1237	9.8	350-600
sudanian	.0124	0.9	> 600

Source: Ancey et al. 1987.

Over 90% of Niger's population lives along the Niger river and near the Nigerian border. In 1988, 15% of the population inhabited urban areas, an increase from 12% in 1975. Between 1975 and 1988 the percentage of population under age 14 increased to 49% from 44%. In 1988 life expectancy in Niger was the lowest in the world, an average 44 years; the adult literacy rate was 11%; and primary school enrollment was 19% (World Bank 1991).

Between 1980 and 1990 GDP grew an average 1.6% per annum in real terms. By 1989 the contribution from agriculture and livestock had fallen to 36%, from 50% in 1975. Average annual decline was 0.4%. The manufacturing and commerce sectors increased their real contribution to the GDP by an average annual rate of 4% and 6% respectively, between 1975 and 1989. Investment in agriculture accounted for an average 37% of the country's total public investment between 1976 and 1978. This investment fell to 17% between 1979 to 1983. In 1984 it rose again to 32% and stayed constant at that level through 1990.

During years of adequate rainfall, Niger has been self-sufficient in cereal production. Between 1960 and 1990, average annual cereal production per capita was 279 kg. Per capita consumption was estimated at 250 kg. Niger's population averaged 2,340 calories per capita daily in 1988, which is high for a low-income country (Ministère du Plan 1991a).

Agricultural and livestock products contribute a declining share of Niger's export earnings. From 1976 to 1980 agricultural products accounted for 42% of the total volume of exports. This decreased to 19% during the period from 1981 to 1985. Agricultural products averaged 6.4% of the total value of exports between 1976 and 1980, falling to only 2% during the period from 1981 to 1985. Until the early 1970s groundnuts, cattle, poultry, sheep, and goats were the main agricultural export products. Groundnuts have since declined in importance and have been replaced by cowpeas. Cowpeas are exported largely to Nigeria. Uranium contributed the largest share of export earnings, an average 80%, during the period from 1981 to 1985. However, due to declining world prices and a subsequent decrease in mining activity in Niger, uranium export receipts declined by 40% from 1985 until 1989.

2.2. Input Supply, Marketing Structures, and Agricultural Policies

Since independence, the principal agricultural policy objective of the Government of Niger (GON) has been to maintain food self-sufficiency. To this end, it has established infrastructure to facilitate the supply of inputs and producers' access to markets, placing special attention on rainfed crops. Infrastructure is geared. Furthermore, it produced a set of agricultural sector policies to ensure an adequate and regular supply of cereals (millet and sorghum), at affordable prices, to cities and deficit rural areas; to guarantee acceptable prices for outputs; and to create national food-security stocks.

2.2.1. Input Supply

Four major organizations were created to subsidize agricultural inputs and facilitate their distribution: the Union Nigérienne de Crédit et de Coopération (UNCC), the Centrale d'Approvisionnement (CA), the Caisse Nationale de Crédit Agricole (CNCA), and the Union Nationale des Coopératives (UNC).

The Union Nigérienne de Crédit et de Coopération (UNCC): UNCC was created in 1962 to organize the rural sector into cooperatives, train cooperative members and leaders, assist in supplying agricultural inputs, and help cooperatives market their agricultural products.

However, as the UNCC developed it became a large, inefficient, bureaucratic agency. It came under heavy attack at a 1982 government-organized seminar to review and evaluate rural development structures. According to the principal criticism, UNCC's centralized management of cooperatives interfered with the development of cooperatives into self-managing structures. In most cooperatives, UNCC agents held positions of authority. Also, UNCC was not functioning well in its role as the intermediary of the agricultural credit agency, CNCA due to its inability to enforce debt repayment.

In 1985 UNCC was abolished. The Union Nationale des Coopératives (UNC) was created to take over UNCC's support activities for cooperatives. UNCC's credit role was abolished.

The Centrale d'Approvisionnement (CA): The CA was created in 1978 as a branch of the UNCC. Its main objectives were to procure, inventory, and distribute agricultural inputs, including raw materials for the construction of agricultural machinery, fertilizer, and plant protection products. Until 1985, when the agricultural input market was liberalized, the CA held a monopoly in providing inputs for crop production. It now competes openly with private merchants. Since the dissolution of the UNCC, the CA has been managed by the UNC.

The CA distributes agricultural inputs to cooperatives through the extension service and donor-funded "productivity projects." Fertilizer, seed, and plant protection products are paid directly, while machinery, animals for traction, and seeds are generally either loaned or repaid in kind. Prior to 1985, pesticides were distributed free of charge in cases of severe insect attacks. The CA's activities were heavily dependent on government subsidies, which averaged from 17% for carts and fungicides to between 41% and 77% for machinery and tools. (By 1985 Niger spent an average 2% of agricultural GDP on agricultural subsidies—0.5% of total GDP or 355 CFA per farm.)(Ministère du Plan 1991b).

Prior to 1985, the CA's farm-level impact was limited by competition from a parallel, unofficial market. Private merchants were able to sell two to three times more fertilizer by taking advantage of the heavy fertilizer subsidies in Nigeria and the favorable CFA-Naira (Nigeria's currency) exchange rate.

The Caisse Nationale de Crédit Agricole (CNCA): The CNCA was created in 1968 as an autonomous bank providing credit for the agricultural inputs supplied by the CA. The CNCA was also to prefinance the marketing of agricultural products, particularly millet, sorghum, cowpea, rice, and cotton. Despite its autonomous mandate, the CNCA maintained close ties to the centralized UNCC which prevented it from direct contact with borrowers. It disbursed loans through cooperatives which it contacted through other intermediaries (UNCC, productivity projects). This distance from its borrowers led to low debt repayment.

The CNCA lacked an appropriate mechanism to reach farmers. Not surprisingly it soon forsook its original mandate and became a source of funds for parastatals and agricultural development projects. By the 1980s, funding of these sorts of activities represented up to 80% of total financing by the CNCA.

In 1984, 72% of loans were not repaid. Fifty-eight percent of these were deemed not recoverable. This led the CNCA to curtail input loans for fertilizer, seed, and fungicides. By 1985, its position had become untenable. It was abolished.

The Union Nationale des Coopératives (UNC): Following the creation of the UNCC in 1962, much of the rural sector in Niger was organized into a hierarchical system of cooperatives, installed mainly in areas where cash crops were cultivated: the groundnut basin (Maradi, Zinder, Dallol Maouri), the cotton zone (Alder-Doutchi-Maggia), and the rice paddies (Niger river).

The cooperatives' main functions were to supply inputs to their members and to market their products. They were supervised by the former UNCC, productivity projects, and the extension service. Due to the heavy involvement of the UNCC, cooperatives were not self-managing structures and thus had little participation of its members. Since 1985, cooperatives have been decentralized and their activities diversified. However, little improvement has been made in their effectiveness in aiding their members, mainly because of their lack of resources.

2.2.2. Marketing Structures

The government's policy to ensure an adequate and regular supply of cereals to cities and deficit rural areas at affordable prices led to the creation of marketing parastatals to control cereal marketing. These parastatal boards were the principal structures for subsidizing consumer prices.

The Office des Produits Vivriers du Niger (OPVN): The OPVN parastatal was created in 1970 with a monopoly in cereal marketing. The ministry responsible for economic affairs was its major stockholder. OPVN set producer and consumer cereal prices by buying cereals at an official ceiling price, then selling at a floor price. Each year panterritorial prices were set by the ministry. To prevent private traders from entering the market, OPVN had intermediaries at all levels: cooperatives were paid for every ton of cereals collected, village leaders were authorized to market local produce on behalf of OPVN in return for a payment, and designated merchants delivered purchased cereals to the OPVN office. All the intermediaries received cash advances to facilitate purchasing.

Despite their sweeping efforts, OPVN was unable to supplant the informal cereal-marketing channels: cooperatives were usually not able to use up all the cash advance due to their weak roles in the rural sector, and village leaders and merchants used the cash advances to make purchases on the informal market which, offered better prices. OPVN was not able to maintain its monopolistic role, marketing only an estimated 10% to 15% of traded cereals. Official producer prices were always lower than market prices, and fixed consumer prices only affected a small number of consumers. These unwanted results were in part due to the high operating costs of OPVN and to its mismanagement. Since the liberalization of the cereal markets in 1984, OPVN has bought cereals from cooperatives and private sellers at the going market rate. Its role has been reduced to (a) assuring food supplies to cities and deficit areas, either by selling cereal in those areas or by distributing free food aid and (b) maintaining a food security stock not to exceed 80,000 tons.

The Société Nigérienne de Commercialisation de l'Arachide (SONARA): The SONARA was created in 1963 to give the government control over the groundnut market. Groundnut was intended to provide the primary source of rural development funds. In 1976 SONARA also became responsible for cowpea marketing. SONARA proceeded in much the same way as OPVN, acting through the same intermediaries and offering official prices. It went bankrupt in 1988, not being able to control the cowpea market. At that time the official producer prices for cowpea were lower than prices on the unofficial frontier markets with Nigeria, where most cowpea is cultivated and marketed.

2.3. Commodity Subsector

2.3.1. The Agricultural Sector

The vast majority of farmers in Niger are smallholders cultivating less than 10 hectares, according to the latest agricultural census in 1980. There is reason to believe that farm size has not changed significantly. Increasing population has been absorbed by an expansion of the total area cultivated. The 1980 agricultural census showed that the average farm size was 4.88 ha, with regional averages varying from 2.0 ha in Diffa to 6.2 ha in Filingué. A farm is typically subdivided into several fields which may, or may not, be adjacent to each other. Table 2 shows that most farms are not heavily fragmented, with an average of only 2.3 fields per farm. The number of plots (i.e. land under the same cropping system) per farm is also low, averaging 2.8 plots nationally and ranging from 4.0 in Maradi to 1.9 in Diffa. This low number of plots per farm indicates little diversification of the types of crops grown.

Between 1983 and 1989, an average 37,269 km^2 were cultivated (table 26). Although low, this figure has grown 2% annually since the late 1970s. Only 25% of arable land is cultivated in Niger. Land expansion, however, is not a viable long-term option for increasing agricultural production. Land quality has deteriorated as declining rainfall has led to greater wind erosion (Sivakumar et al. 1992). Furthermore, population pressure has increased the demand for fuel wood, which in turn has depleted vegetative cover and contributed to soil degradation. The decline in rainfall has also reduced livestock numbers, resulting in less manure to fertilize soils (Ancey et al. 1987).

Table 2. Farm Size by Region, Niger (1980)

	farms	fields		plots	
Region	average size	average number	average size	average number	average size
	(hectares)		*(hectares)*		*(hectares)*
Diffa	2.09	1.4	1.49	1.9	1.09
Dosso	6.11	3.0	2.07	3.0	2.07
Maradi	5.09	3.3	1.54	4.0	1.26
Filingué	6.22	2.0	3.11	2.2	2.79
Tahoua	3.52	2.0	1.76	2.2	1.60
Zinder	4.57	2.0	2.74	2.9	1.55
National	4.88	2.3	2.12	2.8	1.72

Source: Ministère du Développement Rural (1980, Tome 3, p. 5).

Since 1986, Niger's principal crops are millet, sorghum, cowpeas, groundnuts, rice, onions, maize, and cotton, in order of importance according to the quantity produced. The cereals are used mainly as food crops while other crops are traded locally or exported. The agricultural season runs from late May/early June to September/October. Some irrigated lands are cultivated during the dry season.

Irrigated areas can be divided into two categories: those developed by ONAHA, the government agency in charge of irrigated lands, and areas of traditional irrigation, including a variety of methods, from using a watering can to irrigation by canals. Table 25 in appendix 1 shows areas under irrigation as of 1991—almost 13 km^2. The largest areas are in the Tillabery region along the Niger river and in Tahoua in the Ader Doutchi Maggia valley. The principal crops grown on irrigated lands during the rainy season are cotton, sorghum, millet, cowpeas, maize, and other cereals. During the dry season, wheat, peppers, onions, maize, and cowpeas are grown.

A significant portion of the area under traditional irrigation is dedicated to vegetable gardens. Irrigated perimeters provide less than half a percent of total agricultural production, taking into account both rainy season and off-season production. However, investment in irrigated agriculture was as high as 64% of total investment in the agricultural sector in 1989 (Direction des Etudes et de la Programmation 1990).

2.3.2. The Millet, Sorghum, and Cowpea Subsector

Millet, sorghum, and cowpeas comprise 98% of total agricultural production and occupy 99% of the area cultivated during the rainy season. Of the cereals, millet is the most important. In 1990, it accounted for approximately 80% of total cereal production and for 47% of total cultivated area. Millet is believed to have been introduced in the Sahel over 7,000 years ago. It is therefore well adapted to the agroecological conditions.

Millet and sorghum are primarily grown for subsistence. They are the most important foods in the national diet. On average, 200 kg of cereals per person per year are consumed in Niger (Hopkins and Reardon 1992). Millet meal provides about 332 calories per 100g (Platt 1962). Sorghum flour has a similar calorie content. Millet and sorghum together account for some 80% of the national calorie intake.

Although no nationwide cereal consumption study has been conducted, Hopkins and Reardon (1992) are studying consumption of 150 households in western Niger over a four-year period. The data seem to indicate that half the cereal consumed is home grown and that the average Nigerien household is a net crop purchaser. Because the majority of cereal sales take place after harvest and during the cold season, the market price for cereal tends to be low at sale. However, prices for cereal tend to be high because they are purchased later in the season when prices peak.

A fundamental characteristic of Nigerien agriculture is the intercropping of millet, sorghum, and cowpeas and combinations thereof. Table 24 presents the results of a survey conducted in 1990 by the Department of Agriculture, in which a comprehensive attempt was made to estimate intercropped area by cropping system. Only 25% of the total area cultivated with millet, sorghum, and cowpeas was monoculture. Niger has some of the lowest millet, sorghum, and cowpea yields of West Africa (FAO 1989). The prevalence of intercropping is one explanation for these low yields. However, studies conducted by the agronomy and rural economics departments of INRAN have shown that intercropping is advantageous in terms of risk reduction.

Niger is self-sufficient in cereal production, except in years of drought. Surplus production has been maintained since 1960, except in two periods of severe drought: 1972-76 and 1983-90. The latter period is characterized by two drought years: 1984 and 1987. The length of the cereal deficit periods underscores the time required for farmers to recuperate from drought-induced seed and capital depletion. Even in years of good rainfall, the margin of surplus has been diminishing, due to a steadily increasing population and declining average yields (table 3). Between 1961 and 1990, millet yields declined an average 0.7% annually, while sorghum yields declined 2.7%.

Table 3. Average Growth Rates for Millet, Sorghum, and Cowpeas, Niger (1960-65 and 1985-89)

		1961-65	1986-90	annual growth
				(%)
millet	area *(1,000 ha)*	1,774	3,303	2.5
	yield *(kg/ha)*	488	411	-0.7
	production *(1,000 tons)*	867	1,362	1.8
sorghum	area *(1,000 ha)*	460	1,307	4.3
	yield *(kg/ha)*	633	321	-2.7
	production *(1,000 tons)*	292	375	1.0
cowpea	area *(1,000 ha)*	448	1,816	5.8
	yield *(kg/ha)*	129	135	0.2
	production *(1,000 tons)*	58	248	6.0

Source: Calculations made from data in Ministère du Plan 1991a.

Decreased yields can be attributed to farmers increasing cultivation of marginal lands. The aggregate figures in table 3 hide the large spatial variation that exists in agricultural production in Niger. For example, during 1986-90 three regions, Tillabery, Dosso, and Maradi, contributed an average 63% of total millet production. These areas of highly concentrated production have well-functioning market and transport infrastructure. In a country where there is so much spatial variation in yields, it is necessary to look at yield figures at the regional and *arrondissement* levels. For example, yields grew at rates of 1.2% and 0.3% respectively in the Tillabery and Dosso regions between the periods of 1976-80 and 1986-90. Within these regions, the *arrondissements* Filingué and Boboye witnessed an annual increase in yields of almost 2% (table 23 in appendix 1). Temporal variation also exists. Whereas Maradi had the second largest millet production for 1976-80, it dropped to fourth during 1986-90. This can be partially explained by the fact that Maradi has the largest population growth of Niger's five agricultural regions. This has led to increased cultivation of marginal lands.

For sorghum, the picture is more uniform. While all of the regions increased the total area under cultivation, yields declined across the board during 1976-80 and 1986-90. The only exception was Diffa, where there was a decline in area cultivated.

Contrary to yield trends for millet and sorghum, yield of cowpea increased marginally between 1961 and 1990 (table 3). In the more recent years, however, cowpea yield also declined. All regions reported decreased cowpea yields between 1976 and 1990 with Maradi, Tahoua, and Zinder averaging the largest annual declines (table 23). Of Niger's 32 *arrondissements*, only six reported increasing annual yields over the period in question. Among the chief causes of declining yields are worsening climatic conditions and soil degradation. One cause unique to cowpeas is increasing losses due to insects and diseases, especially due to pod borers and thrips. A reason for generally low cowpea yields is that in certain areas, especially those surrounding Niamey and Maradi, cowpeas are grown expressly for fodder production, which lowers yields because the best quality fodder is obtained before the pod matures.

In the 1960s cowpeas replaced groundnuts as Niger's principal cash crop. This is due to their better performance under deteriorating climatic conditions and the strong demand from Nigeria. Hopkins and Reardon (1992) found that in western Niger cowpeas account for the largest part of household income derived from crop sales. Cowpeas are an important agricultural export product. In 1986, it represented 14% of the total quantity of agricultural exports (Ministère du Plan 1991a). However, these figures grossly underestimate the importance of cowpea exports because most cowpea sales with Nigeria and Benin are conducted unofficially. While cowpea exports for 1986 were officially reported at 31,000 tons, a 1989 study estimated that actual 1986 exports were more than five times greater, on the order of 202,000 tons (Rassas et al. 1989). Interviews with extension agents in Niger's southern strip confirmed that official figures include only a small portion of total cowpea exports.

3. AN ORGANIZATIONAL ANALYSIS OF RESEARCH AND TECHNOLOGY TRANSFER

3.1. Agricultural Research in Niger

Following its independence in 1960, Niger's research system continued to be managed by the French. The principal focus remained on cash crops: cotton, groundnuts, and oil palm. Emphasis was on the development of improved varieties and agronomic recommendations concerning fertilizer use for monoculture farming systems with high use of inputs.

In the mid-1970s, two factors served to shift the emphasis of the research system to millet and sorghum. First was the 1972-74 drought, which greatly destabilized Niger's food security. Second was the subsequent nationalization of the research system. Niger's government used the national research institute, INRAN, as a means to obtain its newly defined objective of food self-sufficiency. Food crops thus became the focus of research. Also in the mid-1970s, as French researchers left the system, USAID became involved in Nigerien agricultural research through its Niger Cereals Project which included a research component intended to strengthen INRAN's institutional capacity. By the 1980s, USAID had funded a second and third project in agricultural research. These focussed exclusively on millet, sorghum, and cowpea research. In the mid-1980s, having come under increasing criticism for the lack of farmer input in research priority setting, the research system underwent another change. INRAN shifted from supply-oriented research, that is, a research agenda set by researchers, to a more demand-oriented model, where both consumer and producer needs are taken into account in setting the research agenda. The following section discusses the research conducted during 1975 to 1991, including the mechanisms used to implement these important changes in research approach.

This analysis concerns research on millet, sorghum, and cowpeas, thus INRAN, the main institute doing research on these three crops, is the focus. The other national institution doing research on millet, sorghum, and cowpeas is the University of Niamey. However, because of its limited activities in applied research, its relatively small crop-research budget, and the absence of data on expenditures for research on these crops as revealed in interviews with university professors, university research programs were not included in this analysis.

Research on millet is also conducted by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) at their Sadoré center, 45 km from Niamey. However, the international research center has a Sahelian-wide mandate. Also, none of the technologies being developed by INRAN derive from ICRISAT or are the result of a joint collaboration between the center and INRAN. ICRISAT is thus out of the scope of this study.

Many development projects conducted in Niger since 1975 have included research components. However, few have left records at regional or national agricultural offices in sufficient detail to enable an estimation of the funds associated with donor-supported research in general, much less for millet, sorghum, and cowpea research in particular. Also, research efforts in these projects were and still are carried out independently of INRAN. Interviews with administrators of various projects indicated that research constituted a very small component of their activities compared with extension, input distribution, and credit. For these reasons, research funding, expenditure, and personnel data reported in this chapter relate only to INRAN.

3.2. The Organization and Structure of INRAN

INRAN was created as the national institute for agricultural research in Niger in 1975. Its mandate is to conduct research on the agroecological environment, agricultural production systems, agronomy, animal science, forestry, and fisheries. INRAN is a public institution under the Ministry of Agriculture and Livestock (MAG/EL). However, unlike other institutions or departments of the ministry, it is managed independently and has the authority to spend its allotted funds without the prior authorization of the ministry.

INRAN has been administered by the MAG/EL since December 1989. However, it has been under various ministries since its creation. In 1975, it was under the Ministry of Rural Economics and Climate, which became the Ministry of Rural Development in 1978. From 1979 to 1985 it was under the Ministry of Higher Education. Since then it has remained under the ministry in charge of agriculture. The name of this ministry has been changed four times: Ministry of Rural Development, Ministry of Agriculture, Ministry of Agriculture and Environment, and finally the Ministry of Agriculture and Livestock (MAG/EL). INRAN's activities are supervised by an administrative council ("conseil d'administration") composed of representatives from various ministries affected by agriculture. The council evaluates proposed research activities, approves the yearly government contribution to its budget, and evaluates if established objectives have been met.

Until 1991 INRAN had a stable organizational structure (figure 2) under a director general who was nominated by the president of Niger on the recommendation of the ministry. The position of assistant director general was created in 1987 but did not have a well-defined scope. It was changed to scientific director in 1991. The scientific director is responsible for assisting the director general in planning and programming. INRAN has an administrative and financial unit, a division of programs and studies (DEP), a division of statistics and computers (DSI), a training division (DEF), a research-extension linkage unit (CLRV), a documentation center, and five research departments: agronomy (DRA), soil science and cartography (DRE), rural economics (DECOR), forestry (DRF), and veterinary science and zoology (DRVZ).

Figure 2. INRAN's Organization and Structure (1975-91)

INRAN has various facilities located throughout the country. The Tarna research center (CNRA), established in Maradi by the French in 1927, is the largest and conducts varietal and plant protection trials and laboratory analyses, as well as some seed multiplication activities. The research station at Kolo was created in 1952. Until 1978 its work was limited to experimental trials and some seed multiplication activities. This station has grown rapidly since the formation of its plant-improvement department in 1979. It is now equivalent in importance to the Tarna research center.

On-station trials are conducted throughout southern Niger at three substations (figure 3). Support stations are used to verify the substations' results. Support stations are INRAN's smallest structural units. Unlike the larger unit, they do not have permanent research personnel. INRAN also has three laboratories in Niamey, which specialize in soils, cartography, and cereal quality.

In 1991 a new statute was designed for INRAN. Under the World Bank-funded Projet National de Recherche Agronomique (PNRA), INRAN became the Institut National de la Recherche Agronomique du Niger with a new regionalized structure. Five regional research centers (CERRA) were created by ministerial decree in April 1991 to provide research services to each of Niger's five agricultural regions. Full implementation of the reorganization was not yet complete in 1992. Under the new structure, research is to be conducted within the context of the research programs of each of the five regional centers. Each center will draw on research divisions from other centers, as well as representatives from the divisions common to all. The regional research directors report to the director general of INRAN.

INRAN's collaboration with other research institutes at the national, regional, and international levels has served two main purposes. First, it has increased INRAN's institutional capacity in terms of infrastructure and human resources. Second, it has improved INRAN's communication with other agricultural research organizations in West Africa and the Sahel. INRAN has received financial assistance through its collaborative activities, including support for research programs and training scholarships. Foreign researchers have participated in INRAN research either in the context of bilateral agreements with such countries as the United States, Canada, France, Japan, Holland, and Egypt or through regional (CEAO, CILSS) and international (FAO, UNDP) organizations.

INRAN collaborates in the USAID-funded TROPSOIL and INTSORMIL research projects. These projects team INRAN researchers with professors from universities in the United States. The latter are provided funds to visit Niger; the former are given additional resources for operations. The Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) has a presence in the country, with various of its institutions conducting research in collaboration with INRAN. Funds coming from these projects are usually small and their farm-level scope and impact is generally limited. However, depending on the relationship established between the expatriate and INRAN researchers, they do provide important training opportunities for national scientists and thus help build INRAN's human resource capacity.

Table 38. Benefit-Cost Calculation

	Benefits	Research costs	Additional production costs	Extension costs	Seed multiplication center costs
1975	384,431	27,098,922	3,290	509,560,862	250,451,687
1976	757,717	150,152,659	18,300	436,268,885	698,997,919
1977	96,292,056	282,837,925	36,737,533	739,451,521	776,270,478
1978	185,180,898	276,990,483	62,004,615	718,054,948	1,051,455,327
1979	254,973,544	518,776,123	93,697,196	648,452,530	858,372,967
1980	296,191,683	501,668,106	119,670,679	815,844,008	598,841,724
1981	818,594,954	360,191,454	155,944,977	656,994,915	252,212,054
1982	905,170,941	394,616,338	201,353,611	806,057,511	1,735,683,258
1983	1,151,990,338	911,073,141	240,000,338	894,759,113	2,179,859,462
1984	1,243,410,162	845,443,388	310,972,532	844,849,049	1,362,633,117
1985	762,502,725	824,765,421	140,253,626	840,275,988	3,818,661,794
1986	398,226,465	825,145,928	181,953,685	525,868,042	3,787,754,531
1987	390,195,688	916,959,058	202,163,042	497,986,681	3,618,722,718
1988	852,807,747	1,412,341,334	90,920,333	317,799,257	3,907,109,346
1989	870,743,367	1,742,940,654	114,358,339	312,492,599	302,078,268
1990	873,578,326	1,347,090,490	99,924,076	420,718,952	179,065,938
1991	4,234,036,348	921,306,342	125,956,875	420,718,952	156,841,015
1992	4,552,524,128		129,437,575	841,438	
1993	4,628,118,277		131,090,342	841,438	
1994	5,269,047,934		138,028,439	841,438	
1995	6,204,486,513		276,182,124	841,438	
1996	4,498,110,929		294,903,821	1,262,157	
1997	4,110,655,423		322,453,864	1,262,157	
1998	4,385,792,242		356,910,710	1,682,876	
1999	2,308,950,093		368,956,871	1,682,876	
2000	2,293,417,795		400,483,794	2,103,595	
2001	2,109,828,255		430,962,557	2,524,314	
2002	1,477,219,117		457,082,613	3,365,752	
2003	1,431,957,565		488,711,600	4,207,190	
2004	1,453,962,355		520,926,126	5,048,627	
2005	1,475,967,145		553,140,652	5,890,065	
2006	1,497,971,934		585,355,178	7,152,222	
2007	1,519,976,724		617,569,704	7,993,660	
2008	1,541,981,514		649,784,230	8,835,098	
2009	1,563,986,303		681,998,756	9,676,536	
2010	1,585,991,093		714,213,282	10,938,693	
2011	1,607,995,883		746,427,809	11,780,131	

Units: 1990 CFA

APPENDIX 4

Figure 3. Location of Research Center, Stations, and Substations, SINRAN (1991)

INRAN has the additional advantage of two international agricultural research centers located within a 45 km radius of its headquarters in Niamey. The first of these is the ICRISAT Sahelian Center which, since 1981, conducts breeding work on millet for Sahelian countries. The second, AGRHYMET, was created by CILSS in 1977. AGRHYMET collects and analyzes agroclimatic data from CILSS member countries. INRAN's collaboration with these international centers is limited, however, occurring only on a researcher-to-researcher basis and depending heavily on personal contacts. There are no official, functional linkages to enhance collaboration. For example, none of INRAN's agroclimatology and cartography work uses AGRHYMET's outputs or data. And INRAN's millet breeding activities remain separate from ICRISAT's.

INRAN participates in millet, sorghum, and cowpea research networks organized by ICRISAT and IITA. These are the most fruitful collaborations between INRAN and international research institutions. Through these networks, INRAN researchers meet periodically with researchers from the region to exchange ideas and research results.

3.3. Financial and Human Resources in Agricultural Research

3.3.1. Sources of Funding

Various national funds are available to INRAN in addition to its yearly budget allocation from the government. The Fond de Resèrve is a fund of money unspent by INRAN in a given fiscal year carried forward for future use. Until it was abolished in the mid-1980s the Fond National d'Investissement (FNI), based on Niger's national five-year plans, was subscribed to by donor agencies and used for large investments and counterpart funding for foreign-supported projects. The Budget d'Investissement was established in the mid-1980s to replace the FNI. Allocated on a yearly basis, it totalled some 25.8 million CFA nominally between 1986 and 1990. Other sources of national funds, though very small, include resources generated by INRAN itself through consultancies. A significant portion of INRAN's funding is derived from foreign sources. This takes the form of grants or loans to the government or direct aid to INRAN. This study considers the former as part of public spending on agriculture. The latter is considered foreign assistance to specific institutions.

3.3.2. Support for Agricultural Research[1]

Total funding for agricultural research in Niger grew 2% annually between 1976 and 1990, as shown in table 4. The highest level of funding occurred during 1981-85, when the number of expatriate researchers working at INRAN also peaked. At the same time USAID's largest research project was under way.

Table 4 also shows the importance of foreign funding, which provided 75% of total research funding between 1975 and 1991 and indicates the low government support provided to agricultural research. Government support declined an average 1.0% per annum in its share of total research funding over the period.

Table 4. Total Research Expenditures, INRAN (1976-90)

	1976-1980	1981-1985	1986-1990	annual rate of growth 1976-90
	(thousands of 1990 CFA, annually)			*(%)*
total expenditures	1,549,769	2,271,764	1,839,668	2
m-s-c[a] expenditures	346,085	667,218	1,248,895	14
	(%)	*(%)*	*(%)*	*(%)*
percent of total:				
nationally funded	31	17	29	-1
foreign funded	69	83	71	0.3
in m-s-c	22	29	68	12
percent of m-s-c				
nationally funded	67	31	26	-9
foreign funded	33	69	74	8
USAID funded	21	55	65	12

Source: see appendix 3.
[a] millet, sorghum, and cowpea

[1] Earlier attempts to quantify the total yearly financial support for agricultural research in Niger have been made by Pardey and Roseboom (1989) and ESGE (1985). Both these estimates, however, exclude foreign donor assistance, a large omission since it averaged 75% of the total funds available to INRAN between 1976 and 1990. INRAN documents and pamphlets underreport the full costs of donor assistance by excluding all expenditures that are not directly managed by the institute. In the case of USAID development projects, NAAR and NCR, this has led to an underreporting of 5.5 billion CFA (nominal), or more than US $18 million of foreign aid supporting agricultural research at INRAN between 1982 and 1991.

A common measure of the support received by a NARS is the agricultural research intensity ratio (ARI) which expresses expenditure on public sector agricultural research as a proportion of agricultural GDP (AgGDP). Table 5 shows the average ARI ratio for Niger for the periods of 1976-80, 1981-85, and 1986-90,[2] including both national and foreign support. The average ARI ratio increased by nearly 50% between 1976-80 and 1986-90, indicating increased support for agricultural research. This is largely a reflection of USAID's funding of the Niger Cereals Research (NCR) and Niger Applied Agricultural Research (NAAR) projects which in real terms totalled more than US $21 million over 10 years. It is also important to note that part of the increase in ARI is due to a decreasing real agricultural GDP in the later 1980s. In fact, absolute research funding declined between 1981 and 1990, averaging 1.8 billion 1990 CFA (US $6.1 million in 1990 dollars), decreasing annually by 4% over the decade. Support for agricultural research is fairly low in Niger compared with other areas of Africa and the world.

Niger's average ARI of 0.4% is lower than the conservative 1985 target of 0.5% set by the United Nations at the World Food Conference of 1974 and well below the often-cited 1981 World Bank target of 2% for 1990.

Table 5. Agricultural Research Intensity Ratios (ARI), Weighted Averages (1971-90)

Region/Income Group	1971-75	1976-80	1981-85	1986-90
	%	*%*	*%*	*%*
Niger[a]	-	0.28	0.31	0.40
West Africa (15)[b]	0.55	0.66	0.79	-
Less-Developed Countries (92)	0.34	0.41	0.41	-
More-Developed Countries (18)	1.41	1.60	2.03	-
All Countries (110)	*0.65*	*0.72*	*0.76*	-

Source: Appendix 3 for Niger, Roe and Pardey (1991) for other regions.
Note: Agricultural research intensity ratios measure real agricultural expenditures as a proportion of AgGDP. Regional averages are weighted by each country's share of the regional aggregate AgGDP.
[a] Figures exclude salary costs of foreign technical experts.
[b] Bracketed figures represent the number of countries in regional and income group totals.

[2] Niger figures exclude costs of expatriate technical assistants in order to compare with the other figures. This exclusion is only made in the case of the ARI ratio for comparison purposes–all other calculations include these costs as part of agricultural research expenditures.

3.3.3. Funding of Millet, Sorghum, and Cowpea Research

Millet, sorghum, and cowpeas grew in importance in INRAN's research agenda over the period of 1975 to 1991 as can be seen by the increasing share of financial resources dedicated to the three crops (table 4). By the late 1980s, 68% of total research funding was used for millet, sorghum, and cowpeas. While overall research funding increased by only 2% annually, millet, sorghum, and cowpea funding rose at an average annual rate of 14%. Much of this rise is due to increasing foreign funds focussed on the three crops. Between 1975 and 1980 only 5% of foreign aid for research was devoted to millet, sorghum, and cowpea. By the late 1980s this had increased to over 70%. USAID was the largest supporter, contributing an average 47% of total funding for millet, sorghum, and cowpea research between 1975 and 1991. Again, government support was low (table 4), funding only an average 26% of millet, sorghum, and cowpea research expenditures between 1986 and 1990.

USAID's support was provided through three projects: the Niger Cereals Project (NCP), Niger Cereals Research (NCR), and Niger Applied Agricultural Research (NAAR). Funds were managed in part by USAID and in part by INRAN. USAID-managed expenditures included payment of technical assistance teams, purchase of equipment and vehicles, construction, training, studies, and audits. Gas and electricity, short-term labor, some equipment purchases, gasoline, and other transportation costs were among the expenditures managed by INRAN.

The NCP, begun in 1975, did not focus on research alone. It also included extension, seed multiplication, and agricultural cooperative components. The two other projects, the NCR and NAAR, concentrated solely on research, in particular on millet, sorghum, and cowpea research—thus the large increase in research expenditures on these three crops between 1981 and 1990 (table 4).

When evaluating research investments it is not sufficient to look simply at total research funding, especially when dealing with a young system. A research system in the early stages of development will need to dedicate a large share of its resources to institution-building activities which do not contribute directly to the day-to-day operation of research. In such cases it is useful to distinguish between those expenditures that support operations and those that fund institution building (table 6).

Operations spending includes costs such as water, electricity, gasoline and travel expenses, salaries of temporary laborers, and office supplies, as well as the salaries of all research personnel (national and international) and support staff. Spending on construction, training, and equipment is more appropriately thought of as an institution-building investment. Some 44% of total expenditures went to institution-building activities in INRAN's early years, whereas by 1986-90 this figure had declined to 29%.

Table 6. Expenditures on Millet, Sorghum, and Cowpea Research, INRAN (1976-90)[3]

	1976-1980		1981-1985		1986-1990	
	absolute	relative	absolute	relative	absolute	relative
	('000 1990 CFA, annually)	*(%)*	*('000 1990 CFA, annually)*	*(%)*	*('000 1990 CFA, annually)*	*(%)*
Operations	195,860	56	417,040	62	877,272	71
Institution building	150,225	44	250,178	38	366,623	29
TOTAL	346,085		667,218		1,248,895	

Source: see appendix 3.

Research conducted by INRAN must therefore be evaluated not only on the basis of actual research results but also on the degree to which research capacity within the institution has been developed. As a result of the three USAID-funded projects, INRAN now has a computer center, a library, a soil science laboratory, two grain storage facilities, 43 additional sheds located at its research stations, vehicles, and motorcycles. An FAO project funded the construction of and equipment for a cartography laboratory. All of these new structures have helped to create the base from which INRAN can continue to conduct research. Investments in these activities have been substantial but necessary for the development of the institution. Training of researchers has also contributed to institution building.

For 15 years USAID has provided financial support for INRAN. Unfortunately, this support was divided into three distinct projects, lacking the continuity essential for long-term undertakings such as agricultural research. The level of support fluctuated markedly in the transition years between projects, hence the drastic decline in funding in 1981-82 and the substantial increase in 1988-89 (table 36). INRAN has been especially vulnerable to these changes in funding because its primary funding source is a single donor. In fact, USAID's decertification of its last project in 1990, two years prior to its scheduled completion, greatly reduced INRAN funds and has already affected INRAN's research. In 1991, field trials on millet, sorghum, and cowpeas were reduced by some 50% compared with previous years, a 40% reduction in overall research activities.[4] A unique opportunity has perhaps been missed, namely, for a long-term, continuing agricultural research project to provide for the development of a

[3] For more detailed expenditure figures, see appendix 3.

[4] The 50% figure was estimated from interviews with millet, sorghum, and cowpea breeders; entomologists; and plant pathologists. Given that an estimated 80% of total research activities are focussed on these three crops, this implies a 40% decline in overall research activities.

national agricultural research institute with a coherent and long-term strategy. Instead, INRAN has had to respond to the differing research agendas of three distinct projects, each dependent on shifting priorities as defined by different USAID-Niamey administrations.

Strong donor involvement has also led to financial management problems. In the past 15 years, INRAN and USAID have had shared, not wholly compatible, administrative responsibilities for project funds. USAID became increasingly concerned with INRAN's lack of accountability which resulted in the decertification of the NAAR project. INRAN, on the other hand, expressed frustration with the accounting system that was imposed on them, which they perceived more appropriate for a developed country such as the United States than for a country like Niger, lacking the structures and conditions needed to implement it. In either case, dual management of funds has created an inefficient and bureaucratic system. Delays in disbursements have often resulted in an inability to spend all the funds allocated to a project. US $7.4 million from USAID's NCP, NCR, and NAAR projects were not spent, partly for this reason.

Another issue concerns INRAN's internal management and allocation of funds. There are no procedures that enable researchers to estimate the resources that they will have for operations. This makes planning a research program particularly difficult. In practice, funds are often allocated on the basis of first come first serve, with little or no consideration of overall priorities or program size.

3.3.4. Human Resources

Before the creation of INRAN most agricultural research was conducted by the French institute, IRAT. French researchers dominated the system. Little emphasis was placed on developing a cadre of Nigerien scientists. There were only five Nigerien researchers at the time of INRAN's creation, of a total of 19. None were away for training. Eighty-six percent of the expatriate researchers working in the country at the time were French. Upon its creation, INRAN was faced with the immediate task of developing a national human resource base to make up for the rapid decline in French researchers leaving the research system following its nationalization. By 1991 INRAN had 72 researchers of whom 63 were Nigerien (table 7). This large increase was made possible by USAID funds for training. Training occurred either by sending INRAN staff to academic institutions in foreign countries, or by awarding scholarships to nationals outside of INRAN who were employed by INRAN upon completion of their studies. Because training was done in the context of the three USAID projects, most scholarships were granted for researchers working on millet, sorghum, and cowpeas. Table 7 shows that the proportion of national researchers working on these crops increased markedly over time, from around 11% in 1975 to 40% in 1991. Over half the expatriate researchers at INRAN were working on these three crops which potentially provided additional training possibilities for millet, sorghum, and cowpea researchers. This depended on the training abilities of the expatriate researchers and the degree of involvement of national researchers in the expatriates' research agenda.

Table 7. Expatriate and National Researchers, INRAN (1975-91)

	1975	1976-80	1981-85	1986-90	1991
			(full-time equivalent)[a]		
INRAN researchers					
national	5	18	28	42	63
expatriate	13	19	21	19	9
total	18	36	48	59	72
millet-sorghum-cowpea researchers					
national	2	9	15	23	29
expatriate	5	7	12	11	5
total	7	16	27	34	34

Source: see appendix 4.
[a]Averages for the periods indicated. Figures may not add up to totals shown due to rounding.

Administrative posts at INRAN have generally been filled by scientists with M.S. or Ph.D. degrees. In 1980, three of eight M.S.-degree holders were in administrative posts; in 1985, five out of eleven. By 1991 this ratio had declined to five out of sixteen. However, two of three Ph.D.-level researchers were holding administrative posts in the latter year. This demonstrates that well-qualified researchers are quickly promoted to administrative posts, making limited use of their research training.

Growth in human resources has been uneven across INRAN's programs. Since 1975, the agronomy department experienced the most rapid growth in national research personnel (table 8) and accounted for most of the more highly qualified personnel. Since 1980, DRA has had all of the Ph.D. holders, half the M.S. holders, and some 40% of the B.S. holders. DRA has also had 32 of the 66 expatriate researchers who worked for INRAN since 1975. As a result, INRAN's research has been heavily biased towards agronomy with much less attention being given to soil science, forestry, economics, and veterinary science.

Table 8. Number of National Researchers by Department, INRAN (1975-91)[5]

Department	Research orientation	1975	1976-80	1981-85	1986-90	1991
				(full-time equivalent)		
D.R.A.	agronomy	2	7	12	20	26
D.R.E.	ecology	0	2	5	7	12
D.R.F.	forestry	1	1	1	2	2
DECOR	economics	0	0	1	4	9
D.R.V.Z.	veterinary sci.	0	2	4	7	9
D.S.I.	computer	0	0	1	0	0
C.L.R.V.	research-extension linkages	0	0	1	1	1

Source: see appendix 4.

In a country where soil degradation is a serious hindrance to agricultural production and where over half of the population is pastoral, a good case can be made for considering whether INRAN should channel more of its resources to departments other than DRA. Furthermore, although the low absolute numbers of agricultural researchers in Niger indicate that training should remain a priority, it is important that a strategy be developed regarding the level of training required to solve the most urgent research problems. For example, Ball (1985) showed that during the development of the United States' agricultural research system, from 1890 to 1960, the cadre of researchers was mainly composed of B.S.- and M.S.-degree holders.

3.4. Research Results from the Millet, Sorghum, and Cowpea Programs

3.4.1. The Millet Program[6]

The millet breeding program is faced with the difficult task of developing improved and hybrid varieties superior to the landraces that have adapted to Niger's harsh agroclimatic conditions for more than 7,000 years. The main landraces are Haini Kire, Maewa, Zongo, Guerguera, Ba Angoure, Ankoutess, and Boudouma. To add to the plant breeders' difficulty, there is little spill-

[5] Researchers occupying purely administrative posts, such as director general, are not included in this table and thus the totals do not correspond to the totals in table 7.

[6] Information for this section was obtained from interviews with millet breeders, entomologists, and plant pathologists or from questionnaires filled out by them.

over potential of research results obtained in other breeding programs throughout the world. There are two reasons for this. First, there are relatively few resources devoted to millet breeding (in developing and developed countries alike) compared with other grain crops. Second, Niger's harsh climate limits the amount of transferable technology. The world's largest millet breeding program is in India; much of Niger's breeding efforts in the mid-1970s and early 1980s used Indian parent materials. However, the agroclimatic conditions of Niger are more arid than India's. Most of the introduced material could not even reach the germination stage due to the high temperatures of the Nigerien soil. The millet program has thus had to develop its own full-scale breeding operation.

INRAN's breeding program began in 1975 although in 1979 it had only three plant-breeding researchers. Until 1991 at any one time at least two of those researchers were in administrative posts or on overseas training. These other duties detracted from their millet breeding activities. Having three breeders in the millet program meant that in the early years most activities centered around genetic improvement. The initial emphasis was to collect and characterize local varieties. As the extension service increasingly pressed for appropriate varieties for dissemination, a selection program was initiated to develop a reasonably uniform population from local materials through a careful selection of local varieties. In this manner it took about four years to select a given variety.

Once the principal local varieties had been selected, a cross-breeding program was begun. The main goal was selection for drought resistance, that is, breeding for short- or medium-term varieties. In a given year, between 100 and 300 crosses were made. As the program developed and with the establishment of a climate controlled seed-storage room, exotic varieties were included. Now crosses are made with populations rather than lines in order to increase the base of crossing material. CIVT, a cross between five local varieties, has a wide base and is thus most frequently used for these types of crosses.

INRAN currently has a collection of 3,053 varieties obtained from ICRISAT and 108 varieties from the ORSTOM-ICRISAT collection. Breeders store seeds in coffee pots where they remain viable for two to three years. When the program was small and there were few varieties to keep, this was a workable system because the seeds could be regrown every two years. However, the sheer quantities of lines and populations needed to run a full-scale breeding program now require more sophisticated storage methods. The refrigerated seed store is unfortunately out of use because of the lack of funds for its maintenance. Seed losses are very high as a result.

Between 1985 and 1988 the millet program was transformed to include more agronomy and plant-protection work. By 1991 it had three agronomists and five plant-protection specialists, although none worked solely on millet. The main emphasis of agronomic work has been striga-resistance, striga being the most serious agronomic constraint to millet cultivation. Entomology work has focussed on developing resistance to the stem-borer and head girdler.

INRAN has collaborated with various international institutes. The Institut du Sahel organizes visits to breeding programs in neighboring countries, seminars, and meetings about once a year.

INRAN also exchanges parent materials with international institutes (CIRAD, ICRISAT) and conducts two to three joint trials per year. The USAID-sponsored INTSORMIL project provides scientific and financial support for one or two trials per year.

3.4.2. The Sorghum Program[7]

Since 1975 breeding has been the most important component of INRAN's sorghum program. Pedigree selection is the most resource-intensive aspect, due to the numbers of plants being grown and selected. Approximately 500 breeding lines per year are observed and evaluated for yield characteristics. The crossing of breeding lines is carried out through eight generations (F1 through F7). In 1989, 11 pedigree selections were tested at Tarna, comprising 996 lines. Eight of these 11 were kept for further testing (DRA 1990).

Recurrent selection is a component of the breeding program which began in 1983. Random mating of Nigerien lines was carried out and after some years, lines within the population were selected. However, these selected lines were let to die out and a new collection was requested from ICRISAT. As of 1991 this new collection had not yet been received.

Varietal selection is one of the older activities. About 250 varieties per year are evaluated. These come mainly from ICRISAT, INTSORMIL, Mali, Senegal, Nigeria, and the United States (Texas A&M, Purdue University, University of Nebraska, and Mississippi State University). Preliminary observations are made based on one-row plots with one or two replications. After preliminary and advanced yield trials (which take 4 to 5 years), the varieties passing all of these tests were subjected to multilocational trials supervised by DRA and carried out by extension agents in conjunction with farmers. These trials ceased in the late 1980s. Since 1990, DECOR has included sorghum varieties in its on-farm trials, producing practical feedback for the sorghum program on the adaptability of the varieties being bred and selected. Selected varieties are then used for breeder and foundation seed.

Since 1983 a hybrid program has existed, complementing the variety improvement program. Over the past eight years more than 800 hybrids have been produced. About 20 different female parents were used, while the male parent was changed more frequently.

The breeding program receives varieties every year from the ICRISAT Niger collection. Currently, work is conducted on three main populations: Kolo, Tarna, and Purdue. The first two do not yet show considerable yield potential. The Purdue collection is all exotic material. There have been shifts in emphasis in the breeding program with a marked recent increase in hybrid production and decrease in selecting sorghum varieties for sandy soils. This is mainly because of the small potential for improving on the local varieties for those types of soils.

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[7] All information, unless otherwise indicated, is from interviews with sorghum breeders at INRAN or from questionnaires filled out by them.

The sorghum program has had three plant breeders: a Nigerien at INRAN since its creation (although during 1979-86 he was the administrative head of the Tarna and then Kolo research stations), a Nigerien who joined INRAN in 1988, and an expatriate at INRAN from 1983 to 1992. Five short-term foreign assistants were also present between 1976 and 1991.

Plant protection work on sorghum has increased. Since 1983, selection for resistance to head bugs and long smut have been important new activities. A Nigerien plant pathologist at Kolo has recently been able to inoculate sorghum plants with long smut which will facilitate testing for long smut resistance.

The sorghum program has benefitted from collaboration with other institutions. Sorghum researchers have participated in the West and Central Sorghum Research Network organized by ICRISAT in Mali. Through the network, sorghum researchers have organized regional variety trials with other national programs in the region, attended workshops every two years, assisted training sessions, participated in monitoring tours in which field visits were made to half of the countries involved, and received small amounts of funding. Additionally, the sorghum program has received aid from the INTSORMIL program in the form of foreign technical experts collaborating with local scientists and some limited funding for trials. However, because this aid is tied to the number of local scientists (only two in the program), this aid was very limited. Finally, the sorghum program has benefitted from the exchange of germ plasm with institutions throughout the world, largely resulting from breeders' personal contacts.

3.4.3. The Cowpea Program

A cowpea breeding program was initiated in 1959 under the French institute IRAT. IRAT produced and diffused the cowpea variety TN88-63. INRAN cowpea breeding work began in 1975 with one researcher. In 1988, when a new breeder joined the program, the former went on overseas training. Thus INRAN has continued with only one researcher. Much of the cowpea breeding work conducted since 1975 has focussed on replacing TN88-63 because of its undesirable cooking and digestibility characteristics. As shown in table 9, three new varieties have been developed and disseminated. One of these, TN5-78, was adopted by farmers, effectively replacing TN88-63.

Table 9. Crop Varieties Developed and/or Extended, Niger (1975-1991)

	variety	year of release	yield (kg/ha)	zone (mm)	days to maturity	deriving from	developed by*
millet	P3 KOLLO**	1962 and 1977	2500	500-600	90-95	Niger	IRAT-INRAN
	HKP	1975	2000	350-500	80-90	Niger	IRAT
	CIVT	1977	2500-2800	450-650	90-95	Niger	INRAN
	3/4 HK	1975	>2000	450-650	80-90	Niger	IRAT
	MORO-P1	1985	1800	200-300	70-75	Niger	INRAN
	GR-P1	1985	2500	450-650	90-95	Niger	INRAN
	ANK-P1	1985	1000	300-350	70-75	Niger	INRAN
	HKP3	1982	1500	280-350	70-75	Niger	INRAN
	HKB Tift	1982		<300	70-75	Niger	INRAN
	H-80-10-GR	1983	2300	300-400	80-85	Niger	INRAN
	T 18-L	1982	2000-2500	250+	85-95	Niger	INRAN
	ITMV 8304	1981	2500	300-400	80-85	Mali, Togo, and Niger	ICRISAT-INRAN
	ITMV 8002	1980	2500	300-400	80-85	Africa	INRAN-ICRISAT
	ITMV 8001	1980	2500	400-500	85-90	Africa	INRAN-ICRISAT
sorghum	L-30	1974	3000	400-600	90-100	Niger	IRAT
	1/2 MSB	1977	3500	550-900	90-100	Senegal	IRAT
	A4D4	1977	2500	300-600	80-85	Niger	IRAT
	SRN39	1992	2000-2500	400-600	95-100	Nigeria	INRAN
	SEPON 82	1992	2500-4000	400-700	100-105	Ethiopia, India	ICRISAT-INRAN
	NAD1	1992	2000-4000	irrigation		Sudan	INRAN
cowpea	TN5-78	1985	3000	300-600	70-75	Niger (Tillabery)	INRAN
	TN27-80	1985	3000	300-600	75-80	Niger (Zinder)	INRAN
	TN3-78	1985	3000	600-800	85-90	Niger (Maradi)	INRAN
	TN88-63	1975	3000	300-600	50	Niger (N'Guigmi)	IRAT

Source: Ministère du Développement Rural 1987.
* Refers to the institution which made the selection. It does not take into consideration the institution from where the parent material was obtained.
** P3 Kollo foundation seed stocks were exhausted. Thus it was necessary to regenerate it in 1977.

Cowpea breeding currently comprises collection, selection, and maintenance. Over 300 accessions are maintained (DRA 1991). Each year F2 to F8 populations are introduced from the IITA-ICRISAT collection and are observed and selected for early maturity, an essential characteristic in Niger's dry climate. Recent developments include multiline trials to produce cultivars with a broad genetic base and collaborative trials between INRAN, IITA, and ICRISAT in testing varieties for adaptability to Niger's various agroecological zones. Regional trials organized by the SAFGRAD network have tested varieties from other countries in West Africa. In trials conducted between 1988 and 1990, TN5-78 produced the highest yields in the Nigerien agroclimate.

Since the mid-1980s, agronomic work on cowpeas increased and focussed on millet-cowpea intercropping, the most important farming system in Niger. This reflects a change to a more demand-oriented research strategy. Trials are conducted by DECOR with the agronomy department to determine appropriate planting dates, densities, and fertilizer for obtaining high dry-matter yields of both crops. Cowpeas have recently begun to be tested for forage production because of their importance as forage in the Nigerien farming system. Trials conducted between 1987 and 1990 comparing IITA traditional and selected local varieties showed TN5-78 to be the highest grain producer, the second largest forage producer, and the variety with the highest residual effect, indicating a capacity to replenish soil nutrients (DRA 1991).

Considerable research has also been done on plant protection, including trials for resistance to parasites, striga, and the fungus Macrophomia. Unfortunately, to date limited progress has been made in either pest or disease control. A post-harvest constraint for cowpea production is storage pests, such as pod borer, which cause considerable loss in storage. Work in conjunction with the Department of Agronomy of the University of Niamey is currently under way to find a solution.

3.4.4. Testing Cereal Quality

A two-person laboratory to test cereal quality was created in 1983 under USAID's NCR project. The physical facility already existed but it lacked testing equipment. The laboratory is intended for use by all crop programs at INRAN to test food preparation and taste characteristics. The sorghum program is the heaviest user of the laboratory, because many sorghum varieties tested at INRAN are exotic and therefore must be closely evaluated for taste and cooking characteristics. The millet program uses the laboratory to characterize local varieties according to their cooking characteristics. The cowpea program conducts cowpea oil and protein testing. Neither the millet nor the cowpea program conducts village-level taste tests. Use of this laboratory reflects INRAN's fundamental shift towards a demand-oriented research strategy.

At the request of the sorghum program, the cereal-quality laboratory has developed a test for food preparation and taste for sorghum. This test is conducted close to the experiment stations. It asks village women to prepare "tuo" using four varieties of sorghum for four days. The women comment on the time it took to decorticate the grain, the quality of the flour, the length of cooking time, and the quantity of water required for cooking. Ten tasters test the tuo of each variety every day and are asked to judge it on a scale of one to four. Its color, taste, and texture are judged separately. These tests are conducted prior to the release of a variety to the extension service.

3.4.5. Agronomic Recommendations

Research at INRAN has been primarily centered around plant breeding. Varieties have always been released with accompanying agronomic recommendations. These recommendations can be divided into two distinct time periods. The first covers the period up to 1983, during which agronomic recommendations dealt exclusively with cultivation techniques and fertilizer levels for millet, sorghum, cowpea, peanut, and rice grown in monoculture. Key recommendations included planting time, soil preparation with animal traction, planting densities, application of phosphate fertilizer (single super or triple super in doses of 100 kg/ha and 50 kg/ha respectively); application of nitrogen fertilizer (urea) in doses of 50 kg/ha for rainfed cereals and 200 kg/ha for irrigated rice, thinning three plants per hill and timely weeding, and fungicide application to seeds. These recommendations were principally developed by IRAT.

Agronomic recommendations comprised a standard technological package recommended by research for all agricultural regions of Niger. No distinctions were made for differences in soil or climatic conditions or on-farm practices and characteristics.

Farmers' preference for intercropping and the importance of the intercropping system in terms of land area led the INRAN agronomy department in 1984 to initiate a research program at the Tarna research center on intercropping of millet, sorghum, cowpea, and groundnuts. This work was to be repeated at various substations throughout the country. The following recommendations which were developed during this period also reflect the fundamental changes INRAN underwent to refocus its research on the needs of producers and consumers.

The program consisted of two main areas: research on cultivation practices immediately adoptable by farmers and research on intercropping and its interactions with ecological and production factors. The intercropping studies included research on plant physiology, crop rotation, water usage, and the ability of plants to replenish soil nutrients. On-station trials were conducted on millet-cowpea intercropping, the most popular form of intercropping in Niger.

In traditional intercropping systems, local varieties of millet are used. These are tall, semi-late or late maturing varieties intercropped with photosensitive cowpea varieties. Research identified the local varieties most suitable for intercropping according to climatic zone. Three varieties of cowpea were intercropped with two varieties of millet. The cowpea varieties were the medium-cycle, erect variety (IT82D-716); the medium-cycle, climbing variety (TN5-78); and long-cycle varieties (Sadoré). For millet, the varieties used were two dwarf varieties (3/4 HK and a composite).

Various planting dates of millet and cowpea were tested in relation to the start of the first rains (ranging from May to late July) under various cultivation practices (pure and intercropped). It was found that millet should be planted after the first rainfall of 10 mm or more, normally occurring in the first half of June in the southern part of the country and later in the north. The most appropriate cowpea planting dates for intercropped systems were identified in relation to the millet planting date. Trials showed that each week of delay between millet and cowpea planting dates significantly lowered cowpea yields. The maximum period between the planting of the two crops was found to be 15 days.

Trials were also conducted on the effect of cowpea residues on millet cultivation. In 1984 and 1985 trials of planting density and spacing were conducted at the Tarna research center. These compared the traditional low planting density with various higher densities in terms of millet and cowpea yields. Various spacings were also tested. The most productive combination was that of 10,000 hills of millet and 27,000 hills of cowpea per hectare.

Fertilizer trials have focused on the effects of phosphorus and nitrogen on millet and sorghum and the effect of phosphorus on cowpea. The fertilizer level tested also took rainfall into account in the different agricultural zones. On-farm trials confirmed the positive effects of phosphorus on millet and cowpea and highlighted the economic risk involved in using nitrogen on millet in the climatic conditions prevalent in Niger.

All these trials led to the development of an easy to read "fiche technique" (appendix 5) designed to provide recommendations regarding plant densities, varieties, and fertilizer dosages according to rainfall, fertilizer use, and the farming system (mono or intercrop). This fiche technique is now the principal document used by extension agents throughout the country. It is responsible for the dissemination of customized agronomic recommendations for the different agroclimatic areas and production systems of Niger.

The DRA and DECOR departments collaborated closely to institutionalize a system of on-farm trials. These have greatly increased researchers' knowledge of farmers' production constraints. The approach developed and carried out was to first conduct a socioeconomic survey of the production systems in the area where the trials were to be carried out. Then on-farm trials were conducted to evaluate the adaptability and relevance of the technologies developed by the research system. Agronomic, economic, and social evaluations are conducted before the technology is released to the extension service for dissemination. Five test sites were identified (Magueïro, Kandamo, Liboré, Magaria, and Kouka) and tests were defined for millet-cowpea intercropping:

T1—local varieties with local practices;
T2—improved varieties with local practices;
T3—improved varieties with increased densities;
T4—improved varieties with increased densities and fertilizer application;
T5—improved varieties with increased densities, fertilizer, and pesticide application. (Ly 1992)

In 1990, sorghum varieties also began to be tested and an additional site at Gaya was added. Also, two small-scale projects were initiated during this period. First was a three-year study initiated in 1984 on the water use of intercropped millet and cowpea, comparing them with monocropped systems. The results showed that intercropping made a more efficient use of water than monocropped systems. Second was the atelier de recherche et de développement de technologies (ARDETEC) to evaluate existing weeding tools and develop new ones to lessen the time required for weeding improved millet and cowpea intercropped systems.

3.5. Factors Outside the Research System Affecting Technology Transfer and Adoption

Adoption of improved plant varieties has been low in Niger. It peaked in 1984 when 900,000 ha or 20% of the area under millet and cowpeas was sown with improved varieties. However, the severe droughts of 1985 and 1988 caused many farmers to revert to traditional varieties. Presently less than 12% of cultivated land is sown with improved varieties (figure 4). Adoption of new technologies does not depend on the research system alone, but rather is influenced by factors such as the extension and seed multiplication systems, as well as agricultural policies and the agroclimatic conditions in Niger.

3.5.1 The Extension System

After the severe 1968-75 drought that peaked during 1972-74, Niger's food security was destabilized. The government put into place an agricultural policy aimed at developing the food-crop subsector. An integral part of this policy was to reinforce the extension system.

Administrative Structure: A technology-transfer system has existed since the 1930s. However, it was only after independence that training farmers became an activity organized by the government. In 1965 an extension service was created with its central office under the Department of Agriculture within the ministry responsible for agriculture, and a system of branch offices located in each administrative region (department) and *arrondissement*. The organizational structure of the extension service has changed little over the years. At the departmental level, there is a *Direction Départementale de l'Agriculture* (DDA) that embraces the extension, plant protection, and agricultural statistics services. Each DDA is headed by a director and a deputy director, the latter being solely responsible for the extension services. Each *arrondissement* has a *Service Agricole d'Arrondissement* (SAA) with one head. Finally, there is the agricultural district which represents the smallest administrative entity. At this level there is a *Chef de District Agricole* (CDA) who is in direct contact with farmers and is responsible for reaching 30 to 40 villages or 3,000 to 5,000 farms. Given the numerous tasks assigned to the CDA, including the yearly collection of agricultural statistics, interviews with CDA representatives indicated that on average they spend only one third of their time on extension.

Unlike the research system, the extension system has been greatly affected by its series of relocations among various ministries. The extension service is totally dependent on the ministry in charge of agriculture not only for its core funding, but also for the allocation of funds and spending authorization. Between 1974 and 1986, the extension service was under the Ministry of Rural Economy, the Ministry of Rural Economy and Climate, the Ministry of Rural Development, and the Ministry of Agriculture. In 1987 it came under the Department of Agriculture and then the Department of Extension and Cooperative Development under the new Ministry of Agriculture and Environment. In 1989 it was assigned to the Department of Agricultural Production under the Ministry of Agriculture and Livestock. Finally in 1992 it came full circle and was once again placed under the Department of Agriculture. Each change brought with it a new accounting system. At times the agricultural statistics services were included with the extension services. At times they were separate. Each change involved substantial transfer costs and contributed to a large turnover of extension workers at all levels. High turnover prevented the build-up of knowledge necessary for the development of an effective system.

Human and Financial Resources: The largest constraints felt by the extension service are a lack of well-qualified extension agents and insufficient resources with which to reach farmers. The level of training of extension agents is lower than that required for an innovative system working in a range of agroecological zones. In 1990-91, 66% of extension agents were working for the classical extension service.[8] The remainder were distributed among rural development projects. Only 11% were "ingenieurs"—in general, the minimum level required to be able to devise new orientations in the extension of new material and techniques. Thirty-four percent were "techniciens superieurs" and 51% were "agents techniques". The ratio of extension agents to rural inhabitants is 1 to 12,000, but if one considers only agents who are in direct contact with farmers this ratio becomes 1 to 27,000–well below the rate projected by the government of 1 to less than 10,000 farmers.

The extension service receives funding from three sources. Annual funds come from the national budget and are meant to cover personnel and operating costs for the central and regional extension offices. These funds have been increasingly used for personnel costs leaving little to pay for operating expenses (table 37, appendix 3). A second source of funds, although very small, is the territorial collectives ("collectivités territoriales") which fund certain activities particular to their administrative area. Recently these funds have been used primarily for dry-season crops. Finally, exterior funding of the extension service through development projects constitutes the largest amount of financial resources invested in extension. The general lack of funds for extension led the government to favor the "productivity project" approach to extension. These projects were principally donor funded and provided the needed financial resources for operating expenses. There was one productivity project for each of the five agricultural regions.[9] Each included activities such as credit, farmer training, input distribution and extension.

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[8] Classical extension service shall be used to differentiate the extension structures set up by the government from those of the "productivity projects."

[9] These projects were Projet Productivité Niamey, Projet Productivité Tahoua, Projet "3M" de Zinder, Projet de Développement Rural Maradi, Projet Productivité Dosso, and the Projet d'Appui au Développement Agricole de Diffa.

The Different Approaches to Extension: During the colonial period extension was done through isolated demonstration trials conducted by extension agents focusing on cash crops—cotton and groundnuts. These priorities persisted after independence but did not attain results, mainly because of the lack of farmer participation. In 1965, community education was added to extension activities. However, extension remained a one-way activity in which information flowed only from the agent to the farmer. Until 1972 extension lacked a nation-wide strategy and was based on small, localized efforts. Following the 1972-74 drought, priority was given to rainfed food crops (millet, sorghum, and cowpeas) to attain the government's food self-sufficiency goal. From this time through to the mid-1980s, the classical extension service used a "diffused" extension approach, consisting of setting up demonstration trials in many localities especially close to highly frequented roads or paths. This method, however, failed to address the main constraints faced by farmers on their fields.

In the 1970s, productivity projects were initiated which based their extension activities on the strategy of "farmer self-training." This method consisted primarily of training pilot farmers to act as extension agents and community educators. This system did not produce the desired effects largely because villages generally sent young and unskilled farmers who were the only ones they could spare for the nine-month training course. On returning to their villages, these young farmers did not have sufficient status to convince their elders to adopt the methods they had been taught. Furthermore, they rarely had land on which to implement the techniques themselves.

At the Zinder seminar in 1982, the productivity projects came under heavy criticism for the failure of the "farmer self-training" approach. As the farmer self-training projects were phased out, they were replaced by a "training and visit" system, adopted through the World Bank-funded project, PRSAA, which began in 1991. This is currently in a pilot phase, affecting about half the country (Dosso, Tahoua, and Tillabery).

Linkages with Research: Traditionally, research and extension personnel met twice annually—at the respective yearly meetings of the research and extension staff. These meetings, however, did not provide an adequate forum for discussion and debate. In 1981 a research-extension liaison unit was created within INRAN to improve communication between the two services. Despite the creation of this unit and of a similar unit located within the extension service, there were no official fora providing researchers and extension workers the opportunity to exchange information and create a system which promoted communication between the two services. Since 1988 the research-extension liaison unit of INRAN has received more resources through the USAID-funded NAAR project. This has facilitated communication in the form of more meetings. The PRSAA project at the Department of Agriculture has also been active since 1991 in attempting to promote a research-extension liaison.

3.5.2. The Seed Multiplication System

A system of seed multiplication for millet, sorghum, cowpeas, and groundnuts was started in 1975 with the Niger Cereals Project (NCP) funded by USAID. Before this time, seed multiplication was largely done by research. Seed distribution occurred primarily around the research center in Maradi and the research station in Kolo. Under the first phase of the NCP, a base seed farm in Lossa and five seed multiplication centers in Tillabery (Hamdallaye), Dosso (Guéchémé), Tahoua (Doukou-Doukou), Maradi (Kouroungoussao) and Zinder (Magaria) were created, one center for each of the primary agricultural regions. The seed multiplication system in place was as follows: pre-base seed (M0) was created and maintained by the research centers and given, free of charge, to the Lossa foundation seed farm. The seed farm multiplied the M0 seed to make foundation seed (M1), which was given to the five seed centers for multiplication of registered seed (M2) and certified seed (M3).

The second phase of NCP concentrated on seed multiplication and distribution. It began in 1982 and was called Agricultural Production Support (APS). Under this phase farmers were contracted to produce M3 seed. They were provided inputs such as fertilizer, plows, and pesticide on credit. At the end of the season the farmer paid in kind for the seeds received from the center, and fertilizer costs were deducted from the farmer's pay. The contract obliged farmers to sell an additional 25% of their production to the seed centers (Couvillion 1985). The seed centers inspected the grain produced and bought seed from farmers at a price higher than the prevailing market price to incite the farmers to sell them the grain. Seed center buying and selling prices were set by a committee comprised of the director of agriculture, the coordinator of NCP, the director of the union of cooperatives (UNC), the director of the national credit agency (CNCA), a representative of INRAN, a representative of the national irrigation office (ONAHA), and the head of extension. The committee assembled twice a year and determined the price at which the centers would buy M3 seed from the contracted farmers and the price at which it would sell the seed to cooperatives, government agencies, development projects, and private users. Prices were set at the beginning of each season and applied to the whole country for the entire year. Prices to seed producers were set 25% higher than the official cereal price, whereas prices to consumers were determined by taking the highest market price before planting and setting the price just above it (Couvillion 1985). The committee also decided the quantity and the variety of seed to be multiplied. The principal varieties multiplied by the seed centers were CIVT, HKP, and P3KOLLO for millet, L-30 for sorghum, and TN88-63 and TN5-78 for cowpeas. A groundnut variety was also multiplied for a short period.

The seed multiplication centers encountered many difficulties, largely because the project's considerable scale and scope were unsustainable. Also, the majority of the seed multiplied came from local, "purified" varieties. Because these varieties were not hybrids, it was very easy for farmers to maintain the improved characteristics by selecting and retaining the seed from year to year.

High costs of multiplying the seed also made the operation unsustainable. Due to the high input requirement set by the NCP, the production of certified seed was very costly. Between 1985 and 1988, the average price of producing improved millet M2 seed in the five seed centers was 1,720

CFA/kg, yet the M2 seed was sold to farmers at 100 CFA/kg for the multiplication of M3 seed (Rachmeler 1991).

A further reason for not being able to recover operating costs was the seed service's lack of an effective price-setting mechanism (Couvillion 1985). The informal markets, where most farmers bought and sold seed, were not closely monitored; thus, at times, improved seed cost less than the local variety. In Maradi, for example, the 1985 market prices for millet and cowpeas were 115 and 197 CFA/kg respectively, whereas improved seed was being sold by the multiplication centers at 90 and 140 CFA/kg respectively. The cereals project was managed as a mechanism through which to subsidize producers. As such, the multiplication project became more of an extension service than a seed multiplication system.

Prices of improved seed were set across the nation for the entire year, without any spatial or temporal considerations. This created problems especially for transportation since the differential in transportation costs from distribution centers was not included in the set prices. As a result it was difficult to finance transport, and seeds reached only a few, large markets. In the MAG/EL survey of 1988 and 1989, the most frequent answers given by farmers as to why they did not purchase improved seed were that points of seed distribution were too few and far from their farms. The centers also suffered from a lack of good management. Often, due to heavy administrative procedures for obtaining funds, the centers lacked the resources to purchase M3 seed from producers at the appropriate moment. Producers then sold their seed on the local markets.

Security stocks were insufficient to meet seed demand after years of low rainfall. Given the low levels of production obtained in a drought year, farmers could not fulfill their contracts. They did not sell the required minimum of seed to the centers since cash would do them little good in empty markets. The centers were thus not in a position to provide seed to consumers in a drought year, a time when their services were most needed.

The quality of multiplied seed was also a problem. Due to periodic transportation difficulties, inputs such as fertilizer were not delivered to the farmers on time. And there were too few visits made by qualified personnel to inspect the conditions under which the seed was grown. Often farmers did not respect the isolation distance from their other fields required to maintain purity in the grain grown for seed (Couvillion 1985). When farmers sold the M3 seed back to the centers, the centers did not inspect the seed as they were meant to do. All these factors limited the reach of the seed multiplication centers which, in turn, has constrained the adoption of improved varieties.

3.5.3. Agricultural Policies

Agricultural policies influence the adoption of new technologies through agricultural input subsidies, credit, and price policies. The inability of the CA to reach farmers, described in section 2.2.1, and to provide them with a timely supply of inputs discouraged farmers from using inputs for cultivating improved varieties. The lack of an adequate input supply is highlighted by the fact that the highest adoption rates are found in areas close to the seed multiplication centers and in areas affected by the productivity projects. In a survey on improved seed usage conducted by the MAG/EL in 1988 and 1989, an inverse relationship was found between the levels of adoption of an improved variety and the farmer's distance from a seed multiplication center.[10]

Interviews with heads of the extension service and with extension agents indicated that the highest adoption levels in each agricultural region were obtained during productivity projects. These projects made cultivation of improved varieties economically more attractive because they provided credit and inputs. This result was confirmed by the MAG/EL 1988 survey, which found, for example, an adoption rate of 34% and 9% for CIVT and P3KOLO respectively, in Guidan-Roumdji, well within the area covered by the *Projet Productivité Maradi.* Adoption was only 12% and 3% in Gaya, where there was no productivity project. The fact that proximity to seed multiplication centers and productivity projects had such a strong influence on the adoption of improved varieties indicates that availability and accessibility of improved seeds and complementary inputs are two important constraints for the adoption of improved varieties.

Another illustration of the effects of a lack of market infrastructure for inputs are fertilizer usage patterns in Niger. Fertilizer use on millet, sorghum, and cowpeas is negligible nationwide. However, in the southern strip of the country, along the border with Nigeria, higher rates of fertilizer usage have been recorded (Lowenberg-deBoer, Zarafi, and Abdoulaye 1992). This is because farmers and middlemen import fertilizer from Nigeria, taking advantage of fertilizer subsidies and, until recently, the favorable exchange rate with the Naira. Fertilizer is thus adopted when it is accessible.

The lack of a functional credit system (discussed in section 2.2.1) has constrained the adoption of new technologies that require up-front capital investments (such as purchased inputs). Nigerien farmers are highly dependent on the resources they own. DECOR on-farm trials showed that increasing the planting density for a millet-cowpea intercrop to 8,888 hills/ha for millet and 20,000 hills/ha for cowpea in Kouka are economically profitable only if a farmer has enough labor and capital. In Madarounfa, in addition to a higher planting density, the application of 100kg/ha of super phosphate and 50 kg/ha of urea and insecticide can increase both yields and net revenues if a farmer has enough labor and capital to invest. However, the average planting densities in Kouka are only 4,300 hills/ha for millet and 1,700 hills/ha for cowpeas. In Madarounfa, the average super simple phosphate (SSP) application rate is 17 kg/ha and insecticide is virtually not applied to millet-cowpea intercropped fields (Lowenberg-deBoer, Zarafi, and Abdoulaye 1992). These figures show that even though these technologies have been evaluated as economically profitable, there is very little adoption of them by farmers. A comparison of adopters with non-adopters has led DECOR to conclude that the adoption of certain new technologies is tied to a farmer's access to capital and to the opportunity cost of capital. In fact, adopters in the 1991 DECOR survey had more arable land, more family labor, and more capital, as measured by the value of their animal herds, than non-adopters.

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[10] Conversation with Dale Rachmeler, February 3, 1992.

On the output side, with or without regulation, cereal prices have been too low to make investment in inputs profitable. When farmers can gain access to fertilizer, they tend to apply it to their cash crops, such as rice and vegetables, which have higher market value. Although cowpea is a cash crop, it is mainly grown with millet and sorghum and, therefore, fails to receive fertilizer like other cash crops.

3.5.4. Climate

Climatic conditions are extremely harsh and variable and introduce a considerable risk component to farming in Niger. Total annual rainfall has declined since 1969, as shown by rainfall isohyets for the periods 1945-69 and 1969-90. The isohyets have shifted southward by 100 to 150 km (Sivakumar, Maidoukia, and Stern 1992). Most areas in the country are receiving less rainfall than they were 30 years ago. Between the periods 1945-64 and 1965-88, the length of the growing season has shortened by 5 to 20 days across different locations in Niger. The most significant change occurred in the total rainfall received in August, which declined throughout the country in the two periods in question (table 10).

The changes in the level and spread of rainfall in August have particular consequences for a crop like millet that is sown in early to mid-June. The reduction in supply of water occurs during the sensitive stage of reproductive growth covering flowering and grain filling. Studies conducted in India show that if prolonged stress of 10 to 20 days continued after flowering, severe yield reduction resulted, as the crop's ability to recover was gradually lost (Seetharama et al. 1984). Variability in rainfall is also an important aspect of risk. The more variation in the quantity and distribution of rainfall, the more the production of rainfed crops becomes unstable. Data for the period from 1931 to 1990 show coefficients of variation in total yearly rainfall ranging from 35% in Agadez to 17% in Gaya. These coefficients are highest in areas of low rainfall (Sivakumar 1991). Variability in the onset and ending of the rains, as well as in the length of the growing season has increased. The standard deviation for the date of both the onset and ending of rains has risen between the two periods, indicating that the variability in rainfall timing and distribution has increased over time, augmenting the degree of risk involved in agricultural cultivation (Sivakumar 1991).

Table 10. August Rainfall Data, Niger (1945-64 and 1965-88)

	Rainfall		Rainy days		Duration between rainy days	
Location	1945-64	1965-88	1945-64	1965-88	1945-64	1965-88
	(millimeters)		*(days)*		*(days)*	
Agadez	99.6	43.8[b]	11.9	8.0	2.6	5.5
Birni	241.7	154.8[b]	15.7	13.4[a]	1.4	1.9
Gaya	264.1	229.0	13.3	16.4[a]	1.7	1.5
Gouré	187.7	108.6[b]	11.3	8.3[a]	2.5	4.7
Magaria	281.2	183.7[b]	13.6	12.1	1.7	2.3
Maine	190.6	132.2[a]	14.1	11.7[a]	1.7	2.8
Maradi	257.8	162.9[b]	15.9	13.7[a]	1.4	1.9
N'Guigmi	149.6	93.0[a]	11.1	8.9[a]	2.9	4.6
Niamey	221.2	160.4[b]	15.9	13.2[a]	1.3	2.0
Tahoua	160.4	115.6[b]	15.4	12.1[b]	1.3	2.2
Tillabery	227.7	121.0[b]	15.0	12.0[b]	1.6	2.3
Zinder	244.4	150.8[b]	14.9	11.8[b]	1.4	2.2

Source: Sivakumar 1991.
[a] The difference between the two time periods is significant at the 5% level.
[b] The difference between the two time periods is significant at the 1% level.

The risk that climate imposes on agricultural cultivation in Niger has direct consequences on the level of adoption of new technologies. Climatic variability makes large crop failures a reality. Farmers are less inclined to invest in agricultural inputs, which raise the potential economic losses in case of a crop failure. Certain of the new varieties outproduce local varieties only when rainfall is adequate. Climatic fluctuations thus increase the risk involved in adopting an improved variety. Risk analysis conducted by DECOR (Lowenberg-deBoer, Reddy, and Zarafi 1992) at a number of on-farm sites showed that in good years all cultivation practices carried similar risk components, while in years of bad rainfall the cultivation practices carrying the least risk were use of local varieties with traditional agronomic practices (T1).

Drought, however, also depletes the farmers' seed stock. The only seed then available is that from the seed multiplication centers or from local markets with seed from Nigeria. Following the 1972-74, 1984, and 1987 droughts, adoption of new varieties always suffered a sharp decline (figure 4). Droughts make adoption levels depend highly on the seed multiplication centers' ability to satisfy improved seed demand, which in the past has proved inadequate.

Figure 4. Estimated Rate of Adoption of New Millet and Cowpea Varieties (1975-1990)

4. METHODOLOGICAL OVERVIEW

4.1. Methodology

Research can help improve agricultural productivity by creating appropriate technologies that reduce constraints to production. Investments in research, however, are often costly, risky, and take considerable time before returning benefits. To make the most of research investments, especially in the current climate of declining research funding, research leaders must prioritize research programs. Scarce resources must be allocated to the most appropriate of competing programs. To justify their investment in research, governments and donors must be assured of optimal rates of return. Analytical techniques to assess and monitor the research process can be useful tools in priority setting. Also, they can justify research investments and make agricultural research a more effective means of achieving agricultural development objectives (Schuh and Tollini 1979).

Studies evaluating the returns to agricultural research can be classified into two broad categories: ex-post and ex-ante. The ex-post category evaluates the returns on past investments while the ex-ante category is used to estimate future returns. Ex-post studies include a range of methodologies with varying objectives and evaluation criteria. Schuh and Tollini (1979) summarized ex-post studies as those which measure benefits of research in terms of resources saved, economic surplus, production functions, impact on national income, and changes in the nutritional status of the population. The specific methodology chosen for a given study depends on the characteristics of the country and research system being evaluated, availability of data, and the particular questions addressed. The present study is an ex-post evaluation of research investments made in Niger between 1975 and 1991 using an economic surplus model to measure the rate of return of investments in Niger's agricultural technology system.

Schultz (1953) pioneered the work on measuring the returns to agricultural research investment. To put a value on the technologies developed by the research system, he calculated how much it would cost to obtain the agricultural output of 1950 with agricultural technology from 1910. He then compared that value with the actual costs incurred in 1950 to produce that year's output. Griliches (1958) measured the returns to United States' research by putting a value on increased corn yields using an economic surplus approach. Akino and Hayami (1975) refined this approach by separating economic surplus into benefits accruing to producers and to consumers. They used the case of rice breeding research in Japan. Since then, many studies evaluating the impact of agricultural research on agricultural productivity have been conducted, especially in the United States, Asia, and Latin America. Most of these show high returns (Echeverría 1990). However, few such studies have been done for African agricultural research.[11] Because African NARS are usually at an early stage of institutional development, they are in particular need of such information (Eicher 1990).

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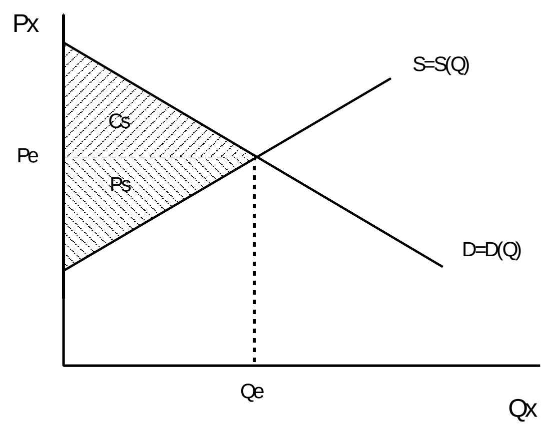
[11] Abidogun 1982; Evenson 1987; Howard 1992; Karanja 1990; Mazzucato 1991; Monares 1984; Norgaard 1988; Sterns and Bernsten 1992.

This study uses the economic surplus methodology because it has fewer data requirements than other methodologies and also because it provides flexibility in calculation to take into account circumstances particular to the system under investigation (Schuh and Tollini 1979). A benefit-cost approach is then used to calculate economic surplus, rather than the Akino-Hyami approach, because the distribution of benefits between consumers and producers is not an important issue in the case of millet, sorghum, and cowpea research in Niger. Nigerien farmers cultivating these three crops are consumers as well as producers. A review of the benefit-cost approach as well as how it was modified to better represent the situation in Niger follows. However, first the economic-surplus methodology, on which the benefit-cost approach is based, is described.

In figure 5, the curve labelled S is an inverse supply curve, S=S(Q), indicating the marginal cost of producing the Qth unit of a good, X. The profit accruing to producers of good X is the price received, P_e , less the cost of production, S(Q). The integral of P_e-S(Q) over the range 0 to Q_e sums the profits for each unit of X produced, assuming no change in fixed costs, to form the measure of producer surplus or aggregate profit for all producers designated by the shaded triangle Ps.

Figure 5. Consumer and Producer Surplus

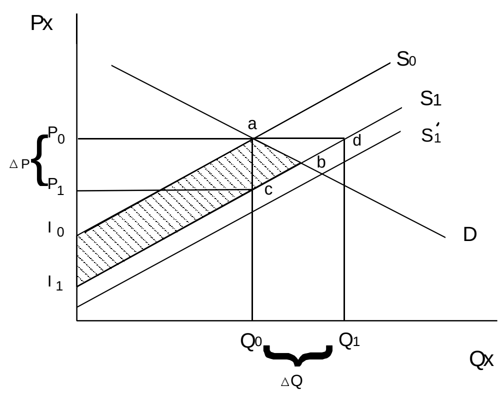


The curve labelled D is an inverse demand curve, D=D(Q), which approximates the maximum amount that a consumer is willing to pay to consume the Qth unit of good X. Consumer surplus, or the aggregate net gain to consumers from consuming quantity Q_e, is calculated by integrating D(Q)-P_e from 0 to Q_e resulting in the shaded triangle Cs.

The sum of the consumer surplus and producer surplus areas in figure 5 is called economic surplus and it is taken to represent the welfare accruing to a society from producing and consuming Q_e units of good X at a price P_e.

Successful research and technology transfer systems, as defined by the economic efficiency criteria used in this analysis, are considered to generate and propagate improved production techniques or technologies that lower per-unit costs of production. These lower costs shift supply curves downward as depicted by the shift from S_0 to S_1' in figure 6. Increases in the costs of production due to new technology create a further shift in the supply curve upward from S_1' to S_1. In the absence of specific knowledge about the shape of the supply and demand curves for the commodities being evaluated in this study, as well as the nature of the shift, supply and demand curves were assumed to be linear and the shift parallel. Under such assumptions the change in economic surplus is measured by the shaded area $I_0 abI_1$ in the model presented in figure 6. However, given the data commonly available for such studies, the area actually measured is $P_0 acP_1$, which is equal to $I_0 acI_1$. When demand is perfectly inelastic, area $I_0 acI_1$ is less than area $I_0 abI_1$ so the area being measured underestimates the change in economic surplus by area *abc*. However, since millet and sorghum are food crops and demand for food crops is generally highly inelastic, area *abc* is most likely very small and economic surplus is being underestimated only slightly.

Figure 6. A Shift in Supply Due to Technological Innovation



Assuming complete and instantaneous adoption of cost-reducing technologies, the shift in the supply curve, as measured by the per-unit cost reduction k is given by

$$k = \frac{\Delta P}{P_0} = \frac{P_0 - P_1}{P_0} \qquad \text{(E-1)}$$

But technologies take some time before they are available and adopted, so the per-unit cost reduction actually realized in year *t* is given by

$$k_t^* = k \times a_t \qquad \text{(E-2)}$$

where

a = rate of adoption of a new variety
t = 1,2,....,n
n = number of years.

The change in total economic surplus, ΔTS, is used to measure the benefits B, arising from research such that

$$\Delta TS_t = B_t = P_t \times Q_t \times k_t^* \qquad \text{(E-3)}$$

where

P = market output price (real CFA/kg)
Q = quantity produced (kg).

In the absence of per-unit cost reduction estimates, on-farm yield differentials, j, were used to approximate k such that

$$j = \frac{\Delta Q}{Q_0} = \frac{Q_1 - Q_0}{Q_0} \qquad \text{(E-4)}$$

When the long-run price elasticity of supply is equal to one, j is exactly equal to k.[12] In the absence of plausible elasticity estimates, this is a realistic assumption.[13] Rates of return estimates are useful summary measures of the social returns obtained from investments in research and technology transfer. If the yearly net benefit stream is calculated by measuring $B_{net,t}$ such that

[12] This follows because

$$k = \frac{j}{\varepsilon} = \left[\frac{\Delta Q}{Q_0}\right] \div \left[\frac{\Delta Q}{Q_0} \times \frac{P_0}{\Delta P}\right] = \frac{\Delta P}{P_0} = j$$

[13] For a more detailed mathematical explanation, see Norton, Pardey, and Alston, forthcoming.

$$B_{net,\ t} = B_t - C_t \qquad \text{(E-5)}$$

where C equals the costs of research and extension investments (real CFA), then the internal rate of return is the discount rate i such that

$$\sum_{t=1}^{n} B_{net} \times \frac{1}{(1+i)^t} = 0 \qquad \text{(E-6)}$$

4.2. The Data

4.2.1. Technologies Being Evaluated

Quantitative evidence of new technologies' economic impacts were estimated for three millet varieties, P3 KOLLO, CIVT and HKP, and one cowpea variety, TN5-78 (see adoption figures, appendix 2). Research on all three millet varieties was initiated by the French prior to 1975. However, INRAN's work contributed significantly to the economic benefits derived. It was necessary for INRAN to redevelop and rerelease P3KOLLO because foundation seed stocks were exhausted at the conclusion of IRAT's research program. For CIVT development was initiated prior to 1975 by IRAT and completed by INRAN. Most of the development work for HKP was completed by the French. It is, however, included in this analysis because much of INRAN's crop management research involves this variety, extension efforts focus on it, and it is the principal variety multiplied by the seed multiplication centers. Since these efforts have contributed to HKP's adoption, it has been included in our analysis. Table 9 shows that there have been other millet varieties developed by INRAN. However, the MAG/EL seed-use survey of 1988 and 1989 indicated little or no adoption of these varieties and they were rarely cited by extension agents as important.

Of the cowpea varieties listed in table 9, only those benefits attributed to the adoption of TN5-78 are considered. TN88-63 was developed before 1975, while TN3-78 and TN27-80, although developed by INRAN, were never adopted to any significant level because they were replaced immediately by TN5-78.

Cowpea hay is an important output from cowpea cultivation due to the extensive use of cowpea forage in Niger. However, cowpea hay was not included in the analysis because of a lack of data on cowpea hay production and prices from 1975 until 1991. It has been shown, however, that TN5-78 is a better forage producer than the varieties it is replacing: TN88-63 and TN3-78 (DRA 1991). It was deemed more accurate to underestimate the benefits arising from the cultivation of TN5-78 than to estimate cowpea hay yield differentials and prices for the entire nation.

The only sorghum variety to be multiplied by the seed multiplication centers and thus adopted throughout the country was L-30, which was not developed by INRAN. Three sorghum varieties released for multiplication in 1992 are included because all the research work leading to their development was conducted at INRAN during the period under investigation.

Many of the agronomic recommendations developed by INRAN have only been disseminated since 1985. It may be too early to expect significant adoption of these recommendations. This is particularly so in light of the state of Niger's extension services, farmers' limited access to credit and other purchased inputs, and the riskiness of such technologies in the marginal production environments that characterize much of the country. In fact, recommendations concerning planting density and fertilizer use have hardly been adopted. Interviews with extension agents at the *arrondissement* and district level verified that planting densities in intercropped systems of millet and cowpea remained substantially below recommended levels. The DECOR adoption survey (Lowenberg-deBoer, Zarafi, and Abdoulaye 1992) measured planting densities in the *arrondissements* of Kouka, Rigial, and Maiguéro. Despite farmers' exposure to high planting densities through the on-farm trials since 1985, adoption remained low. The average planting density used by farmers for millet was 4,270, 5,200, and 5,500 hills/ha in Kouka, Rigial, and Maiguéro respectively. The recommended figure for these locales was 8,900 hills/ha. For cowpea, the average density on farms was 1,640, 2,300, and 2,100 hills/ha for Kouka, Rigial, and Maiguéro respectively. These are substantially below the current recommended rate of 17,800 hills/ha.

Fertilizer-use recommendations have not been adopted either. Even in areas where fertilizer is accessible, its use remains low. The DECOR adoption survey found that farmers in Rigial and Maiguéro, both close to Nigeria's border and receiving an average rainfall greater than 400 millimeters, applied an average of 17 and 72 kg/ha of SSP (phosphates) and 2 and 13 kg/ha of urea respectively. Currently, recommended application rates are 100-150 kg/ha of SSP and 50-100 kg/ha of urea. In Kouka, an area receiving less than 400 millimeters of rain, no chemical fertilizers were used. Despite the low fertilizer use and planting densities, the three locations of the DECOR survey are showing some movement towards the adoption of recommendations. However, the degree to which a recommendation is adopted varies greatly both spatially and temporally. No area-specific data exist on the different degrees of adoption or the associated on-farm yield gains. Furthermore, the question remains as to how much of an increase in the adoption of recommendations can be attributed to research when there are external factors such as increasing soil degradation, which may also encourage farmers to change their practices.

For all these reasons, work conducted by INRAN leading to the development of agronomic recommendations has not been evaluated in this study. However, it must be noted that, since the adoption of recommended practices is low in Niger, their omission will only marginally underestimate the benefits arising from the research and technology transfer systems.

4.2.2. Research-Impact Lags

There are considerable lag times between the initial stages of technology development and the time the technology is adopted by farmers. This length of time is here referred to as the research-impact lag. Research-impact lags in plant breeding tend to be fairly long. An example is the case of hybrid maize in the United States. Some 50 years elapsed between the beginning of hybrid maize research and its wide-scale cultivation. This means that returns to an investment made in breeding research are often realized long after the original investment. Furthermore, continuous financial support may be necessary to generate full potential returns.

In Niger, the research-impact lag consists of a research lag, or the time up to the release of a new technology to extension, and an extension lag, or the time from the release of a new technology to when it attains its peak adoption. As described in sections 3.4.1-3, considerable research lags exist for the millet, sorghum, and cowpea research programs. The technologies being developed by INRAN are based on selection work on local populations and cross-breeding, with the exception of the three sorghum varieties which derive from exotic material. The research lag is between six and eight years for these developments. The longest was ten years for SEPON 82 and the shortest five years for the ITMV millet varieties. The latter varieties were received from ICRISAT. INRAN did the adaptive work. The selection and crossing work that has been done at INRAN involves a research lag of about eight years. This includes time required for selection and testing (six years) and for on-station and multilocational trials (two years).

The extension lag must also be taken into consideration. In the case of the new varieties being considered in this report, the average extension lag was ten years (tables 27-30 in appendix 2). Therefore, the overall time involved from the beginning of the development of a new variety to its peak impact at the farm level in Niger averages eighteen years. Because the period being evaluated covers seventeen years (1975-91), most of the benefits derived from the research conducted during this period are likely to be realized in the future.

4.2.3. The Adoption Model

Estimating the adoption of improved technologies is an essential component of an evaluation of the benefits of research. Because Niger lacks a comprehensive set of adoption statistics on the technologies being evaluated, synthetic estimates were derived of adoption patterns using a variety of information sources. Seed distribution figures were compiled for each agricultural region from data collected and published annually by the MAG/EL in their "Agricultural Statistics Yearbook" for 1975-91. Similar information does not exist at the *arrondissement* level because of the lack of documentation retained and stored and the inconsistency of data collected. Only incomplete spatial and temporal data series exist for the *arrondissements*. Seed distribution figures, however, grossly underestimate use of improved seed. Farmers themselves select and retain seed of improved varieties for use in subsequent years.

We estimated the percentage of improved seed in use derived from farmer-retained seed (or what we shall call own seed) and added this to the quantity of distributed seed to get more realistic estimates of the total amount of improved seed being used in a given year. Interviews with extension agents at the regional, *arrondissement*, and district levels, indicated that in normal years a minimum of 100% of the distributed seed sold is retained and replanted by farmers the following year. Indeed, the retention rate is likely to be more than 100%, although it was conservatively set at this level to account for the genetic degradation that takes place over time with an open-pollinated variety. There are also other means by which a farmer can obtain improved seed. Various on-farm surveys have indicated that gifts of seed are common in Niger. In the MAG/EL seed-use survey, 25% of the farmers interviewed nation-wide had received millet seed as a gift. Hopkins and Reardon (1992) found that in western Niger, households are as willing to give their crops as gifts as they are to sell them. Furthermore, almost all crop gifts were cereals and two-thirds of them millet. Despite the large number of crop gifts, the actual amount of seed transferred tends to be small (MAG/EL 1988; Hopkins and Reardon 1992). The total annual carry-over rate of millet seed averaged 120% (i.e. own seed retained plus gifts).

The carry-over rate of cowpeas is similar to that of millet although there are two additional factors to be considered for this crop. Cowpea is self-pollinated and therefore maintains its genetic purity. There is thus no coefficient of genetic degradation as there is for millet. There are, however, substantial storage losses that reduce farmers' ability to retain mass selected seed for use in later years. Given this offsetting tendency and the results of our interviews with extension personnel, the normal carry-over rate of cowpea seed was conservatively estimated at 100%.

For both millet and cowpeas the carry-over rate was reduced substantially in years following a severe drought, when a farmer's seed stock is depleted to the point that he is obliged to reconstitute his stock through seed purchases. In these years (1972-74, 1985, and 1987) the carry-over rate for millet was reduced to 20%, based on estimates from extension workers, and to 40% for cowpeas because cowpeas fare better in drought than millet.

The relatively stable proportion of areas sown under millet, sorghum, and cowpeas over time indicates little if any intercrop substitution. Therefore, once a total seed utilization figure was calculated for a given crop, it was divided by the total area cultivated and by the seed application rate to obtain a percentage of adoption of improved variety *x*, as shown in the formula below:[14]

[14] For the actual adoption figures estimated, see tables 27-30 in appendix 2.

$$T_{x,t} = (N_{x,t-1} \times F_{x,t}) + N_{x,t} \quad \text{(E-7)}$$

where

T_x = total improved seed used (kg)
N_x = improved seed distributed by seed multiplication centers (kg)
F_x = proportion of improved seed carried over from a given year to the next (own seed)
t = time period (year).

Therefore, the proportion of cultivated area sown with the improved variety *x* was calculated as follows:

$$a_{x,t} = (T_{x,t} \times R_{y,t}^{-1}) \times TA_{y,t}^{-1} \quad \text{(E-8)}$$

where

R_y = seed application rate for crop *y* (kg/ha)[15]
TA_y = total area cultivated with crop *y* (ha)
a_x = proportion of area cultivated with the improved variety *x*.

In order to estimate future adoption patterns for millet, the 1990 level of adoption was held constant to 2011 because there are no improved varieties on the horizon to replace these.

The estimated adoption pattern for TN88-63 from 1978 to 1990 was applied to TN5-78 for 1992 to 2004 because this latter variety is replacing TN88-63. It is then held constant until 2011. These are conservative estimates given that farmers are adopting TN5-78 much more readily than TN88-63 due to its better taste and cooking characteristics. However, much depends on the future success of the seed multiplication system. Since the end of the seed multiplication project in 1990, most regions have reduced their seed multiplication activities. Field visits during the course of this study revealed that availability was a major constraint to the adoption of TN5-78. If the seed multiplication system does not improve, the low adoption figures estimated for TN5-78 may be realistic.

Finally, although no sorghum variety was evaluated for 1975-90, there are three new varieties, SRN 39, SEPON 82, and NAD1, which have all been developed during this period. These are being multiplied in 1992 and will be ready for sale to farmers in 1995. To estimate future adoption of the varieties, it is necessary first to identify the areas where the varieties could possibly be adopted. All three varieties perform better than local varieties only when grown in

[15] The seed application rate used for millet is 8 kg/ha and for cowpeas 6 kg/ha following the estimates of extension agents.

rich soils or on irrigated land. Thus, the maximum area of potential adoption was calculated by adding the area of irrigated land cultivated with sorghum in 1991 and the area sown with pure sorghum in 1990, the only year for which statistics exist on area planted by type of cropping system. Area under sorghum monoculture was chosen because pure stands of sorghum are generally grown on rich valley soils, where farmers have a greater assurance of high yield. This reduces the need to employ risk-minimizing intercropping techniques. Moreover, for these soils the nitrogen fixation obtained through intercropping is generally not needed. Using this procedure, the total area that can be sown with the three new sorghum varieties was estimated at about 110,000 ha (table 31 in appendix 2).

Once the total area of potential adoption was estimated, the maximum level of adoption was defined. According to extension agents who have been involved with the on-farm testing of these varieties, by the year 2015 (20 years after they are available to farmers) only half of the potential area would be sown to these new varieties. Their rationalization was that in drought years these varieties would not perform as well as the local varieties so there is a rather high risk component to adopting these varieties. Furthermore, sorghum is open-pollinated. Sorghum seed would thus have to be purchased periodically to maintain the improved characteristics. In the case of the hybrid variety, new seed would have to be purchased every year. For hybrids, the adoption rate is highly dependent on the seed multiplication system. Given that the system is undergoing major restructuring, it cannot be assumed that it will be able to meet the full demand for improved and hybrid sorghum seed in the near future. Both these factors reduce the new varieties' adoption potential. The adoption rate would increase, however, if farmers used the new varieties in intercropped sorghum or if they shifted lands from intercropped systems to monoculture of the new sorghum varieties. A linear adoption curve was interpolated for the period from 1995 to 2011 using 50% of the total potential adoption area, the quantity of seed multiplied for distribution in 1992 in terms of hectares sown, and a seeding rate of 10 kg/ha.

4.2.4. Estimating the Supply Shift

Estimates of the social benefits arising from investments in research are critically dependent on the nature and site of the research-induced downward shift in the supply curve (section 4.1). Yield relativities have been used to estimate the supply shift as defined in equation (E-4). Ideally, on-farm yield differentials between locally used varieties and new, improved varieties should be used for each location where the new varieties were grown to include site-specific differences in the yield differentials of new varieties. Relativities for different climatological zones were thus interpolated using on-farm yield trials conducted by DECOR as described below.

All *arrondissements* were divided into two climatic zones; those receiving more than 400 mm of rain, and those receiving less than 400 mm, as defined by the average isohyet lines for 1975-90. For the *arrondissements* that fell into both zones, data on the area in each of the two climatological zones were used from AGRHYMET (table 32 in appendix 2).

DECOR's on-farm trials on the millet-cowpea intercropped system were conducted between 1985 and 1991 in five locations. Each site was matched to a climatological zone so that trials conducted in Madarounfa (Maiguéro, Rigial, and Kandamo) and Liboré were considered as representative of areas receiving more than 400 mm of rain, and trials conducted in Kouka were representative of areas receiving less than 400 mm. Because the technologies being tested were modified slightly during the last two years of trials, only data up to 1989 were used to hold all else constant (site, time period, farming practices, purchased inputs). Yields were compared between "T1" trials, where local varieties were used with local practices, and "T2" trials, where improved varieties were cultivated with local practices (table 11). The trials tested different improved varieties according to the site so that variety-specific yield differentials were obtained. Furthermore, by matching the test results to different climatic regions, it was possible to calculate different yield relativities for different regions, thus taking into account spatial yield variability. The trial results were averaged over time to incorporate temporal variation in rainfall into the yield differential calculations.

Average yields by *arrondissement* published by the ministry in charge of agriculture for the years 1975-91 were considered to be representative of yields of local varieties. This is a realistic approach because the low adoption rate for improved varieties means that average yields are not greatly influenced by the higher yields for improved varieties. Average yields were then multiplied by the average *j* calculated from the above-mentioned DECOR trials. Yield differentials were thus obtained for each *arrondissement* between 1975 and 1991. To estimate the supply shift for future years, *j* was multiplied by yields averaged over the period 1975-91 for each *arrondissement* and then held constant for 1992 to 2011.

Improved sorghum varieties are the most recent to be developed. As such, DECOR on-farm trials exist for only one site and year. Because of the lack of other on-farm yield data for these varieties, yield differentials were calculated using the DECOR trials. "T4" trial results were used in which fertilizer is applied to improved varieties, because the improved sorghum varieties only outperform local varieties if fertilizer is used (table 11). Once *j* was calculated for these sorghum varieties, the supply shift was estimated in a similar manner as for millet and cowpeas.

Additional production costs associated with the cultivation of improved varieties were included to model the shift in supply from S_1' to S_1 in figure 6. These costs were taken from the farm budgets calculated by DECOR for their "T1" and "T2" on-farm trials. The additional costs per hectare of cultivating each variety were multiplied by the amount of hectares cultivated with these varieties.

Output prices used in the calculation of the supply shift for all three crops were the average annual market prices, converted to real terms using a 1990 consumer price index (Ministère du Plan 1991a) in each of the seven administrative regions of Niger. A yearly average was used because millet, sorghum, and cowpeas are bought and sold throughout the year with large fluctuations in prices according to the season. An average of 1975-90 prices was used to value the benefits accruing during 1991-2011.

Table 11. Yield Relativities and Additional Production Costs of New Technologies[a]

location	average rainfall	crop	variety tested in T2 trial	yield T1[b]	yield T2	j[c]	production costs T1	production costs T2	additional costs[d]
	(mm)			*(kg/ha)*	*(kg/ha)*	*(%)*	*(CFA/ha)*	*(CFA/ha)*	*(CFA/ha)*
Kouka	303.6	millet	HKP	236.2	288.4	22	13,036	13,172	136
		cowpea	TN5-78	45	65.5	46			
Madarounfa	510	millet	CIVT	368.8	450	22	11,129	11,694	565
		cowpea	TN5-78	69	87.8	27			
Libore	437	millet	P3KOLLO	449.5	545.5	21	8,606	10,264	1,658
		cowpea	TN5-78	---	---	---			
Birni N'Konni[e]	638	sorghum	SEPON82	391	733	87	11,667	23,251	11,585

Source: DECOR on-farm trials.
[a] Trial data from Kouka and Madarounfa are averages for 1985-89; for Liboré they are for 1985-88, and for Birni N'Konni they are for 1991.
[b] In T1 trials local varieties are cultivated with local practices; in T2 trials the indicated improved varieties are cultivated with local practices.
[c] j are the yield differentials as defined in equation (E-4).
[d] The difference between the production costs of T1 and T2 trials. These represent the additional costs of improved seed.
[e] For the sorghum trials T4 results are reported in the T2 column. T4 trials used improved varieties with a fertilizer application of 100 kg/ha urea and 100kg/ha TSP (phosphate). This category of trials was used for the sorghum varieties because they do not outperform local varieties without the use of fertilizer.

4.2.5. Research and Extension Cost Data

Financial resources allotted to extension activities were difficult to discern due to the numerous institutional changes that the extension service has undergone; the independent and dispersed productivity projects and other rural projects; and the lack of a continuous, detailed, and precise accounting system. Data on yearly government allocations to extension were available from the ministry in charge of agriculture for the years 1975 to 1982. However, for 1983 to 1991 it was necessary to draw from the Ministry of Finance budgets to identify the line-items which pertained to extension in the relevant ministerial budget.

The changing structure of the ministries and their accounting systems meant that it was particularly difficult to identify funding for extension. Rather than actual expenditures, for both time periods only the allocated budgets were available. To these allocations 100% of the budgets of the "territorial collectives" (described in section 3.4) was added and 50% of the FNI budget (about half of the total agriculture budget is used for extension).

For specific years it was possible to ascertain not only the total number of personnel in the ministry in charge of agriculture, but also the proportion that worked in extension. An average 54% of total personnel worked in extension. This percentage is used in allocating the total personnel budget of the relevant ministry to extension. Where more detailed information existed (e.g. the proportions of professional and support staff in extension and the budget allocations for their salaries) a more precise estimate of extension personnel costs was used. Interviews with extension personnel on the time spent on extension activities showed that DDAs spend 50% of their time on extension activities, SAAs 50%, and extension agents 33%.[16] These percentages were used to calculate full-time-equivalent extension personnel numbers. All support staff located in departments and *arrondissements* were considered as spending 100% of their time on extension activities. For 1983 to 1991, the percentage of the total budget allocated to extension activities was determined as follows: 60% of operations, vehicle maintenance, gasoline, and transport costs; 30% of equipment and building maintenance costs; and 100% of the farmer training centers and supplementary budgets.

It is virtually impossible to trace all of Niger's rural development projects since 1975 to build up a complete picture of their extension cost components. However, for the largest projects, namely the productivity projects, it is possible to do so. Project reports indicate that extension components ranged between 3% and 10% of total project costs, depending on the project and the year. To factor in the considerable administration and management costs of these projects, their extension components were found equivalent to 20% of the total project cost. The projects' definition of extension excluded the costs for the supply and distribution of inputs and farmer training centers. Once the productivity projects and government extension personnel costs were added together, 80% was estimated as costs for the extension of millet, sorghum, and cowpeas. This was based on the fact that these crops comprise an average 80% of total agricultural production.

Research expenditures were more directly estimated. INRAN's total outlays of government-derived funds were available from unpublished treasury accounting sheets. There was also considerable research expenditure of funds derived from foreign sources, such as USAID, Canadian and French aid, FAO, and the European Community. INRAN's total research expenditure was estimated by adding these national and foreign funds.

The USAID projects focussed almost exclusively on the sorghum, millet, and cowpeas, thus the full costs of these projects were included in this analysis. (The only exception was the first USAID project, NCP, which included a large seed multiplication component. The seed multiplication costs were excluded from estimates of research expenditure.) Under the ASD grant from USAID, only projects directly involving millet, sorghum, and cowpea research were considered. The number of full-time-equivalent researchers working on the three crops was used to estimate the government's expenditures on millet, sorghum, and cowpea research. The premise was that the largest share (an average 70% between 1975 and 1991) of the government's contributions to INRAN were used for personnel costs.

Seed multiplication costs were included by taking into account the costs of improved seed when calculating additional production costs. Although prices of improved seed were subsidized, they

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[16] Extension agents are responsible for various tasks such as collection of annual agricultural statistics which are time-consuming but are not considered by this study as being extension activities.

were deemed a more accurate representation of the value of the seed than the costs of the seed multiplication project which were inflated, given the inefficiency of the centers (section 3.5.2). However, the costs of the seed multiplication project were incurred irrespective of the over-capitalization of the project. Therefore, a scenario was also calculated incorporating the construction, operation, and maintenance of the seed centers, namely USAID's NCP, APS, and ASDG project costs for seed multiplication.

Extension and seed multiplication costs were carried over to the year 2011 because both these activities are needed to diffuse the new sorghum varieties to Nigerien farmers. Costs of extension were calculated as the average extension costs per cultivated hectare multiplied by the estimated total hectares sown with the new sorghum varieties in the future. Seed multiplication costs were included as the additional costs of improved seed incorporated into the additional production cost calculation.

5. ESTIMATES OF RESEARCH BENEFITS

Rate of return methodology measures economic surplus and compares it to the costs incurred to generate the surplus. It is thus a measure of the return to society from investments made in research and technology transfer activities. In this study, the rate of return was calculated as a range rather than as a discrete point estimate. This is due to data limitations that necessitated synthetic estimates of key adoption and supply-shift parameters. The sensitivity of rate of return estimates to changes in the various assumptions that underlie the parameters used in equation E-5 can help place some bounds on the rates of return estimates as well as provide additional policy insights as to current and possible future constraints to benefits from research and technology transfer activities.

Table 12 describes 12 scenarios for which a rate of return estimate was calculated in this study. The results from each of these scenarios are presented in table 13. The scenarios and their results are explained in the following discussion.

The first result is the base scenario and it estimates the rate of return using the most plausible, and in many respects most conservative, set of assumptions. The average yield differentials of improved over unimproved local varieties were obtained from DECOR on-farm trial data and extrapolated to corresponding areas using agroclimatic data. Adoption data were estimated from seed sales assuming a year-to-year carryover of 120% for millet and 100% for cowpeas in years of adequate rainfall and 20% for millet and 40% for cowpeas following drought years. Output prices used in the calculation were the average real annual market prices for each region. The cost calculations of the economic surplus included research, extension, and production costs. An annual stream of benefits was calculated until the year 2011 because past investments in research and technology transfer will continue to produce benefits well into the future. An estimate of future millet, sorghum, and cowpea benefits and maintenance costs was included to account for continuing extension and seed multiplication for the varieties developed up to 1991.

A strict interpretation of an ex-post rate of return analysis requires that all benefits as well as costs be cut off in 1991 so that none of the future benefits from investments made between 1975 and 1991 are counted. Calculated as such, a negative rate of return results in Niger since the most successful of the four varieties under evaluation, TN5-78, was only released in 1985. Such a scenario does not present the most plausible result because there are no improved varieties on the horizon to replace existing improved varieties in the near future. Furthermore, extension and seed multiplication activities will continue to exist and diffuse available varieties. Nonetheless, we mention it here for methodological completeness.

Table 12. Sensitivity Analysis Scenarios[a]

scenario	parameter assumptions for benefit estimates: k[b]	a[c]	p[d]	assumptions regarding costs
1 base	extrapolated from DECOR on-farm trial results	carryover: millet: 120%, 20% cowpea: 100%, 40%	average, yearly market prices for each department	research, extension and production
2 adoption		carryover increased by 25%: millet: 150%, 25% cowpea: 125%, 50%		
3 yield relativity increase	increased by 25%			
4 yield relativity decrease	decreased by 25%			
5 output prices			increased by 25%	
6 production costs increase				production costs increased by 25%
7 production costs decrease				production costs decreased by 25%
8 HKP omitted	all parameters relating to HKP are omitted from the analysis			
9 extension	benefit stream was taken to begin in 1980 rather than 1977			extension costs are excluded
10 TN5-78		adoption for TN5-78 was increased by 25% starting in 1992		
11 sorghum	all sorghum varieties are omitted from calculations			
12 seed multiplication				all costs from seed multiplication centers are included

[a] When a parameter was varied relative to the base scenario, it is marked in the appropriate space; when no change was made to the parameter, the space is left blank.
[b] Yield differential as defined in equation (1).
[c] Level of adoption.
[d] Output prices.

The second scenario used a 25% increase in adoption levels of improved millet and cowpea varieties. Many extension staff interviewed felt the adoption rate used in the base scenario was probably too low. The effect was to more than double the rate of return from 10% to 21%.

The sensitivity of the results to variations in yield relativities was explored in the third and fourth scenarios, reflecting our concerns over using a relatively small sample of DECOR on-farm trial data to infer the average supply shift parameters. Increasing and decreasing the base yield differential by 25% respectively caused the estimated rate of return to increase by 30% in the first instance and decrease by 40% in the second.

Table 13. Rate of Return Results

scenario	rate of return	change from base scenario
	(%)	*(%)*
1 base	10	--
2 adoption	21	110
3 yield increase	13	30
4 yield decrease	6	-40
5 output prices	13	30
6 production cost increase	9	-10
7 production cost decrease	10	0
8 HKP omitted	7	-30
9 extension	11	10
10 TN5-78	17	70
11 sorghum	9	-10
12 seed multiplication	2	-80

In the fifth scenario a 25% increase in output prices was assumed. Current prices for cereals are in general too low to allow farmers to invest in complementary inputs such as fertilizer. The reason for the low prices has not yet been fully investigated although possible explanations are that (a) the large volume of food aid available in Niger depresses local food prices and (b) the favorable exchange rate with the Nigerian Naira until 1985 (Ministère du Plan 1991a) lowered the domestic price of cereals imported from Nigeria.[17] An increase in output prices is likely to lead to increased adoption of both improved varieties and the agronomic recommendations on fertilizer use. Production costs would thus be affected. This, in turn, may increase the yield differentials between unimproved and improved varieties.[18] For this scenario, however, only output prices were varied because the magnitude and direction of the changes just described are unknown. The rate of return increased by about 30% following a 25% increase in output prices.

Production costs were increased and decreased by 25% respectively, in scenarios six and seven. It is possible that the average production cost figures taken from DECOR trials do not present an accurate estimate of the change in average national production costs associated with the use of the new varieties. The rates of return obtained from these two scenarios do not differ greatly

[17] For more discussion on this matter, see University of Michigan Technical Assistance Team 1988, Reeser 1980a, and Herman and Barlow 1991.

[18] See DECOR 1985, 1986, 1987, 1988, 1989, 1990.

from the base scenario as production costs are relatively small compared with research and extension costs. The rate of return varies by only 10%.

The millet variety HKP presents an ambiguous case. It is one of the main varieties on which crop management research is being conducted and it is also one of the varieties on which the extension service focusses. DECOR on-farm trials test HKP in millet-cowpea intercropping systems and entomologists and plant pathologists monitor HKP for resistance to various pests and diseases. HKP is also one of the millet varieties multiplied by the seed centers. But HKP was developed and released before 1975 and is therefore a product of IRAT, not INRAN. Excluding HKP's benefits lowers the rate of return from 10% to 7%.

Throughout the period of investigation, the extension service experienced considerable difficulties arising from its limited and unstable funding base and high staff turnover. It has been difficult for extension agents to reach farmers at large distances from the local extension offices. It can be argued that the extension service may have sped the rate of adoption without increasing the level of adoption. Without extension, farmers reached by extension may have adopted new technologies a few years later than they actually did, depending on their proximity to urban areas or roads. In fact, the MAG/EL adoption survey of 1988 and 1989 showed that between 16% and 27% (depending on the region) of adopters had learned about new varieties through informal channels. For this scenario, the benefit stream was delayed by three years, the time by which extension service is assumed to have accelerated adoption. The benefit stream then begins in 1980 rather than in 1977 as in the base scenario. Postponing benefits nullifies the effect of extension under the assumption that the extension service only increased the rate of adoption, thus the result of this scenario can be interpreted as the returns to research and seed multiplication (without extension). The rate of return increased by 10% relative to the base scenario.

Under the base scenario, TN5-78 exhibits the same pattern of adoption as the improved variety which preceded it, TN88-63. However, TN5-78 appears to be experiencing a greater degree of early success than did TN88-63. This can be attributed to its better taste, shorter cooking time, and greater forage and grain yields. It is possible that the ceiling adoption rate of TN5-78 will be higher than that of TN88-63. An increase of 25% in the level of adoption of TN5-78 increases the rate of return by 70%, resulting in the second highest rate of return of all the scenarios.

The approach in the base scenario was to be reasonably conservative in assumptions about future adoption patterns for new sorghum varieties. However, it can be argued that the likely uptake of these new varieties will be particularly limited. This is because of the very limited areas in which these varieties are likely to do well: irrigated areas and where soils have a rich mineral content. If none of the sorghum varieties are adopted, the rate of return declines by only 10%.

A final rate of return estimate was made including the full costs of the seed multiplication centers. In all other estimates, the farm-level costs of the seed multiplication services were included as the cost of improved seed contributing to the additional production costs. These were deemed more representative of the true costs of the improved seed reaching farmers than the inflated costs of building and running the seed multiplication centers given their inefficiency. However, since the costs of these centers were incurred, irrespective of how they were managed, a scenario was calculated taking the full costs of the centers into account. This scenario produced the lowest rate of return of 2%.

The results from this analysis show that investments in research and technology transfer have made positive contributions to productivity growth in Nigerien agriculture. The rates of return to the genetic improvement aspects of INRAN's work range between 2% and 21% with the most likely outcome of around 10%. These real returns are low when compared with those reported for other studies on returns to research (see Echeverría 1990) but appear to be in line with returns available from other investment options in Niger. Interest rates offered by banks in Niger have fluctuated between 5% and 6% with an average rate of inflation of 3.8% between 1980 and 1989 (World Bank 1991). Thus, the results indicate that in all but one scenario investment in research and technology transfer have returned more than investing money in a Nigerien bank.

Three important conclusions can be drawn:

(1) The adoption parameter has the largest effect on the rate of return. New technologies only realize a social benefit if they are actually adopted. Agricultural research and extension is thus most effective if it is client oriented. Because of the importance of adoption, both the extension and research services could improve their impact by closely monitoring the level of adoption of new technologies. Such monitoring requires nationwide surveys of farmers' production methods and implies that investments in research and technology transfer should include such monitoring mechanisms.

(2) TN5-78 is a variety liked by consumers. TN5-78 yields more than local varieties and satisfies forage needs. This single variety could have a very significant effect on the rate of return to research and technology transfer. In this event, TN5-78 extension should be accorded high priority.

(3) Inclusion of the construction, maintenance, and operating costs of the seed multiplication centers greatly decrease the returns to research and technology transfer investments in Niger. Explaining the negative effect on the rate of return, professionals working in the agriculture sector of Niger point to the inefficiency of the seed centers, as well as their inappropriate scale and scope in relation to the available technology. Here the implications are twofold: (a) due to the centers' ineffectiveness, technologies requiring an effective seed multiplication and distribution service will have limited impact. Unless this constraint is removed, higher priority should be placed on research, such as field and postharvest crop management, which does not rely on such a system; (b) if varietal technologies are developed requiring seed multiplication, possibilities should be examined for a complementary relationship between public research and a private seed multiplication system.

6. SUMMARY AND POLICY IMPLICATIONS

This analysis has shown that the returns to research and technology transfer on millet, sorghum, and cowpeas in Niger ranges between 2% and 21%. Returns were calculated using a range of yield differentials, adoption rates, and research and technology transfer costs. The most plausible estimate was around 10%. This low but positive conclusion can be explained by five factors.

First, Niger's climate and soils are poorly suited to agriculture. Marginal and risky production conditions exist throughout much of the country. Almost 70% of Niger's agricultural area receives an average of just 300 mm to 400 mm of rainfall annually. Less than 1% of the area is irrigated. Deviations below this annual amount lead to crop failures. Four of the past 25 years were classified as severe drought years in which average annual rainfall did not exceed 300 mm in most parts of the country. In such an environment, resource-poor farmers are very unlikely to adopt high-yielding technologies that require even modest levels of purchased inputs.

Climatic factors impose an additional constraint to research by limiting the spill-over potential of agricultural technologies and, in particular, new varieties developed elsewhere. Few countries conduct research on millet. Of these India is the most active. However, when Niger imported improved Indian varieties of millet, they failed to germinate because of Niger's high soil temperatures. Niger has limited prospects for importing appropriate technology in order to decrease the time required to develop new agricultural technologies. Furthermore, the risks that climate engenders in agricultural cultivation mean that the scope for major increases in productivity from crop-production research is also limited. High-input varietal technology is unlikely to be adopted on a large scale because of farmers' difficulty in obtaining yield increases large enough to make inputs profitable in the extremely dry climate of Niger.

A second factor constraining returns to research and technology transfer is the absence of appropriate economic policies. During the period in question, low grain prices acted as a disincentive to invest in millet and sorghum production. Consequently, these crops are grown largely for subsistence. Cowpea is a cash crop but is primarily intercropped with millet and sorghum which limits the use of purchased inputs for its production.

Insufficient infrastructure, such as a well-functioning marketing system, results in high transaction costs and makes farmers unwilling to rely on markets for the family food supply. The lack of transport infrastructure limits the availability of inputs, particularly for those farmers located far from the border with Nigeria. And a virtually non-existent agricultural credit system makes inputs unaffordable to the majority of farmers who lack capital to invest in agriculture.

A poor seed multiplication system is a third factor limiting the impact of research and technology transfer with regard to new varieties. After the severe drought of 1972-74, a new multiplication system was established with the support of USAID. However, the varieties developed could be mass-selected by the farmers themselves. There was thus little demand for the centers' services in years of good rainfall. High subsidies were required to support their unwieldy operations. However, following drought years, seed unavailability was cited by farmers as a major constraint to the adoption of improved varieties.

The extension system also affects the returns from investments in research and technology transfer. From 1975 to 1991 the extension system benefitted from large donor support through a series of productivity projects. These projects provided infrastructure otherwise lacking for the dissemination and adoption of technologies such as agricultural inputs, farmer training, and credit. Despite these projects, extension efforts have been unable to reach many farmers and have left some areas untouched. Because the level of training of extension agents has been low, they tended to offer standard textbook applications of recommended agronomic practices. Local conditions were rarely considered. And there was little dialog between the extension and research services until the mid-1980s, when USAID reinforced the research-extension liaison units of both the extension service and INRAN.

The research system itself is the fifth factor influencing the returns to investment. Before 1983 researchers were working on problems identified during colonial times. The research agenda was largely science-driven, developed by researchers with little or no input from the rural sector. In seeking to improve monoculture production practices, research was considerably out of line with the on-farm realities of Niger. Research began to focus on intercropped systems in the mid-1980s, when it developed systematic on-farm trials to evaluate technologies based on farmers' constraints. This change to a more demand-oriented approach led researchers to develop agronomic recommendations for intercropped millet and cowpeas, the most widely cultivated farming system.

The research system was also under-funded. Contributions from donors (particularly from USAID) augmented INRAN's budget. But donor support to agricultural research has represented only a small fraction of the external support provided to other development activities in the agricultural sector. USAID support to INRAN between 1975 and 1991 was only about 25% of its investment in the seed multiplication centers. Moreover, during the same period funding from the Nigerien government accounted for less than 25% of INRAN's total expenses. Total research funding in Niger averaged only 0.30% of AgGDP between 1976 and 1985. This is well below the West African regional average of 0.73%, the conservative 1985 target set by the United Nations at the 1974 World Food Conference of 0.50% and the often-cited World Bank target of 2.0%.

Research is a long-term process requiring sustained financial support. It is not an investment that can be stopped and resumed in later years at the same point where it was left off. Resources quickly deteriorate as, for example, researchers leave the system, buildings decay from a lack of maintenance, and foundation seed stocks rot. Research requires sustained financing over a long period of time. Research investments should thus be regarded as long-term projects.

Millet and sorghum landraces have taken 7,000 years to adapt to Niger's harsh climate. Breeding better varieties is an extremely difficult and costly undertaking. With multidonor funding several times that of INRAN, ICRISAT at Sadoré has yet to develop a variety that can outperform Niger's landraces. Despite the difficulties, however, breeding work continues to receive the lion's share of resources in Niger's research system. Millet, sorghum, and cowpeas receive an increasing share of financial and human resources, averaging 68% of total expenditures and 58% of total human resources over the period 1986-90. With this in mind, several questions are raised concerning agricultural research in Niger.

First, should INRAN focus less on breeding and more on improving crop, animal, and resource management? Soil and water are the main constraints to cultivation, and Niger's cattle population numbers more than 15 million. Second, could INRAN's cooperation with regional or international research institutions be improved? We have seen that there is little potential for direct spillovers with regard to varietal technologies. Yet plant breeding is a highly resource-intensive activity. This implies that INRAN augments its capacity to do adaptive research which would most allow it to benefit from the nearby millet breeding research conducted at ICRISAT. In so doing it would free scarce domestic resources to be used for research problems particular to Niger. No such functional linkage exists at present between INRAN and ICRISAT and little emphasis has been placed thus far on either networks or cooperative research.

A fundamental consideration when evaluating the impact of millet, sorghum and cowpea research in Niger is that INRAN is a young and relatively small and inexperienced research institute. A significant share of the resources going to INRAN over the past decade and a half have been invested in the physical, human, and even organizational capital required to develop a functioning research organization. Between 1975 and 1985 less than 60% of INRAN's resources were used to pay salary and operating expenses contributing directly to the current research program. Capital investments are beginning to pay off. By 1991 the number of Nigerien researchers increased to 63, from 5 in 1975. INRAN now has a reasonably well-equipped physical infrastructure. Finally, the integrated system of on-farm trials the institute now has in place will increasingly enable it to conduct research that meaningfully addresses Niger's production problems. All this has been achieved with a low level of funding.

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APPENDIX 1

Table 14. Area under Cowpea Cultivation, Niger (1975-1989)

Table 15. Cowpea Yields, Niger (1975-89)

Table 16. Cowpea Production, Niger (1975-89)

Table 17. Area under Millet Cultivation, Niger (1975-89)

Table 18. Millet Yields, Niger (1975-89)

Table 19. Millet Production, Niger (1975-89)

Table 20. Area under Sorghum Cultivation, Niger (1975-89)

Table 21. Sorghum Yields, Niger (1975-89)

Table 22. Sorghum Production, Niger (1975-89)

Table 23. Yield Growth Rates, Niger (1976-90)

Table 24. Intercropped Area, Niger (1990)

% of cowpea area that is:	pure cropped	millet-cowpea	sorghum-cowpea	millet-sorghum-cowpea
Tillabery	0	81	1	18
Dosso	1	76	0	23
Tahoua	0	78	0	22
Maradi	1	22	9	67
Zinder	0	16	13	71
Diffa	74	23	3	0
Agadez	0	0	0	0
Niger total	1	42	7	50
% of sorghum area that is:	**pure cropped**	**millet-sorghum**	**sorghum-cowpea**	**millet-sorghum-cowpea**
Tillabery	10	61	2	27
Dosso	6	24	0	70
Tahoua	14	60	0	26
Maradi	4	22	9	65
Zinder	10	11	12	67
Diffa	77	8	15	0
Agadez	0	0	0	0
Niger total	9	25	8	59
% of millet area that is:	**pure cropped**	**millet-cowpea**	**millet-sorghum**	**millet-sorghum-cowpea**
Tillabery	53	29	13	6
Dosso	32	48	5	14
Tahoua	34	34	23	10
Maradi	16	16	17	50
Zinder	19	13	10	58
Diffa	95	4	0	0
Agadez	0	0	0	0
Niger total	31	25	13	30

Source: République du Niger (1991).

Table 25. Area under Irrigation, Niger (1991)[a]

Department	Irrigation
	(km²)
Tillabery (incl. Niamey)	8.143
Dosso	0.312
Tahoua	3.592
Maradi	0.512
Zinder	0.000
Diffa	0.228
Agadez	0.000
Total	12.787

Source: ONAHA computer printouts.
[a] This includes only area developed by ONAHA and not area under traditional irrigation schemes.

Table 26. Area Cultivated, Niger (1975-1982, 1983-1989)

Department	1975-1982	1983-1989	annual growth rate
	(km²)	*(km²)*	*(%)*
Tillabery	8,318	7,750	-0.88
Dosso	5,886	6,499	1.25
Tahoua	4,626	6,007	3.32
Maradi	5,928	8,454	4.54
Zinder	6,317	7,903	2.84
Diffa	534	653	2.55
Agadez	1	3	23.27
Total	31,609	37,269	2.08

Source: République du Niger 1975a to 1990a and République du Niger 1975b to 1990b.

APPENDIX 2

Table 27. Adoption of Millet Varieties P3KOLLO, HKP, CIVT, Niger (1975-90)

Table 28. Adoption of Cowpea Varieties TN88-63 and TN5-78, Niger (1975-90)

Table 29. Projected Adoption of Cowpea Variety TN5-78, Niger (1991-2011)

Table 30. Projected Adoption of Sorghum Varieties SEPON82, SRN39, and NAD1, Niger (1995-2011)

Table 31. Potential Area for Cultivation of Sorghum Varieties SEPON 82, SRN 39, NAD1

	irrigated sorghum, 1991	monoculture sorghum area, 1990	total
	(ha)	*(ha)*	*(ha)*
Tillabery	0	18,562	18,562
Dosso	0	9,229	9,229
Tahoua	1,212	38,033	39,245
Maradi	205	30,323	30,528
Zinder	0	10,175	10,175
Diffa	0	3,460	3,460
Agadez	0	35	35
Total	1,417	109,817	111,234

Source: ONAHA computer printouts and Ministère du Plan 1991a.

Table 32. Agroclimatic Areas as Defined by Average 1975-1990 Isohyets, Niger

	Isohyets							
Department	<100mm	100-200mm	200-300mm	300-400mm	400-500mm	500-600mm	>600mm	Department Total
				(.....kilometers^2.....)				
Tillabery	0.00	10,681.70	27,713.10	33,888.95	13,294.29	6,522.38	126.95	92,227.37
Dosso	0.00	0.00	0.00	6,420.74	11,680.01	10,753.45	2139.62	30,993.82
Tahoua	0.00	32,268.54	42,473.45	29,785.16	71.09	0.00	0.00	104,598.24
Maradi	0.00	0.00	12,487.88	24,359.10	2,055.57	0.00	0.00	38,902.55
Zinder	321.61	65,734.83	59,664.34	14,051.26	4,756.52	0.00	0.00	144,528.56
Diffa	12,156.17	77,168.43	47,377.94	6,946.48	0.00	0.00	0.00	143,649.02
Agadez	496,735.50	125,684.10	1,751.74	0.00	0.00	0.00	0.00	624,171.39
National Total	509,213.30	311,537.60	191,468.50	115,451.70	31,857.48	17,275.83	2,266.57	1,179,070.95

Source: AGRHYMET data.

Table 33. Yearly Average Market Prices for Millet, Sorghum, and Cowpeas, Niger (1975-90)

Table 34. Exchange Rate and Consumer Price Index, Niger (1975-91)

APPENDIX 3

Table 35. Total Research Expenditure by Source of Funding, INRAN (1975-91)

Table 36. Expenditure for Millet, Sorghum, and Cowpea Research by Category Type, INRAN (1975-91)

Table 37. Extension Personnel and Costs, INRAN (1975-90)

Table 38. Benefit-Cost Calculation

	Benefits	Research costs	Additional production costs	Extension costs	Seed multiplication center costs
1975	384,431	27,098,922	3,290	509,560,862	250,451,687
1976	757,717	150,152,659	18,300	436,268,885	698,997,919
1977	96,292,056	282,837,925	36,737,533	739,451,521	776,270,478
1978	185,180,898	276,990,483	62,004,615	718,054,948	1,051,455,327
1979	254,973,544	518,776,123	93,697,196	648,452,530	858,372,967
1980	296,191,683	501,668,106	119,670,679	815,844,008	598,841,724
1981	818,594,954	360,191,454	155,944,977	656,994,915	252,212,054
1982	905,170,941	394,616,338	201,353,611	806,057,511	1,735,683,258
1983	1,151,990,338	911,073,141	240,000,338	894,759,113	2,179,859,462
1984	1,243,410,162	845,443,388	310,972,532	844,849,049	1,362,633,117
1985	762,502,725	824,765,421	140,253,626	840,275,988	3,818,661,794
1986	398,226,465	825,145,928	181,953,685	525,868,042	3,787,754,531
1987	390,195,688	916,959,058	202,163,042	497,986,681	3,618,722,718
1988	852,807,747	1,412,341,334	90,920,333	317,799,257	3,907,109,346
1989	870,743,367	1,742,940,654	114,358,339	312,492,599	302,078,268
1990	873,578,326	1,347,090,490	99,924,076	420,718,952	179,065,938
1991	4,234,036,348	921,306,342	125,956,875	420,718,952	156,841,015
1992	4,552,524,128		129,437,575	841,438	
1993	4,628,118,277		131,090,342	841,438	
1994	5,269,047,934		138,028,439	841,438	
1995	6,204,486,513		276,182,124	841,438	
1996	4,498,110,929		294,903,821	1,262,157	
1997	4,110,655,423		322,453,864	1,262,157	
1998	4,385,792,242		356,910,710	1,682,876	
1999	2,308,950,093		368,956,871	1,682,876	
2000	2,293,417,795		400,483,794	2,103,595	
2001	2,109,828,255		430,962,557	2,524,314	
2002	1,477,219,117		457,082,613	3,365,752	
2003	1,431,957,565		488,711,600	4,207,190	
2004	1,453,962,355		520,926,126	5,048,627	
2005	1,475,967,145		553,140,652	5,890,065	
2006	1,497,971,934		585,355,178	7,152,222	
2007	1,519,976,724		617,569,704	7,993,660	
2008	1,541,981,514		649,784,230	8,835,098	
2009	1,563,986,303		681,998,756	9,676,536	
2010	1,585,991,093		714,213,282	10,938,693	
2011	1,607,995,883		746,427,809	11,780,131	

Units: 1990 CFA

APPENDIX 4

Table 39. Researchers, INRAN (1975-91)

APPENDIX 5