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

Valentina Mazzucato
and
Samba Ly[1]

I. INTRODUCTION AND BACKGROUND

Agriculture (including livestock) is the largest sector of Niger's economy. In 1988 it employed 88 percent of the country's labor force (FAO 1989) and accounted for 36 percent of gross domestic product (Ministére du Plan 1991). The most important crops in terms of production and consumption are millet and sorghum. In 1990, they accounted for 85 percent of the total quantity of production during the main agricultural season and approximately 80 percent of national caloric intake. Between 1960 and 1990, average annual cereal production was 279 kg/inhabitant (Ministére du Plan 1991), contributing to Niger's relatively high daily caloric intake level of 2,340 calories/inhabitant/day in 1988 (World Bank 1991). Cowpea is Niger's leading cash crop with Nigeria being its major market outlet. Millet, sorghum and cowpea intercropping comprises the most common agricultural production system in Niger.

While cowpea yields have been increasing, national yields for millet and sorghum have been declining between the periods 1961-65 and 1986-90. Cowpea yields increased at an average annual rate of 0.2 percent, but millet and sorghum yields declined at an annual rate of 0.7 percent and 2.7 percent, respectively. Since 1970, there have been 13 years of deficit cereal production, during six of which Niger had to import more than 30 percent of its annual food requirements. This is largely due to the fact that rainfall levels have been declining while rainfall variability has been increasing (Sivakumar *et al.* 1992), exacerbating soil degradation and the extensification of cultivation onto marginal lands.

The greatest challenge for the agricultural sector in the 1990s is to feed one of the world's most rapidly growing populations on the 12 percent of Niger's land that is arable. An average of 70 percent of agricultural land receives between 300 and 400 mm of rain, the bare minimum required for rainfed cultivation, and irrigated land is less than one percent. Four of the past 25 years were classified as severe drought years in which average annual rainfall did not exceed 300 mm in most of the country. Due to population pressure and soil erosion, extensifying cultivation onto cultivated land is not a viable, long-term option for increasing agricultural production. Meeting future food demand will require continuous investment in the generation, transfer and adoption of productive agricultural technologies that facilitate intensified production while conserving the country's few and fragile natural resources. Because such investments are costly and compete for scarce public resources, it is necessary to optimize the allocation of resources. Furthermore, in light of the world-wide trend of declining public funding for agricultural research, it is important that research not only produce results which benefit the population, but that it do so in an efficient and effective manner.

This paper has three objectives: to evaluate the economic returns to agricultural research and technology transfer in Niger; to review the principal institutional, organizational and environmental

factors influencing the development and adoption of new technologies; and to present some of the issues raised by the economic evaluation of research and technology transfer in Niger (Mazzucato and Ly, 1992).

1.1 Millet, Sorghum and Cowpea Research

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. Between 1986 and 1990, 68 percent of the country's public sector agricultural research expenditures and 58 percent of total agricultural researchers were use for research on these three crops (Table 1).

Research conducted nationally on millet, sorghum and cowpeas was principally done by the *Institut National de la Recherche Agronomique du Niger (INRAN)*, the national agricultural research institute. Since 1976, United States Agency for International Development (USAID) invested over 22 million dollars in three millet, sorghum, and cowpea research projects, all of which were executed in association with INRAN. The last USAID project was decertified in 1990 and terminated in June 1992, although a World Bank loan in 1992 has provided on-going funding for research.

Table 1. 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
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
for operational activities	56	62	71	2
for institution building activities	44	38	29	-4

Source: Mazzucato and Ly (1992).
[a] millet, sorghum, and cowpea

The national research system was established in 1975 when the French agricultural research institute, *Institut de Recherches Agronomiques Tropicales (IRAT)*, was replaced by INRAN. Millet, sorghum, and cowpea research conducted during INRAN's early years followed much in the same lines as the research conducted by IRAT. Emphasis continued to be placed on breeding work to develop early maturing, and dwarf varieties, two characteristics suitable for the arid climate of Niger. These varieties were extended across all regions of the country with an accompanying package of agronomic recommendations developed by IRAT, which related to relatively high-input, monocrop farming systems rather than the intercropped, low-input farming practices used extensively throughout Niger.

The varieties being evaluated in this analysis are P3KOLLO, HKP and CIVT for millet, and TN5-78 for cowpeas. This analysis also takes into consideration three new sorghum varieties which are about to be released to farmers, namely, NAD1, SEPON82, and SRN39. Each of these varieties has been worked on by INRAN during the period 1975-91 and has the characteristics described in table 2. The millet variety HKP is included in the base scenario, even though it was developed by IRAT. Since much of the extension and seed multiplication activities continued to focus on it past 1975. However, sensitivity analysis examines the input of excluding HKP from the benefits attributable to the post-1978 TDT program.

Table 2. Improved Millet, Sorghum and Cowpea Varieties Evaluated in the Rate of Return Analysis

Crop	Variety	Year of Release	On-station Yield	On-farm Yield[a]	Zone	Days to Maturity	Deriving From	Developed by[b]
			(kg/ha)	*(kg/ha)*	*(mm)*			
millet	P3 KOLLO	1962 and 1977[c]	2500	545	500-600	90-95	Niger	IRAT-INRAN
	HKP	1975	2000	288	350-500	80-90	Niger	IRAT
	CIVT	1977	2500-2800	450	450-650	90-95	Niger	INRAN
sorghum	SEPON82	1992	2500-4000	733	400-700	100-105	Ethiopia, India	ICRISAT-INRAN
	SRN39	1992	2000-2500	—	400-600	95-100	Nigeria	INRAN
	NAD1	1992	2000-4000	—	irrigation	—	Sudan	INRAN
cowpea	TN5-78	1985	3000	77	300-600	70-75	Niger	INRAN

Source: Ministére du Developpement Rural (1987) unless otherwise noted.

Notes:[a] Five-year average of DECOR on-farm trial results reported in Ly (1992).
[b] Refers to the institution which made the selection. It does not take into consideration the institution from which the parent material was obtained.
[c] P3 Kollo foundation seed stocks were exhausted thus it became necessary to regenerate the variety in 1977.

On-farm trials carried out between 1985 and 1989 obtained average yield increases for the improved millet varieties relative to unimproved local varieties of 22 percent. Corresponding cowpea yield differentials ranged between 27 percent and 46 percent depending on the climatological zone where they are grown. Given that average millet and cowpea yields are low to begin with, these percentages amount to yields of only 200 - 550 kg/hg for millet and 50 - 100 kg/ha for cowpeas.

Seed-distribution data and information obtained from a survey of extension personnel indicated that adoption of improved varieties of millet and cowpeas was low in Niger. Adoption peaked during the 1983-84 when an estimated 900,000 ha or 20 percent of the area under millet and cowpeas was sown to improved varieties. But the severe droughts of 1984-85 and 1987-88 caused many farmers to revert to the traditional varieties available in the local markets, so that by 1991 less than 12 percent of cultivated land was sown to improved varieties.

2. RATE OF RETURN ANALYSIS

A rate of return was calculated to measure the economic returns to investments made in research and technology transfer. The rate of return analysis focuses on the benefits derived from the varietal improvement aspects of INRAN's research program. The base scenario calculations extend to the year 2011, since the varieties evaluated will most likely continue to be used for a number of years to come. A strict interpretation of an ex-post rate of return requires all benefits as well as costs to be cut off at 1991 so that none of the future benefits from investments made in research and technology transfer between 1975 and 1991 are counted. Such an interpretation results in a negative rate of return in Niger, since the most successful of the four varieties being evaluated, TN5-78, was released only in 1984-85 and began to be adopted in 1985-86. It is unlikely, however, that improved varieties developed between 1975 to 1991 will not be grown past 1991 because there are no improved varieties on the horizon to replace them. Furthermore, extension and seed multiplication activities will most likely continue to operate in order to diffuse the existing improved varieties to farmers.

The benefits calculated were measured as the value of increased grain production of improved relative to local, unimproved varieties (appendix I). Yield differentials between improved and unimproved varieties were obtained from data of five years of farmer-managed, on-farm trials conducted by the *Département de Recherches en Economie Rurale (DECOR),* the rural economics department of IRAN, in five locations in Niger. These data were averaged over the five years and extrapolated to different agroclimatic areas of the country as defined by average 1975-90 isohyet zones. This estimate thus accounts for the spatial and temporal variability of yields which are characteristics of Nigerien agriculture. Improved seed distribution data were used to estimated the rate of adoption. However, due to the improved nature of the varieties being analyzed, farmers can easily select and retain seed from year to year so that a large part of improved seed use is not captured by official seed distribution data. It was thus necessary to estimate improved seed retention factor to add to the seed distribution data. The improved seed retention factor was estimated using information obtained from a nation-wide survey of extension agents at the *arrondissement* and department levels. The factor varied according to rainfall levels and crop. Average yearly real market prices for each department were used to value the additional output obtained by using improved varieties. Prices were deflated using a 1990 consumer price index based

on a general "African" consumption bundle as defined by the Ministry of Planning. The increased production costs associated with the cultivation of improved varieties were also included (appendix II).

Cowpea hay is an important output due to the extensive use of cowpea forage in Niger. However, cowpea hay was not included in this analysis due to a lack of data on its production and market prices for the period 1975-91. It has been shown, however, that TN5-78 is a better forage producer than the variety it is replacing. TN88-63 (DRA 1991), which, according to extension agents interviewed throughout the country, is one of the reasons farmers are replacing TN5-78 for TN88-63. It is thus possible to say that the rate of return underestimates the benefits arising from the cultivation of TN5-78.

Costs of the investments which contributed to the production increase include research, extension and seed multiplication costs (appendix I) thus the rate of return measures the returns to investments in technology development and transfer. Millet, sorghum and cowpea research costs were calculated by including funds received by INRAN from foreign donors and from the Government of Niger (GON). Foreign assistance was largely provided by three USAID projects (Niger Cereals Research, Niger Cereals Project and Niger Applied Agricultural Research) and parts of USAID's Agricultural Sector Development Grant (ASDG) to the GON. precise data from USAID's accounting office made possible a detailed and accurate assessment of USAID's contribution to INRAN's budget which covered for almost half of total millet, sorghum and cowpea research expenditures between 1975-91. Other foreign donor projects including the full costs of expatriate researchers associated with millet, sorghum and cowpea research were obtained from the respective donor's or INRAN's project documentation. Expenditures from the GON yearly budget allocations were obtained from the national Treasury. Extension costs included GON yearly budget allocations and foreign funding of the six productivity projects which were part of the GON's extension strategy during the period of investigation. These latter accounted for approximately 54 percent of extension expenditures between 1975-91. The costs of multiplying seeds were included in two ways for two different calculations. First, seed multiplication costs were taken as represented by improved seed prices on the local markets. The second method included the costs of the seed multiplication centers which were funded primarily by USAID. The costs of personnel working at the centers was automatically included in the GON's budget allocation for extension in each case.

Rates of return to TDT activities are calculated for twelve different scenarios to determine a range of possible returns. The results project returns and resulting genetic improvements to TDT investments in Niger since 1975 range from 2 percent to 21 percent during the period 1975 to 2011. These results are low when compared with those obtained in related studies on other countries and/or commodities. However, they do indicate that research and technology transfer activities have contributed to productivity growth within the agricultural sector in Niger despite the considerable agroclimatic and non-technical constraints to production.

Three important conclusions can be drawn from the ROR analysis. These conclusions raise important issues concerning the viability of economic analyses of agricultural research and how to make research most effective.

First, the level of adoption proved to be the single most influential variable on the rate of return, where an increase in adoption levels of 25 percent more than doubled the ROR. This indicates the

need for research to be client-oriented in that new technologies realize a social benefit only if they are actually adopted. The importance of the adoption parameter also emphasizes the need for both the extension and research services to monitor the level of adoption of new technologies if an accurate economic evaluation of their programs is to be made. This implies that investments in research and technology transfer need to address evaluation mechanisms within these systems.

A second related conclusion is concerned with the adoption of a specific variety, namely TN5-78. This variety has great potential for adoption by Nigerien farmers because it is liked by consumers and it can yield more than local varieties and outperforms the improved variety TN88-63 in forage production. Our analysis suggests that an increase in the level of adoption of TN5-78 by 25 percent can increase the rate of return by ? percentage points. In a situation like this, priority efforts to extend the use of this new variety seem to be well justified.

Another important conclusion from the ROR analysis is that the construction, maintenance, and operating costs of the seed multiplication centers greatly decreased the returns to TDT investments. The rate of return declined by 80 percent with the inclusion of these costs given the magnitude of the funds going to seed multiplication centers relative to research, extension and additional production costs. Approximately 51 percent of total investments made in millet, sorghum and cowpea research and technology transfer between 1975-91 were used to find seed multiplication system, as well as the inappropriate scale and scope of the seed project in relation to the available varietal technology, as largely explaining the negative effect on the rate of return. The implications from this result are twofold: (a) given the system's ineffectiveness, technologies which require an effective seed multiplication and distribution service will have a limited impact. Unless this constraint is removed, there is reason to conduct non-varietal research such as crop management or post-harvest which does not rely on such a system; (b) if varietal technologies are developed which require seed multiplication, possibilities should be examined for a complementary relationship between public research and a private seed multiplication, possibilities should be examined for a complementary relationship between public research and a private seed multiplication system.

3. CONSTRAINTS TO TECHNOLOGY DEVELOPMENT AND ADOPTION

Additional issues raised by the economic evaluation of research and technology transfer concern the factors which have most affected the development and adoption of new technologies in Niger. Five factors were identified.

The first factor is Niger's harsh and variable agroclimatic conditions: water supplies are particularly scarce and irregular and soil quality is low. As a consequence, improved varieties from other countries can rarely be imported and used directly. Additionally, the scope for increasing average yields through improved varieties alone is particularly limited given the real prospects of economic losses due to climate-induced crop failures, losses that are magnified when purchased inputs are used in conjunction with these new varieties. Climate effects greatly shaped the estimated pattern of adoption of improved varieties, particularly as periodic droughts require farmers to restock their seeds and mobilize scarce resources to bring stressed land back under cultivation.

Agricultural policies in Niger have acted as a disincentive to adopt improved varieties. Officially-set cereal prices were too low to make it economically profitable to invest in inputs for cereal production. This situation has continued even after the deregulation of prices in 1985. Furthermore, input unavailability was an often-cited complaint by farmers which demonstrated a lack of infrastructure. A virtually non-existent agricultural credit system created a large capital constraint for farmers. Solutions for alleviating this lack of market, transport and credit infrastructure are beyond the scope of this paper; however, if constraints to the adoption of research results are to be removed, Niger must address its lacking infrastructure.

The extension system suffered from a lack of resources, high mobility of its workers, and various mandate changes, all of which slowed its development and limited its impact on farmers.

The seed multiplication system has been a costly operation. Given that varieties developed could be mass-selected by farmers, there was little demand for multiplied seed in years of good rainfall. The system was unable to satisfy the peak demand for seed in years following severe droughts.

The research system itself has been the fifth factor constraining the development and adoption of new technologies. In many respects, the research orientation at INRAN was science-driven for most of the period under investigation. Research focused on issues set by the scientific community but had little relevance to the on-farm constraints faced by the rural sector and thus research outputs had limited adoptability. The research system also lacked resources. Funds from foreign donors (particularly from USAID) greatly contributed to INRAN's budget. But donor support to agricultural research has represented only a small fraction of the external support given to other development activities in the agriculture sector. For example, USAID support to INRAN between 1975 to 1991 was approximately 25 percent of what it invested in the seed multiplication centers. Moreover, during the same period, funding from the Nigerien government covered less than 25 percent of INRAN's total expenses. These low levels of funding have resulted in total research funding in Niger averaging only 0.30 percent of the agricultural product between 1976-85. This is well below the West African regional average of 0.73 percent, the conservative 1985 target set by the UN at the World Food Conference of 1974 of 0.50 percent and the often-cited World Bank target of 2 percent.

4. ISSUES RAISED

4.1 Non-Measured Impacts

Due to the nature of a rate of return analysis and lack of data, there are important impacts of research and technology transfer investments which were not measured by the rate of return analysis but have been studied by Mazzucato and Ly (1992).

One aspect that must be borne in mind when evaluating a young research institution such as INRAN is the degree to which a viable and relevant research capacity has been institutionalized. Between 1976 and 1980, 44 percent of research expenditures in the millet, sorghum and cowpea programs went into physical and human capital investments (table 1). Beginning in 1975, INRAN grew from just five to 63 Nigerien researchers with a B.Sc. level degree or higher. INRAN also

established a documentation center, a computer unit, a cartography and a cereal quality laboratory, and various physical facilities at their substations throughout the country. These factors lay the institutional basis for continuing research activities into the future. This build-up of human and physical capital highlight the fact that research is not an investment that can be stopped and resumed in later years at the same point where it was left off. This is because investments quickly deteriorate as, for example, researchers leave the system frustrated by a lack of resources, experiments are interrupted, buildings decay with a lack of maintenance, and foundation seed stocks rot. To avoid such deterioration, particularly the loss of trained scientists, research requires sustained financing over a long period of time and thus research investments should be planned as long-term projects.

In recent years, INRAN has shifted to a more demand-oriented research agenda. The agronomy department developed time and location-specific agronomic recommendations that are beginning to take into account the different production conditions and practices throughout the country. The resulting *fiche technique* is now the most widely disseminated research output used by the extension service. The rural economics department of INRAN institutionalized a system of on-farm trials that are identifying the more pressing production constraints faced by farmers. A cereal quality laboratory was put into operation to test newly developed varieties for cooking and taste characteristics in order to incorporate consumer concerns in the evaluation of new varieties.

4.2 Further Issues

In Niger, research has been focussed primarily on breeding which is highly human and financial resource intensive. The agronomy department of INRAN, DRA, has conducted mainly breeding work during the period of investigation. It received an average of 52 percent of INRAN's national researchers and 48 percent of expatriate researchers between 1975 and 1991. While this study shows positive returns to such a research program, it does raise the question whether the Nigerien research system should maintain these investment priorities into the future. Productivity gains based on varietal improvements have been hard to come by in the difficult production environment of Niger. This is particularly so for millet and sorghum varieties where thousands of years of natural selection have given rise to a number of local landraces that perform best in Niger's micro-climates and localized production environments. In a country were soil and water are the main constraints to cultivation, and with a cattle population of 15 million, an issued raised is whether INRAN should be focusing more of its research efforts on improved crop and resource management practices and addressing related areas in animal production systems. A structured consideration of INRAN's research strategy and priorities is in order.

A related issue is that of cooperation with other regional or international research institutions. Little emphasis has been placed thus far on either networks or cooperative research. This is particularly so with regard to INRAN's links with the ICRISAT Salelian Center at Sadoré, which do not appear as productive as one would expect from two institutions working on the same research topic 45 km from each other. In light of INRAN's limited financial and human resources, functional linkages to external sources of varietal technologies would allow scarce domestic resources to be dedicated to research problems particular to Niger.

5. CONCLUSION

A fundamental consideration when evaluating the impact of millet, sorghum and cowpea research in Niger is that INRAN is a very young, small and still relatively inexperienced research institute. A significant share of the resources going to INRAN over the past decade and a half have been invested in physical, human and even organizational capital required to develop a functioning research system. During the period 1975-85 less than 60% of INRAN's resources were used to pay salary and operational expenses that contributed directly to the current program of research. Since 1975, INRAN has increased the number of Nigerien researchers by more than twelvefold. It now has a reasonably well-equipped physical infrastructure and an integrated system of on-farm trials that will increasingly enable it to conduct research that meaningfully addresses the production problems facing Nigerien farmers. It has achieved this with a low level of funding. But even at this funding level, the research system, along with technology transfer activities, have contributed to productivity growth in Nigerien agriculture.

APPENDIX

Table 1. Benefits and costs of the development and adoption of improved varieties in Niger, 1975-1991.

	Value of improved grain production for:						
Year	Millet	Sorghum	Cowpea	Additional Production Costs	Research Costs	Extension Costs	Seed Multiplication Center Costs
1975	348	0	0	3	27,099	509,561	157,732
1976	758	0	0	18	150,153	436,269	616,469
1977	96,292	0	0	36,738	282,838	739,452	755,275
1978	185,180	0	0	62,005	276,990	718,055	1,022,266
1979	254,974	0	0	93,697	518,776	648,453	688,197
1980	818,595	0	0	119,671	501,668	815,844	410,241
1981	905,171	0	0	155,945	360,191	656,995	207,356
1982	1,151,990	0	0	201,354	394,616	806,058	1,735,683
1983	1,228,997	0	0	240,000	911,073	894,759	2,179,859
1984	747,594	0	14,413	310,973	845,443	844,849	1,362,633
1985	391,699	0	14,909	140,254	824,765	840,276	3,818,662
1986	379,330	0	6,528	181,954	825,146	525,868	3,787,755
1987	830,858	0	10,865	202,163	916,959	497,987	3,575,090
1988	807,888	0	21,950	90,920	1,412,341	317,799	3,744,574
1989	687,158	0	62,855	114,358	1,742,941	312,493	131,901
1990	968,341	0	186,420	99,924	1,347,090	420,719	107,576
1991	968,341	0	3,265,695	125,957	921,306	841	100,503
1992	968,341	0	3,584,183	129,438	0	841	0
1993	968,341	0	3,659,777	131,090	0	841	0
1994	968,341	0	4,300,707	138,028	0	841	0
1995	968,341	20,975	5,215,170	276,182	0	841	0
1996	968,341	26,648	3,503,122	294,904	0	1,262	0
1997	968,341	32,321	3,109,994	322,454	0	1,262	0
1998	968,341	37,993	3,379,458	356,911	0	1,683	0
1999	968,341	43,666	1,296,943	368,957	0	1,683	0
2000	968,341	49,339	1,275,738	400,484	0	2,104	0
2001	968,341	55,012	1,086,475	430,963	0	2,524	0
2002	968,341	77,017	431,861	457,083	0	3,366	0
2003	968,341	99,022	364,595	488,712	0	4,207	0

Table continued

2004	968,341	121,026	364,595	520,926	0	5,049	0
2005	968,341	143,031	364,595	553,141	0	5,890	0
2006	968,341	165,036	364,595	585,355	0	7,152	0
2007	968,341	187,041	364,595	617,570	0	7,994	0
2008	968,341	209,046	364,595	649,784	0	8,835	0
2009	968,341	231,050	364,595	681,999	0	9,677	0
2010	968,341	253,055	364,595	714,213	0	10,939	0
2011	968,341	275,060	364,595	746,428	0	11,780	0

Source: Mazzucato and Ly (1992).

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ENDNOTES

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