Impacts of Sorghum and Millet Research in West and Central Africa (WCA): A Synthesis and Lessons Learnt

Youssouf Camara, MCS Bantilan
and Jupiter Ndjeunga

1. Introduction

1.1 Background

Agricultural research is generally accepted as an important means of raising agricultural productivity in Africa. However, compared to alternative investments, most donors, due to budgetary constraints, often consider agricultural research as being an expensive activity with few visible results. Thus, securing funds for agricultural research is no longer as easy as it was in the past. National as well as international agricultural research institutions are challenged to answer questions about the effectiveness of their research products and demonstrate a visible socioeconomic impact of new technologies.

Indeed, there is a growing doubt among donors about the impacts of agricultural research on food production in Africa. The hypothesis is that there is little potential for substantial impacts from research on the traditional crops of Africa, especially sorghum and millet. For example, the CGIAR/TAC report of 1995 asserted that there have been no impacts of sorghum and millet research in Western Africa. The report was also very pessimistic about any likely future benefits from this research. However, it had not included recent evidence of increased release of a number of ICRISAT-bred sorghum and millet varieties by national programs in several countries and their adoption by farmers, as shown in Table A5-1 in Annex 5.

Impact assessment demonstrates effectiveness of agricultural research products. It can advance learning and thereby provide clues to improve research program design and performance. A major purpose of impact assessment is to provide policy makers, donors, scientists, and/or those who sponsor agricultural research with indications of its beneficial or negative effects. However, in most African countries, impact assessment studies are not carried out routinely due to problems related to methodology and institutional capacity. Lessons learnt from impact assessments can be used to improve future research strategies, plans and management (Horton et al. 1993).

As Maredia et al. (2000) points out, "in recent years, an increasing number of studies have been undertaken to document agricultural research impacts and to estimate the RORs of agricultural research investment in SSA. These studies provide tangible evidence of the increasing availability of the improved varieties of major food crops to farmers in Africa, the increased food production in regions where adoption has occurred, and the positive returns to research investment." The need to demonstrate accountability is generating increased interest in research impacts assessment studies. This has motivated a large number of empirical studies designed to determine whether agricultural research programs are having their intended effects.

The problem is that, when challenged with a particular question, potential users of research products (eg, policy makers, informed consumers, practitioners or other researchers) often find it difficult or impossible to unearth all the relevant evidence, appraise its quality and decide what it means.

The primary focus of this paper is on the impacts due to varietal improvement technology because: (1) concentration of research resources is greater on developing improved varieties, and consequently (2) the availability of literature on this subject is relatively large. The information available, however, is not uniformly comprehensive across all the sorghum and millet producing countries in WCA. Hence, the review covers a few countries, namely, Burkina Faso, Cameroon, Chad, Mali, Nigeria and Niger, where relatively more breeding research has been conducted. Furthermore, the information presented in this paper is mainly drawn from the diffusion and impacts of varieties generated by

ICRISAT and national program partners of WCA. Since impacts assessment in WCA essentially began in the 1990s, the synthesis would have been more complete if it included the impacts assessments initiatives of the Sahel Institute (INSAH) and Purdue universities. However, only one of the INSAH-Purdue studies on millet and sorghum in WCA was obtained and included in this study.

1.2 Objectives

Indicators of research output such as number of varietal trials, number of varieties released, and potential yield improvements on experiment stations are measures of success at intermediate stages. They do not quantify impacts of research on farm income and consumer welfare, which is a function of the degree of adoption and impact of new technologies by end-users.

The main objective of this paper is to undertake an exhaustive documentation and synthesis of the research benefits from sorghum and pearl millet research in WCA and analyze the results of the adoption and impacts studies on sorghum and millet improved varieties in WCA. In doing so, the current document intends to answer the following questions:

- Do cultivars released in WCA show significant uptake and what factors influence this adoption?
- How appropriate is the currently available sorghum and millet technology given the agro-ecological and socioeconomic conditions in the region?
- What is the magnitude of returns to sorghum and millet R&D in WCA countries?
- What are the lessons learnt and the future prospects for adoption and impacts assessment research in WCA?

This paper is organized around these questions and structured as follows: (1) The methodological framework (2) An overview of sorghum and millet research in WCA (3) The analysis of adoption and impacts assessment results (4) Discussions on analytical methods used and conclusions

2. Methodological framework

This study involves a systematic literature review of the adoption and impact assessment studies on sorghum and millet improved varieties in WCA. It includes interviews and information collected through a questionnaire from scientists and sorghum and millet network coordinators in the region. A set of clearly formulated questions were used to systematically collect, identify, select and critically appraise relevant research, and to analyze data from past studies and survey responses.

2.1 Systematic data collection and literature review

Figure 1 below illustrates the methodology used to compile literature and data for this report. To locate scientific literature published, two activities were undertaken: (1) a search through different bibliography databases and (2) contact with key persons in different countries. First, the relevant research literature on the topic was reviewed. The resulting information provided a comprehensive view of earlier research and analysis, as well as insight into the problems, challenges and needs for research evaluation.

Then, studies were sourced from recognized peer-reviewed books and journals, as well as publications directly produced by national and international research institutions. A comprehensive inventory of adoption and/or impact assessment literature was undertaken through searches in relevant literature databases, such as peer-reviewed books, journals and publications. The impact assessment publications released by ICRISAT were the primary source of a comprehensive data on yield gains, adoption rates and benefit estimates.[1]

Importantly, resource persons and experts who had worked on sorghum and millet research from different countries of WCA were contacted to explain the study and to elicit more relevant scientific literature or internal reports. These experts were asked about their current research and practice, and were requested to provide any monitoring and evaluation data or adoption and impact reports which may be useful for this study.

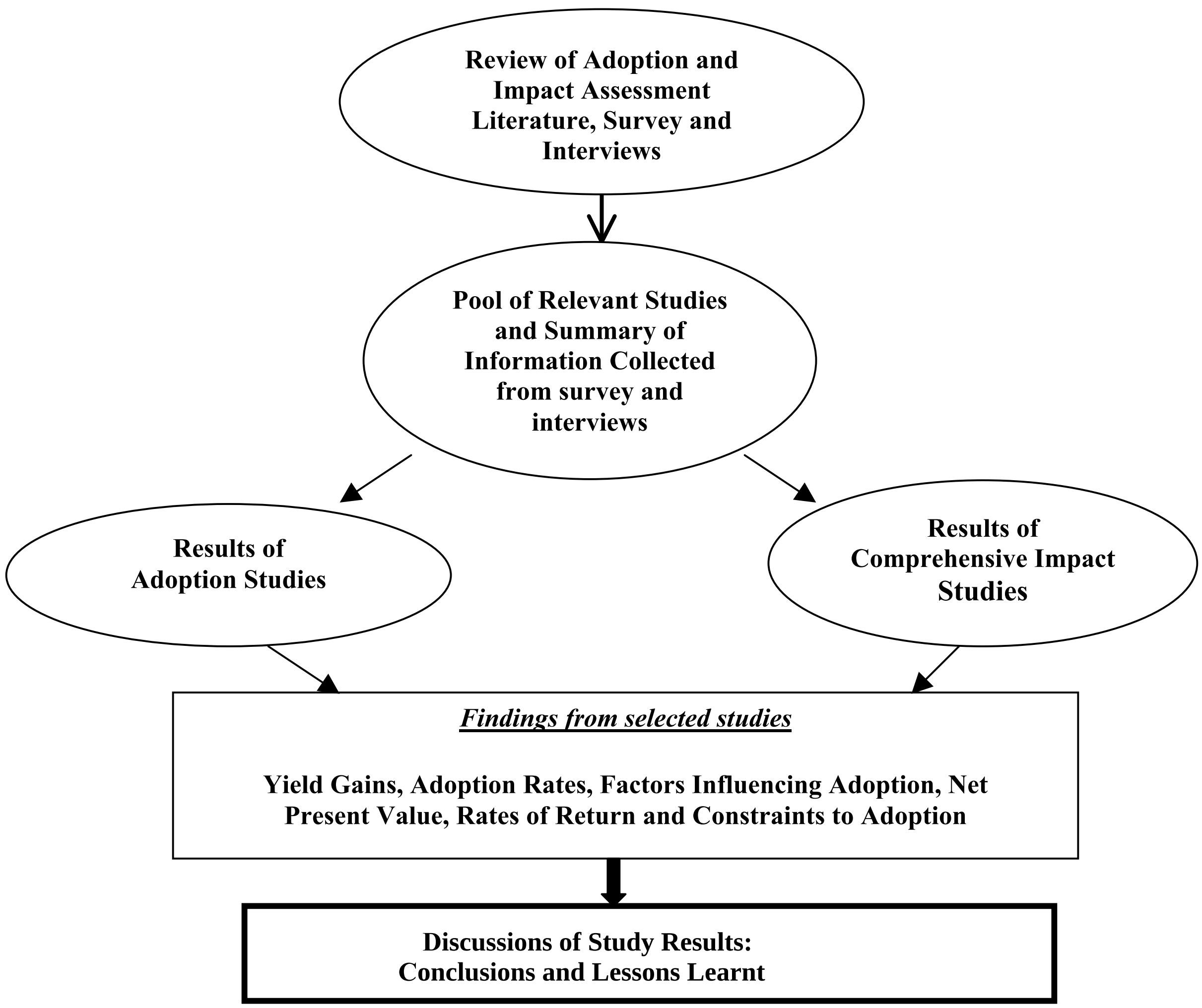

Figure 1. A framework for a systematic synthesis of adoption and impact studies on millet and sorghum technologies in WCA.

1. Sorghum and millet are ICRISAT mandate crops.

2.2 Selection of relevant studies

When all papers and publications were compiled, they were analyzed and the information obtained were categorized under two main aspects: (1) technology adoption; and (2) impact assessment. Only studies published after 1990 were included in the document pool, as lag periods between impacts and data collection (often 3–4 years), as well as between research activities and impacts (commonly more than a decade), mean that studies prior to this year encompass little time for the effects of impact assessment research activities to have become evident. Efforts were made for a comprehensive coverage of relevant studies, to include results and methodologies across countries and time.

Table 1 reviews the adoption and impact studies in WCA. Most of the studies in the literature have been produced through collaboration among international research institutes (eg, ICRISAT), regional organizations and national programs as well as available studies from the INSAH-Purdue University collaborative work on impact assessment (see Annex 4). Noticeably, the evidence on the adoption and impact of new technologies in WCA is relatively limited. Key findings from each of the studies were organized in a database for user-friendly retrieval. The results section below describes key outcomes, including adoption rates, yield gains, factors influencing the adoption of sorghum and millet technologies, unit cost reductions (K-Factor), NPV, ROR and constraints. The final section examines the significant findings, synthesizes key points and lessons learnt for policy recommendation and research priorities.

Table 1. Summary of adoption and impact studies in WCA reviewed.

Author(s)	Country	Commodity	Time Period
Adoption Studies			
Sanogo and Teme (1996)	Mali	Millet, Sorghum	
Ogungbile et al. (1998)	Nigeria	Sorghum	
Macaver (1999)	Nigeria	Sorghum	
Impact Studies			
Ex Ante Studies			
Zarafi et al. (2002)	Niger	Sorghum	
Ex Post Studies			
Sterns and Bernstein (1994)	Cameroon	Sorghum	1979–1998
Sanders (1996)	Cameroon	Sorghum	1980–1992
Mazzucato and Ly (1993)	Niger	Sorghum, Millet, Cowpea	1975–2011
Yapi et al. 1998	Mali	Millet, Sorghum	1990–1995
Yapi et al. 1999	Chad	Sorghum	1990–1995
Yapi et al. 1999	Cameroon	Sorghum	1995
Yapi et al. 2000	Cameroon	Sorghum	1984–1996
Yapi et al. 2000	Mali	Millet, Sorghum	1969–1996
Sedzro 2001	Togo	Sorghum	1979–1996

3. Overview of sorghum and millet research in WCA

Sorghum and millet were chosen for this paper not only because of their importance to food security in WCA but also because of the major role of the research in increasing the sorghum and millet production in this region. Sorghum and millet are staple food crops across the Sahelian agro-ecological belt of WCA and are grown by millions of resource-poor, mainly subsistence, farmers. Both crops are genetically adapted to the harsh drought-prone Sahelian environment and are capable of producing grain and fodder where few other crops cannot even survive. Besides providing food for humans and feed for livestock, sorghum and millet stems are used for a wide range of purposes, including: the construction of walls, fences and thatches; and production of brooms, mats, baskets, fish-traps, sun shades, etc. They are also used as fuel and as a soil additive to improve its fertility. Some varieties of sorghum can be "malted" to produce nutritious foodstuff for infants and for use in bakery products. Malted sorghum can be also used in small-scale traditional beer production, an important income-earning activity for village women in Nigeria.

Before the establishment of the CGIAR, breeding for the improvement of sorghum and millet was done by a number of national programs in WCA. Over the last two decades improved sorghum and millet technologies for West and Central Africa have been developed mainly by ICRISAT, one of 15 CGIAR Centers with significant inputs from its national partners. For both crops the agricultural research effort was focused on the development of higher yielding, resistant to pest and disease varieties, and adaptability to drought-prone environment in order to enhance both crop productivity and yield stability. To augment the successes obtained with high yielding varieties in Asia more efforts have been devoted increasingly to the development of improved production systems, to better address the typical agro-ecological, socioeconomic and institutional conditions of the region.

In the past decade or two, activities of international donor-sponsored research organizations, such as ICRISAT, INTSORMIL-CRSP, and ROCAFREMI have increased in the region and have been a major source of research support to African NARSs attempting to improve sorghum- and millet-based technologies. For example, since 1976, USAID has invested more than $22 million in research projects for these two crops, through the Institut National de Recherches Agronomiques du Niger (INRAN). Important partners such as CIRAD, SAFGRAD and universities such as Nebraska and Kansas and as well as local universities such as the University of Agriculture at Zaria in Nigeria played an important role in this process.

Collaborative Research Output: An Example

After several years of plant breeding research and testing at experiment stations and over 100 farms in Niger, the sorghum hybrid, NAD 1, produced by a collaborative research of INTSORMIL, INRAN and Purdue University, was released in Niger in 1992. The hybrid, which has grain quality acceptable for local food preparations, is well adapted to drought and has consistently high yields, compared to local varieties. Yield results of NAD-1 in on-farm demonstrations have ranged from 3000 to 4500 kg per ha with adequate moisture to 1200–1500 kg per ha on dryland, while the national average (including local landraces) is around 270 kg per ha. INTSORMIL scientists at Purdue and at INRAN have been multiplying NAD-1 seed (750 kg in 1996, 1400 kg in 1997 and 8000 kg in 1998) in response to demand, which exceeds supply. All the hybrid seed produced to date has been sold to farmers, cooperatives and NGOs. This demand encouraged farmers in Niger to get into the hybrid seed production business.

Source: INTSORMIL 1999.

3.1 Breeding research

Sorghum

The first Regional Sorghum Research Network was created in 1984 and became operational in 1986 for a 5-year term, with the financial support from the USAID through SAFGRAD. In 1990, a joint initiative was launched by INSAH and SPAAR, in an effort to develop a NARS-driven system for regional co-operation. This led to the creation, in 1992, of a regional sorghum "pole" by member countries of the Inter-State Committee for Drought Control in the Sahel (CILSS), at the time when the SAFGRAD network was coming to the end of its term. However, until Feb 1993, the pole concept did not include all the sorghum-producing countries of WCA. It became necessary to broaden the concept to bring into its fold Cameroon, the Central African Republic, Nigeria, Ghana, and Sierra Leone. At a regional workshop held from 6 to 11 March 1995 in Bamako, Mali, sorghum-producing countries of WCA endorsed the decision to expand the membership of the pole, and unanimously agreed to replace the pole concept with that of a collaborative research network – the WCASRN, often referred to by its French acronymn ROCARS. The Network Office is based at the ICRISAT research station at Samanko, about 25 km from Bamako, Mali. The overall objective of the WCASRN network is to improve the production, productivity, and utilization of sorghum, to contribute to greater food security and to enhance the economic and social well being of the people of the sorghum-producing countries of West and Central Africa.

Achievements in sorghum breeding in Africa have mainly been in the development and release of improved varieties based on higher grain yield and resistance to diseases, insect pests and *Striga* (Obilana 2004). ICRISAT has been involved in sorghum breeding for more than 30 years, and, in the global research system, bears the leadership for sorghum research especially for the SAT. The Centre has made extensive sorghum improvement efforts in WCA targeting the unique requirements of the diverse array of production systems in the SAT. As Obilana (2004) points out, ICRISAT's involvement in sorghum breeding in WCA began in1979. Its genetic enhancement work in WCA was preceded by IRAT's involvement in francophone territories from 1964. Segregating materials (of exotic and local crosses) and exotic germplasm introductions were the focus of both programs. ICRISAT was also involved in population improvement for grain and food quality among *Guinea* sorghum in Mali.

The local landraces are mostly two types – guinea race and durra-caudatum – in WCA. Initial efforts were targeted to improve the local landrace germplasm by selection within the landraces or in the segregating progenies derived from crosses among themselves and release them as varieties to farmers. Later on, new germplasm, namely zerazeras (caudatum race) were introduced and several lines were developed by selection in the segregating progenies involving introduced caudatums and local guineas. After extensive testing, several varieties were released (see table A5-1) for cultivation by farmers. These caudatum-based varieties were found lacking in local food quality attributes. In the more recent years, therefore, efforts are being made to develop guinea-based hybrid parents to develop guinea hybrids. As guineas have good food quality attributes and adaptation to local drought conditions, the guinea-based hybrids are expected to have good acceptability and good adaptation to moisture-stress environments prevalent in the region.

Millet

In West Africa, nearly 80% of the area grown to millet is in the Sahelian zone. Nigeria, Niger, Mali, Burkina Faso and Senegal produce 84% of the millet in the region. The crop is dual purpose, with the grain mostly used for human consumption, and crop residues constituting a strategic resource for livestock feed. It is the dominant (sometimes the only) cereal crop in the drier zones and an important component of crop/livestock systems.

ICRISAT has also been involved in pearl millet research since the inception of the center, and it has a clear leadership role for improvement of the crop, both in India and Africa. India is the only NARS with substantial research capacity in pearl millet. The US has some international participation in pearl millet improvement through the sorghum-millet cooperative research support project (INTSORMIL), and France has some involvement with the crop in West Africa through a Niger-based ROCAFREMI team that operates independently but in collaboration with ICRISAT. Improved grain yield and downy mildew resistance have been the main thrusts of the pearl millet improvement program. Numerous pearl millet cultivars have been developed and released by the ICRISAT Sahelian Centre and its partner NARS in WCA. Highly promising hybrids are also at various stages of advanced testing and pre-release.

The philosophy underlying ICRISAT commitment to millet research in WCA is the development and /or identification of adapted, diverse pearl millet hybrid parents for the region. The development of downy mildew resistant male-sterile lines was initiated at Kano, Nigeria, during 1996, by introducing NC (d_2) BC_3 from ICRISAT-Patancheru. First set of hybrids based on new male-sterile lines was evaluated during 1999. Selected hybrids and male-sterile lines were tested during 2000 main season. The hybrids between SOSAT-C88 and NC (d_2) derived male-sterile lines (A_4 cytoplasm) were sterile, and therefore, research was initiated to convert SOSAT-C88 into male-sterility with reduced plant height. The development of downy mildew resistant lines for developing hybrids continued. Millet breeding efforts are geared toward producing intermediate products, such as improved populations, and two types of finished products: the OPVs and the hybrids. In the past, the OPVs, improved breeding materials and populations have been the major emphasis. It is anticipated that the OPVs will be the only option in Africa for some time to come (Omaya et al. 2004).

3.2 Sorghum and millet impact assessment in WCA

The impact pathway model used in most agricultural productivity-enhancing research impact assessment is based on Schultz (1964), which states that subsistence agricultural production systems in the developing world are technically efficient, and that farmers maximize profit given available technology. Accordingly, research that leads to the development of new technologies will raise the productivity, which in turn will result in higher quantities of agricultural products supplied at any given price, and this increased level of supply will drive down prices. The outcome is that this improved producer income through higher productivity, coupled with lower prices, which raise consumer purchasing power, will underpin economy-wide growth.

In 1993, ICRISAT's initiative to launch an adoption and impact assessment project in partnership with NARS was a logical strategy. The results of such studies were also viewed as potentially being able to help in rationalizing research priority setting, and where necessary, redirecting specific research programs. The REIA project has thus been developed with the aim of integrating *ex-post* impact assessment with *ex-ante* research priority setting, primarily for ICRISAT, and also potentially for collaborating NARS (Bantilan and Joshi 1994).

In 1994, collaboration on impact assessment studies between INSAH, Purdue University (USA), and NARS began in 1994. The objective was to develop the capacity of the Sahelian research centers to undertake the economic impact assessment of agricultural technologies being released and disseminated in the Sahel. A list of impact studies carried out through this initiative is presented in Annex 4.

Generally, adoption and impact studies undertaken in Africa range in scope and depth of evaluation from partial impact studies to comprehensive assessment of economic impacts. Partial impact assessment studies are more concerned with what the direct products have actually led to in farmers' fields. One popular type of partial impact assessment at the national research centers is adoption studies (or pre-impact studies). They looked at the effects of new technology such as the spread of modern plant varieties on farm productivity and farmers' welfare. Economic impact assessments of the more comprehensive types looked beyond mere yield and crop intensities to the wider economic effects of the adoption of new technology. These studies generally estimated the economic benefits produced by research in relation to associated costs and estimate a ROR to research investments. Unlike adoption studies, which were done only ex-post, economic studies were undertaken both ex-ante and ex-post.

In WCA, more studies have been carried out focusing on the adoption of technologies. However, the few impact assessment studies that have been carried out indicate high RORs. These studies have not only generated considerable empirical evidence on the biophysical and socioeconomic factors of adopting improved crop varieties but also identified the impact on farm-level production and income of switching from traditional to modern varieties. This implies that capacity to carry out impact assessment does exist in the region of WCA.

4. Results of adoption and impacts assessment in WCA

Agricultural research impact is usually recognized, when new technologies, which have the potential to increase yields, are adopted by farmers, resulting in increased production and/or lower costs (Oehmke and Crawford 1996). Consequently, documenting research benefits through impact assessment studies could help demonstrate the effectiveness and efficiency of the research of NARS and IARC.

4.1 Definitions

Adoption

Individual (farm-level) adoption is the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the technology and its potential. At the aggregate level of it is use of a specific new technology within a given geographical area or a given population. An important use of the information from adoption studies is to assess the impact of agricultural research and technology dissemination pathways and to measure returns to investments in these activities. These definitions refer to the degree of use of a new technology as a quantitative measure of the extent of adoption. For new technologies that are divisible (eg, HYV), the intensity of adoption can be measured at the individual level in a given time period by the amount or share of farm area utilizing the technology or the per hectare quantity of input used where applicable.

Impact assessment is a process of measuring whether or not research has produced its intended effect–that of meeting development objectives, such as increases in production and income and improvements in the sustainability of production systems. It is important to demonstrate that the changes observed are due to a specific intervention and cannot be accounted for in any other way. The effects can be measured at the household, target population, national, and regional levels. Impact assessment can be considered to be of two types: *ex-ante* and *ex-post*.

Ex-ante assessment refers to the potential impact of a new technology on the target population. With the declining trend in funding for agricultural research, the *ex-ante* impact assessment has become a powerful tool in research management and planning and in priority setting. It is useful in guiding research priorities and in identifying the optimal combination of research programs.

Ex-post assessment refers to the evaluation made upon the completion of a project to determine achievements and to estimate the impact of research. Returns to investment in R&D are typically assessed using the ex–post concept. These studies also help to understand the process of disseminating technology and the constraints to its adoption.

Ex-ante and *ex-post* impact assessments are interrelated. The findings in the *ex-ante* studies can provide a framework for gathering information to carry out an effective *ex-post* evaluation and can serve as a benchmark against which to assess the actual research impacts.

4.2 Ex-ante impact studies

Investments in research are usually costly and in most cases, the results are not immediate. This raises the issue of how scarce research resources should be allocated among alternative uses. Rationally, such resources should be allocated to those investments that ensure a high ROR. Moreover, pressure on public and private investments in agricultural research has heightened the need to justify such investments in comparison to alternative public investments such as extension and irrigation. Ex-ante impact assessments may be done as an aid to priority setting in order to estimate the future benefits of different research projects.

Only one study by Zarafi et al. (2002), applied ex-ante assessment for the adoption of NAD 1 (a hybrid sorghum variety) in Niger. This study focused mainly on the factors, which would most likely influence the uptake of this variety. The results indicate that seed availability and effective extension services were the factors that would probably influence the adoption of NAD 1 in Niger. This study is a limited ex-ante analysis, which focused on determining the likelihood that certain factors influencing the adoption of a given technology. It did not include calculations of yield trends, potential adoption rates and expected economic rates of return accruing from the adoption of NAD 1.

4.3 Productivity and adoption trends

Oehmke and Crawford (1996) define technology development and transfer (TDT) as a process characterized by four sequential stages: (1) creation of the institutional capacity to develop improved techniques of production, (2) expansion of the technology frontier, (3) transfer of technology to the users, and (4) sustainable changes in long-term productivity. It is the last of these which may lead to people-level impacts, such as improvements in food security or increased incomes. The productivity increase allows the average farm household to produce enough to feed themselves, as well as some surplus to trade or market. Therefore, these are important measures of progress in meeting the conditions necessary for impact. However, further investigation is necessary to quantify the impact of TDT on the welfare of Africans.

Efficiency measures results

Yield growth in sorghum and millet production has been declining in Chad, Mali, and Senegal, while it remains in Burkina Faso, Cameroon, Niger and Nigeria (Figs. 2 and 3). Growth in average yield has dropped, mostly because of adverse climatic conditions (FAO 1994).

However, while the rate of growth in yield is on the decline, absolute increases in yield over time have been on the whole positive (Table 2). Individual studies differ broadly in magnitude. Millet yield gains due to research range from 22 percent in Niger to 63% in Mali. Under the dry conditions of Sahelian countries such as Niger, improved millet varieties were estimated to increase yields by 22% or about 200–500 kg ha^{-1} (Mazzucato and Ly 1993). The improved varieties evaluated were P3KOLLO, HKP, and CIVT for millet, TN 5-78 for cowpea, and three sorghum varieties released to farmers in the early 1990s: NAD 1, SEPON 82 and SRN 39.

The yield gains in sorghum displays a wide range from a low 4 percent to a high 85 percent in Cameroon. Yapi et al. (1999a; 1999b) reports that by 1995, the S 35 varieties in Chad and Cameroon had average yield gains that were 14 to 51% higher than the local varieties, respectively. In Mali, the sorghum varieties evaluated had adjusted average yield gains that were 51 to 55% higher than the local varieties in the improved and traditional cropping systems, respectively. The N'Tenimissa released by the IER is a high yielding, white-seeded, tan-plant, guinea-type variety tolerant of sorghum head bugs. At the extreme, Ogungbile et al. (1998) and sorghum varieties ICSV 111 and ICSV 400 are estimated to have average yields gains of 43% and 34%, respectively, in Nigeria.

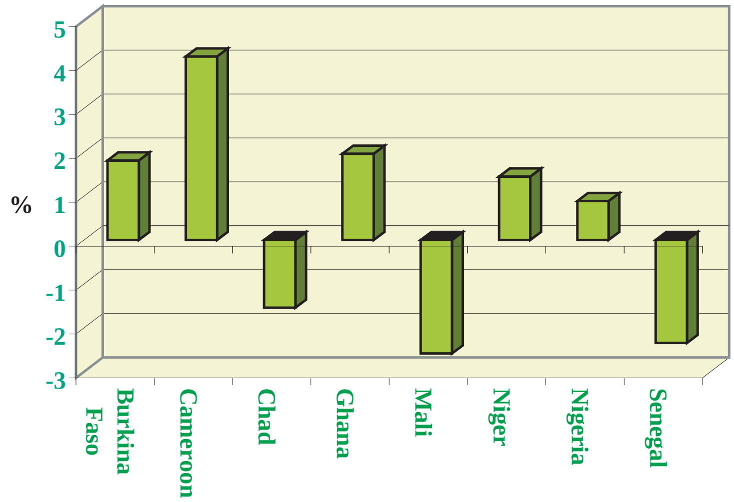

Figure 2. Growth rate of yield for sorghum in WCA (1990–2003).

Source: FAO Report 2004.

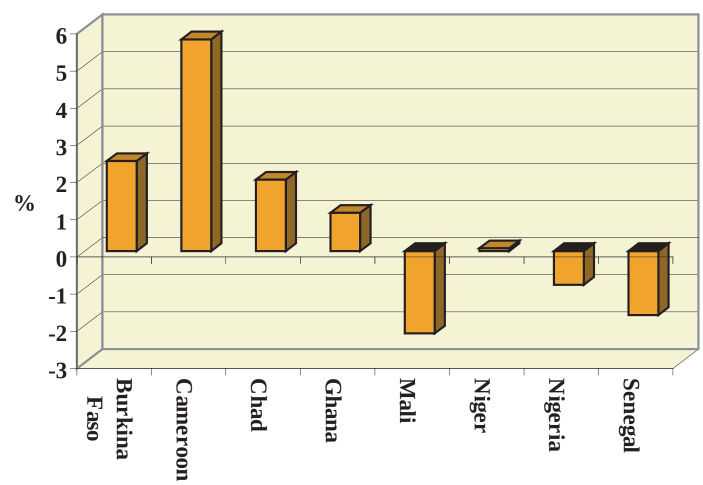

Figure 3. Growth rate of yield for millet in WCA (1990–2003).

Source: FAO Report 2004.

Millet and sorghum research in WCA has had a significant impact in terms of crop yield gains (Table 2). However, these gains vary across the countries as well as within the countries. These variations were attributed to biophysical, socioeconomic, institutional, policy and technology transfer and linkage factors. Reducing gaps in yield gains will improve land and labor use, reduce production costs and increase sustainability in some countries of WCA. These factors have implications for the appropriateness of technology to the farmers' environment and the effective transfer of technology and knowledge to the farmers.

Adoption and diffusion results

A common approach to understanding the impacts of agricultural research is analysis of the extent of technology uptake or rates of adoption. Well conceived and carefully executed adoption case studies can generate valuable insights into understanding how rural households adopt agricultural innovations

Table 2. Summary of yields gains by study.

Source	Country	Years Covered	Variety	Yield Gains (%)
Millet				
Yapi et al. 1998	**Mali**	1990–1995	Improved cultivars	63
Yapi et al. 2000		1996	SOSAT-C88, Toroniou, Benkadiniou, IBMV 8001, Mangakolo, Guefoue HKP, NKK	33
Mazzucato and Ly 1994	**Niger**	1975–1989	P 3 KOLLO, HKP, CIVT	22
Sorghum				
Yapi et al. 1999b	**Cameroon**	1984	S 35	85
Yapi et al. 1999b		1985	S 35	10
Yapi et al. 1999b		1986	S 35	8
Yapi et al. 1999b		1987	S 35	4
Yapi et al. 1999b		1984–1987	S 35	27
Yapi et al. 1999b		1995	S 35	15
Yapi et al. 1999b		1986–1995	S 35	14
Yapi et al. 1999b	Mayo Sava	1995	S 35	36
Yapi et al. 1999b	Diamare	1995	S 35	6
Yapi et al. 1999b	Mayo Danay	1995	S 35	4
Yapi et al. 1999b	Mayo Sava	1986–1995	S 35	36
Yapi et al. 1999b	Diamare	1986–1995	S 35	6
Yapi et al. 1999b	Mayo Danay	1986–1995	S 35	4
Yapi et al. 1999b	**Chad**	1990–1995	S 35	51
Yapi et al. 1999b		1995	S 35	51
Yapi et al. 1999b	Guera	1990–1995	S 35	54
Yapi et al. 1999b	Mayo-Kebbi	1990–1995	S 35	53
Yapi et al. 1999b	Chari-Baguirmi	1990–1995	S 35	46
Yapi et al. 1999b	Guera	1995	S 35	54
Yapi et al. 1999b	Mayo-Kebbi	1995	S 35	53
Yapi et al. 1999b	Chari-Baguirmi	1995	S 35	46
Yapi et al. 1998	**Mali**	1990–1995	Improved cultivars	51
Yapi et al. 2000		1996	CSM 63-E, CSM 219, CSM 388, Tiemarifing, Seguetana, CE 151, ISCV 1063 BF, ICSV 1079 BF	55
Mazzucato and Ly 1994	**Niger**	1975–1989	NAD 1, SEPON 82, SRN 39	22
Ogungbile et al. 1998	**Nigeria**	1998	ICSV 400	34
Ogungbile et al. 1998		1998	ICSV 111	43
Ogungbile et al. 1998	Kano	1996–1997	ICSV 400	33
Ogungbile et al. 1998	Katsina	1996–1997	ICSV 400	7
Ogungbile et al. 1998	Jigawa	1996–1997	ICSV 400	62
Ogungbile et al. 1998	Kano	1996–1997	ICSV 111	40
Ogungbile et al. 1998	Katsina	1996–1997	ICSV 111	27
Ogungbile et al. 1998	Jigawa	1996–1997	ICSV 111	63

and are affected by them (Sechrest et al. 1999). The rates and extent of technology adoption are critical impact indicators for technology-related investments and are pivotal inputs to impact analysis.

Trends in adoption rates of improved sorghum, in terms of area improved, for Cameroon, Chad and Mali varieties are presented in Figure 4 below. The graph depicts an increasing trend in the adoption rate of improved sorghum cultivars between 1990 and 1995, suggesting that sorghum has expanded in area. The reason behind this trend was attributed to the growing importance of sorghum in the food system of these countries. However, this increasing trend could also be due to farming extensification activities due to decreasing soil fertility.

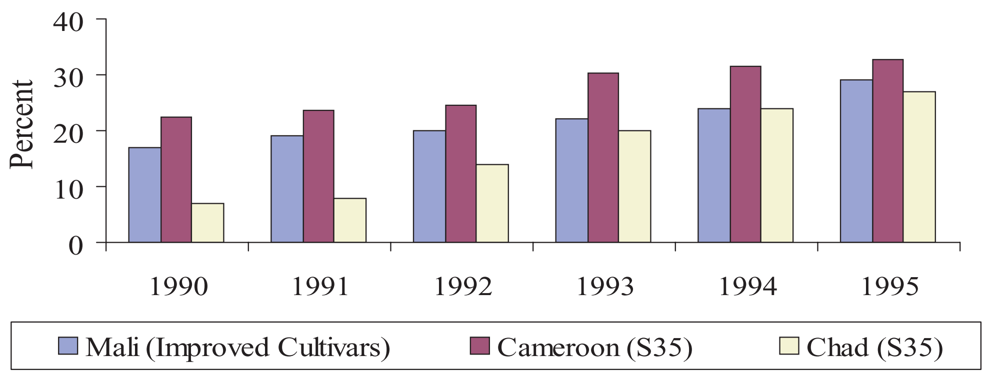

Figure 4. Adoption rates (% of area improved) for sorghum varieties in Cameroun, chad, and Mali.

Table 3 presents an inventory of adoption studies. Most of the studies available reported their results in terms of amount or share of farm area utilizing improved sorghum and millet varieties. They also concentrated on identifying variables that can be associated with the adoption or non-use of agricultural innovations.

Adoption patterns in Cameroon and Chad

The evidence reported by Yapi et al. (1999a) reveals that farmers in drought-prone regions of Chad and Cameroon have started substituting the short duration S 35 for their long-cycle landraces (Djigari, Nadj-dadja, Kouran, and Wakas varieties). For instance, ten years after its release in northern Cameroon, the technology has spread over about 50% of the total rainfed sorghum area in Mayo-Sava where 85% of the farmers have adopted it. The spread of the variety has been less spectacular in the other two study zones in Cameroon, where about 20% of farmers cultivate S 35 on less that 15% of their rainfed sorghum fields. The same variety has been successfully adopted in Chad where it is said to cover between 150,000 and 200,000 hectares (29% to 39% of total sorghum area) (Debrah et al. 1997). Results from another study conducted by Yapi et al. (1999b) in Chad reveal that the spread of the S 35 technology has been spectacular as well, especially in the totally drought-prone Sahelian region of Guéra. Seven years after the variety was released, the adoption rates in terms of area reached 38% in Guéra, 27% in Mayo-Kebbi, and 24% in Chari-Baguirmi. These levels of adoption are consistent with the extent of seed availability and the intensity of extension services in each region.

Table 3. Summary of adoption rate results (% of area) in WCA.[2]

Source	Region	Country	Crops	Years Covered	Variety	Adoption Rate
ICRISAT-SEP report (2000)	WA	Ghana	Sorghum	1998	Improved cultivars	5 to 16
Yapi et al. (1998)		Mali	Millet, Sorghum	1990-1995	Improved cultivars	27
Yapi et al. (1998)			Millet	1990	Improved cultivars	12
Yapi et al. (1998)			Millet	1991	Improved cultivars	13
Yapi et al. (1998)			Millet	1992	Improved cultivars	14
Yapi et al. (1998)			Millet	1993	Improved cultivars	16
Yapi et al. (1998)			Millet	1994	Improved cultivars	19
Yapi et al. (1998)			Millet	1995	Improved cultivars	23
Yapi et al. (1998)			Sorghum	1990	Improved cultivars	17
Yapi et al. (1998)			Sorghum	1991	Improved cultivars	19
Yapi et al. (1998)			Sorghum	1992	Improved cultivars	20
Yapi et al. (1998)			Sorghum	1993	Improved cultivars	22
Yapi et al. (1998)			Sorghum	1994	Improved cultivars	24
Yapi et al. (1998)			Sorghum	1995	Improved cultivars	29
Yapi et al. (1998)			Millet		Improved cultivars	22
Sanogo and Teme (1996)			Millet		Toroniou C1	50
Sanogo and Teme (1996)			Millet		Souna	30
Sanogo and Teme (1996)			Millet		Benkadi-nio	20
Sanogo and Teme (1996)			Sorghum		CE151	36
Yapi et al. (2000)			Millet	1990	Improved cultivars	10
Yapi et al. (2000)			Millet	1991	Improved cultivars	11
Yapi et al. (2000)			Millet	1992	Improved cultivars	11
Yapi et al. (2000)			Millet	1993	Improved cultivars	12
Yapi et al. (2000)			Millet	1994	Improved cultivars	13
Yapi et al. (2000)			Millet	1995	Improved cultivars	15
Mazzucato and Ly (1993)		Niger	Sorghum, Millet & Cowpea	1975-2011	Improved cultivars	12 to 20
Ndjeunga and Bantilan (2002)			Millet		Improved cultivars	16
Ndeunga and Bantilan (2002)			Sorghum		Improved cultivars	17
Macaver (1999)		Nigeria	Sorghum	1998	ICSV-111	5
Macaver (1999)			Sorghum	1998	ICSV-111	24
Ogungbile et al. (1998)			Sorghum	1998	ICSV-111 and ICSV -400	13
Ndjomaha et al. (1998)	CA	Cameroon	Sorghum	1995	S 35	25
Yapi et al. (1999b)			Sorghum	1995	S35	25
Yapi et al. (1999b)			Sorghum	1986	S35	8
Yapi et al. (1999b)			Sorghum	1987	S35	11
Yapi et al. (1999b)			Sorghum	1988	S35	15
Yapi et al. (1999b)			Sorghum	1989	S35	18
Yapi et al. (1999b)			Sorghum	1990	S35	22
Yapi et al. (1999b)			Sorghum	1991	S35	24
Yapi et al. (1999b)			Sorghum	1992	S35	25
Yapi et al. (1999b)			Sorghum	1993	S35	30
Yapi et al. (1999b)			Sorghum	1994	S35	32
Yapi et al. (1999b)			Sorghum	1995	S35	33

2. For more information on the specific varieties, refer to Table 2.

Table 3. *continued...*

Source	Region	Country	Crops	Years Covered	Variety	Adoption Rate
Yapi et al. (1999b)	CA	Chad	Sorghum	1990	S 35	7
Yapi et al. (1999b)			Sorghum	1991	S 35	8
Yapi et al. (1999b)			Sorghum	1992	S 35	14
Yapi et al. (1999b)			Sorghum	1993	S 35	20
Yapi et al. (1999b)			Sorghum	1994	S 35	24
Yapi et al. (1999b)			Sorghum	1995	S 35	27

Adoption patterns in Mali, Niger and Burkina Faso

Sanogo and Teme (1996) estimated the adoption rates of millet varieties in Mali as 50% for Toroniou CI, 30% for improved Soniou, and 20% for Benkadi-nio. With respect to improved sorghum varieties, the adoption rates were 36% for CE 151. Findings of a recent study conducted by Yapi et al. (2000) in Mali indicate that by 1995, 30 percent of the sorghum and 37 percent of the millet areas were sown improved cultivars.

In a recent study, Ndjeunga and Bantilan (2002) report that a survey shows that 33.1% and 20.5% of rural households in Mali claimed to use improved sorghum and pearl millet varieties, respectively. In Niger, about 17.10% and 16% are reported using improved sorghum and pearl millet varieties, respectively. The adoption of improved varieties in Burkina Faso is very low. In effect, less than 5% of farmers have reported using improved sorghum or pearl millet varieties.

In Niger, improved varieties evaluated were P 3 KOLLO, HKP, and CIVT for millet, TN 5-78 for cowpea, and three sorghum varieties released to farmers in the early 1990s: NAD 1, SEPON 82, and SRN 39. Mazzucato and Ly (1993) estimated that the sorghum-millet intercropped area was between 13 and 25 percent of total cultivated area. Thus, during the severe droughts of 1985 and 1988, many farmers reverted to traditional varieties of millets and cowpeas, reducing the total area under improved varieties from the peak adoption percentage of 20% in 1984 to less than 12% by 1991 (Mazzucato and Ly 1993).

Adoption patterns in Nigeria, Ghana and Togo

A number of improved varieties such as ICSV I 11, ICSV 400, ICSV 247, and hybrids such as ICSH 89002 NG and ICSH 89009 NG, were developed and tested on-farm. Two of these varieties, ICSV 111 and ICSV 400, demonstrated good performance in on-farm trials across several locations in Nigeria and were released in Nigeria in 1996. A study was conducted by Ogungbile et al (1998) on sorghum in northern Nigeria to examine the factors influencing the awareness and the adoption of ICSV 111 and ICSV 400 varieties. The sample consisted of 219 farmers and the study focused on three states: Kano, Jigawa and Katsina, in the Sudan savanna zone and one state (Kaduna) in the Northern Guinea savanna zone. The results were as follows in terms of land area devoted to the cultivation of these improved varieties: Kaduna State (29%), Kano State (18%), Katsina State (6%) and Jigawa (3%). The rate of adoption of the two varieties together was between 28 and 30 percent in three states and only 10 percent in Katsina. The high rates in Kaduna and Kano were because many farmers in those states have a market niche, namely the brewery industry.

Macaver (1999) conducted a similar study on ICVS 111 in the following four sub-zones of Katsina state in northern Nigeria, namely: Katsina, Daura, Dutsima and Kankia. The results of their study revealed that the adoption rate, in terms of area planted, ranged from 4.1 percent in Kankia to 6.8 percent in Katsina. The study concludes, contrary to Ogungbile et al. (1999), that the adoption rates were relatively low because ICVS 111 was recently released state-wise.

In Ghana, six improved sorghum varieties were cultivated in 13 districts with adoption rates from 4.6 to 15.8% of farmers. Most farmers surveyed cultivate local varieties or a combination of local and improved varieties; 13% of farmers cultivated only improved varieties. Poor extension and lack of seeds were cited as the principal constraints to wider adoption (ICRISAT 2000)

Following poor sorghum harvests of 1987/1988 in the Savanna Regions of Togo, local officials searched sorghum varieties that were adapted to farming systems characterized by short and irregular rainy seasons in the neighboring countries (Benin, Burkina Faso, Ghana and Senegal) (Sedzro 2001). Farmers found early maturing varieties ("Naga White" and "Kadag") with their counterparts from Ghana and introduced them before the national research institution had completed trials on several improved varieties. The varieties selected by farmers were especially used in the northwest part of the Savanna region, where farming conditions were particularly severe. Since 1996, the NFCI had selected and diffused in a small scale improved sorghum varieties (SORVATO 1, SORVATO 7, SORVATO 10, SOVATO 28, SORVATO 33), as many believed that sorghum producers were still seeking varieties more suitable to the agro-ecological conditions of the region. Sedzro (2001) found that 57% of farmers in the Savanna region had adopted improved sorghum varieties and that less than 37% of the surface area under sorghum production was allocated to the improved sorghum varieties.

It is important to note that the areas covered by these studies are not necessarily representative of WCA overall. They cover a wide range of areas, but most of the samples were purposively selected in major areas for production of millet or sorghum. Therefore, the levels of adoption presented here are not representative of national adoption levels. Nor can adoption levels be directly compared across sites, since the definition of adoption varies across studies. Nonetheless, the data show interesting patterns of adoption.

The results presented in Table 3 suggests that the adoption of improved sorghum and millet varieties has been more significant in Nigeria, Cameroon and Mali, where they were technically and economically superior to local varieties. The question of adoption or non-adoption is important; however, intensity of adoption is actually the most critical criterion in the adoption process. Farmers benefit from the adoption of new technology through opportunities to lower production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs. New technology, such as new crop varieties, may change the optimal levels of inputs used. Widespread adoption of new production technology might also be expected to have important market effects. Market-level impact can then be estimated by aggregating the farm responses, based on an assumed national adoption level.

The evidence presented in Table 3 also shows that that there is a variation in the technology uptake across regions and countries. This is due to the difference in the methods used to estimate the adoption rates in different studies. Some studies measured adoption in terms of the proportion of land under the new crop variety, whereas other studies used the quantity of seeds used to infer the intensity of adoption. In the Niger study by Mazzucato and Ly (1993) and Ndjeunga and Bantilan (2002), the percentage of improved seed in use was derived from farmer-retained seed (also called own seed) and added to the quantity of distributed seed to get more realistic estimates of the total amount of improved seed being used in a given year.[3] The variations can also be due to changes in the farming environment since the earlier adoption studies were carried out. In Sahelian Africa, the adoption of improved agricultural technologies is positively related to improvement in the farming environment as a whole (Yapi et al. 2000).

3. See references for more information.

In order to ensure that improved varieties are widely disseminated in the farmers' communities, it is important that plant breeders be appropriately involved in the transfer process to end-users. The Cameroon and Chad studies show that when farmers are associated with the breeders for the development of improved cultivars, the partnership could be extended to also include other stakeholders, eg, national development agencies, NGOs and the private sector (including the seed sector), in order to create national varietal adoption and dissemination groups. These groups could help develop appropriate strategies to facilitate the adoption and the diffusion of new improved varieties, define activities (eg, training and on-farm trials) and identify respective roles of group members based on their respective comparative advantages in terms of resources and expertise, as well as their interests in the new varieties. For example, in Nigeria, brewing companies provide price incentives for new varieties that have a good grain quality and a high malting yield and, therefore, contribute to promote its adoption by and its diffusion to farmers.

Factors influencing adoption/non-adoption of millet and sorghum technologies[4]

The analysis of factors influencing the uptake of technology is an essential component of the impact assessment practice. Insights gained from this analysis can guide in designing agricultural research programs. Table A5-2 in Annex 5 provides a summary of these factors from the studies reviewed in this paper. Figure 5 below shows the frequency distribution, across all the reviewed studies, of farmers' responses concerning the main factors influencing the adoption of sorghum and millet technology in WCA.

As indicated in Figure 5, the major factors that emerged fall in two categories: characteristics of the variety (early maturity, disease and drought resistance and productivity) and objectives of the farmers (food quality and taste). Clearly the early-maturity characteristics of the variety, its productivity, the quality of the food derived from the variety and its disease and drought resistance are the major factors influencing the uptake of sorghum and millet improved varieties in WCA.

In the Cameroon and Chad studies, farmers across all study sites have indicated preference for S 35 over their traditional varieties because the new variety was early maturing and high yielding with good food and fodder quality. The short-duration trait of S 35 was an advantage in drought-prone areas

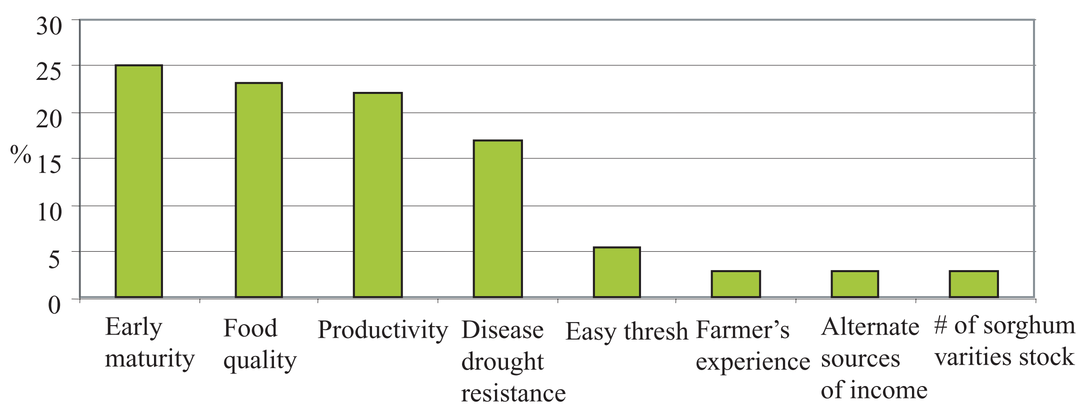

Figure 5. Factors influencing adoption (%).

4. The bar charts on factors influencing adoption, adoption constraints, and reasons for non-adoption were constructed by (1) inventorying the three most important factors from all the adoption studies; (2) counting how many times each factor appeared; and (3) computing a frequency percentage for each factor by dividing the number of times the factor appeared by the total number of factors.

where farmer's long-cycle traditional landraces often failed when rains came late and/or ended too soon. In addition, farmers in Mayo-Sava (Cameroon) and Guéra (Chad) cited the emerging high market value of white grain sorghum as an important reason for using the S 35 variety. Similarly, in the Guéra zone of Chad, local market prices for white-grain sorghums were observed to be higher than prices of local red-grain varieties. This price differential was related to the good food quality of the S 35 flour. In addition, farmers were willing to change their management practices for S 35 and not for their local sorghum varieties, because the required changes are simple, familiar, and easy to implement locally using available family and animal labor. Importantly, the payoffs for making these changes were found to be substantial, including food security, lower unit cost and higher production efficiency.

However, Mazzucato and Ly (1993) reported that in Niger, the negative effects of climate on technology adoption and crop intensification were compounded by other factors such as the low market price for cereals, weak transport and market infrastructure, poor seed multiplication system, and the unavailability of seeds, fertilizer, and credit. The risks that climate creates for 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 the difficulty of obtaining yield increases substantial enough to make inputs profitable in the extremely dry climate.

A better understanding of not only the adoption process and but also constraints to adoption is needed to guide policymakers in designing appropriate policies to stimulate technology adoption. Earlier technology dissemination efforts have neglected constraints considerations, which have resulted in inappropriate targeting of technologies in localities with lower prospects of adoption in many parts of West Africa such as Cameroon, Nigeria and Benin (Whittome et al 1995).

In all the studies reviewed, farmers were asked to identify constraints to the adoption of sorghum and millet improved varieties. The empirical evidence (see summary in Table A5-2) indicates that farmers cited several reasons for not adopting sorghum and millet varieties in WCA. Figure 6 below shows the frequency distribution, across all the reviewed studies, of farmers' is responses concerning the main constraints to sorghum and millet technology adoption in WCA, namely the lack of inputs (seeds and fertilizers), lack of information, bird damage and preference for local varieties.

In Cameroon, Chad and Niger, farmers identified bird attack, lack of improved seed, soil/land infertility, grain mold, and the high cost of grinding as constraints to the adoption and intensive use of the S 35 technology. The first two of these cut across all study sites, while soil/land infertility was

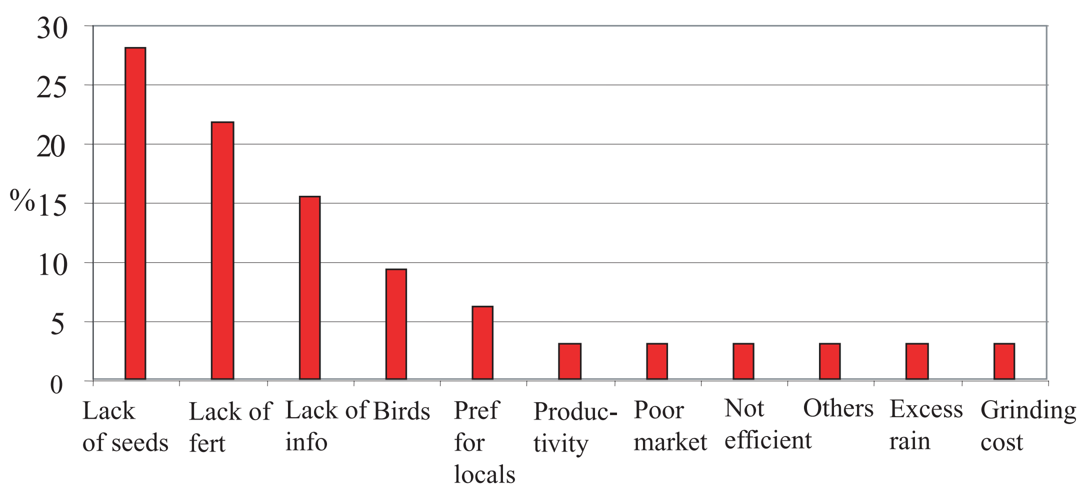

Figure 6. Adoption constraints (%).

specific to Chad, and grain mold was specific to Cameroon. Farmers in Cameroon have also cited the high cost of grinding as another important constraint to S 35 adoption.

Availability of improved seed

Seed plays a pivotal role in linking cropping seasons. It is an important part of the cost of production and a key factor in increasing productivity. Frequently, supplies of seeds play a key role in supporting or limiting adoption of improved crop varieties. Therefore, without effective seed programs, varietal introduction is made even more problematic than it normally is. Lack of effective, improved seed multiplication and distribution was cited as being critical in all the studies as was lack of fertilizer.

Source: Howard et al. 1993

The major reasons for abandoning the technology after initial adoption in Nigeria and Mali are mainly lack of information and bird damage compounded by technical and management related factors. As Yapi et al. (1999a, 1999b) pointed out, these include excessive volunteer seeds that lead to the emergence of hard-to-clear bush, high labor demand, non-adaptability of trees, and lack of knowledge of farming management.

The results of these studies regarding the factors influencing the adoption/non-adoption of millet and sorghum technologies in WCA, underline the location specificity that typify many new high yielding crop varieties. This characteristic of crop improvement agricultural technologies has an important effect on the opportunities of transferring technologies generated by research in other regions or other countries. To encourage the adoption of new technologies, pro-poor agricultural research organizations such as ICRISAT need to be asking farmers about their levels of production and finding ways to increase it, through improved technologies (eg, biotechnology), improved infrastructure and institutions, and improved policies instead of asking whether or not farmers are using improved technologies. This requires strengthening meaningful partnerships with a range of institutions that have a good understanding of local livelihood strategies. The goal is to tailor generic technologies to an enormous range of context specific livelihood strategies. The results of such partnership can have some bearing on the formulation of agricultural policy, and lead to the development of a regional agricultural research agenda to improve the impact of research on agricultural productivity.

Underlying social, economic, and cultural conditions play a crucial role to determine whether a technology will benefit poor farmers in WCA. Not taking such social and institutional factors into account means missing out on valuable lessons about the suitability of new technologies in the future. Thus, all these aspects should be considered in detail before embarking on any program to design new technologies to benefit the poor. For example, the high proportion of concerns about lack of inputs (seeds and fertilizers), lack of information, bird damage and preference for local varieties reported by sample farmers supports the hypothesis that the complementary organizations (eg, market information systems and inputs stores) played a critical role in the adoption decision process.

According to Anand Kumar (personal communication 2005), for IARCs and NARS the challenge continues to be in attempting to improve the performance of sorghum and millet when grown under marginal low input conditions by resource poor farmers. The set of traits that reduce yield losses and confer greater yield stability are well defined. Furthermore, he pursues to channelize the knowledge and genetic backgrounds into stable genetic potential (yield stability, appropriate maturity, tolerant/resistance sources to abiotic stress and biotic stress are known) into locally adapted (agro-ecology) varieties, there is a need of well-funded and staffed crop breeding programs in NARS. There is a need for decent and functioning plant breeding facilities (fields, locations, simple breeding laboratory).

In WCA, improved varieties are available but unfortunately investments in the seed sector is historically very low (ie, because traditionally seeds have not been obtained through commercial channels but only through seed exchange, neighbors etc.). This is perhaps influenced by poor record of success by publicly funded seed projects. Village seed banks are not a good option for highly allogamous crops such as millet as the seed from the 'bank' often results in an undesirable mixture of types. Large companies have little advantage of pursuing locally adapted varieties that have a very small market with insignificant profit margins. What is needed is a harmonious seed regulatory structure in the region, and technologies (eg, production, postharvest and food processing) that can stimulate investment by the private sector.

4.4 Ex-post impact results

The ex-post impact assessment studies included in this review dealt mainly with the estimation of benefits from research activities. Table 4 presents a list of impact assessment studies conducted in WCA. Overall, the studies indicate that millet and sorghum research generate benefits in excess of the opportunity cost of the capital invested in these research activities.

Cameroon and Chad

ICRISAT has, as a policy, distributed a wide range of parental materials to breeding programs in the NARS and private seed industries throughout the SAT. This has contributed to faster and cost-effective development of useful final products by the receiving parties. This study evaluates the impacts and research spillover effects of the adoption of sorghum variety S 35, a pure line developed from the ICRISAT breeding program in India. The S 35 sorghum variety is a nonphotoperiod-sensitive, high-yielding, early-maturing, and drought-tolerant pure line and was later promoted in Cameroon and Chad. Results from the study on the impact of germplasm research spillovers in Cameroon and Chad (Yapi et al. 1999a; 1999b) reveal that the NPV of benefits from S 35 research spillover in the African region was estimated to be US$15 million in Chad and US$4.6 million in Cameroon, representing internal rates of return of 95% in Chad and 75% in Cameroon. These impacts were evaluated from the perspective of national research systems. In this study, the authors underlined the fact that a conscious decision was made to include only those costs associated with national research and extension institutions. All other S 35-related R&D expenditures incurred in India and Nigeria were treated as 'sunk costs', that is, costs, which would have occurred anyway without spillover. If each country had to develop S 35 and associated management practices on its own, the time lag between research and release of the technology would have been longer and consequently the impacts, if any, would have been less significant. The implication is that regional research networking contributes to reducing research costs and, therefore, to improving research's financial efficiency relative to NARSs' independent research. For greater effectiveness in sorghum technology development and transfer in the region, future research and policy actions should take greater advantage of research spillovers through more collaboration, communication, and networking between national, regional, and international research institutions (Yapi et al 1999a). Countries could thereby exploit the advantages of specialization and economies of scale in research.

Mali and Niger

After the independence of Mali, the IER was created to develop the productivity of food crops in partnership with regional and international agricultural research institutes such as IRAT, ICRISAT and

Table 4. Summary of impact assessment results.

Source	Country	Crops	Years Covered	Variety	Impact ROR (%)	NPV	K-Factor
Agib 1996	**Mali**	Sorghum	1985–2009	Striga resistant sorghum	56		
Yapi et al. 1998		Millet, Sorghum	1990–1995	Improved cultivars			
Yapi et al. 1998		Millet	1990–1995	Improved cultivars	69	$25 million	38% ($38t-1)
Yapi et al. 1998		Sorghum	1990–1995	Improved cultivars	50	$16 million	25%($34t-1)
Yapi et al. 2000		Sorghum	1969–2018	Improved cultivars	69	$16.4 million	16 CFA/KG
Yapi et al. 2000		Millet	1969–2019	Improved cultivars	25	$25 million	12 CFA/KG
Mazzucato and Ly 1994	**Niger**	Sorghum, Millet, Cowpea	1975–1991		<0		
Mazzucato and Ly 1994		Sorghum, Millet, Cowpea	1975–2011		2-21 %		
Sterns and Bernsten 1994	**Cameroon**	Sorghum	1979–1998	Drought-escape variety	1		
Sanders et al. 1994		Sorghum	1980–1992		2		
Yapi et al. 1999b	Mayo Sava	Sorghum	1995	S35			26
Yapi et al. 1999b	Diamare	Sorghum	1995	S35			7
Yapi et al. 1999b	Mayo Danay	Sorghum	1995	S35			1
Yapi et al. 1999b	Cameroon – Extreme North	Sorghum	1986–1995	S35			7557FCFA/TON
Yapi et al. 1999b	Mayo Sava	Sorghum	1986–1995	S35			19800FCFA/TON
Yapi et al. 1999b	Diamare	Sorghum	1986–1995	S35			4600FCFA/TON
Yapi et al. 1999b	Mayo Danay	Sorghum	1986–1995	S35			700FCFA/TON
Yapi et al. 1999b	**Chad**	Sorghum	1990–1995	S 35			19887 FCFA/TON
Yapi et al. 1999b	Guera	Sorghum	1995	S 35			26
Yapi et al. 1999b	Mayo-Kebbi	Sorghum	1995	S 35			18
Yapi et al. 1999b	Chari-Baguirmi	Sorghum	1995	S 35			26
Yapi et al. 1999b	Guera	Sorghum	1994–1995	S 35			$38t-1
Yapi et al. 1999b	Guera	Sorghum	1990–1995	S 35			23471FCFA/TON
Yapi et al. 1999b	Mayo-Kebbi	Sorghum	1990–1995	S 35			8091 FCFA/TON
Yapi et al. 1999b	Chari-Baguirmi	Sorghum	1990–1995	S 35			17816 FCFA/TON

CIRAD. A number of improved seed-based sorghum and millet technologies have since been developed and diffused. They were developed from a selection within local germplasm and plant breeding. A study by Yapi et al. (2000) estimated an NPV of US$25 million and an IRR as high as 50% for pearl millet, and an NPV of US$16 million and IRR of 16% for sorghum. The unit costs calculated, based on survey data, were considerably low: CFA 16 per kg for sorghum and CFA 16 per kg for millet. Yapi et al (2000) concluded that the breeding philosophy in Mali should be diversified to respond to the need of changing socioeconomic environment with the 1994 devaluation of the franc CFA. They also recommended that efforts be made to improve the economic farming environment to enable farmers to adopt more productive agricultural technologies, which are necessary for rural poverty alleviation and improvement in national food security.

In Niger, achieving food self-sufficiency has been and still is one of the government's highest priorities for the agricultural sector but enlarging the total cultivated area is not a viable, long-term option. Meeting future food demand required continuous investment in the generation and transfer of productivity-enhancing agricultural technologies. Such investments are costly and compete for scarce public resources. Research on three millet varieties (P 3 KOLLO, CIVT and HKP) and one cowpea variety (TN 5-78) was initiated by the French, prior to 1975. Also three new sorghum varieties were released to farmers: NAD 1, SEPON 82 and SRN 39. All of these varieties have been worked on by INRAN during the period of 1975–1991.

A study by Mazzucato and Ly (1993) analyzed 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. Mazzucato and Ly (1993) estimated a positive IRR by extending the analysis through 2011 under the assumption that the adoption of improved varieties would be no higher than it was at the time of the study. This assumption was reasonable at that time, because international and national organizations had enjoyed relatively limited success in developing crop varieties for the low rainfall conditions in Niger. This meant that the Nigerien seed multiplication system could not produce hybrid seed of adequate quality, restricting breeding activities and reducing adoption of improved varieties. The IRRs estimated for the package of sorghum, millet and cowpea investments, incorporating projected returns to 2011, ranged from 2 to 21%, depending on the assumptions used regarding yield differentials, prices, adoption rates, and production and extension costs. The average yield differentials of improved over unimproved local varieties were obtained from on-farm trial data and extrapolated to corresponding areas using agro-climatic data. The cost calculations of the ES included research, extension, and production costs. An annual stream of benefits were calculated until the year 2011, because it was assumed that past investments in research and technology transfer would continue to produce benefits well into the future.

As Mazzucato and Ly (1993) indicated, a strict interpretation of an ex-post ROR 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.[5] Calculated as such, a negative ROR results in Niger, since the most successful of the four varieties under evaluation, TN 5-78, 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. The positive returns from the Niger study indicates that sorghum, millet and cowpea research and technology transfer have contributed to increased productivity in Niger's agricultural sector. The returns are comparable to those found for research on cowpea (15%) and sorghum (1%) in Cameroon (Sterns and Bernsten 1994).

5. This study analyzes returns to investments in Niger's research and technology transfer system for millet, sorghum, and cowpea between 1975 and 1991.

Togo[6]

As mentioned in the section relative to adoption patterns, farmers found early maturing varieties ("Naga White" and "Kadag") with their counterparts from Ghana and introduced them before the national research institution had completed trials on several improved varieties. The varieties selected by farmers were especially used in the northwest Savanna region, where farming conditions were particularly severe.

However, since 1996, the NFCI had selected and diffused in a small-scale improved sorghum varieties (SORVATO 1, SORVATO 7, SORVATO 10, SOVATO 28, SORVATO 33). Sedzro (2001) carried out an economic analysis of the impact of research and extension of improved sorghum varieties in the Savanna region of Togo. Findings from this study report positive returns to research and extension investments (64.6%) in the Savanna region from 1979 to 1996 and a net social surplus amounting to more than 5.8 billions of FCFA.

5. Discussions on methodological issues

The outcome of impact assessment studies depends considerably on the method, data and assumptions. The following few aspects of methodology help to illustrate this observation.

5.1 Adoption behavior modelling

Except for the Niger studies (see adoption sub-section for detailed discussion), the studies reviewed used both probit and logit models to assess adoption rate (measured by the percentage of farmers using the technology on a continuing basis) and degree of adoption (measured, for example, by the proportion of land under the new crop variety), where the probability of adoption depends on the characteristics of the farmers. If the estimated coefficient of a particular variable is positive, it means that higher values of that variable result in a higher probability of adoption. A lower value implies a lower probability of adoption. Intensity of adoption (measured by the amount of modern inputs used per unit area) was analyzed using a multiple linear regression model.

5.2 NPV and IRR estimation

All the impact case studies share the same conceptual framework: research evaluation in a partial equilibrium setting. They all use the ES approach that estimates changes in consumer and producer surplus to calculate the NPV of investments in a particular research activity. This method is based on the assumption that technology adoption leads to an outward shift in the product's supply curve. Certain assumptions are required about the slopes of the supply and demand curves, the nature of the supply shift, and the relationship between producer and consumer prices. In addition, some base or initial equilibrium sets of prices and quantities are used for making these calculations. The IRR to investment in the technology can be estimated using the ES approach.

The usefulness of using the ES approach is strongly influenced by the specification of supply and demand conditions and the nature of the shift in the supply functions with respect to specific research activity. Moreover, limited data requirements make application of this analytical tools adequate for impact assessment. However, it is important to note that while each of the studies uses the same conceptual background in assessing benefits and costs, there are several decisions about data collection, the scope of the investigation, and other critical variables that the investigator makes in the course of the study. These decisions can and do affect the estimated NPV and IRR.

6. Despite numerous attempts, this is the only INSAH-Purdue impact series study on millet and sorghum research in WCA that was obtained.

For example, impact assessments are sensitive to the starting and ending points chosen by the evaluator. The origin marks the start of the evaluation period. In the early years, expenditures are made on research activities and new techniques are still in the development and transfer process. Thus impacts are small, leading to negative net benefits in the early years. The difference between including projected future benefits and stopping the evaluation at the time of the study is illustrated by the discrepancy between Mazzucato and Ly's projected IRR in Niger of 7-21 percent through 2010, and their baseline finding of negative returns. The case study in Niger is the prime example where the baseline estimates were not overly optimistic but a sensitivity analysis showed higher returns in the future. 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. Considerable research lags existed for the millet, sorghum, and cowpea research programs. The technologies being developed by INRAN were based on selection work on local populations and crossbreeding, with the exception of the three sorghum varieties that are derived 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.

Another issue is related to the inclusion of the benefits and costs of complementary investments. Most, but not all, studies have ignored complementary investments. A number of authors have included the impact of one additional investment, usually extension, in their ROR calculations. For instance, studies of Mali, Cameroon, Chad and Togo, analyzed the impact of research plus extension and found positive IRRs, whereas Mazzucato and Ly (1993) examined the impact of research in the presence of policy distortions and their baseline IRR was negative.

Adoption is a condition for impact. In fact, the single, most influential variable on the payoff to research investment is the level of farmer adoption of a new technology innovation. The importance of adoption underscores the need for both extension and adoption monitoring of new technologies to achieve accurate economic evaluation of investment programs. Monitoring and evaluation mechanisms should therefore be institutionalized as research and technology transfer schemes.

Results of this synthesis study show that the adoption patterns in WCA are uneven. This is important, especially given that some researchers are skeptical about the willingness of farmers in the region to innovate and adopt new approaches. Sanders (1996) noted (1) the extension of the sorghum variety S 35 from Cameroon into Chad; (2) the diffusion of new millet cultivars in Senegal since the 1980s and, more recently, in Mali; and (3) a major effort by a seed company and a beer company to diffuse new sorghum cultivars, including a hybrid, in Nigeria. However, no mention was made of improved sorghum, and to some extent, millet varieties have also been widely adopted in Nigeria (Ogungbile et al. 1998).

Apart from ecological differences, the differential rates of adoption in the countries of WCA can, perhaps, be better explained by the quantity of pure seed made available to farmers in each region. For example, as the primary release target zone, Gue'ra (Chad) benefited, not only from most of the S 35 extension services provided by the ONDR and NGOs, but also from the large-scale pure seed production campaign that was initiated two years before the variety was formally released. According to Yapi et al. (1999a, 1999b), these results were achieved due to individual initiatives by isolated NGOs (eg, SECADEV, CARE, and Voisins Mondiaux). The patterns of adoption and areas sown to S 35 clearly indicate that farmers in the drought-prone regions of Chad have started replacing their long-cycle landraces with the short-duration S 35 variety.

In addition to documenting the adoption and diffusion of sorghum and millet technologies, valuable insights were gained about many factors that can affect the adoption of agricultural innovations in general. Results showed that the adoption of improved sorghum and millet varieties is directly influenced by two sets of factors: (1) characteristics of the technology (eg, early maturity and productivity) and (2) characteristics of the farmer (eg, farmers' consumption preferences).

5.3 Research Payoffs

Significant net benefits, considerable reduction in unit cost of production and high IRR were deduced from the studies. With an average of a 10% discount rate assumed, results show that the average ROR is relatively high compared to alternative investment options. It ranges from 0 to 95 percent, justifying continued investments in agricultural research in those areas. This suggests that funding sorghum and millet research in WCA has been a productive investment.

The returns to sorghum and millet research (as documented in Table 4) are not only positive but are high enough to indicate economic profitability. These findings are remarkable. They provide a direct contrast to the negative views of African agricultural research impacts that have permeated recent discussions. Among the set of studies, only the Niger case study by Mazzucato and Ly (1994) shows baseline ex-post RORs that are negative.

The McIntire Report: Too Soon Too Late?

Where there has been extensive adoption of improved cultivars, yield increments, unit cost reductions and/or IRRs have been impressive. Certainly for WCA some of these findings appear to negate assertions in the McIntire Report[7] that there had been no impact and that there was unlikely to be any impact relating to millet and sorghum work in the region. In places where adoption has not occurred efforts have been made to ascertain reasons.

Source: McIntire et al. 1995.

6. Conclusions

6.1 Lessons learnt

Impact assessment studies are useful in a variety of ways and to different interest groups – research managers, donor agencies and stakeholders. In a time when there is increasing scrutiny about the usefulness of investments in agricultural research, impact assessment studies assist to demonstrate the value of continued investments in research. Results from the adoption and impact studies in WCA included in this synthesis study provide some insights into the following issues:

- Few impact assessment studies on millet and sorghum (including impact assessment initiatives by INSAH and Purdue) have been conducted in the region.[8] Most of the comprehensive impact studies in this study were conducted through ICRISAT/NARS collaboration. While NARS seldom carry out impact assessments themselves, many agricultural research managers and policymakers realize that impact assessment is useful in setting research priorities and demonstrating results. This situation needs to be improved so as to bridge gaps and identify opportunities for impacts in the region. It is important for the NARSs to strengthen their research and analytical capacity for more impact assessment work. The results of systematic assessments can produce insights that can influence the formulation of agricultural policy, and guide the development of a national agricultural research agenda. A demonstration of impact offers a case to argue for enhanced funding of agricultural research from national budgets.

7. The report was also very pessimistic about any likely future effects of this research. This report, however, did not include recent evidence of increased adoption of a number of ICRISAT-bred sorghum varieties by farmers in several countries as evidenced by the findings of the studies reviewed in this paper.

8. See list of INSAH-Purdue impact studies in ANNEX 4. Note that that only the Togo case study is included in this paper because it is the only one we managed to obtain despite many attempts.

- Another lesson from this study is that seed availability is a major constraint to the adoption of improved varieties by farmers in the region. National programs and NGOs should initiate projects, which would decentralize seed multiplication and distribution through individual private farmers and farmer organizations. Seed multiplication and distribution by the private sector would ensure a regular replenishment of quality seeds of improved cultivars to producers so as to maintain a high productivity level, provided that a very strict and effective control mechanism is put in place. Seed multiplication and distribution require, however, skills and expertise, which need to be developed by potential seed producers through special training.
- No study dealt with the gender dimension of the impact of sorghum and millet on women's well being. This raises the question of how to improve the sorghum and millet economics. According to De Leener (2001), in Niger, while harvesting the bad millet or sorghum ears, those which are infested or spoiled by pest attacks or abnormally small, may be collected and stored by women in order to feed the children. Therefore, efforts should be made to include gender implications for the farming system and income distribution within the households depending on whether the commodities are dominated by one gender.
- The high RORs need to be interpreted with caution. The profitability of research depends on technical improvement in other sub-sector stages and improved co-ordination between different sub-sector stages namely input distribution, product marketing and processing.
- It is important to recognize the difficulties the authors of this paper faced in finding a one-stop location to easily access key technology adoption and impact assessment data and analyses on millet and sorghum for every country in WCA. ICRISAT should consider developing an AIAIPWCA based on a project being carried out by the MSU called the *Food Security and Food Policy Information Portal for Africa* (FSIP). The objective of this project is to improve the capacity of African technical as well as social science researchers and policy analysts to enhance the effectiveness of their work through better use and more timely sharing of the tremendous knowledge resources increasingly available electronically. These are the types of resources that can assist in the conduct of research, extension and teaching that aims to increase the use of scientific knowledge in policy analysis and design (Dione et al. 2004). Key specific objectives of the FSIP are to assist African food security and food policy researchers working at the African country and regional-level to
  1. rapidly find important and high quality Internet sources of data and information to assist in their analytical work;
  2. make data and research results produced by African researchers available to a worldwide audience; and
  3. improve capacity for quality research, policy analysis and policy outreach using the Internet as both a vehicle for training and a source of data and information.

6.2 Implications for future research

Although the results discussed above are based on a limited number of available case studies on the adoption and impact of millet and sorghum research in WCA, the general implications for future research on millet and sorghum are as follows:

1. For many types of innovations, the interesting question may be related to the intensity of use (eg, how much land is planted to improved cultivars). Future studies can properly account for a more varied range of responses by employing statistical techniques suitable for the variables considered. Empirical research should recognize that in many cases several innovations, which have degrees of

complementarity are introduced simultaneously. It follows that the adoption decisions for various innovations are interrelated. These interrelationships should be considered in the econometric procedures.

2. Empirical studies on agricultural technology adoption generally divide a population into adopters and non-adopters, and analyze the reasons for adoption or non-adoption at a point in time. In reality, technology adoption is not a one-off static decision, rather it involves a dynamic process in which information gathering, learning and experience play pivotal roles, particularly in the early stage of adoption. A more appropriate conceptual framework for an adoption pathway would be one in which farmers move from learning to adoption, to continuous or discontinuous use over time. This framework would help understand the adoption pathways for improved millet and sorghum cultivars in WCA. However, establishing cause-effect or at least influence linkages, is more complex and is not as simple. Therefore, there is a need for further impact assessment research to develop a model for evaluating and validating the path-to-development impact in order to examine the contribution or at least the influence, of a given intervention to final development goals. This model could also be useful to conduct ex-ante impact analysis of different R&D interventions from organizational models to decision-support tools to technology and information as a criteria for impact assessment research priority-setting. The studies could be structured around the sustainable livelihoods framework, which ensured that poor people's vulnerability and their assets (financial, physical, human, natural, and social capital) are taken into account.
3. Differing conclusions from different regions or countries may be the result of differing social, cultural, and institutional environments (aside from pure economic factors). It is thus essential to provide detailed information about the interactions among the various factors that generate the observed behavioral patterns. Furthermore, in consideration of the dynamics aspects of adoption, descriptive studies may suggest that a given farmer follows a sequential process of adopting several related production practices. Further work is needed to understand any order and regularity in such chain processes. The commodity systems approach to incorporate demand-side considerations from consumers of agricultural products complements the farm-level approach by examining what happens to the agricultural products as they leave the farm. It provides a guide to what product characteristics are valuable to processors, distributors and the final consumers. As the agricultural sector undergoes transformation and the economy becomes more reliant on markets to deliver agricultural products to a growing number of off-farm consumers, the commodity sector approach becomes increasingly important as a tool to maintain the link between consumer demand and farm production. The argument supporting the calculation of IRR to research plus complementary organizations as a package is that these investments together facilitate technology development and technology acceptance by farmers.
4. However, crediting research investment alone with a high IRR can send dangerously misleading policy signals, if this masks additional investments (eg, marketing) needed to facilitate adoption of the technology by farmers that in turn affect economic feasibility. Furthermore, basing policy recommendations on the IRR to research programs in isolation from the effects and costs of complementary organizations, such as tunnel vision, risks missing critical side issues. One set of issues concerns how dependent the success of the research investment is upon simultaneous investments in related organizations, and their associated costs. In Nigeria, the rapid uptake of the new sorghum varieties, and the high level of contacts between improved millet and sorghum adopters and dissemination and input/product marketing agencies, points to the critical importance of policies and complementary organizations in facilitating technology adoption.
5. Increased access to food depends on income growth, and for the majority of WCA smallholders dependent on agriculture, income growth is tied to productivity growth in agriculture. Increased commercialization and integration of rural credit, input, labor, and food markets are likely to be an unavoidable feature of highly productive agricultural systems. Socioeconomic research should be

oriented towards examining the effects of agricultural commercialization on food crop fertilizer use and productivity. These relationships could be investigated through both descriptive and multivariate analyses. Crop commercialization provides a source of cash that allows the household to overcome credit-related constraints on the purchase of improved seeds and other cash inputs such as fertilizers. For example, in northern Niger, participation in a cash crop (eg, tiger nuts) commercialization generally improves the household's access to inputs distributed through the cash crop marketing firm (eg, Nigerian breweries), which have resulted in the household using some of that input on millet production (Camara 2005). What matters is what kind of commercialization, how particular schemes are organized, and their effects on smallholder access to inputs, management advice, market outlets, price levels and price risks, and so on. A major task for future research is to better understand how successful commercialization arrangements linking smallholders and marketing/processing firms have been structured so that their successful ingredients can be replicated and incorporated more broadly into commercialization strategies in other regions. This is likely to yield high payoffs in terms of increasing agricultural productivity and food security.

6. The GIS technology holds sufficient promise that it should be tested as a component of an agricultural research impact assessment system. The practical utility of GIS for research impact assessment has not been fully demonstrated. One use of GIS technology is in spatially explicit interaction of multiple databases at common locations. In view of this broader potential for GIS, pilot testing of GIS-based systems for assessing agricultural technology performance and impact are warranted and as methodologies evolve, use of GIS data may be gradually expanded.

   As Anand Kumar (personal communication 2005) points out, the future prospects for research on these two crops will largely be determined by the priorities that NARS place and provide funding and support and international priorities for these crops and continuing donor interest to reduce poverty. This calls for a clear analysis of past research outputs and utilizing them for formulating on-farm production recommendations. There is also a need for an initiative by NARS and regional organizations to demonstrate that farmers are adopting previous research recommendations and still there are important priority problems that need to be addressed. For example, a priority problem would be to better understand drought, a key abiotic factor limiting yields, in close interaction with lack of soil nutrients. IARCs should accord priority to these crops, for collaborative research with NARS, if improved technologies to increase production and productivity are being adopted by farmers (irrespective of who developed them). These will include improved varieties, practices to reduce yield losses caused by diseases and insect pests and of agronomic practices (including soil fertility improvements). IARC involvement generally brings in contributions from mentor institutions, donor assistance and private sector involvement.

Findings from the reviewed studies show that returns to research (and diffusion) investments are quite high, but the performance varies across countries. These results could be of use to policy makers, donors and other scientists within the region of WCA. This fundamental information about the levels of the adoption and impact of sorghum and millet is critical for priority setting and impact assessment. However, if improved technology is to make a meaningful impact at the farm level, it must be accompanied by at least three complementary factors: (1) an effective extension service; (2) an efficient inputs distribution system, and (3) appropriate economic incentives.

References

Bantilan MCS and **Joshi PK** (eds.). 1994. Summary proceedings of a workshop on research evaluation and impact assessment, 13–15 December, ICRISAT Asia Center, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 148 pp.

Camara Y. 2005. Report on participatory rural appraisal in Niger (*Forthcoming*).

Debrah SK, Tenkouano A. and **Yapi A**. 1997. A coordinated technology generation and delivery system for enhanced sorghum production and utilization in West and Central Africa. Pages 171–178 in Technology Options for Sustainable Agriculture in Sub-Saharan Africa (Bezuneh T, Emechebe AM, Sedogo M and Ouedraogo, M, eds.). Ouagadougou, Burkina Faso: OAU/STRC – SAFGRAD.

De Leener P. 2001. From technology-based to people-oriented synergies: How the in-depth analysis of a synergy between farmers, researchers and developers invites to reconsider some basic perspectives on pro-poor agricultural research. Paper presented at the Conference on Global Partnership Programs by the Global Forum on Agricultural Research (GFAR), Rome, Italy, October 2001.

Dione J, Kagwanja J, Weber MT, Staatz J, and **Kelly V.** 2004. Paper accepted for presentation in plenary session and for publication in proceeding of the Inaugural Symposium of the African Agricultural Association of Agricultural Economists (AAAE), Nairobi, Kenya, 6–9 , MSU, December 2004.

FAO. 1994. Food Outlook. Rome, Italy: Food and Agriculture Organization of the United Nations.

Horton D, Ballantyne P, Peterson W, Uribe B, Gapasin D and **Sheridan K.** 1993. Monitoring and evaluating agricultural research. A sourcebook. International Service for National Agricultural Research, The Hague, the Netherlands. CAB International.

Howard J, Chitalu G and **Kalonge S.** 1993. The impact of investments in maize research and dissemination in Zambia. Part I: Main Report. International Development Working Paper No. 39/1. East Lansing, MI, USA: Department of Agricultural Economics, Michigan State University.

ICRISAT. 2000. SEP Program report. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

INTSORMIL. 1999. INTSORMIL Annual Report. University of Nebraska, Lincoln, NE. Publ. No. 99–6.

Macaver OJ. 1999. Impact analysis of public investment in sorghum research and extension in Nigeria. Unpublished Ph.D. research proposal. Department of Agricultural Economics and Rural Sociology, Ahmadu Bello University, Zaria.

Maredia M, Byerlee D and **Anderson JR. 2000.** Ex-post evaluation of economic impacts of agricultural research programs: A tour of good practice in The Future of Impact Assessment in the CGIAR: Needs, Constraints and Options. Rome, Italy: CGIAR Technical Advisory Committee Secretariat, FAO.

Mazzucato V and **Ly S.** 1994. An economic analysis of research and technology transfer of millet, sorghum, and cowpeas in Niger. Discussion Paper No. 93–06. The Hague, The Netherlands: International Service for National Agricultural Research.

McIntire J, Ouayogode B and **Kio P.** 1995. Report of the Panel on CGIAR Commitments in West Africa. Rome, Italy: CGIAR Technical Advisory Committee Secretariat, FAO.

Ndjeunga J and **Bantilan MCS**. 2005. Uptake of improved technologies in the semi-arid tropics of West Africa: Why is agricultural transformation lagging behind? *e*JADE 2(1):85–102.

Ndjomaha C, Yapi A and **Adamri A. 1998.** Impact of sorghum. S 35 in extreme north Cameroon. Pages 26–27 in *Technology Options for Sustainable Agriculture in Sub-Saharan Africa* (Bezuneh T, Emechebe AM, Sedogo M and Ouedraogo M, eds.). Ouagadougou, Burkina Faso: OAU/STRC – SAFGRAD.

Obilana T. 2004. In Sorghum genetic enhancement: research process, dissemination and impacts (Bantilan, MCS, Deb UK, Gowda CLL, Reddy BVS, Obilana AB and Evenson RE, Eds.) Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 320 pp.

Oehmke JF and **Crawford EW.** 1996. The impact of agricultural technology in Sub-Saharan Africa. Journal of African Economies 5:271–92.

Ogungbile AO, Tabo R, Gupta SC, Ajayi O and **Bantilan MCS**. 1998. Factors influencing awareness and adoption of ICSV 111 and ICSV 400 sorghum varieties. (Unpublished).

Sanders JH. 1996. Agricultural research and new technology introduction in Burkina Faso and Niger. Agricultural Systems 30:139–154.

Sanders JH, Shapiro BI, Reddy KC and **Baker TG.** 1994. Evaluating and adapting new technologies in a high-risk agricultural system – Niger. Agricultural Systems 42(1–2):153–171.

Sanogo O and **Teme B.** 1996. Impact assessment of on-farm trials conducted at the Cinzana Research Station. In Partners in Impact Assessment: Summary Proceedings of the ICRISAT/NARS Workshop on Methods and Joint Impact Targets in Western and Central Africa, 1996.

Sechrest L, Stewart M and **Stickle T.** 1999. A synthesis of findings concerning CGIAR case studies on the adoption of technological innovations – Impact assessment and evaluation group.

Sedzro KM. 2001. Impact economique de la recherche et de la vulgaristaion des varietes ameliorees de sorgho: Le cas de la Region des Savanes au Togo. In Towards Sustainable Sorghum Production, Utilization, and Commercialisation in West and Central Africa, Proceedings of a Technical Workshop of the West and Central Africa Sorghum Research Network, 19–22 April 1999, Lome, Togo.

Schultz TW. 1964. Transforming traditional agriculture. New Haven, CT, USA: Yale University Press.

Sterns JA and **Bernsten RH.** 1994. Assessing the impact of cowpea and sorghum research and extension in northern Cameroon. MSU International Development Working Paper No. 43 East Lansing: Department of Agricultural Economics, Michigan State University

Yapi AM, Debrah SK, Dehala G and **Ndjomaha C.** 1999a. Impact of germplasm research spillovers: the case of sorghum variety S 35 in Cameroon and Chad. Impact Series no.3. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 30 pp.

Yapi AM, Dehala G, Ngawara K and **Issaka A.** 1999b. Assessment of the economic impact of sorghum variety S 35 in Chad. Impact Series no. 6. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 34 pp.

Yapi AM, Kergna AO, Debrah SK, Sidibe A and **Sanogo O.** 1998. Impact of sorghum and millet research in Mali. Pages 76–93 *in* Assessing joint research impacts: proceedings of an International Workshop on Joint Impact Assessment of NARS/ICRISAT Technologies for the Semi-Arid Tropics, 2–4 Dec 1996, ICRISAT, Patancheru, India (Bantilan MCS and Joshi PK, eds.) Patancheru 502 324, Andhra Pradesh, India: International Crop Research Institute for the Semi-Arid Tropics.

Yapi AM, Kergna AO, Debrah SK, Sidibe A and **Sanogo O.** 2000. Analysis of the economic impact of sorghum and millet research in Mali. Impact Series No 8. Patancheru 502 324, Andrha Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 60 pp.

Zarafi M, Bokar M and **Seini H.** 2002. Evaluation Ex-Ante de l’Adoption des Varieties Hybrides de Sorgho (NAD) au Niger. Niamey, Niger: INRAN.

Annexes

Annex 1. Letter of request.

Dear Sirs

My name is Youssouf Camara and I am a Postdoctoral Fellow working with Drs Bantilan and Ndjeunga. We are currently working on a paper entitled " Impacts of Sorghum and Millet Research in West and Central Africa (WCA): A Synthesis and Lessons Learnt". We would be very grateful to you for filling out the questionnaire below.

Best regards

Youssouf

Dr Youssouf Camara
Agricultural Economist/Postdoctoral Fellow
ICRISAT BP 12404
Niamey, Niger
Tel: +227 722529, 722725
Fax: +227 734329
Email: c.youssouf@cgiar.org

Annex 2. List of resource persons or key informants.

Dr Issoufou Kapran, INRAN,
Niamey, Niger
Dr Ouendeba Botorou, Independant Consultant,
Niamey, Niger
Dr Eva Weltzein
Dr Fred Weltzein
Dr Aboubacar Toure, IER Bamako, Mali.
SC Gupta, (ask SEPP-India)
Dr Williams Masters,
Dr Samba Ly (cell: 980668)
Dr M.A. Zarafi, Head of Economics Division,
INRAN
Dr Niangado, Syngenta, Bamako-Mali
Dr Obilana, Tunde (SEPP-India)
Dr Anand Kumar (Ask Ouendeba)
Dr Inoussa Akintayo, WARDA
Mr Jika Naino
(former INRAN pearl millet breeder retired)
Dr Aba (Sorghum breeder, IAR-ABU)
Dr Da San San, Sorghum breeder

Annex 3. Questionnaire.

Title: Impacts of Sorghum and Millet Research in West and Central Africa (WCA): A Synthesis and Lessons Learnt.

Objective: to undertake an exhaustive documentation and synthesis of the research benefits from sorghum and pearl millet research in WCA and analyze the results of adoption and impacts studies on sorghum and millet improved varieties in WCA.

Kindly answer the following questions:

1. What is your viewpoint on the impacts of sorghum and millet research in West and central?
2. In your opinion, what has been and/or continue to be the key constraints to sorghum and millet research in West and Central Africa?
3. Currently in which countries of West and Central Africa, sorghum and millet research is more likely to show the greatest impacts? Please indicate specific varieties to focus on.
4. What are the future prospects for priority research on sorghum and millet in West and Central Africa?

Annex 4. List of INSAH–Purdue universities impact studies.

Country	Institutions	Scientists	Themes
1995/1996			
Burkina Faso	INERA	S. OUEDRAOGO	Diguettes antiérosives dans le plateau central du Burkina Faso
Mali	IER	A.O. KERGNA	Variétés du mil (Toroniou) dans la région de Ségou
Mali	ICRISAT	A. YAPI	Variété de sorgho (CSM388) en zone Mali-Sud
Niger	INRAN	J.-P. ATINDEHOU	Variétés du mil SOUNNA III et du niébé dans les zones Maggia et Gaya
Sénégal	PNVA	A. CISSE	Impact des pratiques culturales et services de vulgarisation sur les variétés du Maïs et du Sorgho
1996/1997			
Bénin	INRAB	S. MIDINGOYI	Analyse des facteurs déterminants les mécanismes d'adoption ou de refus des semences améliorées du sorgho dans le Département du Borgou.
Tchad	DRTA	G. DEHALA	Evaluation de l'impact des variétés améliorées de mil en zone sahélienne du Tchad.
Togo	INCV	K. SEDZRO	Evaluation de l'impact de la recherche et de vulgarisation des variétés de sorgho et mil dans la région des savanes au Togo.
Case Studies (1998)			
Mali		Alpha Oumar KERGNA	Evaluation économique de l'impact de la recherche sur la farine Mileg.
Mauritanie		BAH O/ Moctar O/ Sidy	Evaluation de l'impact économique de la recherche et de la vulgarisation agricole : cas du sorgho dans la Wilaya du Gorgol Sud mauritanien.
Tchad		Gandaoua DEHALA	Etude d'impact économique de la recherche sur le mil en zone sahélienne (Chari Baguirmi).
			Impact économique de la recherche et de la vulgarisation des variétés améliorées de sorgho : cas de la région des savanes au Togo.
Togo		Koffi SEDZRO	Critères d'adoption des variétés améliorées de sorgho suivant les agro-écologies au Togo.

ANNEX 5

Table A5-1. Inventory of adoption and impact studies on sorghum and millet in West and Central Africa.

		Crops													
		Sorghum							Millet						
					Types of studies							Types of studies			
					Adoption		Adoption and Impact					Adoption		Adoption and Impact	
Regions	Countries	Release name of cultivar	Classification	Year of Release	Year	Source	Year	Source	Release name of cultivar	Classification	Year of Release	Year	Source	Year	Source
West Africa	**Benin**	ICSV 111	ICRISAT	1999					GB 8735	ICRISAT	1987				
		bred								CNDRA ITRAD	1994				
	Burkina	E 35 A	ICRISAT Network	1975					SOSATC 88	ICRISAT	1988				
										CNDRA ITRAD	1997				
		IRAT 204	ICRISAT Network	1980					IMCV 89305	ICRISAT					
										INRAN					
		E 35-1	ICRISAT Network	1983					IMCV 92222	ICRISAT	1992				
										INRAN	1997				
		Framida	ICRISAT bred	1986											
		ICSV 1049	ICRISAT bred	1989											
		Sariago-B	ICRISAT Network	1992											
	Cote d'Ivoire	Framida	ICRISAT bred	1986											
		ICSV 1063	ICRISAT bred	2000											
	Ghana	Framida	ICRISAT bred	1986											
		Kaapala													
	Mali	Malisor series		1987					Toroniou C 1						
		ICSV 1079 BF		1993					SOSATC 88	ICRISAT	1988				
										CNDRA IER	1997				
		ICSV 1063 series		1991					**Improved cultivars**			**1998**	**1**	**1998**	**1**
		Tieble		2001											
		Kossa		2001											
		Ngolofing		2001											

continued...

Table A5-1 *continued...*

Regions	Countries	Sorghum: Release name of cultivar	Sorghum: Classification	Sorghum: Year of Release	Sorghum: Adoption Year	Sorghum: Adoption Source	Sorghum: Adoption and Impact Year	Sorghum: Adoption and Impact Source	Millet: Release name of cultivar	Millet: Classification	Millet: Year of Release	Millet: Adoption Year	Millet: Adoption Source	Millet: Adoption and Impact Year	Millet: Adoption and Impact Source
West Africa	**Mali** (Cont'd)	Nazomble		2001											
		Nazondje		2001											
		Soumalemba		2001											
		Marakanio		2001											
		Soumba		2001											
		Yagare		2001											
		ICSV 1063	ICRISAT bred	2000											
		Improved cultivars			**1998**	**1**	**1998**	**1**							
	Niger	SEPON 82	ICRISAT	1993					HKP	INRAN ICRISAT	1999				
		SRN 39	ICRISAT	1993					CIVT GMS	INRAN	1974				
										ICRISAT	1975				
		NAD-1	INRAN	1989					ZATIB	INRAN	1988				
										ICRISAT	1990				
		IRAT 16							SOSATC 88	IER	1988				
										ICRISAT	1997				
		System			**1994**	**2**	**1994**	**2**	ICMV series	ICRISAT INRAN	1988				
									Ankoutess	ICRISAT	1996				
									ameliorее		1998				
									SOSANK	ICRISAT	1998				
									System			**1994**	**2**	**1994**	**2**

continued...

Table A5-1 *continued...*

Regions	Countries	Sorghum: Release name of cultivar	Sorghum: Classification	Sorghum: Year of Release	Sorghum: Adoption Year	Sorghum: Adoption Source	Sorghum: Adoption and Impact Year	Sorghum: Adoption and Impact Source	Millet: Release name of cultivar	Millet: Classification	Millet: Year of Release	Millet: Adoption Year	Millet: Adoption Source	Millet: Adoption and Impact Year	Millet: Adoption and Impact Source
West Africa	**Nigeria**	ICSH 89002 NG	ICRISAT bred	1995					SOSATC 88	IER ICRISAT	1988				
											1997				
		ICSH 89009 NG	ICRISAT bred	1995											
		ICSV 111	ICRISAT bred	1995	1997	2									
					1999										
		ICSV 400	ICRISAT bred	1997	1997	2									
					1999										
		NR 71176	ICRISAT bred	1997											
		NR 71182	ICRISAT bred	1997											
		NSSH 91001	ICRISAT bred	1997											
		NSSH 91002	ICRISAT bred	1997											
	Senegal	IRAT 204	CIRAD	1980					ITMV 8001						
									ITMV 8004						
									Gb 8735						
									ITCP 8203						
									IBV 8004						
									Souna 3						
									ICMV 89305						
	Togo	SORVATO 1		1998											
		SORVATO 28		1998											

continued...

Table A5-1 ***continued...***

		Crops														
		Sorghum							Millet							
					Types of studies							Types of studies			
					Adoption		Adoption and Impact					Adoption		Adoption and Impact	
Regions	Countries	Release name of cultivar	Classification	Year of Release	Year	Source	Year	Source	Release name of cultivar	Classification	Year of Release	Year	Source	Year	Source
Central Africa	**Cameroon**	S 35	ICRISAT bred	1987	1994 1999	2 1	1994 1999	2 1							
		Improved cultivars			1994	2	1994	2							
	Chad	S 35	ICRISAT bred	1989	1999	1	1999	1	GB 8735	GB 8735					
									ITMV 8001	ITMV 8001					
	Rwanda	5Dx160	ICRISAT Network	1980											
		1Kinyamka	ICRISAT Network	1980											

Note: Concerning source of types of studies, 1 = ICRISAT and 2 = others.

Table A5-2. Summary of factors influencing the adoption of sorghum and millet improved varieties in WCA.

Source	Country	Crops	Years Covered	Variety	Main Factors Influencing Technology Adoption
					Constraints of Adoption of New Varieties
Yapi et al. 2000	**Mali**	Sorghum	1996	Improved cultivars	Lack of information, Lack of improved seeds, Preference for locals, Decreasing soil fertilty
Yapi et al. 2000		Millet	1996	Improved cultivars	Lack of information, Lack of improved seeds, Preference for locals, Decreasing soil fertilty
Zarafi et al. 2002	**Niger**	Sorghum		Hybrid NAD1	Others (Lack of improved seeds, Taste, Insects)
Ogungbile et al. 1998	**Nigeria**	Sorghum	1998	ICSV 111, ICSV 400	Low soil fertility, Insects, Excess rain, Lack of seeds
Yapi et al. 1999	**Chad**	Sorghum	1994–1995	S 35	Bird damage, Land degradation, Seed availability, Seed cost
Yapi et al. 1999		Sorghum	1990–1995	S 35	Bird attack, lack of improved seed, soil/land fertility, high cost of grinding
					Farmers' Reasons for Adopting New Technology
Yapi et al. 1999	**Mali**	Millet	1990–1995	Improved cultivars	Earliness, Productivity, Food quality, Striga resistance
Yapi et al. 1999		Sorghum	1990–1995	Improved cultivars	Earliness, Productivity, Food quality, Striga resistance
Yapi et al. 2000		Sorghum	1996	Improved cultivars	Short duration, High yield, Good food quality Striga resistance
Yapi et al. 2000		Millet	1996	Improved cultivars	Short duration, High yield, Good food quality Striga resistance
Macaver 1999	**Nigeria**	Sorghum	1998	ICSV 111	Early maturity, Yield, Disease resistance, Good food quality
Ogungbile et al. 1998		Sorghum	1998	ICSV 111, ICSV 400	Early maturity, Yield, Good food quality, Easy to thresh
Yapi et al. 1999	**Cameroon**	Sorghum	1995	S 35	Early maturity
Yapi et al. 1999	**Chad**	Sorghum	1994–1995	S 35	Early Maturity, Taste, High yield, Drougth resistance
					Farmers' Reasons for Not Adopting New Technology
Zarafi et al. 2002	**Niger**	Sorghum		Hybrid NAD1	Availability, Lack of information, Not efficient
Macaver et al. 1999	**Nigeria**	Sorghum	1998	ICSV 111	No seeds, Unaware, Scarcity/high cost fertilizer, Low yield
Ogungbile et al. 1998		Sorghum	1998	ICSV 111, ICSV 400	Lack of seeds, Poor market, Lack of knowledge, Lack of fertilizer
					Factors Influencing Adoption
Zarafi et al. 2002	**Niger**	Sorghum		Hybrid NAD 1	Farmer's experience, Alternate sources of income, Number of sorghum varieties in stock.
					Characteristics of New Varieties Preferred by Farmers
Ogungbile et al. 1998	**Nigeria**	Sorghum	1998	ICSV 111, ICSV 400	Early maturity, taste, yield, ease of threshing