# Prospects for a Pearl Millet and Sorghum Food Processing Industry in West Africa Semi-Arid Tropics

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## Abstract

Relative to other cereal crops, sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) are still the most important crops in the production systems, and the main staples for the people in the semi-arid tropics of West Africa (WASAT). During the past fifteen years, the shares of total cereal area cultivated to, and production of, the two coarse grains have declined slightly. Sorghum and pearl millet are being replaced slowly by maize, rice and wheat in average diets, especially those of urban consumers. This trend has led some to express pessimism about the ability of sorghum and pearl millet to contribute to poverty alleviation in the medium- or long-term. However, since 1984 the total cereal area planted, and production of sorghum and pearl millet have been increasing in most West African countries. And there is a slowly emerging, small-scale coarse grain food processing industry in the WASAT. There is therefore a need to reconsider the pessimistic conclusions that have been expressed about the future of sorghum and pearl millet.

Negative views of sorghum and pearl millet are based on negative growth in productivity, and limited commercialization of sorghum and pearl millet grains and processed products. This paper presents the necessary conditions for the growth of a coarse grain processing industry in the semi-arid tropics of Africa, and highlights the significant research themes that need to be explored. The adoption of supply and demand enhancing technologies in a coordinated market environment constitutes the bulk of necessary conditions for the growth of a coarse grain processing industry in the WASAT.

## Introduction

The region of West Africa covers a total land area of 1.58 million km$^2$. With the exception of few countries (Senegal, Cote d'Ivoire and Ghana), the region is classified by the World Bank among the poorest third of the world's developing countries, with per capita incomes of US$ 320 or less. The human population, which grows at an annual rate of 2.9%, was estimated to be 185 million in 1986, and is projected to reach 284 million by the year 2000. The urbanization rate is estimated to be about 30% of the total population. It grows at a rate higher than the population growth rate, ranging from 4% in Senegal to 11.3% in Burkina Faso between 1980 and 1995 (Annex 1). Sorghum (*Sorghum bicolor*), pearl millet

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(*Pennisetum glaucum*), maize (*Zay mays*), rice (*Oryza sativa*) and fonio (*Digitaria exilis*) are the main cereal crops grown in the WASAT. They absorb 50 to 80% of total farm resources (Matlon 1987). Millet and sorghum account for 80% of total cereal production, provide more than 75% of total calorie intake, and are the main staple in diets in the WASAT.

Since 1960, area planted, production, and yields of sorghum and millet have presented some mixed patterns in WASAT, characterized by periods of area and production expansion (1960-70), decline (1970-1983) and recovery (1984-1997). The period of negative growth in both area cultivated and production is explained by repeated droughts that occurred during the years 1973 and 1983, depressing both the yield and production of pearl millet and sorghum. Since 1984, the shares of sorghum and millet in cereal area planted and total cereal grain production have declined slightly. Over the same period the total cereal area cultivated to maize and rice, and their share of total cereal production have been increasing. This trend led some scientists to argue that the demand for processed coarse grain products is limited because urban consumers have developed a strong preference for rice, which will not decline significantly, even if cheaper coarse grain alternative are made available (Reardon 1993; Fusillier 1994). The evidence for this argument is limited because the data does not provide a good understanding of the factors that explain the current, evolving supply and demand for coarse grains products in West Africa.

The data show that the total area and production of pearl millet and sorghum have been increasing since 1984. The decline in the share of area planted and production is explained by the growth in area planted and production of maize and rice. But the growth in area planted to maize and rice is constrained by agro-climatic conditions, implying that the share trends can not be projected into the future indefinitely. So pearl millet and sorghum are likely to remain significant in the WASAT cereals economy, contrary to the negative arguments about their future. A fresh view of the evidence can help identify the information and actions needed to enhance the production of pearl millet and sorghum, and overcome concerns about their declining significance in the region.

This paper uses FAO data and secondary sources of information to assess the prospects for a pearl millet and sorghum food processing industry in the WASAT. It presents the necessary conditions for the growth of a coarse grain processing industry in West Africa and highlights significant research themes that need to be investigated. The necessary conditions for the growth of a coarse grain processing industry fall into three categories: 1/ the supply of raw material (grains); 2/ the demand for the processed products and 3/ market organization. The state of knowledge in each of these categories will be reviewed below.

# Raw Material Supply (Supply of Coarse Grains)

## The Bio-Physical Environment - Definition of Production Zones

The semi-arid region of West Africa, roughly referred as WASAT, receives mean annual rainfall between 250 and 1100 mm. This region can be broadly sub-divided into four agro-ecological zones - the sahelian (less than 350 mm), the sahelo-sudanian (350-600 mm); the



sudanian (600-800 mm) and the sudano-guinean (800-1100 mm) - with distinct agricultural systems and potential. Table 1 summarizes the major features of these agro-climatic zones. Roughly 54% of the total land area in Western Africa may be considered arid, defined as those areas where the length of growing period (LGP) is less than 90 days. Twenty percent of the land area is semi-arid (90-180 days), 16% is sub-humid (180-270 days), and 10 % is humid (180-270 days).

## Climate

The four broad categories defined above are distinguished by rainfall and soil suitability parameters (Table 1). Climatic constraints are more limiting in the sahelian zones and decline in importance in the sudanian and guinean zones. The constraints include: a short uni-modal rainy season; high intra-seasonal rainfall variation, with risk of periodic critical drought at the early stages of crop growth; high evaporative demands, with peaks at the beginning and end of the rainy period; and further increases in the risk of drought stress during planting and grain filling. Moreover, high rainfall intensity may cause run-off losses of as much as 60-80 percent of precipitation, contributing to considerable risk of top soil losses through erosion (Matlon 1987).

## Soils

The old and highly weathered soils of the semi-arid tropics of West Africa reinforce the climatic constraints. Soil texture varies from loamy sand in the Northern Sahel to sandy loams in the southern sudanian areas. Except for limited vertisol pockets, clay content is uniformly low (less than 20%), and the soils are structurally inert with poor water holding capacity. Due to the low clay and organic matter content (generally less than 1%), cation exchange capacities tend to be less than 5 milli-equivalents per 100 grams of soils. As a result, soils are highly fragile. In addition to low natural fertility, the low structural porosity and high bulk density reduces root penetration and water circulation. There is a tendency for compacting and hardening during the dry season, which results in early erosion run-off, severely restricting pre- and post season cultivation. This also leads to poor water infiltration (except in eolian sandy soils) due to: rapid surface crushing of soils, even after cultivation; low values of available water compared to typical Asian soils; and increasing susceptibility to erosion with continuous cultivation.

## Farming Systems

Within the broad agro-climatic zones, farmers have adapted to micro-variations with highly flexible management practices. In areas, where soils tend to be droughty, such as the Sahel zone, farmers tend to grow millet and fonio, and migratory livestock rearing is predominant. In the sudano-sahelian zone, where soils are droughty, but receive more rainfall, farmers tend to grow millet, sometimes inter-cropped with cowpea, groundnut and sorghum as secondary crops. The sudanian zone is an area of transition between millet and sorghum based systems. Maize, groundnut and cotton are also cultivated. Finally, in the sudano-guinean zone, which receives rainfall between 800-1100 mm, a wide range of crops are



grown, including cotton, maize, rice, rice, cowpea, groundnut and vegetables. Therefore, movement along the North-South transect, is characterized by increasing rainfall and soil depth, creating more opportunities for farmers to grow a wider range of crops.

Of the sample countries, Senegal, Niger, Mali and Burkina Faso are endowed with more than 80% of their total area in the semi-arid zones. They are referred to as Sahel countries. The other four sample countries (Nigeria, Cote d'Ivoire, Togo and Ghana), have less than 50% of their total area in the semi-arid zone. They are referred to as forest countries (Table 1). Pearl millet and sorghum, which are more drought tolerant, are predominant in the production systems of all Sahel countries. They are expected to gain more ground even in the marginal areas of the forest zones. Estimates indicate that, since 1973, there has been a southward shift of the 300 mm rainfall isohyet by 150 km. This offers a comparative advantage to drought tolerant crops, such as sorghum and pearl millet (Sivakumar 1992).

## Coarse Grain Production

Farmers in the semi-arid tropics of West Africa produced about 9.6 million tons of pearl millet and 9.7 million tons of sorghum, on average, between 1995-97 (Table 2). This compares with a production level of 8.7 million tons of maize and 5.1 million tons of rice over the same period. Sorghum and pearl millet account each for about 29% of the total cereal grain production. The relative contribution of maize and rice are also important and estimated to be about 15% and 26% of the total cereal grain production. Nigeria accounts for about 70% of the total sorghum production, and more than half of the pearl millet production in West Africa. Although Niger after Nigeria comes as the second largest area allocated to millet in West Africa it accounts for only 18% of the total pearl millet produced due to low grain yield.

Except for Nigeria, every country's cereal production share has been declining. Sorghum has lost about 6% of its share from 35% to 29 %, while pearl millet's share has declined from 38 to 29% on average from 1981-83 to 1995-97. In contrast, the relative share of maize in total cereal grain production has marginally increased from 13% in 1981-83 to 15.3% in 1995-97, and the average contribution of rice in total cereal grain production has more than doubled from 14% in 1981-83 to 26% in 1995-1997. The rapid increase of rice in total cereal grain production is mainly explained by the expansion of rainfed and irrigated schemes, and higher yields compared to other cereals. The irrigated areas have more than doubled during the past fifteen years in the Sahel countries.

Within countries, the production shares of the two coarse grains have remained virtually unchanged, especially in the Sahel countries with the exception of Mali. In contrast, in forest countries, there has been a significant production decline in favor of maize production. The share of maize production has almost doubled from 17% to 31% of total cereal production (Table 3).

Although the production shares of sorghum and millet have declined, the region's total pearl millet and sorghum production has increased. Since 1984, pearl millet and sorghum production has increased at annual rates of 3.2% and 3.3% respectively. These rates are less than the production growth of maize, 7.20% and rice, 6.58% (Table 4).



There is not clear evidence that maize production is replacing sorghum or pearl millet production. While maize production has increased overall, most of the increases are in environments better suited for maize production. Maize production has more than doubled in all forest countries. Similarly, in the Sahelian countries of Burkina Faso and Mali, which are endowed with large environments better suited for maize production (800-1100 mm), a significant increase in maize production has been recorded (Table 3). Production of coarse grains is explained by the area planted and yields, among other factors. The following section examines the trend in area planted.

## Coarse Grain Area Planted and Harvested

Farmers in WASAT planted over 14 million ha of pearl millet and approximately 11 million of sorghum on average between 1995-97. Maize and rice are planted on almost 7 million and 3 million ha respectively (Table 5). Nigeria, alone, accounts for 55% of the West African sorghum area. Niger and Burkina Faso also have significant sorghum area. The remaining 5 countries account for less than 15% of the West African sorghum area. Nigeria and Niger each account for about 37% of West Africa's pearl millet acreage. The remaining 6 countries account for less than 25% of the pearl millet acreage.

Over the past fifteen years all countries, except Nigeria, have been losing their regional share of area planted to all cereal crops. Nigeria's share of all cereal crops has significantly increased. For example, sorghum's share of area planted has increased from 42 to 57% of the total WASAT cereal area planted. Pearl millet's share has increased from 23 to 37%, rice area has increased from 46 to 60%, and the maize area has more than doubled, from 32% to 67% of WASAT cereal area planted.

The importance of sorghum and pearl millet within each country can be measured in terms of the proportion of total cereal grain area planted to each crop. Pearl millet accounts for the majority of cereal grain area in Senegal and Niger, 74% and 72% respectively. Sorghum accounts for 51% of the total cereal grain area in Burkina Faso followed by Nigeria (34%), Mali (31%) and Niger (27%). Both sorghum and millet account for more than 90% of the total area planted to cereal in the Sahel countries. In contrast, maize and rice are of relatively minor importance, representing less than 10% of the total cultivated cereal grain area. However the latter two crops are more important in the forest countries. For example, except for Nigeria, both maize and rice account for over 70% of the total cereal area planted compared with about 25% for both sorghum and millet. Including Nigeria, sorghum and pearl millet are important in the production systems, accounting for over 50% of the total grain area (Table 6).

Within countries, since 1984, the shares of total cereal area planted to sorghum and pearl millet have virtually remained constant in the Sahelian countries and have only have slightly decreased in the forest countries. However, in almost all countries, the area planted to sorghum and pearl millet has been increasing. In the WASAT, sorghum and millet area planted has been increasing by 3.98% and 4.20% respectively, but less than the areas planted to maize, 6.24%; and rice, 6.61% (Table 7).

There is little evidence that maize has been displacing sorghum and pearl millet at least in term of area planted. Much of the growth in maize area occurred in the predominantly forest



zone. In the Sahelian countries, area growth to maize is comparable to or less than that of sorghum. In Niger, for example, the growth in area cultivated to maize has been decreasing by about 13% since 1984; whereas, sorghum and pearl millet area cultivated have increased by more than 5%. In Burkina Faso, the area cultivated to maize increased by 2.9 %, about the same as sorghum. Much of the area growth to maize in the WASAT is attributed to maize area expansion in Nigeria. The area cultivated to maize has almost doubled (13 to 27%) while Nigeria's share of the total planted area to maize in the WASAT has increased from 32 to 67% from 1981-83 to 1995-97.

Overall, the area cultivated to sorghum and pearl millet is still increasing in WASAT. There is little evidence that this area is being replaced by maize. While it may be true that the area growth in sorghum and pearl millet results from expansion on marginal lands; sorghum and millet may also be growing in areas that are no longer suitable for maize production. Further investigation is required to ascertain the directions of area growth and assess the area substitution between cereal crops. The growth in area cultivated to sorghum and millet is more than production growth suggesting that yields are depressing production. The following section examines trends in grain yields.

## Coarse Grain Yields

Grain yields for pearl millet and sorghum are low by global standards and significantly less than maize or rice yields. Pearl millet yield across the sub-region averages 679 kg $ha^{-1}$. Nigeria has the highest grain yield (1,040 kg $ha^{-1}$) in the sub-region. In contrast, Niger has the lowest yield in the region, averaging 340 $kg.ha^{-1}$. Pearl millet yield averages less than sorghum in West Africa. Sorghum averages about 866 $kg.ha^{-1}$, with Nigeria achieving the highest average grain yield of about 1,107 kg $ha^{-1}$. In contrast in Niger, where sorghum is the second most important crop, grain yields are averaging about 190 kg $ha^{-1}$ over the period 1995-1997 (Table 8).

Since 1984, West Africa's average yields of two major coarse grains have declined by an annual average of 1.0% for pearl millet and 0.7% for sorghum since 1984. Yield declines for the two major coarse grains may be attributed to low and erratic rainfall. In addition, limited use of improved technologies by cereal growers is a major constraint to increasing yields. Fertilizer use per ha arable land is very low. Grain yields were found to the highest in countries where more than 8 kg of mineral fertilizer is used per ha arable land (e.g., in Nigeria, Mali and Senegal). Yields are the lowest in Niger where less than 1 kg is used per ha arable land (Annex 2).

In contrast to sorghum and pearl millet, maize yields have increased moderately by 1% between 1984 and 1997; and rice yields have virtually remained constant. To remain competitive, pearl millet and sorghum yields must increase.

# The Competitive Position of Sorghum and Pearl Millet

Sorghum and millet are still the most important food grains in West Africa. Since 1984, production and area planted have been increasing. However, production growth results from



area expansion rather than yield. In contrast, maize production has increased as a result of both area and yield growth. Therefore, for sorghum and millet to be competitive in the system, yields must increase. The returns to the major factors of production (land and labor) for millet or sorghum must be raised to stimulate yield enhancing production practices.

Currently the returns to land and labor for pearl millet are lower than that of maize in Niger (Reardon and Hopkins 1990). In 1990, survey results in four sample villages indicated that millet returns to land averages 15500 fcfa.ha$^{-1}$ while maize returns to land averages about 31000 fcfa.ha$^{-1}$ (Annex 5). The net returns to labor for millet were estimated to be 526 fcfa.ha$^{-1}$ slightly higher than that of maize, estimated to be 497 fcfa.ha$^{-1}$. Therefore, if land becomes scarce, farmers will likely allocate more land to maize than sorghum and millet. Similarly in Mali, maize responds better to labor inputs than sorghum and millet. A man-day of work in maize production returns 46.5 kg, roughly one and half times sorghum production and two and half times millet production. Therefore when labor becomes scarce during critical periods of the year, one would expect farmers to allocate more labor to maize than sorghum and millet (Debrah 1993).

Supply enhancing technologies, including labor saving and yield stabilizing technologies, land and water management techniques, and technologies to improve productivity, such as the use of improved varieties combined with fertilizers, are well known and have been extensively studied by many scientists. Labor is usually scarce during critical periods of the year and is one of the principal constraints to cereal production (Hopkins and Reardon 1990, Debrah 1993). Labor saving technologies have the potential of alleviating the labor constraints. They include the use of herbicides and mechanization (e.g., animal traction). Yield stabilizing technologies have the potential of reducing production variability and may increase yields by enhancing crop resistance to chronic yield reducers. For example, IRAT sorghum variety IRAT204, ICRISAT millet varieties IBV8001 and IBV8004 are well adapted in Senegal, and GB8735 is well adapted in more drought prone areas of Niger, Mauritania and Chad.

Overall, total pearl millet and sorghum production and area planted are increasing. There is little evidence that these crops are being replaced by maize in terms of production and area planted. Their competitiveness is severely limited by their poor yield, which is explained by little adoption of improved technologies. Supply enhancing technologies that encompass the use of improved varieties and soil fertility restoration methods are well known. However, demand enhancing technologies that include food processing and storage are still in their infancy in West Africa. The following section reviews the current utilization and consumption of pearl millet and sorghum products and previous studies on demand for grain and processed products.



# Finished Product Demand (Demand for Pearl Millet and Sorghum Processed Products)

## Current Utilization and Consumption

### Utilization

Worldwide, between 1992-1994, it was estimated that 42% of total sorghum produced was used for human food consumption, while 48% was used for animal feed. In contrast, 80% of the world's millet is used for food, with the remaining divided between feed, other uses and waste (ICRISAT/FAO 1997). In the WASAT, sorghum and pearl millet grains are the basic staples and are still almost entirely consumed by humans. Uses as animal feed are not yet developed. Other uses of sorghum and millet include the use of their stalks as building material or animal feed, especially during the dry season.

When consumed as food, the most common meals prepared from sorghum are: thin or stiff porridges; e.g. *ogi* in Nigeria or *tô* in Mali, Burkina and Niger; steamed cook products such as *couscous*; or beverages such as *dolo* in Burkina Faso and Mali, *pito* in Ghana and Togo, or *tchapalo* in Cote d'Ivoire. So far, sorghum products are mainly traditionally processed for family consumption. A slow and emerging industrial use is found in Mali and Burkina Faso with the processing of grains into flour, decorticated sorghum or biscuits. Sorghum flour is being experimented with as a partial substitute for wheat flour. The food technology institute of Mali, the Institut de Technologie Alimentaire (ITA) in Senegal; and the Institute of Agronomic Research in Nigeria have successfully experimented with a wide range of products where sorghum flour substitutes for about 50% of wheat flour (WCASRN& IER 1998).

There is a slow emerging industrial use of sorghum. In western Africa Nigeria is a pioneer in the industrial utilization of sorghum. Following the ban on imports of major cereal grains in January 1988, an industrial scale replacement sorghum for imported barley and malt has been initiated in the production of lager beer, stout, malt-based drinks and weaning food. Industrial demand for sorghum is currently estimated to be about 5% of the total sorghum production in Nigeria (Baidu-Forson, et al. 1995).

Pearl millet ranks first as the major staple in human consumption in the WASAT, providing the bulk of energy, proteins, vitamins and mineral requirements. It has been proven to be a high-energy nutritious food, nutritionally superior to other cereals and especially recommended for children, convalescents and the elderly. Several food preparations are made from millet, including thin and stiff porridges. A survey conducted by the West and Central African Millet Research Network (WCAMRN) on 522 consumers in four countries revealed that millet is the most preferred staple in the WASAT. Millet is consumed at breakfast, dinner and supper, followed by sorghum which is mostly consumed at supper. Rice is mostly consumed at dinner times and maize at supper. Maize was found to be consumed rarely. The main dishes derived from millet vary by country. In Burkina Faso, thin (*bouillie*) and stiff porridges (*tô* and *couscous*) are the main processed products. Ninety-two



percent of respondents reported eating *tô*; 62% drinking *bouillie* and 25% eating *couscous*. In Niger, 75% reported drinking *bouillie*; 63% *pate*; 25% *tô* and 31% *gallette*. In Nigeria; 84% were reported to eat *tô*; 62% *bouillie*; 58% *fourra* and 47% *couscous*. Finally, in Senegal, 80% reported eating *couscous*; *soungouf* (64%), *sankhal* (58%) and *araw* (49%). Pearl millet products are traditionally processed mainly for family consumption (WCAMRN 1998)

The commonalty between these traditionally processed products from is that they are made from sorghum or pearl millet flour. Therefore, the supply of flour is likely to be one of the main industrial products that food processors could supply in urban markets.

## Consumption

Average per capita cereal grain consumption in WASAT was estimated to be 193 kg in 1994-96 and partitioned into 26% sorghum, 26 % pearl millet, 26% maize, 17% rice, and finally 4% wheat products. Since 1984, The consumption shares of sorghum and millet have remained virtually constant in the Sahel countries. They still account for about 70% of the total cereal grain consumed, followed by rice, maize and wheat (Table 10). In contrast, in the forest countries, maize and rice account for more than 60% of per capita cereal consumption. In these countries, the shares of sorghum and millet have significantly decreased, but still account for about 30% of the per capita cereal consumption. About 60 % of the increase in maize consumption is offset by decreases in rice and wheat consumption. Large increases in per capita consumption of maize relative to other cereals are predominantly in the forest countries, driven by Nigeria. In fact, the per capita share of maize to total cereal consumption rose from 10 to 30% between 1981-83 and 1995-97 partially substituting for rice and wheat in Nigeria.

There is some evidence of a changing cereal use pattern, especially in the urban areas. Results from a household consumption survey conducted in urban Niger in 1989-1995 indicate that pearl millet is still the main staple of urban consumers, accounting for 57% of total cereal consumed, followed by rice (18%), sorghum (12%), maize (10%) and wheat (3%). However, per capita millet consumption decreased by 5% (70.4 to 67.1 kg) from 1990 to 1995. Sorghum consumption remained constant. In contrast, per capita maize consumption more than doubled from 33.4 kg to 79.4 kg, whereas rice consumption decreased from 57.9 to 25.8 kg during the same period. While pearl millet and sorghum consumption have remained virtually constant; there seems to be a shift from rice to maize consumption. Maize is supplementing, but not replacing millet. Constraints on sorghum and millet supply cause maize imported from Nigeria to be used as a substitute for making the preferred products such as: *tô*, *boule*, *dambou* and *semoule* (PADER/PNUD 1994).

In Urban Niger, per capita cereal consumption decreases as household size increases. Per capita cereal consumption of cereals averages 258 kg for household sizes of 1 to 2 members and decreases to 191 kg for household size of more than 15 members. There are variations by type of cereals. Per capita millet consumption decreases from 160 kg for household sizes between 1 - 2 members to 93 kg for household sizes with more than 15 members. In contrast, maize consumption follows a different pattern. Maize is consumed less by households of 1-2 members, averaging 10 kg/ person /year and is consumed more by households of more than 15 members; 24 kg/person/year (PADER/PNUD 1994).



Per capita cereal consumption also varies according the employment of the head of household. Cadres, professors, liberales, and jobless individuals eat less than 190 kg/person/year (60% of millet and sorghum). Technicians, civil servants (personnel administratif), low skilled labor, etc eat on average 220 kg/person/year (52% of millet and sorghum). Whereas, retirees, small traders, farmers, livestock herders etc… consume on average 256 kg/person/year (87% of millet and sorghum).

Per capita cereal consumption also varies according to disposable income. Low income groups with less than 50,000 cfaf/annum/person of disposable income consume on average about 185 kg/person/year. This is less than large income groups with disposable income more than 150,000 kg/person/annum who consume about 200 kg/person/year. The highest cereal consumers are located in the middle income group with income ranging between 50,000 and 150,000 fcfa/person/annum, who consume about 230 kg/person/year. However, the share of millet and sorghum decreases with income. For the low income group, sorghum and millet account for 85% of total cereal consumed; higher than the middle income group (67%), and the large income group (47%). In contrast, maize consumption follows a reverse pattern. The low income group demands less maize (8.4 kg/year/person) than the high income group (32 kg/person/year). The same trend is recorded for rice.

In urban Niger, it was also found that per capita consumption varied according to the level of urbanization. In the capital city of Niamey, the largest urban town, the average consumption of cereal grain is estimated to be 180 kg/person/year. In the secondary urban towns, per capita consumption of cereals is estimated to be 228 kg. In the tertiary urban towns, per capita consumption is higher and estimated to be 244 kg/person/year.

Cereals are consumed more in rural than urban areas (282 kg/person/year against 217 kg/person/year in urban area). Millet and sorghum account for almost the entire cereal grain consumed by rural inhabitants. A survey of about 100 rural consumers in 4 villages located in the sahelian and sudanian zones of Niger from 1989-90 indicates that daily cereal consumption is about 200 kg/person/year of dehulled grains. This was found to be lower in villages located in the sudanian zone than in the sahelian zone, probably because of calorie supplements generated from tuber crops. The source of calories varied by zone, and according to accessibility to the main road and markets. Ninety-eight percent of total calorie needs were supplied by household production for those located in poor accessible areas with little access to markets. In villages endowed with markets and road infrastructure, more than one third of total cereals consumed were purchased from the markets. Ninety to 98% of total calorie up-take came from pearl millet (Hopkins and Reardon 1990).

## Demand for Coarse Grain and Processed Products

Few studies have specifically focused on factors determining the demand for coarse grains. Delgado and Readon (1991) investigated the determinants of the changing patterns of cereal use in West Africa and concluded that the pattern is demand driven. However, price and income did not explain the demand but rather, structural factors. Even short-run factors, such as harvest short fall or price dips, are not responsible for the changing patterns. The 1985 and 1986, bumper harvests of coarse grains in the Sahel, with the associated fall in grain prices, did not increase coarse grain consumption. Rather commercial imports of rice and wheat continue to rise.



Evidence from Mali, Senegal, and Burkina Faso (Table 11) show inelastic coarse grain own and cross-price demand elasticities. In Mali, a long-term rise of 1% in coarse grain price is associated with a 0.07% decrease in quantity demanded of coarse grains. Similarly, in Burkina Faso, a long-term rise of 1% in coarse grain price is associated with a 0.5% decrease in quantity demanded of coarse grains. Cross-price elasticities show virtually no impact of wheat and rice price on coarse grain consumption. For example, a long-term rise of 1% in wheat price in Mali is associated with a 0.01% increase in quantity demanded of coarse grains. Demand for coarse grains is also not responsive to income. A rise of 1% in income lead to a decrease of only 0.24% in coarse grain demand in Mali. The situation is, however, different for processed pearl millet and sorghum products. Micro-level evidence from Mali supports the contention that household structural and non-price factors are major determinants for the changing patterns of cereal consumption.

Sorghum and pearl millet grain is still cheaper than maize and rice (Table 12). Following currency devaluation in 1994, millet and sorghum became more competitive than maize. In Niger, maize is mainly imported from Nigeria. With currency devaluation, it became more expensive to import maize. However, this situation did not last long due to an exchange rate re-alignment between the Nigerian's Naira and the CFAF.

In contrast to grains, processed products should be more responsive to income. In Urban Mali, Boughton, et al. (1997) examined the determinants of household purchases of already processed millet, sorghum and maize, and found that the purchases of these processed products rise with the opportunity cost of women's time and household income. Processed millet and processed sorghum are similarly affected by the opportunity cost of women's time and household income.

As with grain, processed sorghum and millet are cheaper than rice, despite their high processing costs. Dibley *et al*. (1995) assessed the processing and preparation costs for rice and coarse grains in urban Mali to show that coarse grain dishes are still cheaper than rice based dishes. The main contributing factors to the higher cost of rice based dishes were the sauce, cereal and preparation costs. This result held through a wide range of rice and coarse grain prices and opportunity costs of time. The study should be applicable to urban Sahel, not just Bamako. Coarse grains need not take longer to process and prepare than rice dishes if the dehulling stage is mechanized. Pre-processed coarse grains are not competitive with household processing given present technology and the opportunity cost of women's time. Coarse grains will not be able to retain the extent of their cost advantage over rice as income and opportunity cost of labor rise without improvement in the efficiency of processing services.

This review suggests that sorghum and millet are still competitive compared to maize. Sorghum and millet grains are still cheaper than maize in the markets. Processed sorghum and millet products are still cheaper than maize and rice products. However, to remain competitive the demand for processed coarse grains must increase. In Mali, Boughton et al. (1997) concluded that to increase demand for processed coarse grains, it is necessary to: promote access to and use of abrasive-disk dehullers at the semi-whole sale level; promote improvements in the quality and cleanliness of the grains available to dehullers; institute grading by grain quality in the marketing system; and finally, increase consumer information

about possible savings realized on purchases of dehulled cereals, via, for example, the Malian Market Information System (SIM).

A demand enhancing strategy requires improving product attributes, such as enhanced nutritional qualities and greater convenience in the form of decreased processing time. Demand expansion also requires that questions of consumer acceptance and product characteristics that affect storage, processing, marketing and consumption be addressed. The end-markets of sorghum and pearl millet may be diversified by introducing use as stock-feed, industrial utilization for clear beer, opaque beer, composite flour and weaning foods. Sorghum and pearl millet demand expansion will be conditional on the availability of a well functioning marketing system, and credit facilities, as well as government policies that affect imports and the purchasing power of consumers.

# Market Organization

The cereals sector of most West African countries is characterized by: (i) dependence on imports; (ii) high variability of coarse grain prices; (iii) poor market organization.

## Grain Trade in the WASAT - Dependence on Imports

All countries are net importers of cereals, with rice and wheat accounting for more than 95% of cereal imports (Table 13). Most of the pearl millet and sorghum are still largely consumed in the area in which they are produced. Little pearl millet and sorghum enters the market. For example, in 1997, it was estimated that only about 8% of pearl millet grain produced enters the market in Niger (Ndjeunga 1998).

## Market Channels and Trading Volume

Overall, two broad types of grain marketing can be identified in West Africa. The long distance grain trade, which involves more than one country in the sub-region and is exemplified by trade in the Western sub-market (Senegal, Mali, Niger, Nigeria); and short distance trading, which is usually an internal grain marketing system. Grain trade is estimated to be roughly 15 to 20% of domestically produced coarse grains. The remaining trade is made up of imported rice and wheat flour. Short distance grain trading is usually an internal grain marketing system. The principal intermediaries for long distance trading are large-scale traders, wholesalers, and producers who sell along the border areas.

At the regional level, often countries that generate surplus grains are net exporters. In the Sahelian countries, Mali and Burkina Faso are potential grain exporters (Annex 4). Maize, millet and sorghum produced in Mali are exported to Mauritania, Senegal, Guinea and Niger by large-scale traders, and to Mauritania and Guinea by producers and wholesalers in the border towns (Debrah 1993). Apart from imported products (e.g. rice) from formal channels where data are well recorded, the trading volume of coarse grains between countries is not well known, due to the informal nature of trade. A survey of cross-border trade between Nigeria and Niger provides an illustration.



Niger is a net importer of cereal grains mainly from the border towns of Nigeria (Kano, Jibia and Maïduguri). In 1994/95, it was estimated that about 100,000 tons of cereal grains were imported from Nigeria, of which 85% was maize, 11% was millet, and 4% was sorghum. This figure could, however, double during the years following droughts. In 1993/94, it was estimated that 200,000 tons of cereal grain was imported from Nigeria. Nigeria has a significant role to play in ensuring food security in Niger. In effect, about one third of cereal domestically traded in Niger comes from Nigeria.

The cereal trade between Niger and Nigeria is led by a few large-scale traders and is organized around 4 networks (Kano-Jibia-Maradi-Niamey, Kano-Zinder-Agadez, Maiduguri-Damassak-Diffa, Jega-Argungu-Dosso). These networks are structured in a pyramidal fashion. At the top is the *Uban Guida* who is the decision-maker. The latter provides funds and bags to intermediaries (barwei and un bara) who purchase and collect grain in the local rural markets. After the grain is collected, it is distributed by intermediaries (Dilali), located in the deficit areas and towns. The latter dispatches to wholesalers and subsequently retailers. Most of this trade occurs during the months of October to February. Cereal is often traded in the form of grains.

In general, cereal grain traded in the markets is of low quality with mixed varieties and a large amount of impurities, and there is an inconsistency of grain supply. This situation can be partially explained by poor competition in the national and regional cereal grain markets. There is a high concentration of cereal trade among a few large-scale traders who exercise their monopsony power. This monopsony power results into low producer prices. This power is likely to be reinforced by the need for heavy initial capitalization to enter the large trade market. This type of market organization offers little incentive for farmers to produce and for traders to improve quality. Therefore, there is a need to establish or foster better market organizations which will allow farmers to appropriate large part of producer gains while keeping good quality (e.g marketing cooperatives).

## Prices - High Variability of Coarse Grain Prices

The cereal sector is characterized by high inter- and intra-annual price variability. In general, prices are low at harvest and progressively increase prior to the planting season. In Niger for example, from October to May prices are generally low, and significantly increase during the period June to September. Moreover, prices are high during the years following drought. For example, following the drought of 1994, prices shot up. Figure 1 provides an illustration of inter- and intra-annual price variability for the years 1990-1996 in one of the largest pearl millet markets: Katako in Niger. The within-year coefficient of variation ranges from 6 to 16%. Due to high price variability and poor storage technologies, grain supply may be unreliable. High price variability may discourage grain producers, as well as investors from entering the food processing industry. Contractual schemes that could reduce this variation are likely to motivate producers, small- or medium-scale food processors. Current contractual schemes such as those occurring in the cotton or groundnut should be reviewed and lessons learned could be extended to cereal trade.



## Poor Market Organization

Sorghum and millet still remain subsistence crops and little grain enters the markets. There is no linkage between the input and output markets. Lessons learned from groundnut or cotton in many West African countries show that better contractual arrangements between grain producers and grain users may stimulate the grain supply. For example, in Senegal, groundnut production is supported by inter-linked contracts between farmers, i.e. groundnut grain producers and users: the largest oil refinery: and the parastatal company: SONACOS. Farmers are provided with seed and fertilizers on credit to produce groundnuts, which are purchased by SONACOS. At harvest, credit is deducted from grain sales. The same experience is recorded in Burkina Faso for groundnut production and for cotton in Mali. In contrast, in Niger, where groundnut is also produced, there are currently no incentives for farmers to supply grain. In the early 1990s, two refineries closed down and groundnut production dropped significantly.

## Technological and Information Constraints on Processing

*Raw material*: More than 33 pearl millet and 32 sorghum varieties have been developed and released by national agricultural research systems and international Agricultural Research Centers in the WASAT. However, very few of these varieties have reached the small-scale farmers. Inconsistent variety release policies, the poor supply of breeder seed, poor demand estimation and distribution systems and poor seed quality have constrained the supply, access, adoption, and demand for improved varieties by end-users. Unsuitability of varieties, poor linkages and institutional building as well as lack of seed laws have been hypothesized to be secondary constraints (Ndjeunga 1997). While governments should develop appropriate schemes to disseminate and enhance the adoption of these varieties; knowledge of the chemical and physical characteristics of those varieties is still limited. The suitability of varieties for making some preferred products are still less well known. Little research has been conducted on the suitability of some varieties for small- to medium-scale industrial processing. Overall, the raw material is not yet well characterized.

*Equipment:* Food processing is still done manually with traditional methods in West Africa. All the necessary steps to processing such as: cleaning, destoning, grading, threshing, thieving, dehulling, milling, and agglomeration are performed manually. A survey on food processing equipment in West Africa indicates that a variety of equipment is available, but not adapted to pearl millet and sorghum. There is therefore a need to adapt this equipment to sorghum and pearl millet processing (ROCAFREMI 1998). The WCAMRN has already made significant progress in adapting threshers, and developing destoners and dehulling disks. However, a lot remains to be done in optimizing the already adapted equipment or developing other adapted to pearl millet and sorghum.



# Product

A number of processed products are available in the urban markets. Very little is known on the demand for those processed products or the determinants of the demand for processed products. Consumers' preference for these products are also poorly understood.

# Conclusion

There are some prospects for a pearl millet and sorghum food processing industry in the WASAT. However, a number of constraints of constraints limit investments in the food processing industry. These constraints can be grouped into four broad categories: (1) the inputs, the grain; (2) the output, the processed products; (3) the processing technology; and the (4) the market.

A research agenda concerning these constraints follows:

***Inputs***

- Laboratory chemical and physical characterization of pearl millet and sorghum varieties for making the basic food products. This characterization should also involve their appropriateness through threshing, dehulling and milling. Economic evaluation of pearl millet and sorghum traits for making some preferred food products should be undertaken.
- Foster the adoption of appropriate technologies (e.g. improved varieties combined with soil restoration technologies and water conservation methods) that will increase the supply of grains through on-farm participatory methods.
- Improve information access to technologies by extension services, NGO, CBO, to food processors.
- Better understanding of the determinants of households' investments and consumption decisions
- Better understanding of the structure, conduct and performance of sorghum and pearl millet national and inter-regional trade

***Processing technologies***

- Develop or adapt proper equipment that should reduce the unit processing costs for threshing, dehulling and milling compared to current traditional practices
- Conduct feasibility studies on current traditional or improved processing technologies

***Output***

- Surveys on processed products likely to be preferred by consumers
- Feasibility and market tests on new products

***Markets***

Current pearl millet and sorghum markets are characterized by high price variability and inconsistent supply of high quality grain.

- Examine current formal contractual schemes between buyers and producers in the sub-region (e.g. on cotton and groundnut) and informal contractual schemes (forward contracts) in the sub-region in order to draw lessons useful for sorghum and millet.



- Identify contractual means to reduce the variability of output prices and ensure consistent supply of high quality grains in the market.
- Improve the information flow between processors and consumers of pearl millet and sorghum.
- Examine the socio-economic, institutional and policy constraints faced by current food processors.

# References

**Baidu-Forson, J. and O. Ajayi.** 1995. Industrial Utilization of Sorghum in Nigeria: Implication of Evidence and Distributive Impacts for Research. Pages 7-18 *in* Regional Workshop on Processing and industrial utilization of Sorghum and related cereals in Africa (Menyonga, et al., eds). The Coordination Office OAU/STRC-SAFGRAD Semi-Arid Food Grain Reseach and Development. Ouagadougou, Burkina Faso.

**Bationo, A., F. Lompo, and S. Koala.** 1998. Research on nutrient flows and balances in West Africa: state of the art. Forthcoming Agriculture, Ecosystems and Environments 1350 1998: 1-18

**Boughton, D. and T. Reardon.** 1997. Will Promotion of Coarse Grain Processing Turn the Tide for Traditional Cereals in The Sahel ?. Recent Empirical Evidence from Mali. Food Policy, 224:307-316.

**Boughton, D., T. Readon, and J. Wooldridge.** 1996. Determinants of Diversification of Urban Sahel Diets into Maize: A Contingent Valuation Study of Processed Maize Demand in Mali. Paper selected for Presentation at the August 1997 Meetings of the International Association of Agricultural Economists, Sacramento, California.

**Byth, D.E. (ed.).** 1993. Sorghum and Millets commodities and research environments. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 124 pp. ISBN 92-9066-272-7. Order Code: BOE 021.

**CBTRN/IAR/ABU & SIM/OPVN.** 1997. Recent Developments in the Cross-Border Grain Trade Between Niger and Nigeria. OPVN and Department of Agricultural Economics & Rural sociology. Ahmadu Bello University, Zaria, Nigeria.

**Debrah, S.K.** 1993. Sorghum in Western Africa. Pages 17-37 *in* Sorghum and millets commodity and research environments. Patancheru, A.P. 502 324, India: International Crop Research Institute for the Semi-Arid Tropics. 124 pp. ISBN 92-9066-272-7. Order code; BOE 021.

**Debrah, S.K.** 1993. The competitiveness of sorghum and millet in the food system of West Africa *in* Sorghum and Millet Marketing and Utilization in Tanzania. SADC/ICRISAT. National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development. Sponsored by the International Development Research Center. Arusha International Conference Center, 3-5 May 1993.

**Dibley, D., D.Boughton, and T. Reardon.** 1995. Processing and Preparation Costs for Rice and Coarse Grains in Urban Mali: Subjecting an Ipse Dixit to Empirical Scrutiny. Food Policy, Vol. 20, No 1:41-50.

**Fusillier, J.L.** 1994. Afrique de l'Ouest et du Centre: maïs ou sorgho ? Afrique et Developpement. 2:20-27.

**Gomez, M.I., L.R. House, L.W. Rooney, and D.A.V. Dendy. (eds.).** 1992. Utilization of Sorghum and Millets. In En. Summaries in Fr, Pt. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 224 pp. ISBN 92-9066-160-7.

**Hopkins, J. and T. Reardon.** 1991. Agricultural Product Trasactions in the Soudano-sahelian and sudano-guinean zones of Western Niger: Preliminary Results for September 1989- August 1990. IFPRI/INRAN Project document.

**Hopkins, J. and T. Reardon.** 1990. Consommation des cereales et des legumineuses par les menages ruraux dans les zones sahehliennes et soudaniennes de l'Ouest du Niger 1988-89: Resultats Preliminaires. Quatrieme document presente a l'USAID/Niger, Septembre 1990. Institut International de Recherches sur les Politiques Alimentaires IFPRI.

**ICRISAT.** 1982. Proceedings of the International Symposium on Sorghum Grain Quality, 28-31 October 1981, Patancheru, India. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

**ICRISAT.** 1987. Proceedings of the International Pearl Millet Workshop, 7-11 April 1986, ICRISAT Center, India. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

**ICRISAT.** 1990. Industrial utilization of Sorghum: summary proceedings of a symposium on the Current status and Potential of Industrial Uses of Sorghum in Nigeria, 4-6 Dec 1989, Kano, Nigeria. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

**ICRISAT/FAO.** 1996. The world sorghum and millet economies. Facts, trends and outlook. Patancheru 502 324, Andhra Pradesh, India: ICRISAT; Rome, Italy: FAO.

**Kumar, A.K.** 1993. Pearl Millet in Western Africa.. Sorghum and millets commodity and research environments. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 124 pp. ISBN 92-9066-272-7. Order code BOE 021.

**Matlon, P.J.** 1987. Prospects for Improving Productivity in Sorghum and Pearl Millet Systems in West Africa. Paper prepared for the Conference on the Dynamics of Cereal Consumption and Production Patterns in West Africa, July 15-17 1987, Dakar, Senegal.

**Matlon, P.J.** 1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. Food Research Institute Studies 121:1-44.

**Menyonga, J.M., T. Bezuneh, C.C. Nwasike, P.M. Sedogo, and A. Tenkouano.** 1995. Processing and industrial utilization of Sorghum and related cereals in Africa. The Coordination Office OAU/STRC-SAFGRAD Semi-Arid Food Grain Reseach and Development. Ouagadougou, Burkina Faso.



**Murty, D.S. and K.A.Kumar.** 1995. Traditional Uses of Sorghum and Millets *in* Sorghum and Millets. Chemistry and Technology. American Association of Cereal Chemists, Inc. St. Paul, Minnesota, USA.

**Ndjeunga, J.** 1997. Constraints to variety release, seed multiplication and distribution of sorghum, pearl millet and groundnut in Western and Central Africa. Pages 34-46 *in* Alternatives strategies for smallholder and seed supply proceedings of an International Conference on Options for Strengthening national and Regional Seed Systems in Africa and West Asia, 10-14 Mar 1997, Harare, Zimbabwe. Patancheru 502 324, Andhra Pradesh, India: ICRISAT.

**Ndjeunga, J. and A. Bationo.** 1998. Stochastic dominance analysis of soil restoration options in South-west Niger. Unpublished. ICRISAT.

**OPVN/SIM.** 1998. Annuaire des Prix des Cereales et du Niebe. Office des Produits Vivriers du Niger avec la collaboration du DIAPER III/CILSS. Systeme d'Information sur les Marchés.

**PADER/PNUD.** 1994.Enquete sur le Budget et la Consommation des menages au Niger "Phase Urbaine' 1989-1990. Volet B: Alimentation et Etat Nutritionnel de la Population. Direction de la Statistique et des Comptes Nationaux et Programme des Nations Unies pour le Developpement. Ministere des Finances et du Plan. Republique du Niger. November 1994.

**Reardon, T.** 1993. Cereal demand in the Sahel and potential impacts of regional cereals protection. World Development 21:17-35.

**ROCAFREMI/WCAMRN.** 1997. Enquête sur les besoins des produits traditionnels et de creation de nouveaux produits.

**ROCAFREMI/WCAMRN.** 1997. Rapport du Monitoring Tour: Projet P5. Promotion du Mil par l'Amelioration des Technologies de Transformation. 09-25 Août 1997.

**ROCAFREMI.** 1998. Typologie des equipements de transformation au Mali, Burkina-Faso, Niger, Nigeria and Senegal. Institut de Technologie Alimentaire ITA. Avril 1998.

**Rohrbach, D.D. and I.J. Minde. eds.** 1993. Sorghum and Millet Marketing and Utilization in Tanzania. SADC/ICRISAT. National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development. Sponsored by the International Development Research Center. Arusha International Conference Center. 3-5 May 1993.

**Rohrbach, D.D. and K. Mutiro.** 1998. Sorghum and Pearl Millet Production, Trade and Consumption in Southern Africa. Forthcoming. SPIM Conference Proceedings.

**Sherman, J.R., K.H. Shapiro, and E. Gilbert.** 1987. La Dynamique de la Commercialisation des Céréales au Burkina Faso. Tome 1. Analyse Economique de la Commercialisation des Céréales. Rapport Final. Elabore par le Centre de Recherche sur le Developpement Economique. Universite du Michigan et International Agricultural Programs. Université du Wisconsin pour l'Agence des Etats-Unis pour le Développement International USAID.



**Sivakumar, M.V.K.** 1992. Climate changes and Implications for Agriculture in Niger. Climate change 20:297-312.

**WCASRN.** 1998. Good Recipes from Sorghum. West and Central Sorghum Research Network in collaboration with the Food Technology Laboratory of the Rurale Economy Institute of Mali.

**World Bank.** 1997. The State in Changing World. World Development Report.

**Table 1. Major characteristics of the principal agro-ecological zones of the WASAT.**

| Agro-climatic zone | Annual rainfall (mm) | Countries (% total area) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Predominantly semi-arid zone | | | | | Predominantly forest zone | | | | |
| | | Burkina Faso | Mali | Niger | Senegal | Ghana | Cote díIvoire | Togo | Nigeria | Total (%) | Cultivable land (%) |
| Sahelian | <350 | 0 | 66 | 79 | 7 | 0 | 0 | 0 | 1 | 40 | 29 |
| Sahelo-sudanian | 350-600 | 14 | 12 | 19 | 33 | 0 | 0 | 0 | 9 | 12 | 30 |
| Sudanian | 600-800 | 26 | 8 | 2 | 22 | 0 | 0 | 0 | 13 | 8 | 37 |
| Sudano-guinean | 800-1100 | 48 | 8 | 0 | 20 | 17 | 0 | 12 | 22 | 12 | 42 |
| Guinean | 1100-more | 12 | 7 | 0 | 17 | 83 | 100 | 88 | 56 | 28 | n.a. |
| Total area ($000 km^2$) | | 274 | 1240 | 1267 | 197 | 239 | 322 | 57 | 924 | 4520 | |
| % semi-arid | | 88 | 93 | 100 | 83 | 17 | 0 | 12 | 44 | 72 | |

Source: Adapted from Matlon 1990 and ICRISAT GIS - Niamey, NIGER 1998.

**Table 2. West Africa: Sorghum, pearl millet, maize and rice production, 000 tons (1981-83 and 1995-97 averages).**

| | Area planted (000 ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sorghum | | Pearl millet | | Maize | | Rice | |
| Country | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 |
| Burkina Faso | 626 | 1154 | 425 | 716 | 100 | 291 | 43 | 90 |
| Mali | 452 | 686 | 573 | 773 | 84 | 275 | 168 | 501 |
| Niger | 345 | 375 | 1306 | 1771 | 8.27 | 5.76 | 42 | 69 |
| Senegal | 123 | 126 | 518 | 565 | 77 | 85 | 118 | 195 |
| Sahel countries | *1546* | *2341* | *2822* | *3825* | *269.27* | *656.76* | *371* | *855* |
| Cote díIvoire | 18 | 21 | 29 | 61 | 413 | 569 | 400 | 929 |
| Ghana | 121 | 343 | 118 | 183 | 299 | 1045 | 58 | 215 |
| Togo | 81 | 160 | 48 | 55 | 149 | 378 | 14 | 41 |
| Forest - Nigeria | *220* | *524* | *195* | *299* | *861* | *1992* | *472* | *1185* |
| Nigeria | 3589 | 6855 | 2710 | 5512 | 838 | 6023 | 1257 | 3103 |
| Forest countries | *3809* | *7379* | *2905* | *5811* | *1699* | *8015* | *1729* | *4288* |
| West Africa | 5356 | 9721 | 5728 | 9635 | 1968 | 8670 | 2098 | 5107 |

**Table 3. West Africa: Sorghum, pearl millet, maize and rice production, 000 tons.**

| | Total cereal production (000 t.) | | % per crop within country | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sorghum | | Pearl Millet | | Maize | | Rice | |
| Country | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 |
| Burkina Faso | 1200 | 2265 | 52 | 51 | 35 | 32 | 8 | 13 | 4 | 4 |
| Mali | 1320 | 2257 | 34.3 | 30.3 | 43.8 | 34.3 | 6.2 | 12.2 | 12.6 | 22.3 |
| Niger | 1705 | 2227 | 20.2 | 16.8 | 76.6 | 79.7 | 0.5 | 0.3 | 2.4 | 3.1 |
| Senegal | 838 | 939 | 14.2 | 13.6 | 60.6 | 59.7 | 9.7 | 8.9 | 15.5 | 17.4 |
| Sahel countries | 5063 | 7688 | 30.4 | 30.4 | 55.5 | 49.9 | 5.3 | 8.6 | 7.6 | 10.7 |
| Cote díIvoire | 867 | 1593 | 2.1 | 1.3 | 3.4 | 3.8 | 47.8 | 35.8 | 46.1 | 58.2 |
| Ghana | 595 | 1786 | 20.9 | 19.2 | 20.6 | 10.2 | 49 | 58.5 | 9.5 | 12 |
| Togo | 297 | 640 | 27.3 | 25.5 | 16.1 | 8.6 | 50.2 | 58.4 | 4.6 | 6.5 |
| Forest - Nigeria | 1759 | 4019 | 12.7 | 13.1 | 11.4 | 7.4 | 48.6 | 49.5 | 26.7 | 29.4 |
| Nigeria | 8306 | 21601 | 43.2 | 31.7 | 32.6 | 25.5 | 10.1 | 27.9 | 15.1 | 14.4 |
| Forest countries | 10065 | 25620 | 37.9 | 28.8 | 28.9 | 22.7 | 16.8 | 31.3 | 17.1 | 16.8 |
| West Africa | 15127 | 33607 | 35.0 | 29.2 | 37.9 | 28.9 | 13.0 | 15.3 | 13.9 | 26.0 |

**Table 4. West Africa: Growth in total production to crops.**

| | Growth rate in total production (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sorghum | | Pearl millet | | Maize | | Rice | |
| Country | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 |
| Burkina Faso | 1.71 | 4.00 | 3.63 | 3.11 | 4.62 | 8.78 | 2.08 | 7.30 |
| Mali | 3.77 | 4.92 | 2.87 | 2.45 | 1.59 | 6.25 | 0.99 | 9.76 |
| Niger | 5.85 | 1.60 | 5.21 | 4.61 | 12.93 | -4.69 | 1.77 | 1.56 |
| Senegal | 0.97 | -0.21 | 0.79 | 0.06 | 7.81 | -2.74 | 3.69 | 1.50 |
| Cote díIvoire | 1.98 | 0.17 | 0.69 | 3.75 | 5.06 | 1.76 | 1.24 | 5.23 |
| Ghana | -3.21 | 7.67 | -0.76 | 3.03 | -4.40 | 4.92 | -1.25 | 10.22 |
| Nigeria | 0.82 | 3.01 | -2.06 | 3.42 | -1.59 | 9.29 | 10.92 | 6.90 |
| Togo | - | 2.52 | -11.95 | -2.60 | 1.13 | 6.83 | -1.77 | 7.31 |
| West Africa | 1.48 | 3.27 | -0.20 | 3.19 | 0.00 | 7.20 | 5.84 | 6.58 |

**Table 5. West Africa: Sorghum, pearl millet, maize and rice area (000 ha) and proportion to West Africa cultivated area to the crops (1981-83 and 1995-97 averages).**

| | Total cereal grain area (000 ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sorghum | | Pearl millet | | Maize | | Rice | |
| Country | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 |
| Burkina Faso | 1073 | 1522 | 920 | 1202 | 134 | 204 | 29 | 49 |
| Mali | 534 | 795 | 776 | 1196 | 81 | 208 | 162 | 302 |
| Niger | 1075 | 1978 | 3086 | 5210 | 12 | 5 | 21 | 30 |
| Senegal | 113 | 147 | 871 | 895 | 76 | 81 | 65 | 74 |
| Sahel countries | 2795 | 4442 | 5653 | 8503 | 303 | 498 | 277 | 455 |
| Cote díIvoire | 33.7 | 54 | 56 | 91 | 520 | 692 | 357 | 650 |
| Ghana | 213 | 322 | 168 | 193 | 382 | 671 | 72 | 105 |
| Togo | 103 | 218 | 67 | 107 | 181 | 391 | 23 | 47 |
| Forest - Nigeria | 349.7 | 594 | 291 | 391 | 1083 | 1754 | 452 | 802 |
| Nigeria | 2215 | 6188 | 1726 | 5293 | 684 | 4648 | 610 | 1876 |
| Forest countries | 2564.7 | 6782 | 2017 | 5684 | 1767 | 6402 | 1062 | 2678 |
| West Africa | 5385 | 11224 | 7670 | 14186 | 2070 | 6900 | 1338 | 3132 |

**Table 6. West Africa: Sorghum, pearl millet, maize and rice area (000 ha) and proportion to the total cereal grain area (%) (1981-83 and 1995-97 averages)**

| | % per crop within country | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total cereal grain area (000 ha) | | Sorghum | | Pearl Millet | | Maize | | Rice | |
| Country | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 |
| Burkina Faso | 2167 | 2998 | 49.5 | 50.8 | 42.4 | 40.1 | 6.2 | 6.8 | 1.3 | 1.6 |
| Mali | 1608 | 2538 | 33.2 | 30.9 | 48.3 | 47.1 | 5 | 8.3 | 10 | 12.3 |
| Niger | 4201 | 7226 | 25.6 | 27.4 | 73.5 | 72.1 | 0.3 | 0.1 | 0.5 | 0.4 |
| Senegal | 1130 | 1203 | 9.8 | 12.3 | 77.1 | 74.3 | 6.8 | 6.7 | 5.7 | 6.1 |
| Sahel countries | 9106 | 13965 | 30.7 | 31.8 | 62.1 | 60.9 | 3.3 | 3.6 | 3.0 | 3.3 |
| Cote díIvoire | 976 | 1506 | 3.5 | 3.6 | 5.8 | 0.6 | 53.2 | 55.9 | 36.5 | 43.2 |
| Ghana | 833 | 1291 | 25.4 | 24.9 | 20.2 | 15 | 45.8 | 52 | 8.7 | 8.1 |
| Togo | 371 | 771 | 26.9 | 28.3 | 17.5 | 13.9 | 47.7 | 50.8 | 6 | 6 |
| Forest - Nigeria | 2180 | 3568 | 15.9 | 16.6 | 13.3 | 8.7 | 49.4 | 53.4 | 20.7 | 22.5 |
| Nigeria | 5279 | 18139 | 42.1 | 34.1 | 32.8 | 29.2 | 12.7 | 25.6 | 11.6 | 10.3 |
| Forest countries | 7459 | 21707 | 34.4 | 31.2 | 27.1 | 25.8 | 23.4 | 30.2 | 14.3 | 12.3 |
| West Africa | 16576 | 35572 | 32.3 | 31.5 | 46.3 | 39.8 | 12.4 | 19.3 | 8.1 | 8.8 |

**Table 7. West Africa: Growth in total area planted to crops by country.**

| | Crop area Growth | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sorghum | | Pearl millet | | Maize | | Rice | |
| Country | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 |
| Burkina Faso | -0.1 | 2.93 | 1.17 | 2.19 | 3.33 | 2.9 | -3.30 | 6.38 |
| Mali | 2.71 | 5.92 | 2.53 | 3.02 | -2.05 | 6.83 | -1.24 | 5.09 |
| Niger | 6.36 | 5.55 | 3.96 | 4.97 | 11.54 | -12.57 | 2.37 | 3.04 |
| Senegal | -1.25 | 0.63 | -0.36 | -0.65 | 6.20 | -1.15 | -1.0 | 0.27 |
| Cote díIvoire | 1.02 | 3.71 | -0.33 | 3.07 | 4.45 | 1.41 | 2.33 | 3.09 |
| Ghana | -0.14 | 3.58 | -2.16 | -0.44 | -0.54 | 1.32 | 0.71 | 3.73 |
| Nigeria | -7.02 | 3.75 | -9.86 | 5.98 | -6.24 | 9.24 | 7.94 | 9.31 |
| Togo | - | 2.87 | -9.35 | 2.80 | 4.34 | 5.48 | 4.09 | 7.39 |
| West Africa | -2.70 | 3.98 | -2.22 | 4.20 | -1.01 | 6.24 | 3.43 | 6.61 |

**Table 8. Average grain yields (kg/ha) for sorghum, millet, maize and rice (1981-83 and 1995-97) averages).**

| | Sorghum | | Pearl millet | | Maize | | Rice | |
|---|---|---|---|---|---|---|---|---|
| Country | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 | 1981-83 | 1995-97 |
| Burkina Faso | 583 | 755 | 462 | 595 | 739 | 1416 | 1567 | 1856 |
| Mali | 847 | 882 | 741 | 660 | 1006 | 1338 | 1052 | 1649 |
| Niger | 322 | 189 | 423 | 340 | 663 | 1106 | 1979 | 2291 |
| Senegal | 1042 | 856 | 572 | 629 | 1017 | 1045 | 1843 | 2164 |
| Cote díIvoire | 538 | 393 | 521 | 666 | 796 | 823 | 1127 | 1429 |
| Ghana | 576 | 1066 | 702 | 942 | 791 | 1557 | 809 | 2052 |
| Nigeria | 1620 | 1107 | 1570 | 1040 | 1331 | 1296 | 2061 | 1657 |
| Togo | 807 | 742 | 796 | 520 | 840 | 955 | 613 | 892 |
| West Africa | 1000 | 866 | 747 | 679 | 972 | 1257 | 1568 | 1631 |

**Table 9. Growth rates in yields for the periods 1970-1983 and 1984-97.**

| | Sorghum | | Pearl millet | | Maize | | Rice | |
|---|---|---|---|---|---|---|---|---|
| Country | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 | 1970-83 | 1984-97 |
| Burkina Faso | 1.81 | 1.07 | 2.46 | 0.92 | 1.29 | 5.88 | 5.38 | 0.92 |
| Mali | 1.06 | -1.0 | 0.34 | -0.57 | 3.64 | -0.58 | 2.23 | 4.67 |
| Niger | -0.51 | -3.95 | 1.25 | -0.35 | 1.39 | 7.98 | -0.60 | -1.48 |
| Senegal | 2.22 | -0.84 | 1.15 | 0.71 | 1.61 | -1.59 | 4.69 | 1.23 |
| Cote díIvoire | 0.96 | -3.54 | 1.02 | 0.68 | 0.91 | 0.35 | -1.09 | 2.14 |
| Ghana | -3.07 | 4.09 | 1.40 | 3.47 | -3.86 | 3.60 | -1.96 | 6.49 |
| Nigeria | 7.84 | -0.74 | 7.80 | -2.56 | 4.65 | 0.05 | 2.98 | -2.41 |
| Togo | - | -0.35 | -2.60 | -5.40 | -3.21 | 1.35 | -5.86 | -0.08 |
| West Africa | 4.18 | -0.71 | 2.42 | -1.00 | 1.01 | 0.96 | 2.41 | -0.03 |

**Table 10. Per capita cereal consumption (kg) and proportion to total cereal grains (%).**

| | Per capita Cereal consumption | | Proportion | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Percent sorghum | | Percent pearl millet | | Percent maize | | Percent rice | | Percent wheat | |
| Country | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 |
| Burkina Faso | 175 | 241 | 50.0 | 49.6 | 33.5 | 31.3 | 8.3 | 11.3 | 5.7 | 5.8 | 2.2 | 1.5 |
| Mali | 202 | 221 | 30.8 | 31.8 | 39.3 | 33.3 | 8.1 | 12.0 | 14.9 | 20.2 | 4.0 | 1.9 |
| Niger | 306 | 264 | 20.0 | 15.2 | 72.0 | 76.9 | 0.9 | 0.3 | 4.3 | 4.5 | 2.6 | 3.0 |
| Senegal | 229 | 200 | 11.6 | 8.1 | 37.0 | 36.4 | 6.3 | 7.1 | 35.6 | 36.0 | 9.4 | 12.3 |
| Cote díIvoire | 162 | 157 | 1.3 | 1.1 | 2.0 | 2.7 | 29.4 | 25.6 | 52.9 | 59.4 | 13.9 | 10.6 |
| Ghana | 68 | 119 | 18.1 | 16.9 | 15.2 | 9.1 | 45.0 | 48.4 | 10.7 | 17.7 | 11.0 | 6.9 |
| Nigeria | 135 | 198 | 34.1 | 29.3 | 26.6 | 23.5 | 10.3 | 29.7 | 17.9 | 14.2 | 11.2 | 3.3 |
| Togo | 131 | 157 | 22.7 | 22.8 | 13.2 | 8.6 | 41.4 | 53.6 | 9.4 | 9.0 | 11.8 | 5.1 |
| West Africa | 149 | 193 | 29.1 | 26.4 | 30.7 | 26.4 | 12.3 | 25.5 | 19.6 | 17.2 | 9.3 | 4.2 |

**Table 11. Demand elasticities for grain from aggregate data in three sahelian countries 1966-86**

| | Countries | | |
|---|---|---|---|
| | Mali | Senegal | Burkina Faso |
| % change in sorghum/millet/maize demand with respect to a 1% change in: | | | |
| Own price | -0.07 | -0.11 | -0.50 |
| Wheat price | 0.05 | -0.03 | 0.02[3] |
| Rice price | 0.24 | 0.13[3] | 0.05 |
| Income | -0.28[3] | -0.24 | 1.13[3] |
| Rice demand | | | |
| Own price | -1.50[3] | -0.66 | -0.96 |
| Wheat price | -0.08[3] | 0.01 | -0.39 |
| Sorghum/millet/ maize price | 0.75 | 0.13[3] | 0.48[3] |
| Income | 0.91 | -0.17 | 1.71 |
| Wheat demand | | | |
| Own price | -0.20 | 0.36 | -0.51 |
| Wheat price | -0.26[3] | 0.02[3] | -0.06 |
| Sorghum/millet/ maize price | 0.47 | -0.06 | 0.32 |
| Income | 2.44 | 0.51 | 0.73[3] |

1. Cell values are compensated demand elasticities: a 1% in the variable in the left hand column is associated with the % change in demand indicated in the corresponding row, estimated by separate complete demand systems regressions by country, 21 years of annual data with source detailed in Delgado 1989. The Almost-Ideal Demand Systems (AIDS) was used and homogeneity and symmetry were imposed.
2. Burkina Faso estimated are for millet and sorghum only
3. Not statistically significant at 10%



**Table 12. Relative prices of pearl millet and sorghum over maize price in three large selected cereal markets in Niger.**

| | Departments | | | | | |
|---|---|---|---|---|---|---|
| | Maradi | | Katako/Niamey | | Zinder | |
| Year | Sorghum/ maize | Pearl millet/ maize | Sorghum/ maize | Pearl millet/ maize | Sorghum/ maize | Pearl millet/ maize |
| 1990 | 0.93 | 0.96 | 1.00 | 1.01 | 0.76 | 0.89 |
| 1991 | 0.82 | 0.87 | 0.99 | 0.97 | 0.81 | 0.89 |
| 1992 | 0.84 | 0.84 | 1.01 | 0.98 | 0.63 | 0.76 |
| 1993 | 0.98 | 0.94 | 1.03 | 1.03 | 0.79 | 0.93 |
| 1994[1] | 0.95 | 0.96 | 0.99 | 1.07 | 0.84 | 0.98 |
| 1995 | 0.64 | 0.65 | 0.81 | 0.76 | 0.68 | 0.72 |
| 1996 | 0.89 | 0.85 | 0.95 | 0.94 | 0.86 | 0.92 |
| 1997 | 0.83 | 0.86 | 0.98 | 0.95 | 0.82 | 0.91 |

[1] Year of currency devaluation.
Source: OPVN/SIM 1998.



**Table 13. West Africa: net imports of alternative cereal grains, averages during the three periods (000 tons)**

| | Sorghum | | Pearl millet | | Rice | | Maize | | Wheat | | Total cereal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 | 1981-83 | 1994-96 |
| Burkina Faso | 7.14 | -1.47 | 0.00 | -0.52 | 28.72 | 66.47 | 5.61 | 0.00 | 27.49 | 36.68 | 68.92 | 101.09 |
| Mali | 0.00 | 1.67 | 0.03 | -20.00 | 53.96 | 26.43 | 36.13 | 1.00 | 58.13 | 41.93 | 148.47 | 51.03 |
| Niger | 20.80 | 9.52 | 9.02 | 0.00 | 36.80 | 40.00 | 9.06 | 3.27 | 45.55 | 67.52 | 122.30 | 121.31 |
| Senegal | 32.67 | 5.83 | -1.94 | 0.00 | 342.10 | 443.60 | 6.21 | 16.71 | 120.98 | 203.74 | 500.02 | 669.59 |
| Cote díIvoire | 0.83 | 0.00 | -0.10 | 0.99 | 358.09 | 317.64 | 8.02 | -0.15 | 199.40 | 226.97 | 566.33 | 545.78 |
| Ghana | 20.00 | 1.48 | 0.00 | -0.07 | 27.02 | 171.81 | 58.17 | 1.05 | 82.80 | 141.91 | 187.98 | 337.17 |
| Nigeria | 8.86 | -20.00 | 10.0 | 0.00 | 579.92 | 316.67 | 212.28 | 5.33 | 1129.26 | 699.81 | 1947.07 | 999.97 |
| Togo | 1.05 | 0.00 | 0.00 | 0.03 | 20.63 | 1.74 | 1.35 | 2.30 | 42.93 | 32.46 | 65.96 | 52.52 |
| West Africa | 91.36 | -19.57 | 17.19 | -2.98 | 1447.23 | 1400.35 | 341.83 | 24.19 | 1705.5 | 1451.0 | 3670.5 | 2878.46 |

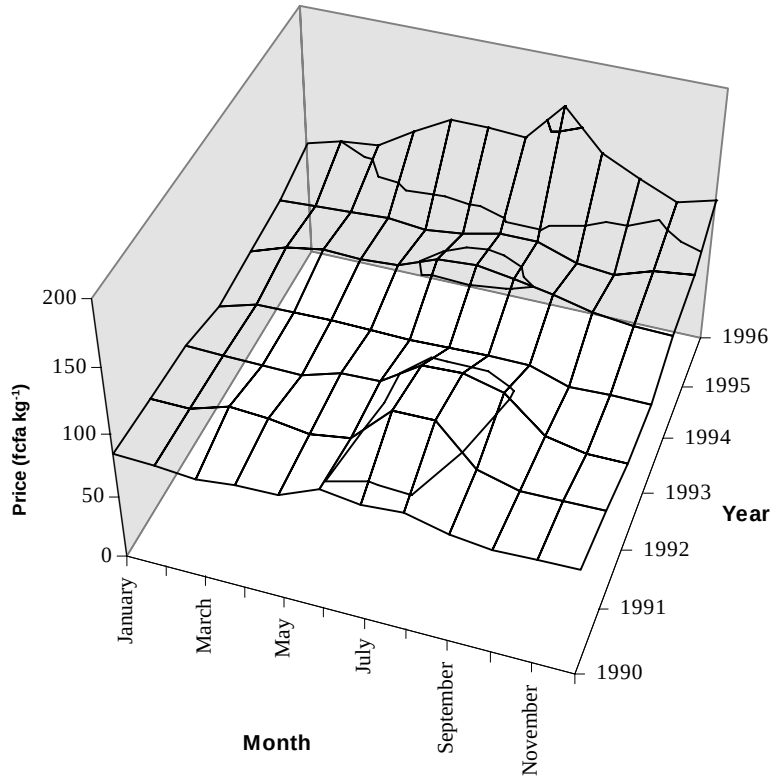


**Figure 1. Inter- and intra-annual trends in nominal pearl millet consumer prices in one of the largest cereal market, Katako, Niamey, Niger.**

**Annex 1. Basic and macro-economic indicators in 8 West African countries.**

| Indicators | Countries | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | With a high predominant Sahel Zone | | | | With a high predominant Forest zone | | | |
| | Burkina Faso | Mali | Niger | Senegal | Nigeria | Ghana | Cote díIvoire | Togo |
| Surface area (000 km$^2$) | 274 | 1240 | 1267 | 197 | 924 | 239 | 322 | 57 |
| Arable land (000 km$^2$) | 33.90 | 46.06 | 49.94 | 22.45 | 303.71 | 28.00 | 29.00 | 20.70 |
| Population (mil. Inhabitants -1995) | 10.4 | 9.8 | 9.0 | 8.5 | 111.3 | 17.1 | 14.4 | 4.1 |
| Population growth rate (1990-95) | 2.8 | 2.9 | 3.3 | 2.7 | 2.9 | 2.8 | 3.1 | 3.0 |
| GNP per capita (1995 dollars) | 230 | 250 | 220 | 600 | 260 | 390 | 660 | 310 |
| Average annual growth rate GDP 1990-1995 (%) | 2.6 | 2.5 | 0.5 | 1.9 | 1.6 | 4.3 | 0.7 | -3.4 |
| Trade as a percent GDP in 1995 | 45 | 38 | 30 | 69 | 81 | 59 | 76 | 65 |
| Aid as a percent of GNP in 1994 | 23.5 | 24.5 | 25 | 17.2 | 0.6 | 8.5 | 24.8 | 13.8 |
| Agricultural labor force as a percent of total labor force in 1990 | 92 | 93 | 91 | 76 | 43 | 60 | 60 | 66 |
| Crop land (% total land area-1994) | 13 | 2 | 3 | 12 | 36 | 19 | 12 | 45 |
| Adult literacy (% - 1995) | 81 | 69 | 86 | 67 | 43 | na | 60 | 48 |
| Urban population (% total population in 1995) | 27 | 27 | 23 | 42 | 39 | 36 | 44 | 31 |
| Agriculture value added in 1995 (% GDP) | 34 | 46 | 39 | 20 | 28 | 46 | 31 | 38 |
| Average annual growth rate in agricultural GDP in 1990-95 (%) | 4.6 | 3.1 | na | 1.3 | 2.3 | 2.4 | 0.3 | 3.3 |

Source: World Development Report 1997 and FAO 1998.

**Annex 2. Plant nutrient use (kg) per hectare of arable land by country (1984 - 1996).**

| | Countries | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Burkina Faso | Côte d'Ivoire | Ghana | Mali | Nigeria | Níger | Senegal | Togo |
| 1984 | 3.9 | 18.0 | 3.7 | 25.0 | 9.8 | 0.7 | 7.8 | 3.5 |
| 1985 | 4.1 | 17.4 | 5.2 | 9.7 | 10.2 | 1.0 | 8.8 | 4.9 |
| 1986 | 5.4 | 12.2 | 3.2 | 7.2 | 9.1 | 0.6 | 9.0 | 5.6 |
| 1987 | 5.8 | 13.6 | 4.4 | 7.7 | 10.1 | 0.8 | 9.0 | 5.4 |
| 1988 | 4.3 | 17.0 | 4.9 | 6.5 | 10.7 | 0.5 | 11.1 | 6.1 |
| 1989 | 5.8 | 16.1 | 3.3 | 8.7 | 12.9 | 0.8 | 5.4 | 5.9 |
| 1990 | 6.0 | 14.7 | 4.8 | 7.4 | 13.6 | 0.6 | 5.1 | 5.6 |
| 1991 | 5.7 | 17.8 | 2.9 | 7.3 | 14.4 | 0.1 | 6.6 | 5.7 |
| 1992 | 6.1 | 22.2 | 3.6 | 10.5 | 16.7 | 0.4 | 7.3 | 5.9 |
| 1993 | 6.1 | 18.6 | 2.7 | 10.2 | 16.8 | 0.4 | 10.7 | 4.8 |
| 1994 | 6.7 | 22.4 | 4.3 | 8.4 | 9.8 | 1.4 | 8.5 | 5.5 |
| 1995 | 7.2 | 22.1 | 4.3 | 8.4 | 6.0 | 2.0 | 7.1 | 7.9 |
| 1996 | 7.1 | 24.1 | 4.6 | 6.9 | 4.4 | 2.2 | 6.7 | 8.5 |
| Average | 5.7 | 18.2 | 4.0 | 9.5 | 11.1 | 0.9 | 7.9 | 5.8 |

Source: FAO data 1998.



**Annex 3. Summary statistics of grain yields and cash returns by fertility options in Banizoumbou and Karabedji - Niger; 1996-1997.**

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Control | SSP | PRT | PRT&SSP | 15-15-15 | SSP&CAN |
| Statistic | Banizoumbou - Pearl millet grain Yield (kg/ha) | | | | | |
| Mean | 331 | 568 | 423 | 527 | 681 | 801 |
| Standard deviation | 196 | 317 | 289 | 357 | 342 | 364 |
| Minimum | 56 | 97 | 35 | 86 | 220 | 187 |
| Maximum | 827 | 1373 | 1293 | 1460 | 1633 | 1507 |
| Average yield gains over the control | 0 | 237 | 92 | 196 | 350 | 470 |
| | Banizoumbou - Cash returns (cfaf/ha) | | | | | |
| Mean | 31547 | 32267 | 37833 | 46363 | 38958 | 38416 |
| Standard deviation | 25284 | 40348 | 38118 | 45568 | 43318 | 46327 |
| Minimum | -5716 | -32229 | -15757 | -12648 | -28877 | -46681 |
| Maximum | 95091 | 134472 | 150472 | 167428 | 159052 | 128879 |
| Average cash returns gains over the control | 0 | 720 | 6286 | 15816 | 7411 | 6869 |
| | Karabedji - Pearl millet grain yield (kg/ha) | | | | | |
| Mean | 432 | 656 | 499 | 692 | 738 | 783 |
| Standard deviation | 255 | 281 | 268 | 262 | 285 | 305 |
| Minimum | 103 | 95 | 167 | 112 | 328 | 236 |
| Maximum | 1436 | 1749 | 1945 | 1639 | 1359 | 1392 |
| Average yield | 0 | 224 | 67 | 260 | 306 | 351 |
| Average yield gains over the control | | | | | | |

*Continued*

*Annex 3 continued*

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Control | SSP | PRT | PRT&SSP | 15-15-15 | SSP&CAN |
| Karabedji - Cash returns (cfaf/ha) | | | | | | |
| Mean | 47294 | 49089 | 50842 | 74872 | 53700 | 46757 |
| Standard deviation | 32596 | 39702 | 34246 | 38231 | 42026 | 46371 |
| Minimum | 1992 | -35502 | 5891 | -11856 | -14513 | -40164 |
| Maximum | 176088 | 184480 | 237188 | 191235 | 136367 | 122952 |
| Average cash returns gains over the control | 0 | 1795 | 3548 | 27578 | 6506 | -538 |

The local pearl millet variety was used in the trials. SSP: Super Single Phosphate applied at 13 kg $P.ha^{-1}$ broadcast PRT: Tahoua Rock Phosphate applied at 13 kg $P.\ ha^{-1}$ broadcast PRT & SSP: Tahoua Rock Phosphate applied at 13 kg $P.\ ha^{-1}$ and 4 kg of $P.ha^{-1}$ of SSP hill placed 15-15-15: Commercial NPK applied at 13 kg of $P.ha^{-1}$ broadcast SSP & CAN: Super Single Phosphate applied at 13 kg $P.ha^{-1}$ and 30 kg of N from Calcium Ammonium Phosphate broadcast
Source: Ndjeunga and Bationo (1998, p. ).

**Annex 4. Per capita cereal grain surplus/deficits in few countries in WASAT (1987-1997).**

| | Countries | | | |
|---|---|---|---|---|
| Year | Burkina Faso | Mali | Niger | Senegal |
| 1987/88 | -33 | -37 | -56 | -14 |
| 1988/89 | -13 | -13 | 3 | -17 |
| 1989/90 | 10 | 61 | -5 | 0 |
| 1990/91 | -34 | 9 | -36 | 2 |
| 1991/92 | 34 | 1 | 12 | -20 |
| 1992/93 | 34 | 3 | -2 | -22 |
| 1993/94 | 29 | 10 | -57 | -14 |
| 1994/95 | 19 | 2 | -7 | -14 |
| 1995/96 | -2 | 7 | -12 | -30 |
| 1996/97 | -1 | -9 | 16 | -12 |
| 1997/98 | -18 | -11 | -29 | -34 |
| 1998/99 | 14 | 11 | 44 | 5 |
| Per capita average yearly surplus/deficit (kg) | 3.25 | 2.83 | -10.75 | -14.17 |
| Per capita official cereal consumption (kg) | 190 | 204 | 242 | 185 |

Source: CILSS/DIAPER, AGRYMET Niamey, Niger. 1998.



**Annex 5. Net returns to land and labor (principal crop only) by region and by crop enterprise 1990 (hcfa.ha$^{-1}$).**

| Region | Net return to | Millet/ cereal | Millet/ pulse | Sorghum | Maize/ sorghum | Maize/ rice | Maize | Rice | Fonio | Peanut | Wanzou |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sudano-sahelian zone | | | | | | | | | |
| Northern Boboye | Land | 10838 | 8569 | 7583 | 15290 | ñ | ñ | ñ | ñ | 22887 | 48156 |
| | | (0.73) | (0.62) | (-) | (1.21) | | | | | (1.07) | (0.56) |
| | Labor | 258 | 312 | 157 | 209 | ñ | ñ | ñ | ñ | 17 | 324 |
| | | (0.54) | (0.65) | (-) | (0.57) | | | | | (0.98) | (0.76) |
| Southern Boboye | Land | 17638 | 9256 | -4572 | ñ | ñ | 38764 | 28503 | ñ | 35330 | 57798 |
| | | (0.83) | (1.78) | (-8.64) | | | (0.86) | (-) | | (0.84) | (0.98) |
| | Labor | 734 | 280 | -59 | ñ | ñ | 795 | 416 | ñ | 196 | 426 |
| | | (0.63) | (3.34) | (-11.9) | | | (0.22) | (-) | | (0.98) | (1.35) |
| | | Sudano-guinean zone | | | | | | | | | |
| Dallol Mauri | Land | 10901 | 8180 | 6943 | 22606 | 8725 | 20073 | 47780 | 7362 | 17005 | 21224 |
| | | (1.24) | (0.91) | (1.50) | (-) | (1.33) | (0.24) | (0.60) | (1.40) | (0.90) | (0.54) |
| | Labor | 348 | 350 | 136 | 323 | 1063 | 173 | 1269 | 246 | 178 | 260 |
| | | (1.29) | (1.29) | (1.38) | (-) | (1.88) | (0.49) | (0.40) | (1.37) | (0.95) | (0.55) |
| Gaya Plateau | Land | 11749 | 12226 | 9223 | 28183 | ñ | 21597 | ñ | 13574 | 7620 | 23554 |
| | | (0.54) | (0.56) | (0.59) | (0.92) | | (0.91) | | (0.63) | (1.01) | (1.49) |
| | Labor | 384 | 402 | 305 | 449 | ñ | 249 | ñ | 415 | 144 | 149 |
| | | (0.64) | (0.84) | (0.30) | (1.74) | | (0.80) | | (0.73) | (1.02) | (0.63) |
| Gaya River | Land | 25446 | 23936 | 26141 | 20136 | 43628 | 66795 | 58102 | ñ | 365 | -1772 |
| | | (0.58) | (0.44) | (0.80) | (0.86) | (1.00) | (0.53) | (1.05) | | (63.24) | (-) |
| | Labor | 806 | 595 | 628 | 336 | 336 | 1361 | 324 | ñ | -60 | -25 |
| | | (0.86) | (0.69) | (0.82) | (0.85) | (0.97) | (0.64) | (0.60) | | (-4.91) | (-) |

*Continued*

*Annex 5 continued*

| Region | Net return to | Millet/ cereal | Millet/ pulse | Sorghum | Maize/ sorghum | Maize/ rice | Maize | Rice | Fonio | Peanut | Wanzou |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total sample | Land | 15517 | 12185 | 14911 | 22220 | 26177 | 30854 | 47975 | 10541 | 18754 | 32932 |
| | | (0.85) | (0.99) | (1.58) | (0.89) | (1.34) | (0.86) | (0.70) | (0.93) | (1.20) | (1.19) |
| | Labor | 526 | 380 | 369 | 361 | 700 | 497 | 877 | 333 | 154 | 269 |
| | | (0.94) | (1.45) | (1.40) | (1.29) | (1.98) | (1.02) | (0.70) | (0.98) | (1.18) | (1.22) |
| | Sample size | 90 | 95 | 18 | 39 | 8 | 15 | 7 | 43 | 74 | 61 |

Number in parentheses represent coefficient of variations.
Source: IFPRI/INRAN survey 1990.