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# Uptake of Improved Technologies in the Semi-Arid Tropics of West Africa: Why Is Agricultural Transformation Lagging Behind?

J. Ndjeunga and M.S.C .Bantilan[1]

*International Crops Research Institute for the Semi-Arid Tropics,*
*BP 12404, Niamey, Niger*
*n.jupiter@cgiar.org*

**Abstract**

*During the last 3 decades, donors and governments have invested in the development and dissemination of new technologies in the semi-arid tropics of West Africa. Though a wide range of improved technologies has been developed, adoption remains low without a significant impact on crop productivity, rural income and poverty. Agricultural transformation as occurred in East Asia has not yet occurred in the semi-arid tropics of West Africa. This paper uses data from a regional survey of rural households in 3 countries in West Africa (Burkina Faso, Mali, and Niger) to identify the determinants of uptake of improved technologies. Limited productivity gain is found to be a major constraint to the uptake of technologies. In addition, poorly functioning institutions, lack of information or poor exposure of farmers to agricultural innovations, and poor functioning or missing markets have also hindered the uptake of many new technologies.*

**Key words:** *institutions, technology, markets, road infrastructure, information, agricultural productivity.*

## 1. Introduction

Donors and governments have invested in agricultural research and development in the semi-arid tropics of West Africa (WASAT) during the last three decades. These efforts led to the development of a wide range of technologies that have been disseminated through public, non-governmental organizations or parastatal institutions. However, the level of adoption of technologies is low, and most of these efforts have had little impact on the livelihood of the rural poor.

[1] International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 502324 Andhra Pradesh, India

Countries in the semi-arid tropics of West Africa (WASAT) are classified by the United Nations as among the least developed countries in the world. The low level of economic activity coupled with high population growth in these countries over the past decade has led to negative or stagnant growth in real per capita incomes (World Bank, 2003). In most of these countries, more than 30% of the population falls below the international poverty line of $1 a day. Other indices such as life expectancy at birth and human development index indicate low levels of human welfare. Yet, human population in these countries is projected to grow at average annual rates between 2.1 and 2.9% over the next 15 years (UNCTAD, 2003). The literacy rate is low, less than 50% unfavorably compared to 59% in all countries in Sub-Saharan Africa, 71% in all developing countries, and 96% in East Asia. Many people in the WASAT still have little access to safe water or sanitation. This is in contrast with countries in East Asia where only about 10% of the people have no access to safe water and just 1% to proper sanitation.

Agriculture plays an important role as it accounts for more than 30% of the gross domestic product, employs 82 and 92% of the total labor force and is the main source of livelihood for the poor. In almost all the countries, domestic food production has not kept up with the rising population. Between 1990 and 1999, per capita food production grew at an annual rate ranging from -0.1% in Niger to 1.1% in Mali or Burkina Faso (UNCTAD, 2003). The transformation of the agricultural sector is still lagging, and crop productivity is very low compared to many countries in East Asia. The yields of the major cereal crops are 2.5 times higher in East Asia than those in West Africa. Land productivity is low; it ranged from US $33 per hectare in Mali to US $93 in Burkina Faso. Labor productivity ranged from US$ 182 to US $256 per worker in Niger compared with an average of US$ 392 per worker in sub-Saharan Africa as a whole. Between 1980 and 1995, labor productivity declined at an average rate of 0.9% per year in Niger, but increased modestly in the remaining countries. The labor/land ratios across the Sahelian countries appear to be low, reflecting land abundance relative to labor availability (Lusigi and Thirtle, 1997). Total factor productivity (TFP) estimated by Trueblood and Coggins (1997) using a set of 117 countries from all world regions for 1962-1990, encompassing a much wider range of technologies, shows that the technology gap between Africa and the rest of the world is widening.

Research led by the consultative Group of International Agricultural Research (CGIAR) centers, Advanced Research Institutions (ARI), and National Agricultural Research Systems (NARS) have generated a wide range of technologies. However, adoption of improved technologies has been low and not on a sufficient scale to lead to increases in agricultural productivity or per capita food production during the last three decades. Lessons from East Asia showed that productivity growth is the entry point to agricultural transformation. Other major ingredients that have contributed to the broad-based growth of Asian economies are the improvement of inputs, credit, and product markets in addition to adequate road infrastructure to ensure that households' access to needed improved farm inputs. These institutions are induced to change by the advent of improved rice and wheat technologies in Asia, as it has enhanced the profitability of institutional innovations (Hayami and Ruttan, 1985 and Hayami 1997).

This paper focuses on the assessment of agricultural transformation in the semi-arid tropics of West Africa. It uses a regional survey of rural households in 3 countries to determine factors explaining uptake of improved technologies focusing on fertilizers and improved varieties of sorghum and pearl millet varieties, which are the major cereal crops grown in the WASAT.

The paper is presented in four sections. Section 2 describes the data and sampling methods, followed by an overview of sorghum and pearl millet sectors in the semi-arid tropics of West Africa in Section 3. Section 4 presents the determinants of uptake of improved technologies, and Section 5 assesses priorities and the relevance of the East Asian experience in the context of agricultural research and development in the semi-arid tropics of West Africa.

## 2. Data and sampling methods

This paper uses both secondary sources of information and primary data from a regional survey of rural households conducted in Mali, Burkina Faso and Niger in 2000-2001 (ICRISAT/NARS/IFAD, 2000 & 2001). Three types of data were collected: the village, the household and the plot. Forty-six (46) villages were chosen using 3 criteria: agro-climatic zone, road and market access. Agro-climatic zone was defined by the Length of Growing Period (LGP); (a) the areas with a period of less than 100 days of LGP were considered suitable for pearl millet production (Sahel); (b) areas with a LGP between 100 and 150 days were considered suitable for sorghum (Sudanian), and (c) areas with a LGP of more than 150 days were considered suitable to sorghum and maize production as cereals. Villages located at less than 5 km from the nearest markets were defined to have good access to markets, and other villages were considered to have poor access. Similarly villages located at less than 5 km from the main road were regarded as favorably accessible, while villages that were more than 5 kms away were poorly accessible. Overall, 16 villages were selected in Mali, 23 in Burkina Faso and 7 in Niger (See Annex). Out of the 46 villages selected, 28 had good access to the main road, whereas 16 villages had good access to input or product markets. Thirteen villages were located in the most drought prone areas of the Sahel, with 26 villages in the Sudanian zone and the remaining in the Guinean zone (see Table 1).

**Table 1 Distribution of villages based on access to institutions and agro-climatic zones**

| Criteria for village selection | | Mali | Burkina Faso | Niger | Total |
|---|---|---|---|---|---|
| Number of villages with: | | | | | |
| Road access | | 14 | 10 | 4 | 28 |
| Market access | | 7 | 6 | 3 | 16 |
| Proximity to old seed multiplication village | | 8 | 8 | 6 | 24 |
| Existence of credit institution | | 12 | 9 | 6 | 27 |
| Agro-climatic zone | < 100 days | 7 | 4 | 2 | 13 |
| | 100-150 days | 7 | 14 | 5 | 26 |
| | >150 days | 2 | 5 | 0 | 7 |
| Total number of villages selected | | 16 | 23 | 7 | 46 |

***Source:*** Surveys NARS/IFAD/ICRISAT, 2000-2001.

In addition, 24 villages were found to be at close proximity to seed multiplication units, and 27 villages were endowed with credit institutions. At the village level, data was collected on rural livelihood assets, which included the institutions and projects operating in the village, the endowments on natural resources, the socio-demographic profile, and important economic activities at the village economies.

In each village, an average of 20 rural households were randomly selected using the village census. A structured survey was administered to 983 rural households chosen from the 3 countries in 2000-2001. At the household level, data was collected on the socio-demographic profile, agricultural equipment, land ownership and utilization, livestock and crop stocks, transactions, soil fertility management practices and farmers' perception of soil restoration practices, water conservation methods, and sources of information on agricultural innovations. Similarly data was gathered on village seed markets and its structure, conduct and performance, variety management, and motivations for participating in the seed markets, particularly for sorghum and pearl millet, which are the two most important crops grown in WASAT.

In each household, data was collected on the major communal and individual plots. These included input/output data and plot characteristics such as crop production and plot area, types of crops and varieties used, quantities and types of seeds, and fertilizer used, seed and fertilizer supply sources, plot ownership, farmers' prior knowledge on plot soil fertility and, method and period of application.

A K-means cluster analysis was used to classify rural households into wealth status such as the high, middle and low class farmers. Logit models were used to assess the determinants of uptake in fertilizer and improved variety use. Analyses were performed using SPSSPC+ 9.0 (SPSS, 1999) for the cluster analysis and STATA Version 7.0 for regressions analyses (StataCorp, 1999).

## 3. Overview of the sorghum and pearl millet sectors.

Over 14 million ha of pearl millet and approximately 11 million of sorghum were planted between 2000-02 in WASAT. Maize and rice are also important and are planted on almost 7 million and 3 million ha, respectively. Pearl millet accounts for the majority of cereal grain area in Niger, 75.8%. Sorghum accounts for 44.2% of the total cereal grain area in Burkina Faso, 25% in Mali and 20.9% in Niger. In contrast, maize and rice areas represent less 20% of the total cultivated cereal grain area. The distribution of pearl millet and sorghum production roughly matches the distribution of area planted. The West African region as a whole produced about 9.6 million tons of pearl millet and 9.7 tons of sorghum between 2000-02. Sorghum and pearl millet each account for about 29% of the total cereal grain production.

Average per capita cereal grain consumption in WASAT was estimated at 193 kg in 1999-2001, 26% sorghum, 26 % pearl millet, 26% maize, 17% rice, and 4% of wheat products.

As is shown in Table 2, pearl millet and sorghum yields are low by global standards. In 2000-02, pearl millet yields across the sub-region averaged at 707 kg per ha. Burkina Faso has the highest grain yield (705 kg per ha) among the three countries. In contrast, in Niger, where pearl millet dominates the cropping systems, the lowest yields in the region were recorded, averaging at 391 kg per ha. Pearl millet yields average less than that of sorghum in West Africa as a whole. Sorghum averages are about 856 kg per ha, with Burkina Faso achieving the highest average grain yield of 894 kg per ha. In contrast in Niger, where sorghum is the second most important crop, grain yields averaged at about 225 kg per ha over the period 2000-02.

**Table 2 Sorghum and pearl millet area (000 ha) and production and proportion to the total cereal grain area or production (%) (2000-2002 averages)**

| | | Country / region | | | | |
|---|---|---|---|---|---|---|
| | | Burkina | Mali | Niger | West Africa | SSA |
| Cereal grain area (000 ha) | in 2000-2002 | 3061 | 2769 | 7693 | 40514 | 77123 |
| (%) per crop within country | Sorghum | 43.0 | 28.9 | 31.9 | 31.4 | 29.5 |
| | Pearl Millet | 41.9 | 45.3 | 67.5 | 37.2 | 26.3 |
| Cereal production (000 t.) | in 2000-2002 | 2838 | 2713 | 2678 | 37659 | 75700 |
| % per crop within country | Sorghum | 44.2 | 25.0 | 20.9 | 28.9 | 24.9 |
| | Pearl Millet | 32.1 | 31.8 | 75.8 | 28.3 | 17.4 |
| Yield (kg/ha) 2000-2002 | Sorghum | 894 | 835 | 225 | 856 | 830 |
| | Pearl Millet | 705 | 695 | 391 | 707 | 650 |
| | Cereals (total) | 923 | 980 | 347 | 930 | 982 |
| Growth rate of yield (%) 1984-2002 | Sorghum | 1.51 | -0.93 | -1.65 | 0.26 | 0.52 |
| | Pearl Millet | 1.78 | -0.65 | 0.25 | -0.30 | -0.36 |
| | Cereals (total) | 2.20 | 0.82 | -0.30 | 0.23 | 0.21 |

**Source**: *Computed from FAOSTAT Database, 2003.*

Since 1984, West African's average yields of two major coarse grains have been relatively stable with an annual growth rate of 0.26% estimated for sorghum and a decline of 0.30% estimated for pearl millet. Yield declines are observed due to drought and low and erratic rainfall. In addition, limited use of improved technologies by sorghum and millet growers is also a major constraint to increasing yields. Fertilizer use per hectare of arable land is very low and positively correlated with yields. Yields are the highest in Mali and Burkina Faso, where fertilizer use is the highest (10 kg of mineral fertilizer is used per hectare of arable land), whereas in Niger (where less than 1 kg is used per hectare of arable land) yields are the lowest.

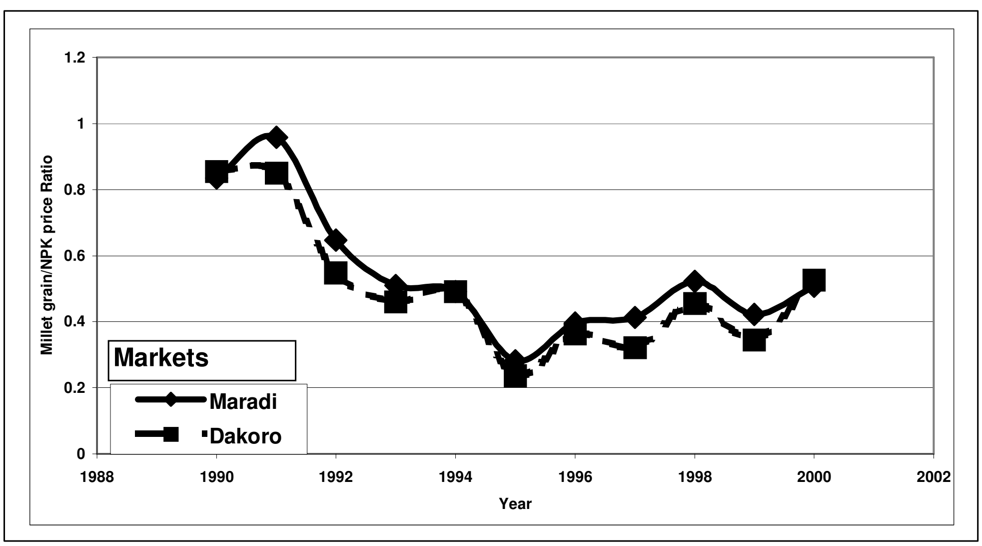
Research led by the CGIAR centers, ARI, and NARS have generated a wide range of technologies. More than 33 pearl millet and 32 sorghum varieties have been developed and released by NARS and the International

Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Similarly, there is evidence of high productivity gains through the application of small doses of fertilizers. On-farm fertility trials under farmers' management offer more than 30% yield advantage over the no-fertilizer regime. There are very few studies in the WASAT that show high returns from research investment in sorghum and millet. The introduction of S35 in Chad and Cameroon has generated a net present value of research investment estimated at US$ 15 million and US$ 4.6 million, respectively, representing internal rate of returns of 95% and 75%, respectively, in sorghum growing areas (Yapi *et al.* 1999a, 1996b). In Mali, the return to research investment in sorghum was estimated at US$ 16 million and the return to research in pearl millet was estimated at US$ 25 million, representing internal rates of return of 69% and 50%, respectively (Yapi *et al.* 2000)

In general, adoption of improved technologies has been slow, and not on a sufficient scale to lead to increases in per capita food production during the last three decades. Few of these varieties have reached the small-scale farmers. Inconsistent variety release policies, poor supply of breeder seeds, poor seed demand estimation and distribution systems, coupled with poor seed quality, have constrained seed supply, acess and adoption of improved varieties by small farmers. Unsuitability of varieties, poor linkages and institutional building as well as lack of seed laws, have been found to be secondary constraints (Ndjeunga, 1997). Fertilizer use is still very low and ranges from 0.7 kg per ha of arable land in Niger to a high of 11.5 kg per ha in Burkina Faso (compared to 140 kg per ha in East Asia). The percentage of irrigated cropland vis-à-vis total cropland is estimated at 1.5% in West Africa against 23% in East Asia (FAO, 2002).

Uptake of inorganic fertilizers is constrained by its availability and its high real price. The productivity potential is constrained by increasing fertilizer prices relative to grain prices(see Figure 2). For example in Niger, prior to 1994, year of currency devaluation, fertilizer prices were relatively high compared to the grain price; in 1991, it took 1 kg of millet grain to purchase 0.83 kg of fertilizer, whereas in 1995 only 0.28 kg of fertilizer could be purchased with one kg of pearl millet grain.. However, soon after the currency devaluation, this trend was slowly reversing. In year 2000, for example, with 1 kg of millet grain farmers could purchase 0.5 kg of NPK fertilizer. Macro-policies in the form of over-valued currencies largely explained high fertilizer costs. In addition, there are large transaction costs involved in land-locked countries, where transport costs represent more than 25 % of the fertilizer cost.

**Figure 2.** Millet grain price relative to NPK fertilizer price




***Sources***: Prices are based on government fertilizer supply store (adjusted for government subsidies and transport costs to reflect farm gate prices) and Market Information Systems (SIM) Niamey, Niger.

## 4. Determinants of Uptake of Improved Technologies

### *4.1. Uptake of improved pearl millet and sorghum varieties*

Results from the regional survey of rural households in the WASAT indicate that 33.2% and 20.5% of rural households in Mali claimed to use improved sorghum and pearl millet varieties, respectively(see Table 3). In Niger, about 10.9% and 33.2% have reported using improved sorghum and pearl millet varieties, respectively. The uptake of improved varieties in Burkina Faso is very low. In fact, less than 5% of farmers have reported using improved sorghum or pearl millet varieties.

Adoption rates for improved varieties are increasing, but the rate of productivity gains has been slow. This is due to a combination of factors including the limited productivity gains recorded from using improved varieties, the limited access to information or experimentation on new varieties, and the limited access to seeds of improved varieties. In fact, new varieties derived from agricultural research programs may not be suited to the environments and preferences of small-scale farmers. In other cases, farmers simply do not know about the new varieties or have not tested these varieties. Even if farmers have experimented with the performance of these varieties, few farmers have ready access to quality seeds of most new crop varieties. This is explained by the underdevelopment of national and regional seed markets. Retail distribution channels for seeds are often very few and limited to urban areas.

Many farmers plant seeds from their own stock. The rate of seed renewal (whether local or improved) is estimated at 10 years and 13 years, respectively for sorghum and pearl millet in Mali, and 9 years for both crops in Burkina Faso and Niger. Therefore, it is unlikely that these seeds would be pure and have the ability to maintain their production potential. In Mali and Burkina Faso in 2000, for example, more than 90% of farmers drew their seeds from their own stock, and
in case of insufficient seed stock, farmers appealed to family, friends and neighbors to get seeds. In Niger for example, nearly 30% of farmers got pearl millet seeds from friends and family. In 2000, 8.1% and 5.1 % of rural households got seeds from the formal sources in Mali, 0.2% and 0.0% in Burkina Faso, and 6% and 9% in Niger. Most transactions are made in the form of barter or exchange of varieties (Ndjeunga et al. 2003).

**Table 3 Quantities (kg) and proportion of modern sorghum and pearl millet varieties planted by farmers in Mali, Burkina Faso and Niger in 2000**

| Country | Type of variety | Crop: Sorghum | Pearl Millet |
|---|---|---|---|
| | | Quantity planted (kg) | Quantity planted (kg) |
| Mali | | | |
| | Total modern varieties (kg) | 2664 | 2380 |
| | Total local varieties (kg) | 5367 | 9234 |
| | Percentage (%) modern varieties | 33.2 | 20.5 |
| Burkina Faso | | | |
| | Total modern varieties (kg) | 295 | 107 |
| | Total local varieties (kg) | 8557 | 5182 |
| | Percentage (%) modern varieties | 3.3 | 2.0 |
| Niger | | | |
| | Total modern varieties (kg) | 449 | 2799 |
| | Total local varieties (kg) | 3669 | 5624 |
| | Percentage (%) modern varieties | 10.9 | 33.2 |

Source: NARS/ICRISAT/IFAD Survey 2000-2001.

Limited access to information on improved varieties and ability to experiment improved varieties are important factors affecting the decision to uptake. Out of the 381 sorghum producers surveyed in Burkina Faso, about one fifth never heard of improved sorghum varieties. Of those who had heard of improved varieties, 63% never tested improved varieties. Among those who had tested, only 23% continue to plant those varieties. In regard to pearl millet in Niger, 93% had heard of improved varieties, out of which, 63% tested the varieties and out of those who have tested, 74% continue to plant these varieties. In Burkina Faso, most farmers continue to plant small quantities of improved varieties and are still experimenting with them.

Only limited yield gains have been obtained from the adoption of most improved varieties. Results from on-station trials show that there are no statistical differences between the local and improved varieties. In 1994 and 1995, on-station trials conducted in Niger by 3 institutions, West and Central Africa Millet Research Network (WCAMRN), The Institute National de la Recherche Agronomique du Niger (INRAN), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)), showed no significant differences in pearl millet yields between the local pearl millet variety (Sadore local) and a range of improved varieties(see Table 4).

**Table 4 Performance of modern pearl millet varieties compared to the local variety (Sadore local), grain yield (ton./ha) in Sadore, Niger in 1994 and 1995**

| Varieties | 1995 rainy season | | 1994 rainy season | | |
|---|---|---|---|---|---|
| | WCAMRN | INRAN | WCAMRN | ICRISAT/NARS | INRAN |
| Local varieties | 1.59 | 1.96 | 1.88 | 1.46 | 0.93 |
| Modern varieties | 1.28 | 1.63 | 1.23 | 1.04 | 0.81 |

Sources: ICRISAT Sahelian Center – Genetic Enhancement Division. Pearl Millet Breeding. Annual Reports 1994 (p. 108&109) & 1995 (P.164-166)
Location: Sadore, Niger. Fertilizer (kg.ha-1): 46N:36$P_2O_5$ Design: RBD

In fact, results from on-station trials carried out by WCAMRN showed no significant differences in yields between the local variety and the 10 improved varieties engaged in the west and central African regional trials. Similarly, on-station trials conducted in Sadore from 1996 to 1998 show that the yield of local varieties was significantly more than the two best improved pearl millet varieties (HKP and CIVT) widely used in Niger (Gerard and Buerkert, 2001). On-farm trials conducted in Karabedji-Niger show that yields of local varieties are significantly higher than improved varieties for grain and stover under traditional and improved management systems (Dr Andre Bationo, TSBF personal communication). These results are consistent with the regression analysis of yields using plot level surveyed data showing no significant effects of improved variety or fertilizer on sorghum or pearl millet yields in Mali (Table 5).

Table 6 presents the definition of variables used in the regressions while the descriptive statistics for the explanatory and dependent variables for the Logit model results are presented in Table 7. The dependent variables include binary variables on the use of improved sorghum or pearl millet varieties, the use of organic or inorganic fertilizers and the intensity of organic or inorganic fertilizers used in year 2000. The latter is measured by the total quantities of fertilizer applied divided by the total cultivable area in year 2000. Logit models were used to analyze the determinants for uptake of improved varieties or organic fertilizers.

The explanatory variables include household socio-economic profile, road infrastructure, markets and institutions; information and experimentation on improved technologies, and environmental factors. The socio-economic profile of the rural household includes the age of the household head (AGEHH), the level of education proxied by the proportion of educated household members (EDUCHH), and the family size (FAMISIZE). Resource availability was represented by the number of adult equivalents, the number of cattle (CATTLEOWN), cart ownership (CART), and household type based on agricultural equipment. Market orientation was measured by a binary variable representing whether a farmer cultivated cotton (COTTON), and the proximity to major product or input markets (PROXMARK). Access to seeds was measured by the proximity of old seed multiplication centers (PROXSEEDU). Three dummy variables were used to represent the agroclimatic zones, i.e. the Sahel (SAHEL), the Sudanian (SUDAN) and the Guinean (GUINEA) zones.

**Table 5 Yield regressions of sorghum and pearl millet in Mali using plot level data**

| | *Crop* | |
|---|---|---|
| | *Sorghum* | *Millet* |
| *Variable* | *Coef.* *(t-statistic.)* | *Coef.* *(t-statistic.)* |
| In organic fertilizer (kg/ha) | 19.2 (0.552) | -74.9 (-1.264) |
| In organic fertilizer (squared) | -0.5 (-0.591) | 1.1 (1.003) |
| Use of modern varieties (0=does not, 1=Use) | -296.4 (-0.865) | 1541.8 (1.385) |
| Agroecological zone (0=Guinean, 1=Sudanian) | 184.6 (1.124) | -484.1 (-1.476) |
| Farmer perception of plot fertility (0= poor, 1=fertile, 2=very fertile) | -17.6 (-0.136) | -54.6 (-0.952) |
| Number of years under continuous cultivation (years) | 8.5 (1.048) | 12.6*** (3.164) |
| Plot ownership (0=does not own, 1=own) | 331.7 (1.066) | 203.0 (1.068) |
| Constant | 7.7 (0.237) | 806.0 (2.042) |
| R-squared | 0.2229 | 0.1741 |
| Adjusted R-squared | 0.087 | 0.0960 |
| Number of plots | 320 | 210 |

***, **, * Significant difference of means (at 0.1%, 1%, or 5%), for the t-test of equality of means for independent samples

**Table 6 Variables used in the Logit regressions**

| Variable | Explanatory variables |
|---|---|
| *Socio-economic profile* | |
| AGEHH | Age of household head (years) |
| HHSIZE | Total number of family members resident on farm |
| EDUCAT | Proportion of household members educated (%) |
| *Production technology* | |
| COTTON | Farmer grows cotton (0=does not grow, 1=grow cotton) |
| CATSTOCK | Number of CATSTOCK owned by the household |
| FARMSIZE | Total farm size (ha) |
| AREASOR | Area planted to sorghum by the household (ha) |
| AREAMIL | Area planted to pearl millet by the household (ha) |
| NUMCART | Number of carts owned by the household |
| *Markets, institutions and road infrastructure* | |
| PROXSEEDU | Proximity to old seed multiplication unit (1=< 5 km from the nearest, 0=> 5 km for the nearest seed unit) |
| PRODMARK | Proximity to product markets (1=< 5 km from the nearest, 0=> 5 km for the product market) |
| PROXROAD | Proximity to the paved road (1=< 5 km from the nearest, 0=> 5 km for the road) |
| *Wealth status* | |
| HIGHCLAS | Households that are wealthier (1=wealthy households, 0=not wealthy) |
| MIDDLECLA | Middle class households (1=middle class, 0=not middle class) |
| LOWCLASS | Poor households (1=poor households, 0=not poor) |
| Climatic factors | |
| SAHEL | Less than 75 days of length of growing period (LGP) (1=located in the Sahel, 0=not located in the Sahel) |
| SUDAN | Between 75 days and 100 days of LGP (1=located in the Sudanian zone, 0=not located in the Sudanian zone ) |
| GUINEA | More than 100 days of LGP (1=located in the guinean zone, 0=not located ) |
| | *Dependent variables* |
| IMPMIL | Farmers using improved pearl millet varieties (0=did not use, 1=did use) |
| IMPSOR | Farmers using improved sorghum varieties (0=did not use, 1=did use) |
| APPMIN | Farmers whom applied mineral fertilizers (0=did not apply, 1=did apply) |
| APPORG | Farmers whom applied organic fertilizers (0=did not apply, 1=did apply) |

**Table 7 Descriptive statistics for the variables used in the Logit regressions in Mali and Burkina Faso**

| Variable | Mali Mean | Mali Std. Dev. | Burkina Faso Mean | Burkina Faso Std. Dev. |
|---|---|---|---|---|
| *Socio-economic profile* | | | | |
| AGECUPA | 45.0 | 11.9 | 49.9 | 10.8 |
| HHSIZE | 21.2 | 15.5 | 15.7 | 11.2 |
| EDUCAT | 0.42 | 0.29 | 0.13 | 0.16 |
| *Production technology* | | | | |
| CART | 1.11 | 0.93 | 0.53 | 0.63 |
| FARMSIZE | 9.97 | 8.23 | 3.59 | 5.22 |
| CATSTOCKOWN | 5.19 | 8.76 | 2.97 | 12.4 |
| COTTON | 0.11 | 0.33 | 0.27 | 0.45 |
| *Markets, institutions and road infrastructure* | | | | |
| PROSEEDUN | 0.50 | 0.50 | 0.43 | 0.50 |
| PROXMARK | 0.63 | 0.48 | 0.42 | 0.49 |
| PROXROAD | 0.88 | 0.33 | 0.64 | 0.48 |
| *Wealth status* | | | | |
| LOWCLASS | 0.73 | 0.45 | 0.84 | 0.37 |
| HIGHCLAS | 0.03 | 0.18 | 0.01 | 0.11 |
| AVERFA | 0.24 | 0.43 | 0.15 | 0.36 |
| *Climatic factors* | | | | |
| SAHEL | 0.44 | 0.50 | 0.07 | 0.26 |
| SUDAN | 0.44 | 0.50 | 0.62 | 0.49 |
| GUINEA | 0.12 | 0.33 | 0.31 | 0.46 |
| ***Dependent variables*** | | | | |
| IMPMIL | 0.30 | 0.46 | - | - |
| IMPSOR | 0.26 | 0.44 | - | - |
| APPORG | 0.85 | 0.35 | 0.69 | 0.47 |
| APPINORG | 0.44 | 0.50 | 0.50 | 0.50 |
| INTORG | 1881.22 | 3656.12 | 255 | 607 |
| INTINORG | 16.0 | 33.7 | 19.8 | 133.82 |
| **Sample size** | **321** | | **421** | |

The estimated coefficients, t-statistics, and other relevant statistics are presented in Table 8. For the case of sorghum, at sample means, the estimated coefficients indicate that the most important determinants of the probability of increasing uptake are the location in the high rainfall zones (Guinean zone), and the proximity of seed multiplication and distribution centers. The marginal effects of the age of the household head, farm size, location in the Sahelian zone, proximity to input/product markets, and proximity to the road on the probability of uptake are positive but insignificant. Similar results are found for the case of pearl millet. However, the negative effects of access to input/product markets and proximity to the main roads are unexpected. In fact, farmers growing pearl millet are located in the less favorable rainfall zones, where markets are under-developed and the road infrastructure is poor.

Crop improvement programs have put less emphasis on "demand-led" breeding where the farmer is the centerpiece. Farmers like to experiment and should be exposed to a range of choices. It is now common to test a wide range of varieties on the fields of small-scale farmers and review what farmers think of these cultivators. Such participatory methods have recently been adopted whereby farmers themselves make varietal selections over several generations of breeding. This would undoubtedly improve the likelihood of adoption if the significantly improved seed is ultimately made available. It is increasingly known, however, that one cannot achieve the productivity gains with varieties alone. Improved varieties have to be linked with improved management practices. The next section presents the uptake of soil fertility and water management practices by rural households.

**Table 8 Determinants of uptake of improved sorghum and pearl millet varieties in Mali**

| *Variable* | *Crop* | |
|---|---|---|
| | *Sorghum varieties* | *Pearl millet* |
| Constant | -15.605<br>(212.31) | -4.4114**<br>(2.3329) |
| *Socio-economic profile* | | |
| AGEHH | 0.1<br>(0.605) | 0.1<br>(1.570) |
| AGEHHSQ | -0.0007553<br>(0.008) | -0.001<br>(-1.389) |
| HHSIZE | -0.021<br>(-0.801) | -0.007<br>(-0.316) |
| EDUCAT | -0.4<br>(-0.793) | 0.6<br>(1.113) |
| *Production technology* | | |
| FARMSIZE | 0.1<br>(1.138) | 0.1<br>(1.582) |
| FARMSIZESQ | -0.0014078<br>(-0.720) | -0.0005586<br>(-0.835) |
| *Climatic factors* | | |
| SAHEL | 0.047<br>(0.087) | 0.32<br>(0.916) |
| GUINEA | 1.9***<br>(3.529) | -1.9**<br>(-2.395) |
| *Wealth status* | | |
| HIGHCLAS | 0.9<br>(0.542) | -0.5<br>(-0.372) |
| LOWCLASS | -0.5<br>(-0.839) | -0.3<br>(-0.479) |
| *Market, institutions and infrastructure* | | |
| PROXMARK | 0.2<br>(0.331) | -2.7***<br>(-5.243) |
| PROXSEEDU | 1.7***<br>(3.679) | 2.8**<br>(6.291) |
| PROXROAD | 13.6<br>(0.064) | -0.3<br>(-0.516) |
| | Correct classification = 76%<br>Log likelihood function -106.5249 | Correct classification = 78%<br>Log likelihood function -132.9405 |

*** significant at 1%, ** significant at 5% and * significant at 10%.
t-statistics in parentheses.

### *4.2. Uptake of inorganic and organic fertilizers by rural households in 2000*

The use of inorganic and organic fertilizers remains the most popular methods for soil fertility restoration options. In all countries, about 50% of the rural households used inorganic fertilizers and 70% used organic fertilizers (Table 9). Fallow, crop residues, rotation and association are also methods practiced by farmers.

**Table 9. Proportion of surveyed households using alternative soil fertility management (SFM) options in Burkina Faso, Mali and Niger, 2000**

| | *Country* | | |
|---|---|---|---|
| *SFM method* | *Burkina Faso* | *Mali* | *Niger* |
| Mineral fertilizers | 48.0 | 50.5 | 59.7 |
| Organic fertilizers | 76.7 | 79.8 | 73.6 |
| Compost | 20.7 | - | 22.5 |
| Fallow | 35.4 | 32.4 | 10.4 |
| Crop rotation | 39.4 | 30.2 | 6.9 |
| Green manure | 1.1 | - | 2.6 |
| Crop association | 24.0 | 25.5 | 22.1 |
| Crop residues | 32.5 | 13.1 | 8.7 |
| Others | 10.9 | - | 9.5 |
| No method | 1.9 | 1.2 | 3.9 |
| Sample size | 421 | 321 | 231 |

*Source*: Surveys NARS/IFAD/ICRISAT, 2000-2001.

Farmers are well aware of potential productivity gains derived from using improved management practices. Most farmers have reported declining soil fertility and many of them perceived organic and inorganic fertilizers as being complementary. However the limited use of fertilizers is explained mainly by high fertilizer costs, poor access to fertilizers, and poor access to credit.

Fertilizer use remains extremely low on all fields except those growing a few cash crops. Farmers do not use the research and extension recommendations except for cash crops such as cotton. For example, farmers use 10 kg/ha of fertilizer on sorghum, whereas research and extension recommendations are 100 kg of NPK and 50 kg/ha of urea. National extension recommendations for semi-arid areas continue to call for high rates of fertilizer, manure and insecticide application. Farmers producing a commercial crop are more likely to adopt improved soil and water management practices including the use of fertilizer, timely planting, better ploughing and the application of contours. This implies that crop management advice needs to be more closely linked with efforts to expand commercial production. Blanket recommendations for crop management practices need to be replaced by targeted recommendations suited to each farmer's marketing objectives. This raises questions about how best to provide a wider range of different sorts of extension advice to different farmers.

The estimated coefficients, t-statistics and other relevant statistics are presented in Table 10. In Burkina Faso, at sample means, farm size (FARMSIZE, FARMSIZESQ), proximity to markets (PROXMARK), ownership of cattle (CATTLEOWN) and carts (CARTOWN), proximity to the main roads (PROXROAD), education (EDUCAT) and the location (SAHEL) in the Sahel are the important variables in the uptake for manure or

**Table 10 Determinants of uptake of organic fertilizers by rural households in Mali and Burkina Faso in 2000**

| *Variable* | ***Country*** ***Mali*** | ***Burkina Faso*** |
|---|---|---|
| Constant | 8.1612<br>(203.88) | 2.6203<br>(2.5499) |
| *Socio-economic profile* | | |
| AGEHH | 0.044844<br>(0.527) | -0.072848<br>(0.717) |
| AGEHHSQ | -0.0003477<br>(-0.365) | 0.0007795<br>(0.764) |
| HHSIZE | 0.12771***<br>(3.456) | -0.013136<br>(-0.766) |
| EDUCAT | -0.11122<br>(-0.198) | -2.5***<br>(-2.774) |
| *Production technology* | | |
| FARMSIZE | 0.01854<br>(0.151) | 0.4***<br>(5.529) |
| FARMSIZESQ | 0.0017726<br>(0.340) | -0.016981***<br>(-4.698) |
| NUMCART | -0.3<br>(-0.492) | 0.024098<br>(0.091) |
| COTTON | 2.5*<br>(1.803) | -0.6<br>(-1.440) |
| CATSTOCK | -0.019084<br>(-0.817) | 0.0011714<br>(0.043) |
| CHARBOE | 1.1**<br>(2.060) | 1.5**<br>(2.512) |
| *Climatic factors* | | |
| SAHEL | 0.2<br>(0.390) | 2.5*<br>(1.620) |
| GUINEA | -0.9<br>(-0.910) | 0.1<br>(0.238) |
| *Wealth status* | | |
| HIGHCLAS | -6.7***<br>(-3.467) | 1.5<br>(0.500) |
| LOWCLASS | 2.5***<br>(2.795) | -0.03183<br>(-0.056) |
| *Market and infrastructure* | | |
| PROXROAD | -12.6<br>(-0.062) | -1.5***<br>(-3.676) |
| PROXMARK | 0.4<br>(0.931) | 1.7***<br>(4.171) |
| | Correct classification = 87%<br>Log likelihood function -102.10 | Correct classification = 79%<br>Log likelihood function -173.03 |

*** Significant at 1%, ** significant at 5% and * significant at 10%
Standard errors in parentheses.

**Table 11 Determinants of uptake of inorganic fertilizers by rural households in Mali and Burkina Faso in 2000**

| | Country | |
|---|---|---|
| *Variable* | *Mali* | *Burkina Faso* |
| Constant | -0.72710 | -0.68332 |
| | (1.8362) | (2.6011) |
| *Socio-economic profile* | | |
| AGEHH | -0.024818 | -0.007304 |
| | (-0.336) | (-0.070) |
| AGEHHSQ | 0.00020908 | -0.0002231 |
| | (0.260) | (-0.216) |
| HHSIZE | -0.022774 | 0.0066107 |
| | (-1.120) | (0.498) |
| EDUCAT | 0.2 | -0.9 |
| | (0.419) | (1.017) |
| *Production technology* | | |
| FARMSIZE | 0.2*** | 0.2** |
| | (4.877) | (2.351) |
| FARMSIZESQ | -0.0018904** | -0.0043236 |
| | (-2.455) | (-1.389) |
| *Climatic factors* | | |
| SAHEL | -0.3 | 0.4 |
| | (-0.998) | (0.791) |
| GUINEA | 3.2*** | 0.0038319 |
| | (4.128) | (0.010) |
| *Wealth status* | | |
| HIGHCLAS | 2.0 | 0.3 |
| | (1.509) | (0.283) |
| LOWCLASS | -0.4 | -0.5 |
| | (-0.826) | (-1.063) |
| *Market and infrastructure* | | |
| PROXROAD | 0.057793 | 0.9** |
| | (0.141) | (2.364) |
| PROXMARK | 0.3 | 1.2** |
| | (3.267) | (3.876) |
| COTTON | | 2.3*** |
| | | (5.481) |
| | Correct classification = 72%. Log likelihood function=-163.798 | Correct classification = 77% Log likelihood function= -172.9101 |

*** Significant at 1%, ** significant at 5% and * significant at 10%
Standard errors in parentheses.

organic fertilizers. In effect, the positive signs on ownership of cart and cattle suggest that both lack of transport methods and unavailability of cattle are critical constraints utilization of manure by farmers. Not only should manure be made available through ownership of cattle because there is no manure market, but also manure needs to be transported in the field with carts.

The farm size variables had the expected signs. The negative sign on the square term (FARMSIZESQ) suggests that there is an optimal farm size above which there is less pressure by farmers to intensify. The negative and significant signs on the proximity to markets may suggest that organic fertilizers are the main inputs available to farmers especially in environments where road accessibility is very poor. The positive signs on the location in Sahel again points to the availability of organic manure. In fact, livestock ownership which is strongly correlated to manure availability is high in the Sahel region than in others regions.

The estimated coefficients and relevant statistics from the regression on the inorganic fertilizer use are presented in Table 11. The results indicate that in Burkina Faso at sample means, access to markets, proximity to the main road, farm size and the cultivation of cotton are the significant variables with positive impact on the probability of use of inorganic fertilizers. Farmers who are close to markets are likely to apply more fertilizers to derive more surplus for sales. Similarly, farmers located in environments with better access to the main road are more likely to invest in fertilizers because they incur less transport cost in purchasing inputs from the markets. Although not significant, other variables had the expected signs. Similar results were found in Mali.

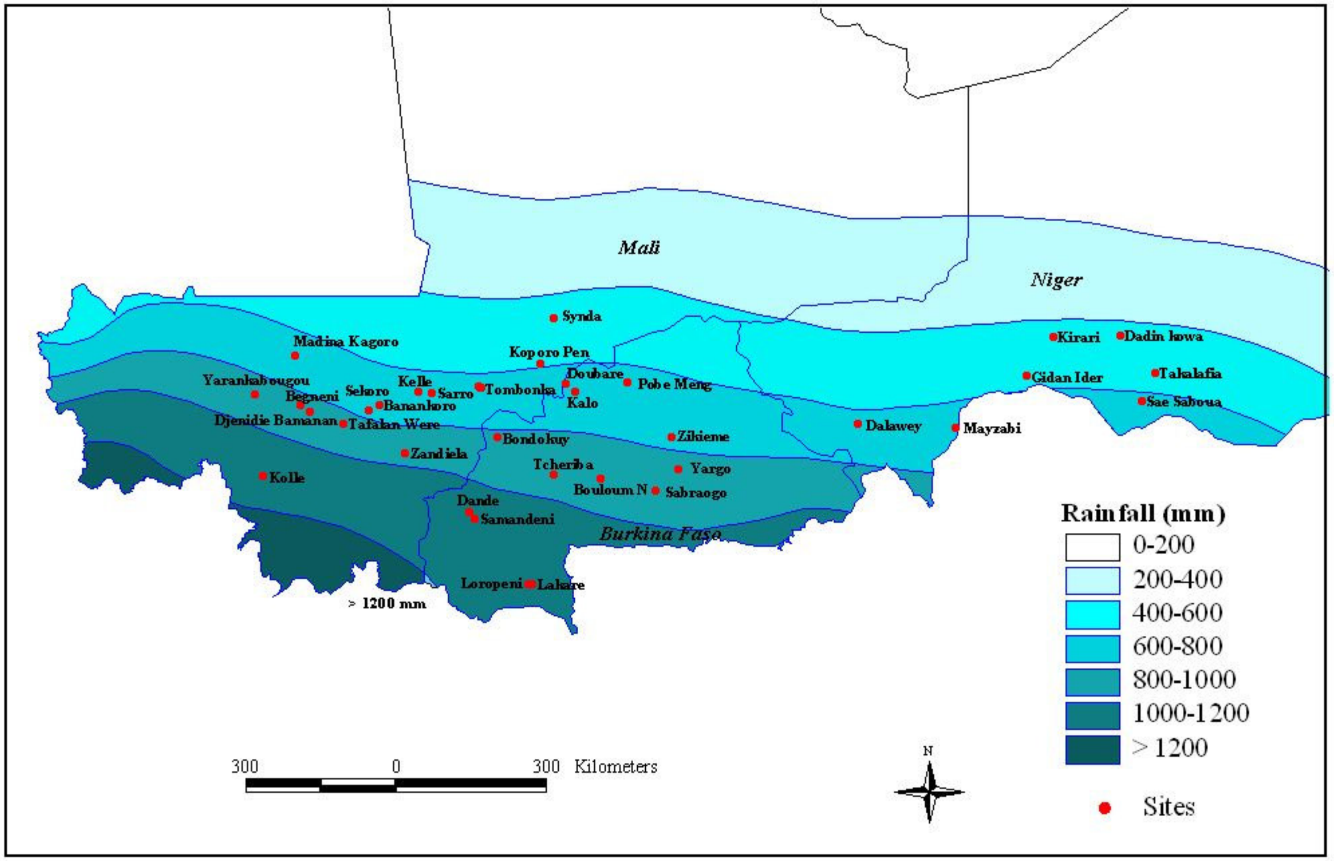
## 5. Conclusions and implications for research and development priorities

This paper focuses on uptake of sorghum and pearl millet improved varieties and adoption of soil fertility restorations options in three countries in the semi-arid tropics of West Africa. It identifies constraints to uptake of improved technologies. Results from the regional survey show that sorghum and pearl millet productivity gains have been limited by low performing varieties, poor functioning institutions which are supposed to supply and deliver technologies at low costs, poor functioning credit, fertilizers and seed markets, missing markets and poor road infrastructure.

The agricultural transformation is likely to happen if policy makers could foster investment in road infrastructure to reduce transport or transaction costs and provide an enabling environment for the development of input and product markets. Scientists should continue to develop technologies that could be adopted by farmers for the purpose of high productivity gains. In addition, efforts should be made by scientists to design institutional arrangements that will facilitate technology flow up to the farmers.

## Annex

**Figure 1 : Regional Survey Sites in West Africa**



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