NEW TECHNOLOGIES, MARKETING STRATEGIES AND PUBLIC POLICY FOR TRADITIONAL FOOD CROPS: MILLET IN NIGER

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Abstract

New technology introduction in this semiarid region of the Sahel is hypothesized to be made more difficult by three price problems in the region. First, staple prices collapse annually at harvest. Secondly, there is a between year price collapse in good and very good years due to the inelastic demand for the principal staple, millet, and the large changes in supply from weather and other stochastic factors. Thirdly, government and NGOs intervene in adverse rainfall years to drive down the price increases. Marketing strategies were proposed for the first two price problems and a public policy change for the third. To analyze this question at the firm level a farm programming model was constructed. Based upon surveying in four countries, including Niger, farmers state that they have two primary objectives in agricultural production, first achieving a harvest income target and secondly achieving their family subsistence objective with production and purchases later in the year. Farmers are observed selling their millet at harvest and rebuying millet later in the year. So the first objective takes precedence over the second. A lexicographic utility function was used in which these primary objectives of the farmer are first satisfied and then profits are maximized. According to the model new technology would be introduced even without the marketing strategies. However, the marketing strategies accelerated the technology introduction process and further increased farmers' incomes. Of the three marketing-policy changes only a change in public policy with a reduction of the cereal imports substantially increases farmers' incomes in the adverse years. In developed countries crop insurance and disaster assistance is used to protect farmers in semiarid regions during bad and very bad (disaster) rainfall years. In developing countries finding alternatives to the poverty-nutritional problems of urban residents and poor farmers to substitute for driving down food prices in adverse years could perform the same function as crop insurance in developed countries of facilitating technological introduction by increasing incomes in adverse rainfall years.

Keywords: inventory credit, marketing strategy, inorganic fertilizers, fertility depletion, farm level programming, micro-fertilization, sidedressing

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Introduction

A principal production requirement of agriculture is that to produce crops major and minor nutrients are required. Without sufficient nitrogen and phosphorus yields will stagnate and decline to low level equilibriums (for an estimate of this yield decline using simulation to take out weather effects see Ahmed, M. and J.H.Sanders, 1998, p. 258). Providing adequate nutrients for crop production in Niger is not a risky option that farmers can avoid. It is a prerequisite for removing crop production from a downward cycle of fertility depletion and yield decline.

With continuing population pressure leading to the breakdown of traditional fertility replacement strategies, such as fallowing and migration to new areas, and the nutrient inadequacy of others, such as manure and rock phosphate, there needs to be a focus on increasing input purchases of nutrients (inorganic fertilizers). For farmers to adopt these inputs, they need to be profitable. Moreover, the risks from low yields in adverse rainfall years need to be reduced with technology or policy.

In developed countries, such as the US, institutional development (availability of crop insurance managed by the private sector but with an important public sector subsidy plus disaster assistance funded by the public sector-see Dismukes and Glauber, 2005) allows farmers in semiarid regions to lose fertilized wheat or sorghum or experience low yields in inadequate rainfall years without going bankrupt. Then in normal and good rainfall years these activities are often very profitable. Africa is more dependent upon semiarid crop systems than any continent except Australia (Shapiro and Sanders, 2002, pp. 270-274).

Using farm level programming we evaluate first whether farmers would adopt new technologies with higher fertilization levels. Secondly, we analyze the effects of the introduction of new marketing strategies and a public policy on farm level incomes and adoption. Finally, for an adverse rainfall year in which yields are substantially lower than in normal or good years are there policies that would protect farmers from taking losses?

In the next section we describe the region’s production system, weather and price variability and new technology options. Then we define the farm model and detail the estimation of the parameters from fieldwork. The results section considers the various alternative scenarios discussed above. First, the potential for adoption of new technologies is analyzed. Then farmers’ response to resolving each of the three price problems is evaluated. Further analysis of these options can be undertaken at the regional and national level. Here we focus on the farm level effects.

Finally, in the conclusions some policy and research issues in analysis and implementation of technology introduction, the marketing strategies, and public policy alternatives are considered.

The Region

Household Production Systems in a Marginal Rainfall Region

Niger is one of the poorest countries in the world with a per capita income of $200 in 2003 and a population of 11 million. In 2001 40% of the children in Niger were malnourished (World Bank, 2004, p. 255). In 1996 61% of the population earned less than 1 $/day a day and 85% earned less than 2 $/day. Moreover, in the main economic activity, agriculture, productivity is falling (World Bank, 2005, pp. 257, 259, 261.). In the ‘90s agricultural output growth of 2.6 % did not keep up with population growth of 3.4% (World Bank, 2001).

Millet (generally associated with cowpeas in Niger) is the basic staple and is produced on 5.2 million ha in Niger as compared with 9.4 million ha in India and 6.1 million in Nigeria. Niger has the lowest yields (481 kg/ha) and is the only one of the top three major producers that has not substantially increased its yields. India has doubled its yields from the ‘60s and Nigeria increased its aggregate yields by two thirds. In 2004 millet yields were 851 kg/ha in India and a metric ton/ha in Nigeria. In 2004 Niger produced 2.5 million tons while Nigeria had 6.1 and India 8 million tons (all data for the three countries above is from 2004; FAOSTAT Database Results, 2005).

The Fakara plateau (Figure 1) is a typical region in this Nigerien production system. Farmers first settle the higher fertility river valleys and then move to the plateaus as land becomes scarce. But even farmers concentrating in the valley want some land higher up to cover themselves for the risks of flood years. Similary, Farkara farmers try to get access to some low lying land to cover the risks of the dry years.

On the Farkara plateau rainfall is low (an average of 450 to 500 mm over the period 1990-2000) and irregular. Soils are predominantly sandy with low nutrient levels and they are especially deficient in phosphorous, nitrogen, and organic matter. Water holding capacity of the soils is generally poor.

Farms average 7 ha which is very small for marginal rainfall regions. Households are a mixture of single and multiple families averaging 7 members (World Bank, 2001). All adults- above 14 years old- labor on the communal fields. Most adult females also are given small areas (as 0.1 ha) for private fields in which they can work after their joint responsibilities on the communal fields are fulfilled. Women keep or sell the production on their private fields for their own use. Those with access to underground water can produce fruits or vegetables out of season

Crop production provides 40 to 60% of household income with the rest from livestock and non-farm activities. Farmers raise goats, sheep and chickens. Non-farm activities include a range of commerce and semi-skilled professions (barbers, carpenters) demanded in the village.

Riskiness of Agriculture: Weather

Table 1 indicates the probabilities for the various types of years based upon rainfall data collected from the Dosso station on the edge of the Farkara plateau for the period, 1931-2000. In defining the periods there was a focus both on the total rainfall during the year and on the distribution of rainfall during August, when flowering and seed setting take place. Originally there were eight states defined and this was reduced to five states (for further details see Abdoulaye, 2002) very adverse, adverse, normal, good, and very good. In very adverse states farmers lose most of their harvest. These major drought years are well known in the Sahel, 1972-74, 1983-84, 1994-95 and 2004-05 or a little more frequently than once a decade. Farmers can not include this very adverse state in their planning horizon as yields in general collapse and livestock either die or are sold at very low prices as few have sufficient pasture. In these years Nigerien farmers depend upon drought relief as American farmers depend upon disaster assistance. So these very adverse years (14% probability) were excluded from farmers' calculation of expected values as they are unable to plan for these disaster years. Hence, only four states of nature are relevant. States of nature are the combined rainfall quantities and qualities defining the different types of year such that all possible year types are defined and the probabilities of the different types sum to one.

Expected yields are based on on-farm trial data at Goberi and Karabedji in the Farkara plateau from 1996 to 2000. Yields are mapped to the years that correspond to the given state of nature. The four states of nature included very good, good, normal, and very bad rainfall years. Since the trial periods (1996-2000) did not include very good years this year type was calculated as equal to 2 standards deviation above the overall mean.

Riskiness of Agriculture: Price Variation

Besides the variation from weather, insects and disease farmers also face substantial price variation. Price variation partially offsets the yield variation since in good years prices collapse and in bad years prices become very high.

In the local regional market of Dosso during the 1999-2004 period the prices varied from 110 CFA/kg to 170 CFA/kg (Figure 2) during the harvest season of October to December. This demonstrates the price collapse that occurs with basic staples as weather and other stochastic factors result in substantial annual output shifts. Very bad and very good years are not represented in these five year. In very good years the millet price can fall to 50 FCFA at harvest.

Besides the between year price variation the annual price collapse at harvest (October-November) is clearly illustrated. Harvest prices should be compared with the "soudure"-hungry season prices in the June-August period. For good rainfall years such as 1999-2000 and 2003-04 prices of millet increase from 110 to 150 and from 130 to 150 respectively in this regional market. In the second consecutive adverse year 2002-03 prices started at 170 but there was substantial government selling of stocks and imports and the price fell to 140. Then in the following year, a normal year, the public sector bought substantial quantities and the millet price went to 230. So the returns to storage will be substantially influenced by what the public sector does. But there is substantial price variation both within years and between years.

The third cause of low prices is government and NGO interventions in bad cropping seasons. For example in July 2001, the government put 10,000 metric tons of millet on the market at a price of 100 FCFA/kg while the market price was 210 FCFA/kg in Niamey (Agence France Presse, 2001). In 2005 after a bad rainfall season and locust attacks in the north millet prices were over 200 CFA in Niamey and the government was calling for food aid from donors in the spring of 2005.

New Technologies

One difference in the region from much of Niger has been the opportunity to observe fertilization. Since 1982 IFDC-ICRISAT (International Fertilizer Development Center-International Center for Research in the Semiarid Tropics) have had experiments in the region. In the late ‘80s and early ‘90s with active development programs here fertilizer use was much higher than now (Mokwunye and Hammond, 1992).

In the last five years farmers have been using micro-fertilization. Small quantities of inorganic fertilizer (compound fertilizer of NPK) up to 25 kg/ha are put in the planting hole along with manure and the seed. With the rainfall variability at the start of the season repeated planting of millet is often required. Micro-fertilization by improving germination reduces the need for repeated planting and gives a start to the seedlings.

The next two logical steps are to improve the nutrient content of the micro fertilization and to increase the quantity of fertilizer with side-dressing. The improved micro fertilization is with 20 kg of DAP (Diamonium Phosphate:18-46-0). This is a higher concentrate fertilizer than the NPK (15-15-15). The numbers in parentheses are the percentages of the three major nutrients, nitrogen, phosphorous and potassium. The difference between the sum of the numbers and 100 is filler of no nutrient value. So there are more nutrients with DAP. Moreover, Sahelian soils generally have sufficient potassium. Unfortunately, this potassium is mined rapidly when crop yields are increased (Dureau et al., 1994). But for the short term impact there will be more effect from DAP because it has not only a higher percentage of nutrients but the two nutrients it contains are the most deficient in Sahelian soils.

The new fertilizer based technologies are an improved micro dose (20 kg/ha of DAP put into the planting hole with the seed) and an improved moderate dosage (60 kg/ha of compound fertilizer with the three major nutrients of nitrogen, phosphorous and potassium-NPK) or 50 kg/ha of SSP. SSP (simple super phosphate) actually has a lower nutrient content than the other two fertilizers but it has only phosphorous and P is generally considered to be the most limiting nutrient in the sandy soils of Niger.

NPK (15-15-15) is known in the Sahel as cotton fertilizer and is the most widely available fertilizer. The testing and adaptation process of inorganic fertilizers for cereals in low rainfall zones has been going on since the early ‘80s but cotton research started in the Sahel in the ‘50s and development programs extending fertilizer for cotton since the ‘60s (Sanders et al, 1996).

Only a small quantity of fertilizer can be put in the hole without burning the seed so the next higher level of fertilization after 25 kg/ha will need to be sidedressed. Sidedressing is more efficient than broadcasting since the fertilizer is closer and more accessible to the plant. But sidedressing requires more labor and a separate operation as broadcasting and micro-fertilization are done at planting time. Sidedressing can also be tied to the existence of early rains so its riskiness can be reduced.

After raising fertilization levels the introduction of new cultivars, that are more responsive to higher fertility conditions than traditional cultivars, is the next logical step. Table 2 reports on the expected yields over the four states of nature and the yield variability of present and new technologies. There are gains in profits from all the activities but the gains are very small for the micro doses (Table 3). There is a fairly substantial gain for the sidedressing with SSP and new cultivars. Note that this is not sustainable over time as there will be a need for N and K soon.

The Model

Basic Equations

The farm programming model consists of the ten equations below. The general algebraic formulation of the model is as follows:

$$Max \quad EW = \sum_{s=2}^{5} \theta_s w_s \tag{1}$$

$$subject \quad to$$

$$P_{1is} q_{1is} \geq \bar{I}, \quad (2 \leq s \leq 5), \quad for \quad all \quad i \quad (crops) \tag{2}$$

$$C_s + B_s \geq \bar{C}, \quad (2 \leq s \leq 5) \tag{3}$$

$$C_{is} + q_{1is} + q_{2is} = Q_{is}, \quad for \quad all \quad s \quad and \quad i \tag{4}$$

$$\sum_i a_{ij} x_i + \sum_t a_{tj} x_t \leq bj, \quad for \quad all \quad j \tag{5}$$

$$Q_{is} = \sum_i y_{is} x_i, \quad for \quad all \quad s \tag{6}$$

$$r_t = \sum_t \alpha_{ts} l_t \quad for \quad all \quad s \tag{7}$$

$$w_s = \sum_i P_{2is} q_{2is} + \sum_t r_{ts} + M_s - \sum_i c_i x_i - \lambda P_{2is} B_s \tag{8}$$

$$W_s^* = w_s + \lambda P_{2is} B - M_s \tag{9}$$

$$\sum_s \theta_s (W_s^* + (\sum_i P_{1is} q_{1is}) + p_{cs} c_s) = \Psi \tag{10}$$

Where the subscripts are: s for states of nature, i for crops, t is other activities, 1 and 2 for crop sale periods (1 is harvest and 2 is the price recovery period), j is resources.

Variable Definitions

E	The expectation operator
W_s	The value of after harvest sales plus net returns to other activities plus the remittances minus the costs of millet purchased later in the year adjusted for the risk coefficient (λ). Note below that for the income definition in equation 9 we take out this expenditure. The rationale for equation 8 is given in the text
θ_s	The probability of state s with $\sum_s \theta_s = 1$
p^e_{2is}	Expected price for crop i in state s in the price recovery period (6 months after harvest)
Q_{2is}	Quantity of crop i sold in the price recovery period (6 months after harvest) during state s
r_t	The revenue of the tth livestock or non-agricultural activity
c_i	The input cost per hectare ith crop activity
x_i	The number of hectares of the ith crop activity
λ	Risk premium coefficient
P_{1is}	The price in state s for crop i at harvest
Q_{1is}	The quantity sold in state of nature s for crop i at harvest
$\bar{I}$	The income required at harvest
$\bar{C}$	The required quantity of millet for household subsistence
C_s	The quantity of millet produced for home consumption in state s
B_s	The quantity of millet purchased for home consumption in state s
Q_{is}	The total production of crop i in state s
y_{is}	The yield per hectare of activity I in state of nature s
p_{cs}	The price for millet produced and consumed by the household.. Note that this price is averaged over the consumption period with weights according to the volumes consumed
Ψ	The expected total household income
a_{ij}	The technical coefficients
l_t	Unit of other activities (livestock and non-agricultural)
α_{ts}	Per unit return to other activities (livestock and non-agricultural) in state s
w^*_s	Household income includes income from crop, livestock, and non-farm activities. In the results first income from crop activities and then total income will be presented.
M	Remittances during the adverse state of nature. Remittances generally come at the start of the season and are part of the capital available. In adverse years migrants send food or money during the “soudure” or earlier.
b_j	Availability of resource j

Explanation of Equations and Parameter Values

The first equation is the objective function. This is the maximization of “adjusted income” (W_s) over the alternative states of nature (s). Equations 2 and 3 are the two components of the lexicographic utility that the farmer needs to fulfill according to the field interviews in four countries.

First, the farmer has his harvest income goal (Equation 2). Based on field studies in Niger, Mali, Senegal, and Mozambique (Abdoulaye, 2002; Vitale, 2001; Sidibe, 2000; Uaiene, 2004) farmers’ principal objective is this harvest income goal, which takes precedence over their desire to set aside cereals for consumption during the year and over profit maximization. Not only did farmers say that this household income goal was more important than the storage subsistence goal but farmers were also observed selling off their primary staple and repurchasing it later in the year in most states of nature in Niger and in adverse states of nature in the other Sahelian countries.

At harvest the farmer needs to have sufficient income to pay taxes, which are collected then, and school fees. He needs to repay his loans at harvest. Then he needs to pay household wages to family members. These are paid in the form of clothing, especially to female family members, and as advances to the male members of the household, who migrate to urban Niger or out of the country after the harvest and return next year for the crop season. Weddings also take place after harvests. With their wide circle of close friends farmers have to pay for gifts even when their family members are not getting married.

With so many farmers selling at harvest, staple prices collapse. Millet prices then gradually recover climbing until they reach their peak in the “soudure” or “hungry season” (Figure 2). The ‘soudure” is the period when food reserves are almost gone and the new crops are not yet ready for harvest.

This household income goal is calculated from the actual expenditures of the households in a normal rainfall year and in the model was set at $98 based upon the field interviews with 100 families (Abdoulaye, 2002; Using the Feb 2001 exchange rate of 711 FCFA/$, IMF, 2001). This was 21% of total household income, the average observed in the sample. In continuing work we have estimated this harvest income requirement for different states of nature. In good and very good years farmers make more investments at harvest in human and physical capital, i.e. farmers pay for medical expenses and improvements to their housing (Baquedano, forthcoming).

Equation 3 states the millet consumption goal for the household. This is achieved with production (C_s) and with purchases (B_s) later in the season. This equation is tied to Equation 8 as with this adjusted income from selling crops later in the season and from non-farm and livestock activities plus remittances from the migrants in adverse rainfall years, the farmer needs to purchase sufficient millet to achieve his subsistence goal for millet production. The choice between production and purchase of millet is made in the modeling. This internal cost of production of millet is set equal to the expected purchase price later in the year (P_{2is}) as long as λ is equal to 1.

Low income farmers in difficult climatic regions are nervous about being dependent upon the market for the supply of their primary food staple. So in the model farmers continue producing millet even though they could buy it cheaper later in a normal year on the market. The rationale is that the price for millet six months after harvest is only the expected price. Moreover, farmers will need to find the income for these purchases. Prices will be higher in adverse years and millet may not be available. Therefore the value of λ is adjusted until the model prediction is consistent with what farmers are doing. This adjusted income is thus a manner of achieving the subsistence goal and allowing farmers to be more food secure.

Remittances in Equation 8 help in purchasing sufficient grain later in the year in adverse rainfall years. Remittance were estimated at the median in our sample as $86 for adverse years and zero otherwise (Abdoulaye, 2002; also see Rain 1999, who found a range of 0 to $287 in his sample; the mean value of Rain was $183 but our estimate was of the median value). Note that the household head partially finances the migrants to go out after harvest. So part of this payment to migrants is for services received during the crop season and part is a type of insurance premium. In future activities these two functions of the payments to migrants could be separated.

In equation 9 the definition of income received six months after harvest is then the usual value for income adjusted by netting out expenditures on food and the transfer payment of remittances. In equation 10 there is the definition of total household income including w_s^* plus the harvest income goal, plus the value of home consumption. The value of home consumption uses the market value of millet weighted by when it was consumed. Household income includes the implicit payments to family labor. Crop income is also calculated by deducting livestock and non-farm income (r_j) from the household income estimates of Equation 10.

Finally, the millet consumption goal ($\bar{C}$) was 200 kg/year for the adult male equivalent. This was based upon average consumption in normal years. This was adjusted for the gender and age of the family members in the household.

Equation 4 is an identity dividing the total millet produced on the farm between the millet consumed on the farm, and the millet sold in periods 1 (post harvest) and 2 (six months after post harvest).

Equation 5 would actually be several equations for the resource constraints. Note that there are three activities on the farm, specifically crop production, livestock production and non-farm activities, such as small scale commerce or skilled trades. The use of labor and capital in these three activities is determined endogenously in the model. Crop activities are responsible for 40 to 60% of household incomes (Abdoulaye, 2002)

Equations 6 and 7 are production functions for the crop production and non-farm incomes. There would also be a production function for livestock production. Both the livestock and non-farm production functions are based upon constant rates of return estimated in previous studies (Abdoulaye, 1995; Abdoulaye and Lowenberg-Deboer, 2000).Upper level constraints were put upon non-farm activities as there are only so many kola nuts that a farmer could sell or hair that he could cut in the village.

Equations 8 through 10 have already been discussed above.

Calibration and Validation

With the risk premium (λ) set at one millet production is increased until the cost of production of the next unit (opportunity cost) is equal to the expected purchase price (p_{2is}^{e}) in a normal season six months after harvest, 113 FCFA/kg. At this level of millet production farmers are entirely dependent upon millet purchase in adverse years and leave part of their crop land idle. Neither of these is consistent with observed farmers' practices. So the risk premium was successively raised. At $\lambda = 1.77$ crop area is fully occupied and farmers produce millet until the cost of production is 200 FCFA/kg. This is consistent with the price in the "soudure" (hungry season-the period right before the next harvest) for an adverse year. In 2001, millet prices reaching 210 FCFA/kg and 220 FCFA/kg were reported in Niamey and other major cities of Niger (Agence France Presse, 2001). In Dosso the millet prices were well over 200 FCFA/kg in both 2000-01 and 2001-02 (Figure 2).

This higher risk premium is employed and farmers continue producing millet until their costs of production are 77% higher than the expected purchase price for millet in normal years. But this value is consistent with the price of millet expected later in the year in adverse years. Moreover, in adverse years farmers still need to purchase 32% of their consumption requirements. Millet purchases in adverse years and even in more favorable years have been regularly observed in Niger. The same phenomenon has been reported for basic food staples in other countries (Arndt et al., 2001; Barrett, 1996; Weber et al., 1988).

Adjusting with the Consumer Price Index (IMF, 2002; 700 FCFA/$), for the same base year (1995) the model estimate here of $587 in household income is reasonably close to the Hopkins-Reardon (1993) estimate of $453 for northern Boboye (also in the Fakara Plateau).

Alternative Scenario Results

Introduction of New Technologies

Farmers' current practices have a common characteristic, which is their low out of pocket expenses (0 and $2/ha cash expenses). All improved fertilizer based technologies have higher expenditures than the current farmer practices due to the increased fertilizer costs and the additional labor required. Their higher expected revenues pay for the additional costs (Table 3).

If farmers have the alternative available to introduce higher levels of micro doses of fertilizer and side dressing once the plants have germinated (the 60 kg/ha choice), farmers choose these activities since they increase expected crop incomes 85% and expected household incomes 37% (Table 4). The area in the types of fertilization is about equally divided between higher levels of micro doses of fertilizer and area with side dressing.

This technology raises incomes in all states of nature and was sufficiently profitable to be introduced even without changes in marketing strategy. Note that in the very adverse state the farmer still needs to depend upon the public sector.

Harvest Price Collapses -- Storage and Inventory Credit

A primary price problem for farmers is the annual post harvest price collapse. Merchants purchase at harvest time and then store to take advantage of the price recovery later in the year. Farmers could also benefit from selling part or all of their harvest later. To put off the sale, farmers need credit or some other source of income during the period they are storing, waiting for the price recovery. Farmers' associations are increasingly being formed in the Sahelian countries including Niger for storage and collective selling.

With the inventory credit program farmers can sell crops later in the years and they receive higher prices. This price increase corresponds to an increase in the price of millet from \$0.13/kg (91 FCFA at harvest) to \$0.16/kg (113 FCFA) in a normal year (Table 5). Price increases are even larger in the adverse climatic year. Price increases of 50% between harvest and the next planting season are common (République du Niger, 2000).

With inventory credit available farmers increase slightly the use of micro fertilizer and reduce the side dressing (Table 6). There is a further increase of crop and household incomes. These income increases are now 97 and 42% respectively. So there is only a small increase in the additional incentive to use higher levels of inputs. There are costs of interest and storage to use inventory credit and these would be expected to go down over time with learning by doing.

As more farmers and merchants do this storing and selling over time, the seasonal price variation will ultimately disappear. But in Sub-Saharan Africa this price smoothing effect is not expected for a decade or two judging from the long term experience in Ghana with these programs.

Good Year Price Collapses and New Markets

The second critical type of price collapse is the between year effect resulting from the production increases of good years. People can eat only so much of their basic staple, so it is difficult to increase consumption rapidly or to find new markets once the price has collapsed. Economists refer to this classic problem of food staples as price inelasticity of demand. Moderating the price collapses of the basic food staples by developing new markets is expected to encourage a more rapid introduction of new technologies by shifting the demand and increasing the elasticity.

One of the fastest growing sectors in the Sahel is the food processing of the traditional cereals, millet and sorghum (Ouendeba et al., 2003). In developed countries rice and wheat consumption requires minimum time of the housewife because food scientists have developed labor savings methods of processing and preparation. Now these same techniques have been applied to millet and sorghum.

Packaged couscous and a series of other millet products are increasingly available across the Sahel especially in Dakar and Bamako. In Dakar, Senegal there are 11 local semi-industrial firms producing processed millet products including, tchakri-yogurt, arraw, dégué, flour and infant food (Ouendeba et al., 2003). Moreover, some of those small scale food processors are even exporting millet based products to West Africans in Europe and the US.

Given the importance of millet in both production and consumption the potential market size for processed food is not expected to utilize more than 5 to 10% of the supply. Nevertheless, a small sector of better farmers are benefiting from the increased urban demand for processed traditional cereals. Besides the direct effect of market expansion an indirect effect on technology use by other producers would be expected. So even farmers not involved in the new markets would have the demonstration effects of the new technologies and some technology adoption would be expected. For these farmers producing for local markets and their own use new technology adoption would have a food security increasing effect.

For these market expansion programs the price effects are substantial for the good and very good years (Table 6).The technology introduced is a continued shift out of micro dosis and to sidedressing with a net increase in fertilizer use. Household incomes are almost doubled from new technology alone. Crop incomes are now increased by 136% and household incomes by 60% with the combination of new technologies and improved markets (Table 6). By concentrating on the good and very good year price collapses the largest effects on farmers' incomes are possible. But farmers need the income gains even more in bad and normal rainfall years and there is little help of the two marketing strategy or of new technology in these years (Table 7).

Public/NGO Intervention in Adverse Rainfall Years

Sahelian governments are preoccupied with low food prices due to concerns with urban political disturbances (Angé, 1997, cited in Yangeen 1997; Bates, 1981). Higher prices can have short-run, adverse effects on both urban consumers and those farmers purchasing food supplies. Even in a normal cropping season, small farmers often shift from net food sellers at harvest to net food buyers later in the year (Barrett, 1996, Weber et al, 1988). However, there are alternative poverty policies besides depressing food prices.

Besides the public sector, development projects and NGOs also become involved in food aid and other assistance programs. One probably unintended effect of the programs that bring in substitute products such as maize or wheat, is to keep millet prices low. However, farmers need to make profits to purchase inputs and to justify the continuing investments for increased production.

With the recommended policy of a decreased intervention of the government in adverse rainfall years the prices in the bad rainfall year went from $0.18 to $0.32 (first columns of Table 5). With this change the household income is increased by 56% from the new technology and less governmental intervention (Table 6). Even more important household incomes in adverse years increases from $529 with just new technologies to $ 775 (Table 7).

While inventory credit and advances in product markets can offset the price collapses and increase expected incomes, neither strategy helps farmers in the adverse years when incomes are the lowest. So convincing public policy makers and NGOs that many farmers benefit from the staple price increases in adverse rainfall years is important for technology introduction.

Conclusions

New fertilizer based technologies are adopted by farmers according to model results. Introduction of new marketing strategies results in an accelerated intensification and higher incomes to farmers. Only the public policy substantially increased returns in adverse rainfall years.

Inventory credit is already being rapidly adopted in the Sahelian region as is the development of new markets for the traditional food crops especially in Senegal (Ouendeba, 2003). From the farm level perspective Sahelian governments may need to find other methods of attacking poverty that do not depress farmers' incomes. Measures to increase the incomes of the poor in urban and rural sectors (including many farmers) would enable low income consumers to increase food expenditures even when food prices are high. This would be expected to benefit both consumers and producers in the long run by increasing farmer incentives to use inputs and to make investments in their farm operations. Costs and benefits on a national scale would be a next step in this analysis.

Ministries of Agriculture and agricultural research agencies in Sub-Saharan Africa focus on supply. They need to put more attention on demand factors to understand how to encourage the evolution of feed and feed processing sectors and to evaluate alternative methods of helping poor people attain nutritional objectives that are not deleterious to the evolution of production and productivity incentives in the agricultural sector.

A short run adjustment is to encourage countries and donors to buy the cereals in the higher rainfall regions of the recipient country in adverse rainfall years rather than importing them. Donors and countries have been starting to do this in the Sahel. This strategy is more difficult in Niger than in most of the Sahel as there is so little area in Niger with higher rainfall.

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Table 1: Yields and prices in the different states of nature and the probabilities for each state from farm surveys and SIMA marketing studies.

States of Nature	Probabilities (%)	Millet yields- no fertilizer (kg/ha)	Millet yields- manure and 8 kg/ha of NPK (kg/ha)	Millet price at harvest ($/kg)	Millet price 6 months later ($/kg)
Adverse	17	288	332	0.18	0.23
Normal	43	359	415	0.13	0.16
Good	28	431	498	0.07	0.09
Very good	12	467	539	0.05	0.05
Expected Value		379	438	0.11	0.14
Standard Deviation		52	60	0.05	0.05

Source: Survey and trial data, SIMA (Systeme d'Information sur les Marches Agricoles) database and authors calculations

Note: Very adverse states are not included in the farmers' probability calculations. In these states farmers count on support from the public sector and NGOs. When these very adverse states are included, the probabilities are 14% for the very adverse state, 15% for the adverse state, 37% for the normal state, 24% for the good and 10% for the very good state. Very adverse states are the famous drought years such as 1971-1974, 1983-84, 1994-95 and 2004-05. These major drought years occur approximately once a decade. Farmers can plan on and do something about these four states of nature above.

Table 2. Expected yields of cropping activities of present and new technologies from long term trials of ICRISAT/IDRC.

	Monoculture	Intercrop	
	Millet (kg/ha)	Millet (kg/ha)	Cowpea (kg/ha)
A. Current practices			
1- No fertilizer	379 (52)		
2 -Manure (1400 kg/ha) + 8 kg/ha of NPK	438 (60)		
3 - Micro dosage (3 kg/ha of NPK)		285 (39)	120 (54)
4 - Moderate dosage (25 kg/ha of NPK)		424 (58)	135 (62)
B. New technologies			
5- Improved micro doses (20 kg/ha of DAP)	544 (59)		
6 - 5 + New cultivars	633 (148)		
7- Improved Moderate dosage (60 kg/ha of NPK)		520 (218)	261 (63)
8- Improved Moderate dosage (50 kg/ha of SSP)		524 (211)	302 (85)
9- 7 + New cultivars		630 (309)	370 (143)
10- 8 + New cultivars		635 (301)	434 (176)

Source: ICRISAT/IFDC (International Center for Research on the Semiarid Tropics/ International Fertilizer Development Center) farm trial data furnished by Andre Bationo (Standard deviations are presented in the parentheses above). Note that these are expected values for all four states of nature. DAP is Diamonium Phosphate with nutrient levels of (18-46-0). NPK refers to compound fertilizer containing 15% each of nitrogen, phosphorous, and potassium generally known in the Sahel as “cotton fertilizer.” SSP is simple super phosphate with nutrient levels of (0-18-0).

Table 3. Expected returns ($/ha) to cropping activities presently practiced and to new technologies from survey data on prices and costs with yields of Table 2..

	Monoculture			Intercrop		
	Cash cost	Total cost	Net return	Cash cost	Total cost	Net return
A. Current practices						
1- No fertilizer	0	25	14 (11)			
2 -Manure (1400 kg/ha) + 8 kg/ha of NPK	2	33	15 (12)			
3 - Micro dosage (3 kg/ha of NPK)				2	33	15 (8)
4 - Moderate dosage (25 kg/ha of NPK)				8	47	18 (11)
B. New technologies						
5- Improved micro doses (20 kg/ha of DAP)	7	39	19 (17)			
6 - 5 + New cultivars	14	44	20 (15)			
7- Improved Moderate dosage (60 kg/ha of NPK)				18	63	27 (11)
8- Improved Moderate dosage (50 kg/ha of SSP)				12	59	38 (12)
9- 7 + New cultivars				26	76	39 (18)
10- 8 + New cultivars				19	73	52 (17)

Source: Authors’ calculations

$1=711 FCFA (IMF, 2001).

Note: Numbers in parenthesis are standard deviations for the net returns.

Table 4. Farm Plans and Expected Incomes with the Current Production System and New Technologies (model results).

	Current System (No New Technologies)	Introduction of New Technologies
1. Current practices (ha)		
No fertilizer	2.26	-
Small doses of fertilizer	3.74	-
2. New technologies (ha)		
Micro doses	-	2.70
Moderate doses	-	3.30
Expected Household Income (US $)	587	805(37%)
Expected Crop Income	279	515(85%)
Opportunity cost of capital	95%	130%

Source: Model results

Note: Numbers in parenthesis are percent increases from current practices.

Current practices. The no fertilizer practice is monoculture millet without any fertilization. Small doses of fertilizer are a millet/cowpea intercropped activity (3kg/ha of NPK and Manure plus 8 kg/ha of NPK).

New technologies. Micro doses are monoculture millet fertilized with (20 kg/ha of DAP). Moderate doses activities include millet/cowpea intercropped activities with NPK (60 kg/ha) and also with SSP (50 kg/ha) both using improved varieties.

Table 5. Expected millet prices ($/kg) for different states of nature and with different marketing strategies (SIMA data).

	New technologies	Inventory credit	Between year price collapse moderation	No government intervention in adverse years
Adverse	0.18	0.23	0.23	0.32
Normal	0.13	0.16	0.16	0.16
Good	0.07	0.09	0.16	0.09
Very good	0.04	0.05	0.16	0.05
Expected	0.11	0.14	0.17	0.15
Standard deviation	(0.05)	(0.06)	(0.03)	(0.08)

Table 6. Land allocation, returns to capital, and income effects of current practices, new technologies, and the combination of new technologies and improved marketing strategies (model results).

	Without new technologies	With new Technologies	New technologies and inventory credit	New technologies with less government (and NGO) intervention in bad years	New technologies and new markets
1. Current practices					
No fertilizer (ha)	2.26	-	-	-	-
Small doses of fertilizer (ha)	3.74	-	-	-	-
2. New technologies					
Micro doses (ha)	-	2.70	2.65	2.39	1.52
Moderate doses (ha)	-	3.30	3.45	3.61	4.48
3. Household Income ($)	587	805	835	914	939
4. Crop Income ($)	279	515	550	633	657
5.Percent change in household income (from present practices)	-	37%	42%	56%	60%
6. Percent change in crop income (from present practices)	-	85%	97%	127%	136%
7. Opportunity cost of capital	95%	130%	130%	130%	130%

Source: Model results
$1=711 FCFA (IMF, 2001).

Table 7. Household incomes (in dollars) for different technology and marketing strategy for the different states of nature (model results).

	Without New Technologies	With New Technologies	New technologies And inventory credit	New technologies with less government intervention in bad years	New technologies and only moderate price collapse in good and very good years
Adverse	459 (159)	529 (244)	528 (246)	775 (478)	530 (249)
Normal	583 (278)	794 (504)	827 (543)	849 (574)	792 (511)
Good	647 (334)	914 (623)	955 (670)	1018 (736)	11146 (865)
Very good	640 (322)	977 (684)	1016 (731)	1107 (826)	1559 (1278)
Expected income	587 (279)	805 (515)	835 (550)	914 (633)	939 (657)

Source: Model results.

Note: Numbers in parentheses are crop income.

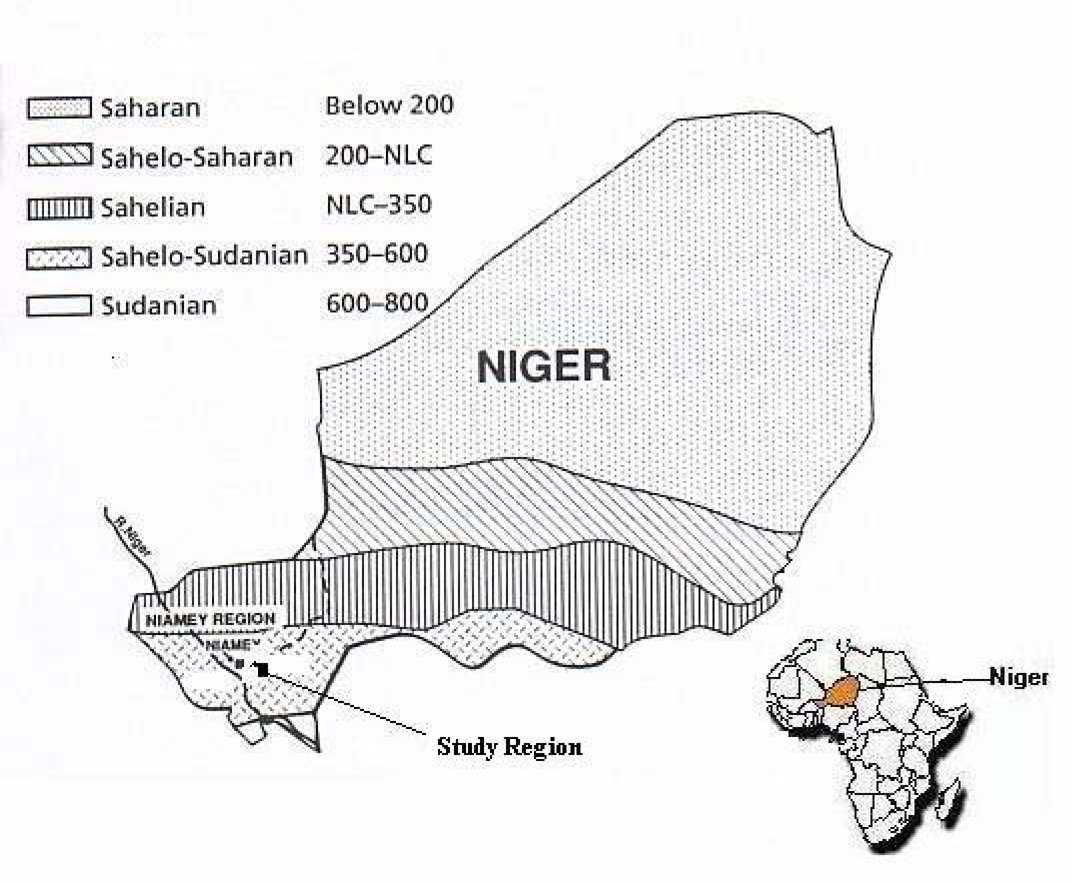

Fig. 1. Isohyets and study region in Niger.

Note: NLC is the northern limit of cropping. The isohyets refer to 90% probability.

Source: Adapted from Sanders et al., 1996

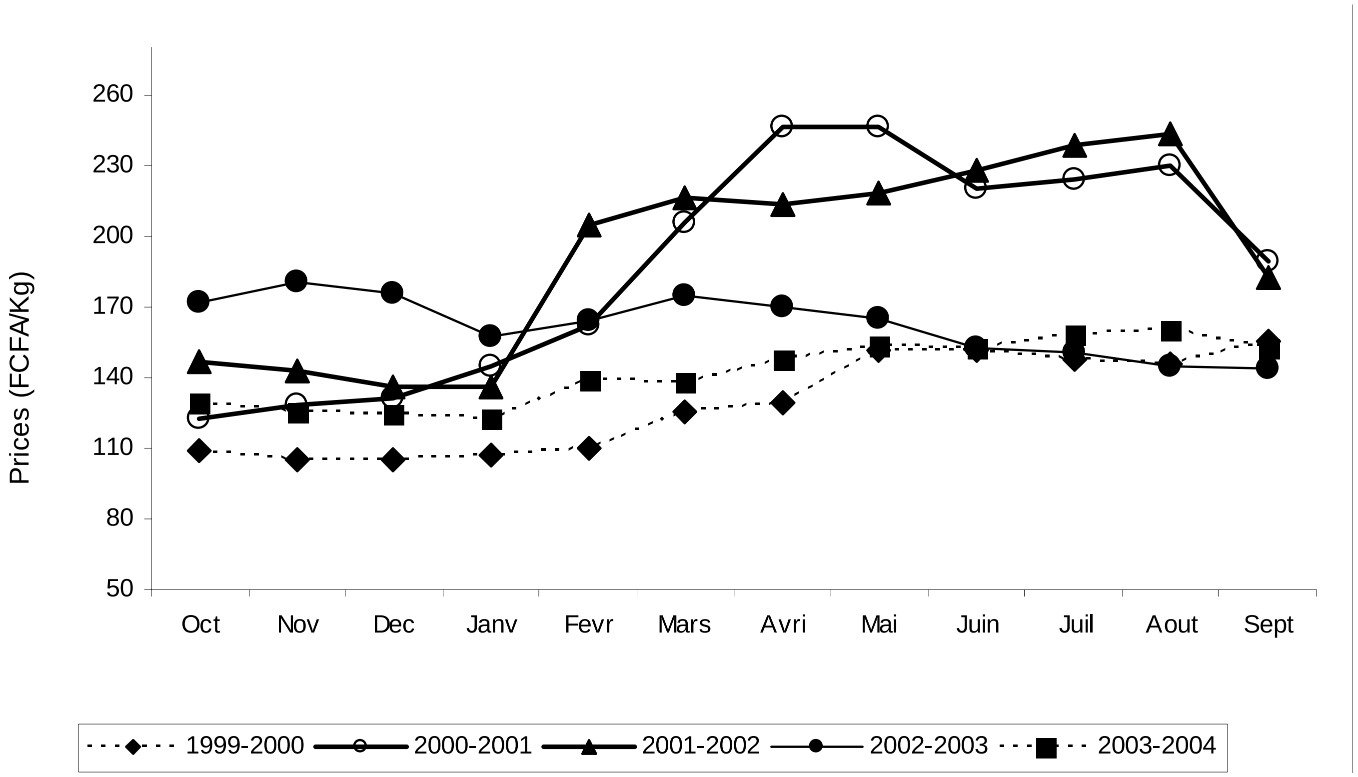

Figure 2. **Dosso Retail Monthly Millet Prices, 1999-2004**.
Source: SIMA database.