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# EXPECTED EFFETS OF DEVALUATION ON CEREAL PRODUCTION

## IN THE SUDANIAN REGION OF MALI

BY

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# Expected Effects of Devaluation on Cereal Production in the Sudanian Region of Mali

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## *ABSTRACT*

*The Sahelian countries have been much more successful attaining higher yields of export crops, including cotton and peanuts, than with increasing yields of their cereals and other food crops. One principal explanation has been the poor economic and agricultural policy support historically given to food crops. Now this is being changed with structural adjustments, including the 1994 devaluation of the CFA. Intensive cereal production became more profitable with a lag after devaluation. In southern Mali, even highly risk-averse farmers will adopt intensive sorghum technologies, according to risk programming results. Credit can be generated internally for this activity by selling some of the livestock. Returns were very high for this intensification but its further expansion would require more internal liquidity or the expansion of credit in order to increase purchases of inorganic fertilizers.*

Key words: structural adjustment, devaluation, inorganic fertilizers, intensification, risk-neutral, risk-averse

# INTRODUCTION

On January 12, 1994 the CFA Zone (14 countries in West and Central Africa in a monetary union coordinated by France) devalued the CFA franc 50% in foreign-currency terms (IMF, 1994). Most discussion of structural adjustment, of which devaluation has been an important component, is on the macro or national economy level. But the micro-economic adjustments included in structural adjustment, designed to "get the prices right," are aimed at firms. Thus, the firm-level effects of these economic changes are critical for anticipating the national-level effects. This particular analysis is on farm-level adjustment in southern Mali. However, the same types of responses to relative prices and farmer responses are expected to be relevant to other developing countries undergoing these macro policy changes and especially other members of this French-speaking monetary union.

Devaluation was designed to restore profitability to domestic sectors discriminated against by overvalued currencies, such as the agricultural sector. We evaluate the net effects of the price changes from devaluation (and other factors) on farm-level profits and potential adoption of new yield-increasing technologies in an agricultural zone of domestic food staple production.

We (1) investigate the effects of one part of the structural adjustment program in Mali, currency devaluation; (2) document the changes in the relative prices of cereals to inorganic fertilizers in the three years since the major devaluation of the CFA; (3) with a farm-programming model, examine how farmers will respond to the new price signals resulting from devaluation. In particular, we focus on introduction of new technologies for the domestic cereals and constraints to their introduction, especially liquidity requirements for working capital; and (4) examine policy implications.

## EVOLUTION OF CEREAL PRICES SINCE DEVALUATION

A basic concept of structural adjustment is that profitability can be restored to an economy by unleashing markets, providing price incentives, and adopting policies that allow producers to respond to price incentives. Historically in the CFA countries, prices of imported foodstuffs were reduced with overvalued exchange rates, subsidized imports, and food aid. Cereals imported from developed countries often benefitted from export subsidies. Rice has entered cheaply from low-cost producers (Thailand) and from countries anxious to obtain sufficient foreign exchange (Vietnam).

With the resulting low prices for domestic food products and the difficulties of acquiring critical purchased inputs, especially inorganic fertilizers, the response of basic staple producers has been to retreat to subsistence, specifically to produce many commodities at low purchased-input levels with minimal marketed surplus. With population pressure, land has become scarce and frequently soil nutrients are mined due to the breakdown of the traditional soil-restoration method of fallow rotation. Output increases will increasingly depend upon the intensification of agriculture.

When does devaluation start making more intensive practices profitable? From devaluation there are pushes in two opposite directions on food prices relative to input prices: (1) Higher prices for imports affect the prices of fertilizer, fuel, and some implements. Since intensification with higher input use is increasingly critical to agricultural output increases, these higher input prices slow output growth. The structural adjustments of the late ‘80s removed most input subsidies in Mali and other Sahelian countries. Then devaluation further increased imported input prices. (2) The substitution effect: As prices of imported foodstuffs (rice and wheat) increase, the prices of domestically produced cereals (millet, sorghum, and maize) follow. The extent of increases in the prices of these domestic cereals (millet, sorghum, and maize) will depend upon the substitutability between wheat and rice and the above domestic cereals (Delgado, 1991; Reardon, 1993). An important note here is that rice is also produced domestically on a large scale both in irrigated regions and in low-lying areas of farms in wetter regions, especially in Mali but also in other CFA countries.

We examine first how relative prices of domestic cereals have changed since the devaluation of January 1994. The effect of devaluation was immediately apparent in the prices of imported inorganic fertilizers. In the first growing season following devaluation, 1994, inorganic fertilizers increased 50% in price and had doubled in price by the second growing season. However, the critical price is not the absolute price change of fertilizer but its price relative to the output price (Fig. 1).

For cereal prices, the presence of stocks plays an important role. Due to the farm-level accumulation of cereal stocks in 1993, cereal prices did not increase appreciably in 1994. Legume and millet prices remained constant and sorghum increased only 20%. For the first two growing seasons following devaluation, the prices of imported inputs relative to cereal prices increased; hence, the profitability of intensive technologies, which demand inorganic fertilizers, declined.

By 1996, subsidies on imported wheat and rice and on domestically produced rice had been reduced and stocks of traditional cereals were depleted by the increased cereal exports of 1995. The relative price of millet to fertilizer increased 28% over the level before devaluation. For cereal producers in 1996, devaluation (and other factors) were now making the agricultural sector more profitable and encouraging the use of fertilizer and other intensive technologies.

If farmers do not rapidly increase supply as food prices go up, there will be increasing political pressures from the urban sector to revert to the prior policies of subsidizing food imports. Urban consumers have become accustomed to cheap rice and wheat and they tend to be very influential in Mali and other developing countries (Bates, 1981). Meeting national food requirements with imports diverts scarce foreign exchange from other uses and further worsens the balance-of-payments crisis that had prompted the devaluation in the first place. Therefore, it is critical to evaluate the potential of Malian farmers to respond to higher cereal prices.

## FARM SYSTEMS IN THE SUDANIAN REGION OF MALI

### Technologies

The new technologies available to farmers in the Sudanian region of Mali include animal traction and improved cereal, groundnut and cowpea cultivars. Over the past two decades, there has been rapid adoption, over 85%, of animal traction into the region (Coulibaly, 1995). Animal traction has increased the number of improved soil-preparation techniques available to farmers. Ridging, a widespread technique in the region, has been a significant improvement over traditional plowing in increasing yields through better water retention. Further yield increases can be obtained with tied ridges, increasing the depth of plowing (the deep-plowing technique) and light plowing just prior to the initial rainfall (Table 1).

Breeding has focused on short-cycle, early-maturing cultivars to provide better protection against late-season drought. Several improved cultivars have been introduced into the region. Unfortunately, early cultivars are unable to take advantage of inputs in adequate and good rainfall years, so the expected yield gains from earliness are small (Shapiro et al., 1993). Still, there are promising technologies yet to be adopted. For sorghum and millet production, farmers have been slow in adopting technologies which combine the use of improved cultivars, inorganic fertilizers, and the water-retention technique already adopted, the ridging.

### Constraints to Production

The Sudanian agroecological zone has an annual rainfall of 600 to 800 mm at 90% probability. Rainfall is characterized by large intra-annual and inter-annual rainfall variability, further exacerbating the problems of inadequate soil moisture. Crusting of clay soils prevents adequate water availability. Ridging and other soil-preparation techniques reduce soil crusting but place large work demands on draft animals. Sandier soils have the opposite problem because water infiltrates rapidly beyond the reach of crop roots. Here the necessary technology is to build up the organic matter to hold the water in the soil longer (Shapiro and Sanders, 1998).

Water availability and soil fertility are the main constraints to increasing cereal yields in the Sudanian region. As land quality deteriorates, cereal yields fall and cultivation is pushed into marginal grazing or communal areas that generally are farther up on the toposequence (Vierich and Stoop, 1990). This response accelerates the soil-degradation process since it removes vegetation and other natural barriers against wind and water erosion.

The stock of soil nutrients, mined by crops and lost from soil erosion, must be maintained. Otherwise the existing cropping system will not be sustainable. The key question is how to replace the soil nutrients. We investigate whether price changes from devaluation will encourage the profitable introduction of technologies that increase the use of inorganic fertilization.

Once the importance of increased nutrient levels is defined, the next critical problem is how to pay for them. Liquidity is the amount of capital available to farmers in their purchase of inputs. Prior to structural adjustment, liquidity was less important to farmers since credit from government programs was available for the purchase of inputs for the cash crops. Structural adjustment has removed nearly all of these subsidies and it is unlikely that public and parastatal credit programs will be reinstated. Farmers must now look elsewhere for sources of liquidity to purchase inputs.

There are formal and informal lending agencies. But the rural banking system is not well-developed and access to its credit services is typically reserved for the larger farms. Informal credit can be obtained from various sources but is usually reserved for individuals in dire need of cash and involves very high implicit interest rates. Until a banking system develops, it will be left to the farmers themselves to internally generate their own capital for increased input purchases.

There are several on-farm sources of liquidity, including sales from crop and livestock, household production activities, off-farm work, and remittances from other household members. The largest source of wealth is livestock. Just as farmers cash in livestock for big family-consumption items, such as a wedding or funeral, livestock could also be liquidated for working-capital investments in inorganic fertilizer. As with the cereals, livestock prices have more than doubled since pre-devaluation. Relative to the price of imported inorganic fertilizers, livestock prices have increased 30% (Dalton, 1996).

The programming model considers the feasibility and profitability of farmers adopting new intensive technologies that often require larger amounts of purchased inputs. Whether farmers will be prepared to sell off their assets and increase their purchase of fertilizer is an empirical issue. Increasing investments in crop production will divert resources from other household activities and will occur only if crop returns are large enough to justify a reallocation.

## RISK FARM-PROGRAMMING MODEL

Risk needs to play an important part in a model of farmer decision-making in semiarid regions with substantial price variability. Risk enters in two fashions: (1) Five states-of-nature are included to reflect the variability in yields and prices. These data were based on farm interviews of the Institute d'Economie Rural for the present activities and experiment-station data and expert judgments for new or potential activities (Coulibaly, 1995). (2) Farmer risk-aversion is incorporated in the model since farmers apparently make tradeoffs between the profitability and riskiness of their activities, depending upon their degree of risk aversion.

The direct expected-utility maximization (DEMP) approach (Lambert and McCarl, 1985; Coulibaly, 1995) was utilized, with the negative exponential utility function as the objective function (Freund, 1956). This function allows for the use of net farm returns rather than wealth in calculating expected utility. One disadvantage of the negative exponential function is a relative risk-aversion coefficient, which increases as wealth grows larger. Intuitively, with higher levels of wealth, the entrepreneur will be in a stronger financial position and therefore expected to be able to absorb higher losses.

In mathematical form: Maximize $E[U(Y)] = \Sigma_i \, prob(i) \exp(-rY_i)$ (1)

subject to:

$Y_i = \Sigma_j \Sigma_k A_{ijk} X_{jk} P_{ji} - \Sigma_j \Sigma_k C_{jk} X_{jk}$ (2)

$(R_0)(X_{jk}) \leq B_0$ (3)

$(X_{jk}) \geq 0$ (4)

where $Y$ = net farm returns

$Y_i$ = net farm returns in the ith state-of-nature

$A_{ijk}$ = yield outcome of the jth crop in the ith state-of-nature using the kth technology

$B_0$ = vector of resource endowments (land, labor, and capital)

$C_{jk}$ = cost associated with the jth crop using the kth technology

$P_{ji}$ = farmgate price of the jth crop given the occurrence of state i

prob(i) = probability of occurrence of the ith state-of-nature

$r$ = coefficient of absolute risk aversion

$R_0$ = matrix of resource requirements (land, labor, and capital)

$X_{jk}$ = acreage of the jth crop using the kth technology.

Equation (1) is the objective function, which represents the expected utility from cropping activities. This is calculated as a weighted sum of the utility of income associated with each of the states-of-nature. The weights are the probabilities assigned to the likelihood of occurrence of each state-of-nature. The absolute and relative coefficients of risk aversion are: $R_{absolute} = - U''(Y)/U'(Y) = r$ (5)

$R_{relative}(Y) = - Y\,[U''(Y)/U'(Y)] = Y\,r.$ (6)

Equation (2) expresses the net returns from cropping activities in the ith state-of-nature. States-of-nature are determined by both yield and price outcomes.

Equation (3) contains resource constraints for human and animal labor, capital, and land. Labor constraints are included for 10 time periods from soil preparation to harvesting. The lefthand side of this equation contains the resource demands that depend upon the technology type. Resource availability is given by the righthand side.

Equation (4) expresses nonnegativity constraints that assure that the decision variables, $X_{jk}$, are positive.

If farmers are assumed to be risk-neutral in their crop decision-making, the risk-aversion coefficient used in the DEMP is zero ($r=0$). In this case, the DEMP collapses to a linear program and the objective function is the expected farm profit realized over the five states-of-nature.

### Technologies Considered

The model includes a total of 35 different technologies for the four crops. Thirteen activities are defined for sorghum, 13 for millet, 4 for groundnut, and 5 for cowpea. Each technology specifies the type of cultivar, the soil-preparation technique, and fertilizer application. The type of cultivar in each technology is either a local or improved variety. For the new technologies, experimental data and consultations with agricultural scientists are utilized. Both organic and inorganic fertilizers are included in the activity levels, ranging from zero to extension-recommended application levels.

### Constraints Included

The model includes constraints for human and animal labor, liquidity, and land availability. Food-processing and organic-manure-production activities are not included. The manner in which the heads of household allocate liquidity to crop activities is not well understood. The model assumes separability of the crop production with other activities and requires that purchases of agricultural inputs be self-generated from crop or livestock receipts. With large families in this region, subsistence claims nearly all of the crops; hence, livestock is the main source of liquidity among agricultural activities. Field observations indicate that income from sale of one-half of a mature cow represents the amount of liquidity a farmer obtains for agricultural-related expenditures.

## Data

The farm-programming model requires data for yields, prices, input usage, and resource endowments. Cereal yields are modest, about 570 kg/ha for present farmer practices, which combine traditional varieties and ridging without either inorganic or organic fertilizers (Table 1). Sorghum yields are more responsive to fertilizers and water-retention techniques than millet. Increasing inorganic fertilizer usage to recommended levels with improved varieties raises sorghum yields to 1300 kg/ha. Even larger gains in sorghum yields are achieved with better water-retention techniques than ridging. With deep plowing and tied ridges added to the package, sorghum yields can reach 1670 kg/ha (Table 1).

The existing legume grain technologies already use improved varieties and apply inorganic fertilizer. This leaves water-retention and improved soil-preparation techniques to increase yields. Groundnuts are more responsive than cowpeas to the improved methods. Adopting tied ridging and light plowing raises expected groundnut yields 30%. For cowpeas, tied ridges and deep plowing result in only a 12% increase in expected yields.

Expected nominal cereal prices have more than doubled since devaluation. Millet has increased from 11 to 25 US cents/kg and sorghum from 10.4 to 22.7 US cents/kg (Table 2). Expected legume prices have increased less rapidly than the cereals. Both groundnuts and cowpeas have increased in expected price by 50%. Urea and the cereal compound, the two principal imported inorganic fertilizers used in cereal and legume production, have doubled in price. This is consistent with the 100% devaluation.

The representative farm unit has 16 ha of land available for cropping activities. One-half of a typical household is in the farm labor force. In this model, family labor included 3 men, 3 women, and 4 children. Throughout the growing season, labor is supplied principally by the household; however, during critical periods additional household members temporarily enter the farm labor force. Before devaluation, the endowment of capital used to purchase inputs is $120. The marked increase in livestock prices since devaluation has eased the liquidity constraint for farmers. In the post-devaluation scenario, capital availability increases in proportion to livestock prices to $276.

## RESULTS

Model results for the predevaluation risk-neutral case differ substantially from farm observations (Table 3; Coulibaly, 1995). The model selects 2.3 ha of an improved sorghum variety with 50 kg/ha of compound cereal fertilizer; it does not include either of the grain legumes even though 2.0 ha are empirically observed. Model results are much closer to field-observed farm practices with a moderately high value of relative risk aversion (2.5). Here, the farm model in the predevaluation scenario selects well the millet, cowpea, and groundnut acreage (Table 4; Coulibaly, 1995). Both field observations and the model's omission of fertilized sorghum suggest that farmers associate a high level of risk with intensifying cereal production. This is not surprising since the region is characterized by low and erratic rainfall and periodic price collapses of the cereals.

In the risk-averse formulation, the model fails to include the 3 ha of the traditional sorghum cultivar at minimal inputs and the traditional millet area is overstated in the model by an almost equal amount. The model has difficulty distinguishing the traditional sorghum and millet varieties since it contains only one soil and there is little difference between millet and sorghum returns. If modeling had better differentiated soils, sorghum would have been expected on the heavier soils lower on the toposequence with better soil moisture (Vierich and Stoop, 1990). For the legumes, the model results accurately predict the cowpea acreage at .5 ha and underestimate groundnut acreage. The observed use of 100 kg/ha of compound cereal fertilizer on the groundnuts is also captured by model results.

The devaluation, through the combined effects of higher farmgate prices for the cereals and higher livestock prices increasing the cash available for agricultural investments, enables farmers to increase their use of inorganic fertilizer by 32%. With the rise in the relative price of sorghum to inorganic fertilizer, the intensive sorghum technology (improved cultivar and 50 kg/ha of cereal compound fertilizer) is introduced on 3.2 ha. Sorghum is more responsive to fertilizer than millet, so farmers fertilize the sorghum even though the millet price has increased more (Tables 1 and 2). Over the past decade, adoption of this sorghum technology has been limited to a small percentage of farmers in the region (15%). The model results indicate that devaluation, specifically the 1996 relative prices, will accelerate the adoption of inorganic fertilizers. Farmers retain ridging since the opportunity cost of labor in the soil-preparation period is high and the yield increase from other more intensive soil-preparation techniques is insufficient to pay for these additional labor demands.

Liquidity constraints and risk are conventional explanations for why farmers do not adopt intensive cereal technologies. In the Sudanian region of Southern Mali, there is substantial potential for farmers to increase liquidity through livestock sales. Livestock herd size averages between 10 to 20 for households of this size. The value of this herd size is 20 to 40 times higher than the amount of liquidity used in the model (Dalton, 1996). Risk was not found to be a significant factor since even the most risk-averse farmers adopted intensive sorghum technologies in the model results. Thus, the observation that farmers cash in very little of their livestock for investments in crop production apparently results from farmers' perceptions that such investments are too risky rather than from a lack of liquidity or actual risk.

Farmers are able to shift production in response to price signals from devaluation. Model results indicate that with post-devaluation prices of 1996, real farm profits increased from $1,711 to $2,332, or 26%. The increased income streams from cropping activities place households in a stronger financial position and better able to internally generate further investments in improved technologies. Continued investments in intensification are expected since estimated rates-of-return of the farm-programming model were 500 to 600% for this intensive sorghum technology. The principal constraint to respond to these highly profitable alternatives is the availability of working capital. If farmers sell off more livestock, obtain more remittances, or obtain outside sources of capital, they are expected to accelerate this intensification process given the high rates of return.

# CONCLUSIONS

Conventional wisdom has been that there is something different about African farmers; they diversify rather than intensify their production. There is little evidence that this uniqueness has stemmed from anything other than poor policies that have ignored agriculture with their emphasis on urban and industrial sectors. These policies have twisted the price structure against domestic producers and reduced the profitability of agriculture. Consequently, farmers have been hesitant to make investments in more intensive technologies.

Structural adjustment was designed to make the agricultural sector more profitable. Cereals are relatively low-value products; hence, it it difficult to justify high transportation costs for them. Without policy distortions, domestic cereals would become competitive with imported cereals. Prices of domestic cereals were expected to increase more than input costs once most of the distortions on the prices of rice and wheat were removed.

According to a risk-programming model, with 1996 prices the intensification of the basic cereal crops is profitable and even strongly risk-averse farmers will adopt. With observed levels of farm investments, the areas adopted are small. But further model results indicate that the shift toward the intensive cereal technologies continues as investments in agriculture are increased.

Livestock sales could be used to fund investments required for adopting intensive cereal technologies. But most farmers are observed retaining their livestock and other fixed assets rather than intensifying cereal production. This strategy allows farmers in years of poor production to sell livestock or other assets to purchase cereals to meet subsistence needs.

This suggests that future modeling needs to more explicitly include subsistence objectives as well as high levels of risk aversion.

Nevertheless, the increased profits from devaluation should ease farmers' concerns about subsistence as their wealth accelerates. As subsistence becomes less pressing, the implicit weight that farmers assign to it in their objective function will decrease. Farm profits will become a more important objective and over time farmers will shift toward the expected utility objective function used in the model. Moreover, risk aversion is expected to decline as wealth increases.

Now that price signals have been properly tuned for domestic cereal producers, complementary practices need to be implemented to ensure an adequate response by farmers. As investments in intensive production methods increase, so too will the demand for seeds, fertilizers, and animal-traction implements. Attention needs to be directed not only to developing input markets but also to new marketing uses of the traditional cereals, such as for bread, beer, and ultimately animal feed. Consumer food demand for local cereals is expected to remain strong as imported cereal prices remain high from devaluation. Improved infrastructure would facilitate commodity flows from rural to urban areas. Producers need to respond quickly to these shifts in demand before consumers successfully pressure the public sector for the return of subsidized food imports.

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## Table 1

Expected yields (kg/ha) for the crop technologies utilized in the model[a]

| Fertilizer Application[b] (kg/ha) | Sorghum Local | Sorghum Improved | Millet Local | Millet Improved | Groundnut Improved | Cowpea Improved |
|---|---|---|---|---|---|---|
| 0-0-0-0 | 565 | | 578 | | | |
| 0-0-0-5000 | | 1510 | | 1300 | 1361[c] | |
| 0-50-100-0 | 792 | 1300 | 768[d] | 960[e] | | |
| 0-0-50-0 | | 1115 | | 950 | | |
| 0-50-0-0 | | 1060 | | 905 | | |
| 0-50-50-0 | | 1197 | | 1060 | | |
| 0-0-100-0 | | 1217 | | 1130 | 1032[f] | 1213[g] |
| 100-50-0-0 | | 1360[h] | | | | |

Source: Adapted from Coulibaly (1995).

[a] Except as noted, the technologies use the ridging soil-preparation technique.

[b] Fertilizer application is given in terms of: cotton compound-urea-cereal compound-manure.

[c] This technology uses deep plowing rather than ridging.

[d] Expected yields for other soil-preparation techniques: DP-725 and light plowing with tied ridging (LTR)-850.

[e] Expected yields for other soil-preparation techniques: DP-1145, TR-1245 and LTR-1345.

[f] Expected yields for other soil-preparation techniques: DP-1128 and LTR-1395.

[g] Expected yields for other soil-preparation techniques: DP-1287, TR-1296, DPR-1327 and DTR-1359.

[h] Expected yields for other soil-preparation techniques: deep plowing (DP)-1454, tied ridging (TR)-1488, deep plowing with ridging (DPR)-1624 and deep plowing with tied ridging (DTR)-1670.

## Table 2

Nominal prices and costs used in the model

| Expected prices[a] | Before devaluation (US cents/kg)[b] | After devaluation (US cents/kg)[b] |
|---|---|---|
| Sorghum | 10.4 | 22.7 |
| Millet | 11.0 | 25.0 |
| Groundnut | 16.4 | 24.5 |
| Cowpea | 17.2 | 25.8 |
| Fertilizer prices | | |
| Cotton compound | 23.5 | 43.0 |
| Urea | 19.6 | 39.1 |
| Cereal compound | 20.5 | 42.1 |

Sources: Coulibaly (1995) and Suivi Evaluation Permanent (SEP) data base, Sikasso, Mali.

[a] Crop prices are included for each of the five states of nature and represent average values for crop sales over one year.

[b] The nominal Malian prices were converted to cents with the average exchange rate of 1996, 511 FCFA/US$ (*International Financial Statistics*, 1996). This was the year utilized for the post-devaluation case.

**Table 3**
Linear Programming Results (Risk Neutral)

| | | Before Devaluation | | Current Prices[a] |
|---|---|---|---|---|
| **Crop** | **Technology[b]** | **Farm Observations** | **Model Results** | **Model Results[c]** |
| Sorghum | Local variety with no inorganic fertilizer | 3. | 0. | 0. |
| Millet | Local variety with no inorganic fertilizer | 8. | 11.0 | 8.7 |
| Sorghum | Improved variety with 50 kg/ha of compound cereal fertilizer[d] | 0. | 2.3 | 4.5 |
| Groundnut | Improved variety with 100 kg/ha of compound cereal fertilizer[d] | 2.0 | .6 | .6 |
| Cowpea | Improved variety with 100 kg/ha of compound cereal fertilizer[d] | .5 | .4 | 0. |
| | TOTAL RETURNS (US$)[e,f,g,h] | 1,749 | 1,711 | 2,332 |

[a] Prices were taken from 1996 data (see Table 2).

[b] The soil-preparation technique of ridging is included with all activities.

[c] This scenario assumed farmers' liquidity increased in proportion to livestock prices (130% increase).

[d] The composition of compound cereal fertilizer is: N:P:K (15:15:15)

[e] Crop prices used in calculating total returns are producer prices averaged over one year.

[f] Total returns include home consumption (valued at producer price) plus market sales minus out-of-pocket expenses.

[g] Total returns are given in 1996 US$ (511 FCFA/US$) and were calculated using a consumer price index (*International Financial Statistics*, 1996).

[h] Rates of return on purchased inputs for model results were 600 and 500% for the before-devaluation and current-price scenarios, respectively.

**Table 4**
Farm-Programming Model Results for Before Devaluation and With Current Prices (Risk Averse)[a]

| | | Before Devaluation | | Current Prices[b] |
|---|---|---|---|---|
| **Crop** | **Technology**[c] | **Farm Observations** | **Model Results** | **Model Results**[d] |
| Sorghum | Local variety with no inorganic fertilizer | 3. | 0. | 0. |
| Millet | Local variety with no inorganic fertilizer | 8. | 11.5 | 10.1 |
| Sorghum | Improved variety with 50 kg/ha of compound cereal fertilizer[e] | 0. | 0. | 3.2 |
| Groundnut | Improved variety with 100 kg/ha of compound cereal fertilizer[e] | 2.0 | 1.4 | .6 |
| Cowpea | Improved variety with 100 kg/ha of compound cereal fertilizer[e] | .5 | .5 | .4 |
| | TOTAL RETURNS (US)[f,g,h] | 1,749 | 1,711 | 2,332 |

[a] Results were obtained using a relative risk-aversion coefficient of 2.

[b] Prices were taken from 1996 data (see Table 2).

[c] The soil-preparation technique of ridging is included with all activities.

[d] This scenario assumed farmers' liquidity increased in proportion to livestock prices (130% increase).

[e] The composition of compound cereal fertilizer is: N:P:K (15:15:15)

[f] Crop prices used in calculating total returns are producer prices averaged over one year.

[g] Total returns include home consumption (valued at producer price) plus market sales minus out-of-pocket expenses.

[h] Total returns are given in 1996 US$ (511 FCFA/US$) and were calculated using a consumer price index (*International Financial Statistics*, 1996).

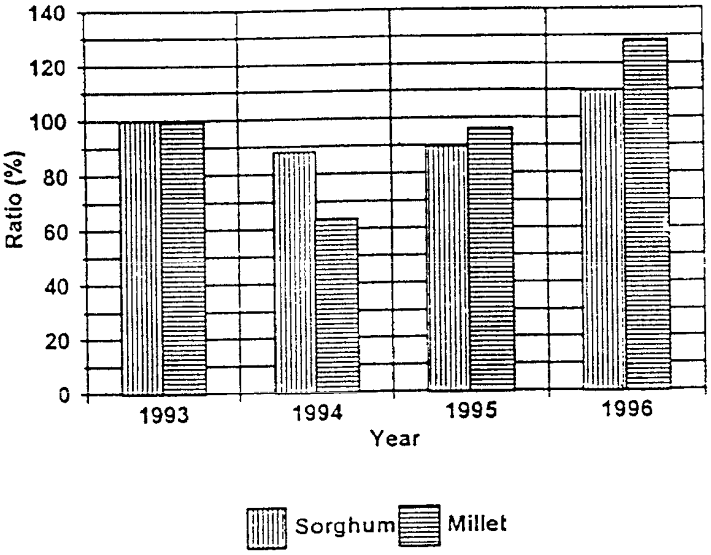

Fig. 1. Farm-level cereal/fertilizer price ratios, 1993-1996