Introducing Inventory Credit into Nigerien Agriculture: Improving Technology Diffusion

Felix G. Baquedano and John H. Sanders

Abstract

A critical component of agriculture in developing countries is increasing soil fertility in response to depleted soils and declining crop yields. An inventory credit program was introduced in western Niger to generate savings for farmers' groups to facilitate the purchase of inorganic fertilizers. This program is compared with a more traditional inventory credit program, which provides credit at harvest but lets farmers sell their grain in the post-harvest period after grain prices have recovered. The evaluation of the two programs for their impacts on farmers' incomes and farm-level technology adoption is undertaken with a linear programming model. The decision-making framework of this model comes from interviews of farmers in a number of African countries. Farmers are found to be risk averse, but exhibit a different type of decision making than the usual expected income-income variability tradeoff.

Key words: fertilizer, inventory credit, Niger, risk aversion

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In order to meet farmers' cash flow and liquidity requirements at harvest when prices collapse[1] and to encourage higher use of inputs, non-government organizations (NGOs) in Sub-Saharan Africa have developed a financing mechanism based on inventory credit. Present inventory credit programs in Niger purchase the grain at harvest prices and capture the gains from seasonal price increases for the farmers' groups. Then these farmers' groups buy fertilizer with a quantity discount and make it available to the village farmers at the discounted prices.

This study evaluates the benefits of this program and compares it with an inventory credit program in which farmers directly receive the income gains from the increased seasonal prices. Moreover, we consider the potential effects of reduced interest costs from lending by a regional or local institution that could charge a lower loan default risk premium from better knowledge of its farmer clients.

The remainder of the paper proceeds as follows. First, to evaluate the present program and two proposed changes to it, we present the farmer decision-making mechanism based upon our fieldwork. Next, this decision-making framework is incorporated into a linear programming model based upon a utility function representing lexicographic preferences.

[1] There are three price problems faced by farmers in developing countries: the harvest-price collapse, the good-season price collapse, and the public sector-induced price collapse. Inventory credit programs respond to the harvest-period price collapse.

A section is then devoted to a description of the present and potential inventory credit program and production technologies available. Following the introduction of the formal model, current program benefits are analyzed and compared to a revised program with and without reduced interest costs. The final section highlights some policy implications and offers conclusions about development policy directions.

Farmer Decision Making

In empirical studies in Sub-Saharan Africa, farmers state two primary objectives, and there is an implicit third objective: (*a*) a harvest income goal; (*b*) a subsistence consumption objective for the staple crop, millet in this case; and (*c*) income maximization once the above objectives are attained.

Relative to the first objective, the harvest income goal, farmers need money at harvest to pay for their purchased and family labor,[2] finance out-migration of family members after the crop season, pay school fees, taxes, health costs, and finance weddings and other ceremonies. The financial obligations pressuring farmers to obtain income at harvest time are so pervasive that most developing countries experience staple price collapses at harvest time. To encourage farmers to benefit from the price recovery six to eight months after harvest, an inventory credit program needs to provide credit at harvest.[3]

The second farmer objective is to put aside sufficient quantities of the main staple to assure subsistence consumption during the year. Many modelers in developing countries have placed this as the first constraint. In contrast, a series of empirical studies (Rain, 1999; Abdoulaye, 2002; Baquedano, 2005; Uaiene, 2005) have shown farmers consistently rank the household income goal above the acquiring and storage of subsistence consumption needs until the next harvest. This priority ranking is most obvious in bad rainfall years when many farmers are unable to set aside sufficient subsistence consumption. They rely on the market or private/public assistance to obtain sufficient staples later in the year.[4] Nevertheless, farmers will still first attempt to meet their harvest income goal.

Farmers' third (implicit) objective is to maximize income after these first two objectives have been achieved. This is the standard income-maximization objective, but satisfying the two above objectives first makes the farmer risk averse. Although continuity of the objective function is violated, this is how farmers explain their decision making.

Farmers can produce their own subsistence crop and/or purchase it. Farmers do not know what the purchase price and availability of their subsistence staple will be in purchase periods later in the year. Hence, they often show a preference for producing more than what would be economically optimal given the expected prices six to eight months after harvest. Rather than producing up to the expected price, we would expect farmers to produce their subsistence crop up to the price they foresee in an adverse rainfall year. This food availability in bad years is a primary risk to which farmers feel the need to respond. Later in this paper, we test this hypothesis with farm-level observations.

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[2] Family labor is compensated by purchasing clothing, giving grain for other family members (besides the household head) to sell, and financing for the younger male members of the household to go to the capital or the coast to find employment until the next agricultural season.

[3] Estimates of the opportunity costs (difference between prices at harvest and six months later) for obtaining the harvest income goal will be discussed later.

[4] Rain (1999) argues that farmers' willingness to sell their grain in bad years despite its scarcity is enabled by their reliance on complex social ties with family members working in other regions. These ties are a type of social insurance policy in which family members are counted on to provide money and/or food primarily in bad rainfall years. In disaster years, not included in the farm-level modeling, the public sector and NGOs step in to provide aid.

Inventory Credit in Niger

A traditional inventory credit program provides loans guaranteed by grain stocks to farmers to meet their harvest income requirements. The farmer is able to sell the grain later in the year and then repay storage and interest costs (Coutler and Onumah, 2002; Coutler, 2002). In this study, we examine two programs: (*a*) the program currently implemented in Niger to generate savings for farmers' groups to purchase inorganic fertilizer for the next crop season, and (*b*) a more conventional inventory credit program in which the farmer benefits by receiving higher grain prices and credit at harvest.

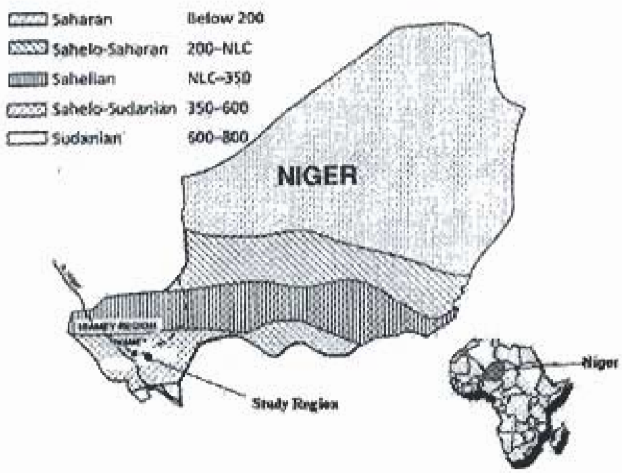
This study uses village-level data from the village of Karabedji in the Fakara region of Niger. A map showing our study area is presented in Figure 1. As previous fieldwork conducted by Abdoulaye (2002) utilized data from this village, collected in the 1999–2000 production season, we re-collected data from farmers in this same location to characterize the 2002–2003 production season. Karabedji is considered to be representative of the millet-cowpea zone (the Sahelo-Sudanian zone in Figure 1) for Niger. This Sahelo-Sudanian zone is the principal zone of agricultural production in Niger. One distinction of the Fakara region's Karabedji village is that it has been used by international agricultural research centers [ICRISAT and the International Center for Soil Fertility and Agricultural Development (IFDC)] over nearly three decades for regional trials; hence there has been more exposure to new technologies than in most other regions.

The Food and Agriculture Organization's (FAO's) Inventory Credit program, begun in the Fakara region of Western Niger in 1998, has as its principal objective the increased use of fertilizer. This program operates through farmers' organizations. These organizations take over the middleman role of buying the grain at harvest and then selling it later after the price recovery. With the profits generated from the sale of the grain later in the year, after deducting interest and storage cost, the producers' organization purchases fertilizer at a discounted price by buying in quantity. The fertilizer is then sold at the discounted price. In this manner, the farmers' organization creates a revolving fund for obtaining bulk purchases of fertilizer. Farmers benefit from the low-priced fertilizer in the next production season and from the technical recommendations associated with the fertilizer and improved seeds.

The more traditional inventory credit program permits farmers to sell their grain six to eight months after the harvest and then repay the storage agency, such as the farmers' organization, for the costs of storage and interest. The program provides credit at harvest time based upon some percentage of the harvest-time grain price. The organization holds the grain until the farmer repays the loan plus interest and storage costs. This allows farmers to capture the price variation for their staple crop between harvest and later in the year. The potential millet price increase, which farmers can receive from a modified program in Niger, fluctuates between 2% and 38% six months after harvest, as observed over the last five production seasons (2000–2001 through 2004–2005; Figure 2).

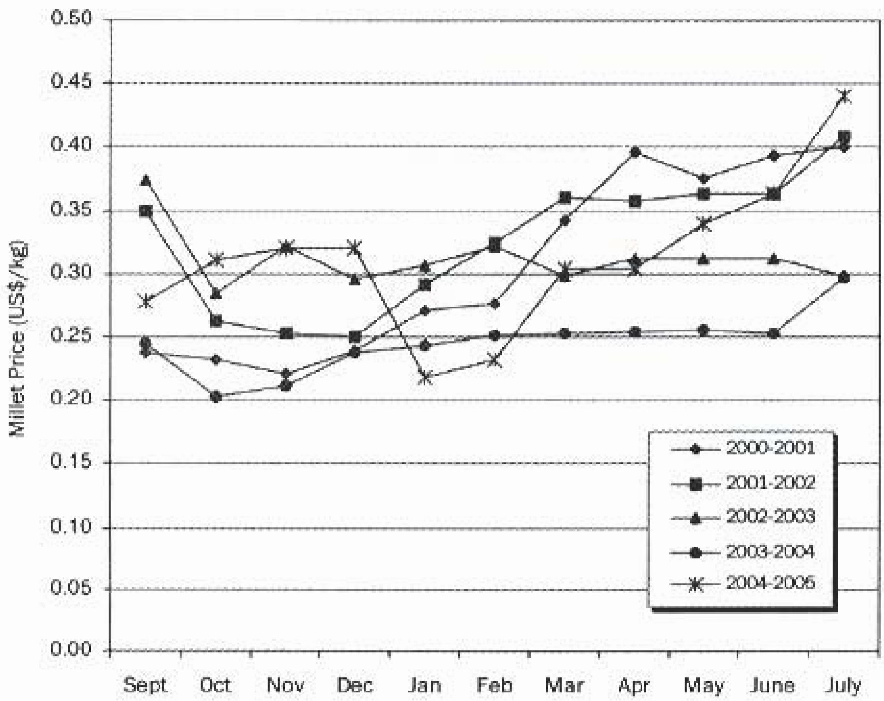
Empirical Model

In the representative household, preferences are ordered lexicographically, responding to the hierarchal ordering in which farmers in Niger satisfy their objectives in this risky environment with substantial price and weather risk (see also Abdoulaye and Sanders, 2006). Diagrammatically, this is illustrated in Figure 3. The three components of the African farm households' utility function (the harvest income requirement, subsistence consumption, and maximization of expected income) can be divided into three noncontinuous segments. Up to income level (*D*), the farmer attempts to achieve his harvest income goal by maximizing his utility



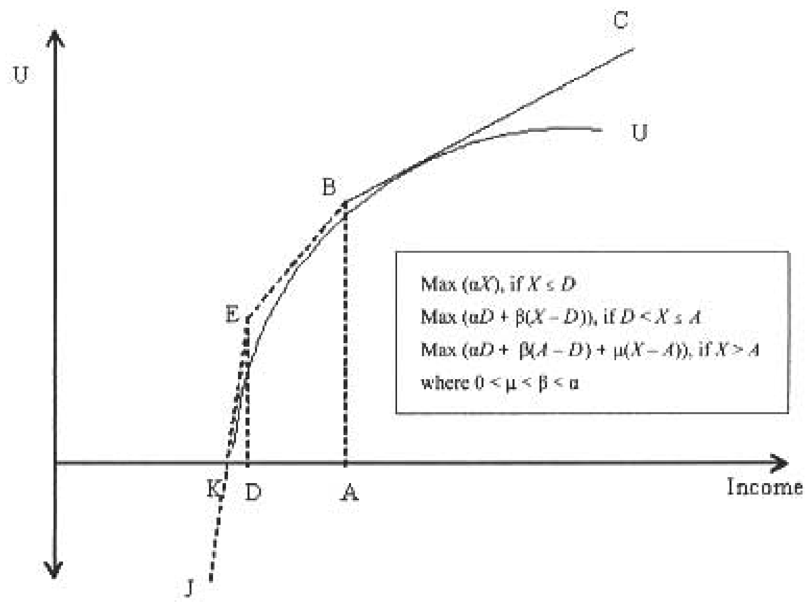
Source: Adapted from Sanders, Shapiro, and Ramaswamy [1996].

Figure 1. Map of West Africa Divided by Agro-climatic Zones



Source: Authors' calculations from SIMA (2003).

Figure 2. Variation of Millet Prices in Real Terms Between Harvest (September) and Other Points of the Year for Five Production Seasons in Niger (base year = 2003)



Source: Yigezu (2005).

Figure 3. The Lexicographic Utility Problem in African Households

function along (*JKE*). Once income level (*D*) has been attained, the farmer tries to put aside (*DA*), the money value of his millet consumption goal, until reaching (*A*). His utility function in this region is maximized along (*EB*). Once at (*A*), the farmer then maximizes expected income along (*BC*) (see also Yigezu, 2005).

The model considers four states of nature with respect to rainfall: bad, normal, good, and very good. A fifth state of nature—a very bad year or major drought year—is excluded from the model. The probabilities of the first four states of nature are the only ones relevant to farmer decision making as there is nothing that can be done at the farm level to avoid the disaster of a drought. Moreover, the public sector and NGOs intervene when a major drought occurs. So the probabilities[5] of these first four states of nature sum to one (Table 1).

Technology Packages Available to the Household

There are three traditional technology packages in the model and four proposed or new packages (Table 2). The technological packages (TPs) involve three crops: millet, cowpeas, and peanuts. Millet and cowpeas are the focus here as these are the main subsistence crops and there are substantial technology backlogs available to be introduced in the production of these two crops. The first TP, no fertilizer use, is for millet alone, while the other two traditional TPs are

[5] The probability of a state of nature to occur was estimated using rainfall data from 1931–2004. A disaster or very bad year occurred approximately once a decade (as in 1984, 1992, and 2004). This type of year is excluded from the calculation of probabilities. The probabilities of the four other states of nature then must equal one. In spite of the availability of price information for the past 14 years, the price distribution was defined using only the last five years, because this more recent period reflects a structural shift in government policy to intervene less. Donors have been pressuring the Nigerien government not to drive grain prices down in bad and normal years, and there has been more response to this pressure in the last five years.

Table 1. Probability of Observing a State of Nature and a Type of Year and Distribution of Prices at Harvest and Six Months Later in a State of Nature

State of Nature	Probability of a State of Nature (%)	Distribution of Prices at Harvest (US$/kg)	Distribution of Prices Six Months Later (US$/kg)
Bad	25	0.26	0.37
Normal	42	0.23	0.31
Good	17	0.20	0.25
Very Good	16	0.17	0.19

Sources: Authors' calculations from Abdoulaye (2002); Système Nigérienne de la Météorologie; and Système D' Information sur les Marches Agricoles (SIMA).

Note: Farmers face five states of nature: very bad year (probability = 9%), bad year (probability = 23%), normal year (probability = 38%), good year (probability = 15%), and very good year (probability = 15%). But the first state (very bad) does not enter the model given that there is very little farmers can do in this state. Therefore, the effective probabilities faced by farmers are: bad 25%, normal 42%, good 17%, and very good 16%.

Table 2. Expected Yields of Current and Potential Production Systems in Four States of Nature

Technology Packages[a]	Bad Millet	Bad Cowpeas	Normal Millet	Normal Cowpeas	Good Millet	Good Cowpeas	Very Good Millet	Very Good Cowpeas
Traditional:			— (Yield, kg/ha) —					
1 No Fertilizer (millet in monoculture)	208		279		351		387	
2 Micro Dosage (3 kg/ha of NPK)	216	24	270	100	323	175	350	210
3 Moderate Dosage (25 kg/ha of NPK)	302	26	402	111	482	196	522	239
New Technologies:								
4 Improved Moderate Dosage (60 kg/ha of NPK)	175	162	433	236	691	310	949	385
5 Improved Moderate Dosage (50 kg/ha of SSP)	191	167	440	268	689	369	938	470
6 **4** + New Cultivars	131	165	519	307	863	468	1,233	673
7 **5** + New Cultivars	144	200	528	348	862	552	1,220	820

Source: ICRISAT/IFDC in Abdoulaye (2002).

Note: Farmers face five states of nature: very bad year (probability = 9%), bad year (probability = 23%), normal year (probability = 38%), good year (probability = 15%), and very good year (probability = 15%). But the first state (very bad) does not enter the model given that there is very little farmers can do in this state. Therefore, the effective probabilities faced by farmers are: bad 25%, normal 42%, good 17%, and very good 16%.

[a] Definitions of fertilizers: NPK = Nitrogen, Phosphorous, and Potassium; SSP = Super Simple Phosphate.

millet intercropped with cowpeas. The yields reported for the TPs in the model come from the on-farm trials in the Fakara region, carried out by ICRISAT/IFDC since the 1980s (Abdoulaye, 2002). The data capture the yields for the different states of nature of the most common production systems as well as new technological packages developed in the ICRISAT/IFDC project over almost a decade.[6]

As shown in Table 2, the new TPs include increased dosages of fertilizer with improved application methods and new cultivars. The most common practice in the region is to mix very small quantities of fertilizer with the seed at sowing time and to put them together with some manure in the planting hole. The new technologies include increasing fertilization with side dressing with and without new cultivars.

The new TPs have a millet yield advantage over traditional technologies ranging from 55% to 89% (Table 2). With regard to cowpeas, the yield advantage ranges between 136% and 248% in comparison to traditional practices.

Model Representation

The objective function in the model, as stated in equation (1), maximizes the expected value of adjusted post-harvest income, subject to the farmers' objectives of first meeting their harvest income goal and then fulfilling their staple consumption objective. The model requires that the income goal [equation (2)] be met through sales of crops in every state of nature at harvest prices in that particular state. The harvest income goal in each state of nature was estimated from farm-household interviews and from estimates in the literature.[7] The consumption requirement [equation (3)] can be met from consumption of stored grain or purchases from the market. The consumption requirement[8] of 2,000 kg/annum/household of millet was taken from government estimates.

$$(1) \qquad \text{Max } E[I] = \sum_s \theta_s I_s$$

s.t.:

$$(2) \qquad \sum_i S_{1is} P_{1is} \geq HI_s.$$

$$(3) \qquad C_{is} + B_{is} \geq Cr.$$

Only after these harvest income and subsistence consumption objectives have been met does the household maximize income. By incorporating the farmers' main objectives under different states of nature, the model responds to the farmers' risky environment in the way farmers explain their own behavior. This approach has been followed previously by Vitale and Sanders (2005) in Mali; Abdoulaye and Sanders (2006) in Niger; Uaiene (2005) in Mozambique; and Yigezu (2005) in Ethiopia.

Equation (4) defines how grain from own production in the household can either be consumed, sold at harvest, or sold six months later:

$$(4) \qquad Q_{is} = C_{is} + S_{1is} + S_{2is}.$$

Equation (5) is maximized in the objective function and is defined as "adjusted net income" from grain sales six months after harvest and income from other activities:

[6] The ICRISAT/IFDC data used for production coefficients were consistent with averages obtained from the farm interviews in Karabedji for the two production seasons of 1999–2000 and 2002–2003. For details on the yield data, see Abdoulaye (2002) and Baquedano (2005).

[7] The harvest income goal was estimated from various sources, as follows: bad rainfall year, US$99 (Abdoulaye, 2002); normal rainfall year, US$200 (Hopkins and Reardon, 1993); good rainfall year, US$280 (Baquedano, 2005); and very good rainfall year, US$364 (Rain, 1999). All values were adjusted for inflation to 2003 values using the GDP deflator (IFS 2003 = 100).

[8] The consumption requirement has been adjusted to take into account the differences in consumption between adults and infants as well as males and females.

$$(5)\quad I_s = \sum_i S_{2is}P_{2is} - \sum_k Rt_{ks}Z_k - RM_s - \sum_i S_{2is}St_i - \sum_j \left(\sum_n a_{nj}X_n \right) P_j - \lambda \sum_i PP_s B_{is} - \sum_L HL_L W_L - Cf_s .$$

Relevant costs for grain storage, production inputs, labor, and financing have been deducted to obtain the net value. Note that the income maximization in equation (5)—after assuring the two priority objectives of harvest income and subsistence consumption—also enables the farmer to buy the part of his subsistence requirement not achieved by his own production. Additional consumption greater than that produced by the farmer is bought with his income earned and with transfers from his family.[9]

Equation (6) returns the income definition in equation (5) to a more standard income definition by adding back the value of food purchases multiplied by λ (to be explained below) and subtracting the value of remittances:

$$(6)\quad I_s^* = I_s + \lambda \sum_i PP_s B_{is} - RM_s .$$

Equation (7) defines total expected household income, which is the sum of income in equation (6), sales at harvest, and the value of own consumption:

$$(7)\quad \sum_s \theta_s \left(I_s^* + \sum_i S_{1is}P_{1is} + \sum_i C_{is}PC \right) = TI.$$

As stated previously, the household can choose to meet its consumption requirement from own production or through purchases from the market. What balances the tradeoff between consumption from own production and purchases from the market in the model is the own food production premium lambda (λ) in equation (5). The parameter λ enables an increased shadow price of production of millet above the expected price six months after harvest to compensate for the desire of farmers to assure much of their own grain for consumption and to reduce their dependence on the market for millet (Abdoulaye and Sanders, 2006). When λ = 1, the farmer produces millet until the value of his marginal product is equal to the expected purchase price of millet six months later. However, farmers state that they want to assure sufficient grain in a bad year when prices are substantially higher (Abdoulaye and Sanders, 2006). Hence, farmers base their price expectation for later in the year on a bad year. In that regard, λ allows the on-farm production cost to increase, thereby assuring more of own production for bad rainfall conditions.

At a lambda value of one in our model, farmers relied on the market for their consumption of millet at a substantially higher rate than the observed market purchases of farmers. After calibrating the model to observed farmer behavior of millet production and purchases for different states of nature, a value of 1.78 best represented observed farmer behavior.[10] At this higher level of lambda, the farmer produces millet at a cost 78% higher than the expected purchase price six months later for millet. This translates into an expected price of 377 FCFA/kg[11] for millet in bad years. This is high, but consumer prices often reach 250 FCFA/kg in poor rainfall years, and in the summer of 2005 the price for millet surpassed 300 FCFA/kg. Farmers are apparently willing to produce millet even up to a shadow price higher than they would pay in bad rainfall years.

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[9] There is evidence that households rely heavily on remittances in bad years to meet their subsistence goal (Rain, 1999). To reflect these empirically observed additional funds forthcoming for grain purchases in bad years, remittances were added into the model. Remittances for a bad year were valued at US$89 (Abdoulaye, 2002), and adjusted for inflation to 2003 values using the GDP deflator (IFS 2003 = 100).

[10] The own food premium in our model quantifies how much a farmer is willing to pay to avoid relying on the market for his subsistence consumption by increasing the marginal value product of his own production of the staple, millet.

[11] The International Monetary Fund (IMF) exchange rate for Nigerien FCFA is 572.43 FCFA = US$1 (2003 base year).

Equation (8) defines production as the area planted under the technologies available in the model times their respective yields:

$$(8)\qquad Q_{is} = \sum_{n} Y_{ins} X_n .$$

Equations (9) and (10) define land and labor constraints, respectively:

$$(9)\qquad \sum_{n} X_n \leq Ld ,$$

$$(10)\qquad \sum_{n} X_n LR_{Ln} - \sum_{k} Z_k LR_{Lk} \leq HSL_L + HL_L .$$

Capital is exogenous in the model, and drives the model results since the new technologies raise the capital requirements. The capital available to the household in the model is the sum of investments incurred by the household in agricultural and nonagricultural activities observed in the 2002–2003 season.[12] The total initial capital available to the household in the model for all activities is US$264 (excluding the remittances in bad years). The model is solved using linear programming, and a detailed description of all variables is given in Table 3.

The Effects of Inventory Credit in Niger

The current inventory credit (CIC) program in the Fakara region of western Niger does not result in the farmer receiving a higher seasonal price. Rather, the profits generated through grain sales six months later are reinvested in purchasing fertilizer at a discounted price, which is sold at that price back in the village. The savings to farmers from the lower-priced fertilizer in the current program are between 6% and 15%, depending upon the type of fertilizer (Table 4).

To determine the benefits of the CIC program on the household's adoption of new technologies and income, those farmers receiving and not receiving the fertilizer price discount for fertilizer are compared. Farmers who live in a village where a CIC program is established (or in close proximity) have access to new technologies and other institutional support promoted by the program to implement these new technologies. Farmers without access to the program do not have the institutional and logistical support that the program provides. Hence, their access to or knowledge of new technologies is limited.

In our model, we distinguish between program farmers who have access to new technologies with a lower price for fertilizer, and nonprogram farmers, who use only their traditional technologies. For both program and nonprogram farmers, the price they receive for their millet is the harvest price.[13]

According to model results, the current inventory credit program in Niger does increase fertilizer usage and provides higher incomes for program farmers over nonprogram farmers, but the gains are small.[14] Program farmers' expected household income is US$88 (8%) higher than for nonprogram farmers (Table 5). These model results are based upon technical coefficients at the median level for samples of Karabedji farmers in the Farkara region.

[12] This capital is internally generated by cashing in the farmers' own assets, as there is no outside source of capital except informal money lenders at high interest rates. Households own various assets that they can and do cash in on the market—including grain stocks, small animals (i.e., chickens), and even larger animals (sheep and goats). These capital levels in the model reflect observed investment levels of farmers from selling off these assets.

[13] In Niger in remote villages, it is common for farmers to sell to merchants who do not even give them the harvest market price as paid in regional markets for their crops. Farmers take this price because they do not have information on prices or they have no other alternatives for selling their grain.

[14] When relaxing the assumption that only members of the current inventory credit program have access to new technologies and allowing nonmembers access to all technologies, only marginal differences in income were found between the two groups. Household income increases by only US$5 (0.45%) from the effect of reduced fertilizer cost alone. Use of fertilizer for both groups, if they had equal information, was then identical. The price-saving effect alone was then very small, as can be appreciated by the minimal changes in income.

Table 3. Definition of Notational Subscripts, Variables, and Parameters in the Empirical Model

Item	Definition
Subscripts:	
I	Crops available for production (millet, cowpeas, peanuts)
S	State of nature (bad, normal, good, very good)
K	Nonagricultural activity
N	Technology package
J	Input
L	Labor
Variables:	
I_s	Adjusted post-harvest income in state *s*
I_s^*	Post-harvest income in state *s* plus the value of food purchase adjusted by its opportunity cost minus remittances and cost of financing
Q_{is}	Production of crop *i* in state *s*
C_i	Consumption of crop *i* in state *s*
B_{is}	Purchase of crop *i* in state *s*
S_{1is}	Sales of crop *i* in period 1 (harvest) in state *s*
S_{2is}	Sales of crop *i* in period 2 (six months after harvest) in state *s*
Z_k	Quantity of nonagricultural activities *k* undertaken
St_i	Storage cost of crop *i*
a_{nj}	Use of input *j* by production technology *n*
X_n	Area planted of production technology *n*
HL_L	Amount of labor hired in labor period *L*
Parameters:	
θ_s	Probability of state *s* to occur
Cr	Millet minimum consumption requirement
P_{1is}	Price of crop *i* in period 1 in state *s*
HI_s	Immediate post-harvest income requirement in state *s*
P_{2is}	Price of crop *i* in period 2 in state *s*
Rt_{ks}	Return to nonagricultural activity *k* in state *s*
RM_s	Remittances in state *s*
P_j	Price of input *j*
λ	Own food production premium
PP_s	Post-harvest consumer price in state *s*
W_L	Wage rate of labor in labor period *L*
Cf_s	Interest cost of financing
TI	Total household income
Y_{ins}	Yield of crop *i* under production technology *n* in state *s*
PC	Weighted average of consumption price of millet
Ld	Amount of land available
LR_{Ln}	Labor requirement in labor period *L* by technology package *n*
LR_{Lk}	Labor requirement in labor period *L* by activity *k*
Lab_L	Adult equivalent male labor available in labor period *L*
$Flab_L$	Adult equivalent female labor available in labor period *L*

Table 4. Farm Gate Prices of Fertilizers Available in the Model

Fertilizer[a]	Current Program Price (US$/kg)	National Price (US$/kg)
NPK	0.40	0.47
DAP	0.44	0.47
SSP	0.44	0.47

Sources: SIMA (2003) and authors' calculations from survey data.

[a] Definitions of Fertilizers: NPK = Nitrogen, Phosphorous, and Potassium; DAP = Diammonium Phosphate; and SSP = Super Simple Phosphate.

Table 5. Comparison of Household Income in Four States of Nature Between a Farmer in the CIC Program Using New Technologies and a Farmer Not in the Program Under Traditional Technologies

State of Nature	No Program, Traditional Technologies (US$)	CIC Program, New Technologies (US$)	Change (%)
Bad	791	760	−4
Normal	1,124	1,197	6
Good	1,253	1,395	11
Very Good	1,316	1,569	19
Expected	1,093	1,181	8

Source: Authors' model results.

Note: Marginal value for capital for farmers in the CIC program is 20%. Farmers not in the program also have a 20% marginal value for capital.

The higher incomes for farmers in the CIC program result from: (*a*) increased production due to higher fertilizer use, (*b*) the ability of farmers to capture the price increase by selling some production later in the year from their own storage, and (*c*) a savings in fertilizer cost (the direct program effect). Program farmers, according to modeling results, have an expected increase in production of 984 kg over nonprogram farmers. The production effect[15] accounts for US$73 (83%) of the difference in household income between nonprogram and program farmers.

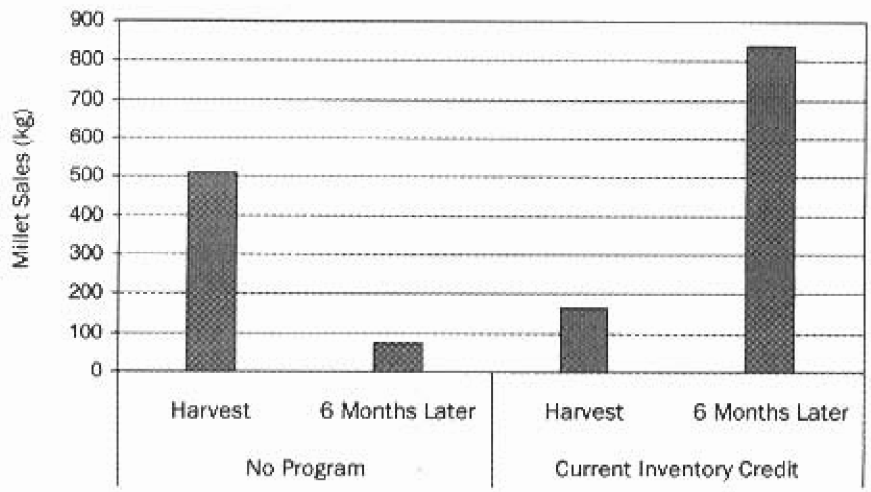
Farmers in the CIC program have expected sales of millet six months after harvest that are 764 kg higher than those of nonprogram farmers (Figure 4). This price effect is much smaller than the production effect—i.e., the expected price difference between harvest and six months later is only US$0.08/kg. The increased income from selling six months later for program farmers over nonprogram farmers is US$15. The increase in sales six months later contributes only 17% of the total difference in incomes between program and nonprogram farmers.

Improving Farmers' Incentives Under Inventory Credit

In this section, the effect on fertilizer use and incomes of enabling farmers to capture a higher price for millet instead of a lower price for fertilizer will be evaluated. In contrast to the CIC program described above, this program has not been implemented in Niger. The higher price for millet by selling later and taking advantage of the seasonal price increase for the farmer is the operating concept of most inventory credit programs.

The improved inventory credit (IIC) program is compared to the current inventory credit (CIC) program where farmers' only incentives are lower-priced fertilizer and greater technology information. Farmers in the IIC program pay the national price for fertilizer, and it

[15] There are two effects from inventory credit: (*a*) a production effect, due to the access to more fertilizer and/or new varieties, and (*b*) a price effect given that farmers might generate sufficient surplus which would allow them to store and sell later at a higher price. The production effect is the residual of total effects, and is calculated as 1 − *Price Effect*. The price effect is calculated as $(P_6 - P_H) * \Delta Q_6 - I - S$, where P_6 is millet price six months after harvest, P_H is harvest millet price, and ΔQ_6 is the difference in sales six months after harvest between nonprogram farmers and program farmers. We calculate the production effect as a residual of the price effect, because the former captures simultaneously the changes of cowpea and millet production given their intercropped production system. The price effect is unambiguous as it only comes from the change in sales of millet six months later.



Source: Authors' model results.

Figure 4. Distribution of Expected Millet Sales Between Farmers Under No Program and the Current Inventory Credit (CIC) Program

Table 6. Millet Prices at Harvest and Six Months Later in Real Terms in Four States of Nature

State of Nature	Price at Harvest (US$/kg)	Price Six Months Later (US$/kg)
Bad	0.26	0.37
Normal	0.23	0.31
Good	0.20	0.25
Very Good	0.17	0.19

Sources: Authors' calculations from SIMA (2003).
Note: A complete listing of all prices can be found in Baquedano (2005).

is assumed that the value of the loan received to meet the farmer's harvest income is equal to the full harvest value of the grain deposited as collateral.[16]

The price advantage to storage under the IIC program is the price difference between the harvest price and the price for millet six months later. This price difference times the quantities sold later net of the cost of storage and financing is the return to the later sale. Farmers' seasonal price gains from storage depend upon the state of nature faced by farmers. The highest price gains to storage for farmers are in bad and normal years (Table 6). In bad years (poor rainfall), prices increase US$0.11/kg (42 %), while in normal years they increase US$0.08/kg (35%).

The returns to storage must be sufficient to cover interest and storage cost.[17] The model indicates that farmers under the improved inventory credit (IIC) program use more fertilizer than those in the current inventory credit (CIC) program

[16] Providing farmers with 100% of the value of their grain stored in loans is the practice in the inventory credit programs in Niger. Later in the analysis, this assumption is relaxed and the amount given as a loan to farmers varies from 70% to 95% of the harvest value of their grain deposited in the program as a loan.

[17] Under the IIC program, farmers finance their harvest income goal at the current real monthly interest rate of 2.58%. The inventory credit program in Niger allows only millet and peanuts as collateral for financing. Therefore, these are the only crops allowed in the model to be stored under the inventory credit program. Any sales of cowpeas six months later must cover payment of the farmer's own cost of storage of US$0.15/kg (as estimated from interviews), and farmers risk losing up to 50% of the stored cowpeas due to insect infestation (FAO, 2004).

Table 7. Land Allocation to Technologies Between the Current Inventory Credit (CIC) and Improved Inventory Credit (ICC) Programs

Technology Packages	CIC Program	IIC Program, 2.6% Real Monthly Interest
Traditional:	— (hectares) —	
1 No Fertilizer	3	2
2 Micro Dosage (3 kg/ha of NPK)		
3 Moderate Dosage (25 kg/ha of NPK)		
New Technologies:		
4 Improved Moderate Dosage (60 kg/ha of NPK)		
5 Improved Moderate Dosage (50 kg/ha of SSP)		
6 **4** + New Cultivars		
7 **5** + New Cultivars	3	4
Expected Household Income (US$)	$1,181	$1,275

Source: Authors' model results.

Note: Definitions of Fertilizers: NPK = Nitrogen, Phosphorous, and Potassium; and SSP = Super Simple Phosphate.

(Table 7). Area fertilized under a new technology, which intercrops millet with cowpeas and uses 50 kg/ha of side-dressed SSP, increases by 1 ha (33%) in moving from the CIC program to the IIC program.

The income advantage for farmers under the IIC program over the CIC program is a result of: (*a*) higher overall total sales due to increased production, and (*b*) greater sales six months later at a higher price. Farmers under the IIC program have an expected household income that is US$94 (8%) greater than their counterparts in the CIC program (Table 8).

As observed from Table 8, the income advantage is larger in every state of nature for farmers under the IIC program than for farmers under the CIC program except in a bad one. In a bad state of nature, the yield effects are small; hence, income differences between program and nonprogram farmers are low. This result is not surprising given that improved cultivars are less drought tolerant than traditional varieties and can't take advantage of higher dosages of fertilizer when faced with low water availability. Fortunately for farmers, the bad rainfall years with poor yields are the years in which the seasonal price change is the largest.[18]

Table 8. Comparison of Household Income in Four States of Nature Between a Farmer in the Current Inventory Credit (CIC) Program and a Farmer Under the Improved Inventory Credit (IIC) Program

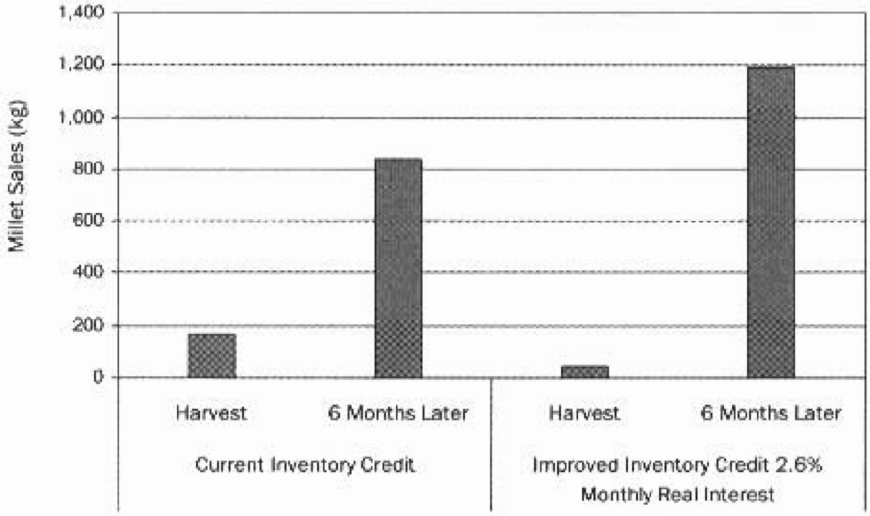
State of Nature	CIC Program, New Technologies (US$)	IIC Program, 2.6% Real Monthly Interest (US$)	Change (%)
Bad	760	732	-4
Normal	1,197	1,337	12
Good	1,395	1,504	8
Very Good	1,569	1,717	9
Expected	1,181	1,275	8

Source: Authors' model results.

Note: Marginal value for capital for farmers in the CIC program is 20%. Farmers in the IIC program have a 16% marginal value for capital.

Crop production increases by 570 kg for farmers in the IIC over those in the CIC, accounting for US$77 (82%) of the change in income between farmers in these two programs. This income gain comes from increasing fertilizer expenditures by US$33. Expected sales six months later at the higher seasonal price for farmers under the IIC program increase 352 kg over those for CIC program farmers (Figure 5), accounting for US$17 (18%) of the income increase between farmers in the IIC and CIC programs.

[18] But this also implies farmers need to have sufficiently high yields to put aside some of their harvest to sell later.



Source: Authors' model results.

Figure 5. Distribution of Expected Millet Sales Between Farmers Under the Current Inventory Credit (CIC) Program and an Improved Inventory Credit (IIC) Program

Effects of a Lower Cost of Financing

As reported in Table 9, farmers face a 36% annual nominal interest rate under the current inventory credit program. Taking out the average inflation rate over the past 13 years of 5% (IFS/IMF), and assuming a 10% long-term return to investments,[19] implies that farmers in Niger are charged a 21% loan default risk premium.

In an inventory credit program, such as the CIC, the producers' organization should be able to reduce the riskiness of the credit by knowing its members and utilizing group pressure to encourage repayment (Jain, 1996). Given the very low default rates for microfinance programs in other developing nations (Year of Microcredit, 2005), a risk premium of 5% seems reasonable for Niger.[20] This adjustment of the risk premium results in a nominal annual interest rate of 20%. In real terms, the change in the interest rate would be from 31% to 15%, or 1.25% monthly assuming the continuation of 5% annual inflation.

Table 9. Observed and Suggested Cost of Financing in Nominal Terms

Description	Suggested Rate (%)	Program Rate (%)
Rate of Return	10	10
Inflation	5	5
Risk of Default	5	21
Annual Rate	20	36
Monthly Rate	1.67	3

Source: Authors' calculations from survey data.

[19] The return of a low-risk alternative, such as a U.S. Treasury bond, averages 5% to 6%. Assuming a return double that average in a high-risk environment such as Niger seems reasonable. Lowenberg-DeBoer, Abdoulaye, and Kabore (1994) have found even higher rates of return for Nigerien village-level investments.

[20] The similarity of the macroeconomic environment described in the studies of microcredit in various countries reviewed by the authors is the justification for the 5% loan default risk for Niger. Clearly, there is a need for empirical studies to establish a range of loan default risk for Niger. Such an objective would be useful for a future study but is beyond the scope of this work.

The model is rerun at this 1.25% monthly real interest rate, varying the percentage of the inventory holdings given as a loan. The analysis in the previous section assumed that farmers receive 100% of the value of their stored millet as a loan. The credit given in most inventory credit programs is 50% to 100% of the value of the stored crop (FAO, 2000). By varying the amount of the harvest value of stored crop received as a loan, we evaluate the effects of restricting credit on farmers' participation in inventory credit. The analysis in this section concentrates on two effects: (*a*) how farmer participation changes when the interest rate is lowered and the amount the farmer can borrow varies, and (*b*) the effect on farmers' incomes and technology use from the lower interest rates.

Farmer participation in the program is measured by the amount borrowed by the farmer. More borrowing from the program is indicative of more millet being stored under inventory credit. The model results provide evidence that the incentive for farmers to participate in the inventory credit program increases substantially as the cost of credit is lowered. When the cost of credit is lowered from 2.58% to 1.25% monthly, the expected amount of borrowing increases by US$77 (98%) (Table 10). At the lower interest rate farmers would borrow at 70% of the harvest value of their grain, whereas at the higher interest rate they only utilize program credits at 75% of the harvest value and above.

When looking at the changes in income, these are positive but small effects. They result from only an interest cost savings since production practices are not affected by the reduced interest rates. Under the higher interest rate, income increased by US$94 (8%) when switching from the CIC to an IIC program (Table 11). When the interest rate is lowered from 2.58% to 1.25%, income increases by US$129 (11%) when switching from the CIC to an IIC. Hence, the net effect in household income from lowering the interest rate in the new inventory credit program is an additional US$35 (3%).

When credit is reduced to 95% of the harvest value of stored grain, at the higher interest rate, income increases by US$44 (4%) when changing from the CIC to the IIC program (Table 11). When the interest rate is lowered, income increases by US$119 (10%) when shifting from the CIC to the IIC program. This implies a net effect of a lower interest rate on income of US$75 (6%) when credit is reduced to 95%. Restricting credit to 90% of the harvest value of the stored grain increases income by US$40 (3%) from the CIC to the IIC program. When the interest rate is lowered at the reduced level of credit of 90%, income increases by US$109 (9%) from the CIC to the IIC program. This results in a net effect from the change in the interest rate of US$69 (6%) when credit is restricted to 90%. The increase in income continues to favor the IIC at the lower interest rate over the higher interest rate program up until valuation of grain given as a loan is 80%. When credit is reduced to 75% or less of the harvest value of stored grain, the income differences between the two programs (IIC with a higher interest rate and IIC with a lower interest rate) practically disappear.

The modeling results of varying the interest rate and the amount of credit received as a loan suggest that not only does participation increase at a lower rate of lending, but farmers can also obtain reasonable increases in income. At the higher interest rate, the gains in income quickly decrease as the amount given as a loan is lowered (Table 11). No significant production effects were found when varying the interest rate and the loan amount, as the production plans did not vary. The effects on income result from the savings in interest cost from reducing the risk of loan default.

Conclusions

In the current inventory credit program, where farmers do not capture the higher crop prices later in the season but instead

Table 10. Expected Level of Borrowing of Harvest-Value Income Under the Improved Inventory Credit (IIC) Program Under Three Costs of Capital and Five Valuations of Grain Stored

Monthly Interest Rate	Value of Grain Stored						
	100%	95%	90%	85%	80%	75%	70%
	— US$ —						
2.58	78	64	64	64	64	64	0
1.25	156	156	156	156	156	132	132
Change in Borrowing: US$/(Percent)	77 (98%)	91 (142%)	91 (142%)	91 (142%)	91 (142%)	68 (106%)	—

Source: Authors' model results.

Table 11. Changes in Expected Household Income from the Current Inventory Credit (CIC) Program in Niger to an Improved Inventory Credit (IIC) Program Under Two Costs of Capital and Three Valuations of Grain Stored

Description	Value of Grain Stored						
	100%	95%	90%	85%	80%	75%	70%
	— US$ / (Percent) —						
IIC (2.58% monthly rate)	94 (8%)	44 (4%)	40 (3%)	35 (3%)	31 (3%)	27 (2%)	24 (< 2%)
IIC (1.25% monthly rate)	129 (11%)	119 (10%)	109 (9%)	99 (8%)	89 (8%)	35 (3%)	27 (2%)
Expected Net Change: US$/(Percent)	35 (3%)	75 (6%)	69 (6%)	64 (5%)	58 (5%)	8 (1%)	3 (< 1%)

Source: Authors' model results.

receive a lower price for fertilizer in the next season, program participant farmers increase their incomes and fertilizer use. The current inventory credit program in Niger clearly is an improvement over no program. Nevertheless, currently farmers' contributions to the program average 1.1 bags of millet, which represents less than 4% of their total production in the 2002–2003 production season. There is an increasing number of participating farmers but minimal increase in participating farmers' contributions. This is consistent with the low returns found in the modeling, and brings into question the sustainability of the current program and its effectiveness to further increase fertilizer use.

The modifications to inventory credit indicate that the income benefits are greater when farmers are allowed to retain the profits from the later sales of their millet staple. The use of fertilizer also increases substantially when comparing the current inventory credit program to a program where the farmers' organization retains the profits. According to the model results, improving inventory credit by redistributing back to farmers the net returns to storage provides a larger economic incentive to use more fertilizer than lowering input prices.

The improved inventory credit program has the potential to offer its greatest benefit to farmers in bad years when seasonal price increases are highest between harvest and later in the year. However, the technology data and the modeling results indicate that the response of new technologies in bad rainfall years is small under inventory credit. Farmers' ability to take advantage of the bad-year price increase depends upon their ability to increase yields in these years. So, in the future, there needs to be more emphasis on improved technology for these low rainfall years, such as water harvesting technologies (see Sanders, Shapiro, and Ramaswamy, 1996).

In spite of large changes in interest rates, the additional income effects are small. The gains here are in the costs of storage in better rainfall years, as there is little surplus to sell in adverse rainfall years. The benefits to storage are less in good rainfall years because there is much less price increase. Clearly, the main constraint to inventory credit programs is increasing yields in bad rainfall years when the seasonal price increases are substantial.

Another market improvement is to respond to the between-year price collapse in good rainfall years by selling to higher value markets. The animal feed market or food processing markets are important responses to the between-season price collapse (Vitale and Sanders, 2005; Ouendeba, Abdoulaye, and Sanders, 2003). This market expansion will become more important as incomes increase and as the price differences within years are reduced, since more farmers will be obtaining inventory credit.

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