Effects of Storage Losses and Grain Management Practices on Storage: Evidence from Maize Production in Benin

Authors & affiliation
Didier Kadjo[1], Jacob Ricker-Gilbert[2], Corinne Alexander[3], Abdoulaye Tahirou[4]
[1]Graduate Research Assistant, Purdue University Department of Agricultural Economics
[2] Assistant Professor, Purdue University Departments of Agricultural Economics
[3] Associate Professor, Purdue University Departments of Agricultural Economics
[4] Outcome /Impact Economist International Institute of Tropical Agriculture

Corresponding author contact information
Didier Kadjo[1]
Mailing and Physical address:
403 W. State Street, Room 618
W. Fayette, In 47907
USA
Phone: +1 (765) 494 -4260
Fax: +1 (765) 494-9176
Email: dkadjo@purdue.edu

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Abstract

This study uses nationally representative data from 360 farm households in Benin to estimate how access to storage technologies and storage losses from insects affects a smallholder African farmer's decision to hold grain from production, in an environment of high price variability. We find that access to storage chemicals increases the average amount stored by 196 kilograms with results approaching statistical significance. Farmers who use plastic bags store 293 kilograms less grain on average, likely because bags are used for transport to market in addition to storage. Results from our study also suggest that market-driven farmers rely on high price variability as shield against storage losses, whereas subsistence farmers jeopardize their food security in lean season because of aversion to stock losses. Expected post-harvest losses might therefore be more detrimental to storage decision for farmers with low physical and financial assets. These findings highlight the need to develop effective and accessible new or improved storage technology for small farmers in SSA (Sub-Saharan Africa).

Keywords: food security, price variability, storage losses, storage technology, Benin, SSA.

1. Introduction

Farmers in sub-Saharan Africa (SSA) not only face many constraints to producing staple crops, but they also face many grain management challenges after harvest. By not being able to store effectively, most farmers cannot take advantage of price increases that occur during the production cycle. They often shift from sellers to buyers of grain during the storage season and therefore weaken their food security.

Access to storage technology remains one of the most problematic issue throughout the post-harvest chain, because devastating pests such as the Large Grain Borer (LGB) can cause up to 30 % dry –weight-losses (DWL) in six months of storage (Boxall, 2002; Golob, 2002). In addition, when effective storage technology is not available, traditional storage technologies often unable to dry and store grain properly can even lead to increased losses during storage (Golob et al., 2002).

Unfortunately, farmers are limited in strategies to cope with storage losses because of credit constraints (including high cost of capital), risk aversion, lack of modern storage technology, and unreliable information about grain prices. As a result, many farmers sell immediately after harvest in order to mitigate pest loss. Therefore, they forgo potential profits that they would have earned had they held stocks at harvest and sold later in the marketing year when prices are typically much higher (Renkow, 1990; Saha and Stroud, 1994; Stephens and Barrett, 2011). In other words, pest damages and forced early sales create a situation that undermines household food security for small farm households in SSA. Early sales reduce farmers' profits which in turn lower profitability of agricultural production and diminish farmers' incentives to invest in productivity increasing technologies. Nevertheless, very little attention has been paid to post-harvest losses and storage technology in studies on household grain management.

The objective of this paper is therefore to determine how access to storage technology and post-harvest losses from pests affects a farmer's storage decision, in the face of potential pest damage, and large fluctuations in maize prices. In doing so, this study bridges the gap between the entomology literature on DWL from pests, and the economic literature on household grain management decisions in an environment of price volatility.

Storage economics in developing countries cite farmers' financial and physical assets to explain what is called the puzzle "sell low and buy high" (Stephens and Barett, 2011; Park, 2006). For instance, this puzzle supposes that farmers with little liquidity asset sell grain early at low price during harvest period, while they buy grain later at high post-harvest price. Although storage losses continue to plague the main farm asset, namely production, storage technologies are overlooked in grain management studies in developing countries. In fact, in most studies, storage losses and technologies are submersed in the overall storage cost (Brennan, 1958; Renkow, 1990; Saha and Stroud, 1994; Fulgie, 1995) to the extent that there is no measure of the isolated effect of storage losses.

Moreover, to our knowledge, in SSA there is no explicit models of storage. Previous work uses the inter-seasonal sale decision by households as a dependent variable, and higher sales during harvest infer lower levels of storage. Such an approach does not consider the fact that storage behavior can inversely condition sale decisions, because households use storage technology. That is to say the effectiveness of storage technology can determine the scale of losses and subsequently farmers' ability to undertake successful inter-seasonal sale choices. Thus, this study contributes also to the literature on storage economics in SSA by proposing an explicit storage model that incorporates storage losses and technology along with marketing variables to understand the effects of pest damages on farmers' decision to hold grain.

Understanding how storage technologies and potential grain losses after harvest affect the household's storage decision is important because of the economic and food security consequences. These consequences include (i) increased dry weight loss (DWL) expediting the need to purchase in the post-harvest period at a higher price, (ii) early sale at low harvest prices to avoid storage losses, and/or (iii) later sale of damaged grain at discounted price because of lower quality. These situations result in income and food insecurity trap for many households who rely on grain for consumption and livelihood.

This study tests two hypotheses related to the storage decision in the harvest period. First, the amount of maize that a farmer expects to lose due to insect pests has no statistically significant effect on the maize quantity that a farmer decides to store after harvest. Second, storage technologies have no statistically significant effect on the maize quantity a farmer stores after harvest. To test these hypotheses, we use cross section data about the grain management practices over the 2011/2012 season collected from 360 rural households of Benin.

In order to argue for a causal effect of storage losses and technology on storage decision in harvest period, we deal with potential endogeneity that may arise from the nature of the covariates of interest. Storage losses are exogenous since depending on farmers' own experience about pest damages. Among the storage technologies, only chemical use raises endogenity issue, because access constraints prevent farmers to randomly choose to spray chemical protectant. We deal with the endogeneity issue for chemical protectant by using the presence of extension agent in the village as an instrumental variable. We do our best to deal with endogeneity in a cross-sectional context, but inferring true causality from our results should be taken with caution.

Results from this study suggest that access to storage chemicals has a positive effect on increasing quantity stored. We find that chemical use increases the average stored quantity by 196 kilograms, and the effect is close to marginally significant with a p-value less than 13%. The other storage technologies are not significant to explain the storage decision, except the negative and significant effect of plastic bags on the quantity stored. Similarly, the expected loss rate decreases the grain storage without being significant. Instead, price variation seems to drive the storage decision, since a 1% increase of the expected percentage of price variation increases the average quantity store by 8.4 kilograms, with p value less than 1%. However, this price effect seems tied to the sale goal during the storage decision. Our findings from Benin may also be applicable to other SSA countries with similar pest damages and price patterns.

2. Background and previous literature

Storage Economics in developing countries

The grain storage literature emphasizes the inter-seasonal price decision as the primary storage motive. Inter-temporal price arbitrage is relevant when prices fluctuate markedly between seasons as observed in staple grain markets in many developing countries (Sahn, 1989).

Farmers integrate the storage technology in the inter-seasonal price decision by analyzing the storage cost. In fact, farmers who adopt a technology to store grain, anticipate an increase of post-harvest price sufficient to cover the storage cost. Thereby, storage occurs only if the expected planting season price is greater than the harvest price plus marginal storage cost (Saha and Stroud, 1994). In other words, the storage cost must enable farmers to take advantage of price variation (Working, 1949).

In most studies, storage cost identities all costs incurred during the storage process so that there is no specific treatment for the storage technology. Brennan (1958) defines the marginal cost of storage as the marginal outlay on physical storage costs plus a marginal risk-aversion factor minus the marginal convenience yield on stocks, the convenience yield being the reduction in transaction cost from holding of physical stocks. Fulgie (1995) incorporates in storage cost, storage loss along with marketing cost like marketing inputs. Saha and Stroud (1994) follow Renkow (1990), and indicate that the net cost of storage includes the value of storage loss reflecting the effectiveness of storage technology. Therefore, constraints on the access to effective storage technology raise the storage cost. In this respect, Stephens and Barrett (2011) state that appropriate storage technologies might not be available in developing raising inter-temporal storage cost to the point that storing for future sales becomes not profitable.

Farmers consider also variables other than storage cost to make storage decision and benefit from price seasonality. As the inter-seasonal price variation guarantees resource transfer between seasons, storage can represent a precautionary saving only if farmers possess sufficient wealth to forgo harvest sales. Giles and Yao (2007) find however that an income increase from off farm migrant labor decreases the precautionary saving in rural areas from China. Lee and Sawada underline (2010) that households with better access to credit markets decrease holding stocks in Pakistan. In contrast, in West Africa, Lowenberg-DeBoer *et al.* (2000) state that credit access increases liquidity and allows farmers to wait for higher prices. Similarly, Stephens and Barrett (2011) find that in the presence of pronounced price variability, households with sufficient access to liquidity successfully avoid selling low and buying high in maize market in Kenya. They contend that credit use reduces the likelihood of farmers' market entry as sellers in the harvest period. In addition, they suggest that off-farm income reduces the likelihood of purchases in lean period.

In many other respects, price seasonality is insufficient to explain storage decision in developing countries. Renkow (1990) proposes the first model of storage opposing price arbitrage to food security in the household's storage decision. Although Renkow's model encompasses the two goals of the household decision, it fails to consider the major assumption of risk aversion in developing countries (Saha, 1994).

Many households are, indeed, risk averse in Least Developed Countries (Binswanger, 1980, Walker and Ryan, 1990). Under price risk, on-farm storage is de facto a form of forward contract to meet the farm household consumption needs (Saha and Stroud, 1994). In other words, a risk averse household can carry positive stocks even if the expected discounted next-period price is less than or equal to current price plus the marginal storage cost. In addition, under risk aversion, a household's production ceases to be separable from consumption or off-farm labor supply decisions (Walker and Ryan, 1990; Saha, 1994).

Storage is therefore integrated in the total resource allocation in the household. Park (2006) underlines that production, storage and sales decisions are not made in isolation of each other, but in coordinated strategy. The author suggests that grain management decisions balance the goals of maximizing profits and reducing price risk. The household considers its cash wealth, grain availability and current grain market condition, instead of focusing on the amount wealth to save each period given exogenously determined incomes. Park's model emphasizes the tension between the desire to maximize income as a producer and reduce exposure to uncertainty on grain consumption.

Maize storage in Benin

In Benin post-harvest losses (PHL) are among the major threats to food security because of storage losses (ADA, 2010). LGB represents the main storage pest in maize stock with destructive effects over long periods of time (Maboudou et al., 2004). Storage loss is estimated around 15 to 30% depending on regions (ADA, 2010). The dryer Sudan Savanna in the North records 2.5% while in the Guinea savanna average losses can reach 10% (Adda et al.,2002). In contrast, higher average losses are observed over a cropping year in the more humid southern Benin where high insect pressure exists due to favorable environmental conditions of high air moisture and temperature (Fiagan, 1994). Storage losses in South can reach 20% to 50% after six months of storage with traditional structures (Diop et al., 1997; PADSA, 2000; Maboudou et al., 2004).

Traditional storage technologies remain the prevailing storage methods across Benin. These technologies vary in shape and structure, and from one place to another, depending on agro-climatic conditions, ethnic and some socio-economic factors (Hell et al., 2000; FAO 1992; Fiagan, 1994). Wooden granaries are found in the South under two types locally called “Ago” et “Ava”. The conical roofing of ‘Ago’ is made of straws and the body is made of palm tree branches (Adegbola, 2007). The ‘Ava’ granaries have only a cylindrical body and straw roofing (Hell et al., 2000). Earthen granaries are used in southern and northern Benin, though they dominate in the north and some areas in the Center.

Farmers in the region use several traditional methods to preserve grain from insect attacks. These methods include exposition of cobs to the sun, and use of products such as ash, kerosene, diesel oil, leaves and neem extracts (Adegola, 2007). In southern Benin, for instance, farmers also place maize harvested from the first raining season over the fireplace, the smoke keeping the cobs dry and repelling insects (Foua-Bi, 1989; Gansou et al., 2000).

Besides, some farmers spray farm pesticides on stored grains (Adegbola, 2010). These hazardous uses of farm pesticides raise concerns about health risk (Pedune-Benin, 1999).

Several projects have promoted improved storage technologies. For instance, FAO developed improved granaries systems in 1992 extended by the Danish project called "Programme d'Appui au Développement du Secteur Agricole (PADSA)". These projects disseminated also protection measures such as chemical (Sofagrain, Actellic) and integrated control methods of pests. According to PADSA (2000), the introduction of improved storage structures induced significant reductions in loss rates to 5% and 1% respectively for improved wooden and clay made granaries.

Despite the proven effectiveness of the improved storage technologies, their success were limited among farmers. In the North, the protectant measures, "Sophagrain", were more widely adopted than the improved granaries. Farmers indicated that the availability of the protectant and the ease of use facilitated adoption (Maboudou, 2003). In the South, high proportions of early adopters in 2002 had abandoned improved technologies by 2008 (Adegbola, 2010). Farmers reported high cost as one of the major reasons of the disadoption followed by constraints on village access, and family labor.

3. Theoretical Framework

The theoretical framework used in this study is a two-time additively separable utility maximization model based primarily on Saha and Stroud (1994). It extends Saha and Stroud's work by incorporating specifically the storage loss as a measure of effectiveness of the storage technology. This theoretical framework examines also the storage decision alongside the marketing decision to identify trade-off decision variables between harvest and post-harvest periods.

The model is built around harvest and post-harvest period, and therefore encompasses one consumption cycle, before a new harvest period.

The household produces a main staple crop, maize, along with other staple and cash crops. Since there is no production during the harvest period, other staple crops belong either to food consumption bundle during harvest period or to sales.

In each period, the household obtains utility from consuming the main staple grains *(C)* and a composite tradable good *(Y)*. The household decision during the consumption cycle is then a utility maximization problem over harvest (H) and post-harvest period (L).

$$\text{Max V} = U_H(C_H; Y_H) + \gamma \, E_H U_L(C_L; Y_L) \qquad (1)$$

The term U is a twice differentiable utility function, and the term (E_H) the expectation operator during the harvest period. The term γ is the discount scalar time. At the harvest period, the household realizes its level of grain output, *Q*. This quantity is allocated to consumption (C_H), storage (S_H), and sale. Grain uses in the household are balanced with grain sources as follows

$$Q + S_{H-1} + A_H = C_H + S_H + M_H \qquad (2)$$

In Equation (2), grain in harvest period is also sourced from carry-over stocks (S_{H-1}), and purchases from the market A_H. The household spends its income on any good including grain.

The household's income comprises income from on-farm and off-farm activities. Income is balanced according to equation (3)

$$I_H = P_H . M_H + F_H + L_H + rB_t - C(S_H) - P_H . A_H \quad (3)$$

Where P_H denotes grain price in harvest period. Assumption of market atomicity holds in harvest period so that purchase and selling prices are supposed identical. The term $C(S_H)$ denotes the net cost of storage. The term (F_H) represents on- farm income other than maize income, whereas L_H accounts for off-farm income.

The household uses its income to realize expenditure (D_H) on grain (A_H) and other goods (Y_H) at harvest period. By normalizing the price of other goods with unity, this expenditure can be set out as

$$D_H = P_H A_H + Y_H \quad (4)$$

The household's change in savings between lean season and harvest season is formulated as

$$B_L - B_H = I_H - E_t \quad (5)$$

Substituting (3) and (4) into (5) and solving for Y_H *yields*

$$Y_H = P_H.M_H + \Delta B_H + F_H + L_H - C(S_H) - 2P_H.A_H \quad (6)$$

where $\Delta B_H = (1+r)B_H - B_L$ is the variation in saving.

In harvest period consumption of grain and other goods consumption are summarized as:

$$C_H = Q + S_{H-1} + A_H - S_H - M_H \quad (7)$$

$$Y_H = P_H.M_H + \Delta B_H + F_H + L_H - 2P_H.A_H - C(S_H) \quad (8)$$

In post-harvest period, consumption of grain and other goods can be derived as in harvest period, but with some adjustments inherent in this period. There is no production in post-harvest period and all grain used is sourced from storage and purchases. The quantity in stock is sourced from harvest storage discounted by storage loss. No storage cost is incurred in post-harvest period for the stock, because the quantity stored at the end of post-harvest is either the remaining grain from harvest or this stock rest completed by potential purchase from the market.

Consumption in post-harvest period is therefore given by

$$C_L = (1-\delta)S_H + A_L - S_L - M_L \quad (9)$$

$$Y_L = P_L.M_L + \Delta B_L + F_L + L_L - 2P_L.A_L \quad (10)$$

Where the variable are defined as before, but with the subscript (L) denoting for post-harvest period.

Equation 10 is rewritten to account for storage in harvest period, and yields

$$\mathrm{Y_L} = \mathrm{P_L}.(1-\delta)\mathrm{S_H} + \Delta B_L + \mathrm{F_L} + L_L - P_L A_L - \mathrm{P_L}\ (\mathrm{C_L} + S_L) \quad (11)$$

The farm household's optimization problem in two periods is represented as follows:

$$\text{Max V} = U_H\big(\mathrm{Q} + \mathrm{S_{H-1}} - \mathrm{A_H} - \mathrm{S_H} - M_H;\ \mathrm{P_H}.M_M + \Delta B_H + \mathrm{F_H} + -2\mathrm{P_H}.A_H - \mathrm{C}(\mathrm{S}_H)\big) + \gamma\, E_H U_L[\,(1-\delta)\mathrm{S_H} - \mathrm{S_L} - M_L;\ \mathrm{P_L}.(1-\delta)\mathrm{S_H} + \Delta B_L + \mathrm{F_L} + L_L - P_L.A_L - \mathrm{P_L}\ (\mathrm{C_L} + S_L)] \quad (12)$$

The optimal solution is obtained mainly from the first order condition

$$V_{M_H} = -U_{HC_H} + P_H U_{HY_H} = 0 \quad (13)$$

$$V_{S_H} = -U_{HC_H} - C_{S_H}(S_H)U_{HY_H} + \gamma\,(1-\delta)\,(E_H U_{HC_1} + \mathrm{P}_L\ E_H U_{LY_L}) = 0 \quad (14)$$

$$V_{B_{t+1}} = -U_{HY_H} + \gamma\,(1+\mathrm{r})E_H U_{LY_L} = 0 \quad (15)$$

If the second-order condition of equation 14) is satisfied, the optimal storage decision under the reduced form, suggests trade-off between determinants from harvest and post-harvest period. These are utility for maize consumption and other goods in harvest period, storage losses and cost, expected utility for consumption for the maize and other goods in post-harvest period, and maize prices.

4. Empirical estimation of the storage decision

Empirical Model

The empirical model focuses on the quantity stored from farmers' harvest. Though this empirical model relaxes the assumption of the joint estimation inferred from risk considerations, it attempts to account for risk aversion by taking into account farmer's motive of storage. The literature on storage economics indicates, indeed, that farmers whose motive includes sales might integrate price arbitrage in their decision compared with consumption – driven farmers.

Our hypotheses of interest is to estimate the degree to which storage losses and grain management practices affect the grain storage decision during harvest season, the model storage is defined as follow

$$\mathbf{S} = \beta_0 + \mathbf{L}\beta_1 + \mathbf{T}\beta_2 + \mathbf{P}\beta_3 + \mathbf{C}\beta_4 + \mathbf{Sa}\beta_5 + \mathbf{Q}\beta_6 + \mathbf{So}\beta_7 + \mathbf{M}\beta_8 + \mathbf{E}\beta_9 + \mathbf{R}\beta_{10} + \varepsilon \quad (16)$$

Where ***S*** represents the kilograms of grain stored from production during the harvest season. The parameter $\boldsymbol{\varepsilon}$ denotes the error term.

The main hypotheses are tested through the coefficient and the standard error for the covariates of interest. The vector ***L*** denotes the expected percentage of losses. The vector ***T*** represents the technologies the farmers use to store grain. It is decomposed in chemical use, and the set of storage equipment. The vector ***T*** takes the values 1 when the farmer used a given technology or 0 otherwise.

The empirical model incorporates variables identified in the theoretical framework. The vector ***P*** measures the expectation of price increase (in %) from harvest to post-harvest period. Post –harvest prices are obtained from naïve farmer expectation. This vector serves also as a proxy for expected price increase when the farmer makes a decision during the harvest period. The vector ***C*** is the daily food intake per capita during the harvest period. This vector represents the measure of maize preference in the household through food habit. The vector ***Sa*** is the saving amount at the beginning of harvest period. It is a measure farmers' cash wealth from off-farm and on-farm activities, at the beginning of harvest season. The vectors ***Q*** and ***So*** identify the quantities of maize produced and the carry-over stocks, respectively. The vector ***M*** is the farmer's motives for storage. It represents also a proxy for maize utility during post-harvest period. A measure of farmer's ability to meet preference for other goods during post –harvest period is also determined by expectation of cash from loan and reimbursement represented by the vector ***E.***

The Vector ***R*** represents a vector of control variables that may affect the main covariates and interact with the error term. They are identified through the literature review on storage behavior. This vector includes 1) department dummies to accounts for spatial food scarcity and pest infestation in Benin 2) household characteristics such as age, education and sex 3) the amount of loan from formal or informal sources during harvest period 4) vectors of correlated to the tested covariates, defined in the identification strategy.

Identification Strategy

In order to make an argument about the causal effect of technology and the expected losses on the quantity stored from harvest, we deal mainly with omitted variable bias and endogeneity that may arise from the covariates of interest (Angrist and Pischke, 2009; Wooldridge, 2010).

Although no studies provide background on determinants of expected storage losses to account for probable omitted variable bias, there is no reason to believe that the expected storage losses are endogenous. This covariate is indeed, derived from farmers' experience on storage losses, which is pre-determined at the time the storage decision is made. Farmers have a rational expectation about the storage losses based on their experience about the prevalence of pest infestation in their area and the technology they use to preserve the grain. The main covariate that might affect this expected loss is the number of years the farmer has been using the storage technology. The years of technology use may also be an implicit measure of farmer's experience in storage practice. This covariate is therefore includes in the vector ***R.***

We build on studies examining adoption of storage technology to identify covariates that may generate omitted variable bias for technologies. Following the findings from Adegbola

(2010) and Maboudou *et al*. (2004), we identify 1) quality of the road to the district in the village 2) membership to an association. Access to the village throughout the year may facilitate farmer's market transactions and acquisition of storage technologies like chemicals. Likewise, membership to the association may ease the transfer of information about the storage innovation and may also play a role of social safety for food security. These two covariates are integrated in the vector ***R*** as dummy variable taking the value 1 or 0.

We complete findings of the storage literature in Benin with a set of variables that might be correlated to the covariate and the error term. We introduce these variables in the vector R. These are 1) the presence of input dealer in the village 2) the use of traditional protectant technology 3) production of cash crop, and 4) possession of cell phone. The presence of input dealer in the village may facilitate the access to storage technology such as chemical and plastic bags. Farmers might also make exclusive choice of protectant type to preserve their grains by not combining traditional methods with chemical protectant. The production of cash crop (cotton, palm oil, pineapple, and cashew) represents an opportunity to access pesticide, misused as protectant. In addition, the cash crop can generate a diversified farm portfolio to mitigate income risk. Revenue from cotton for instance is obtained in the first quarter of the year, the post-harvest period for most farmers in the North and the Center. The possession of cell phone reduces information asymmetry about market prices (Aker, 2010*)* and may improve knowledge about storage innovations.

If farmers are unconstrained to choose their storage equipment, chemical use raises however a possible endogeinity issue. The failure of diffusion of improved granaries has contributed to the prevalence of traditional storage methods. Farmers can thus choose randomly to store maize in their traditional systems (granaries, ceilings, etc), as they are used to do. Polypropylene Plastic bags are also widespread in any local of regional market so that farmers can acquire it for about 300 F CFA ($ 0.50). But sales in harvest period might also motivate the use of bags. Nonetheless, this technology remains conditionally exogenous in the econometric model, since we control for determinants of harvest sales such as quality of the road to the main district, expected price increase, financial needs (savings and loans), and household size.

Conversely, storage protectant is presumed endogenous, because studies and field observations reveal that many farmers face severe access constraints to obtaining the technology. Adegbola (2010) and Maboudou (2003) point out that protectant access constraints the adoption of new technology of storage. The most recommended chemical is Sofragrain, is sold by certified seller. But in practice, many farmers have access to farm pesticides and other uncertified chemicals to preserve grains.

To account for possible endogeneity of chemical use, we use a control function approach. The control function (CF) is more efficient than two stage least squares when we test for binary endogenous variable (Wooldridge, 2010). For doing so, we predict chemical use probability using a probit instrumenting regression. This reduced form implies to include all the exogenous variables from the structural equation 16) and at least one instrumental variable. The generalized residuals of the reduced-form probit are then generated and subsequently included as an additional regressor in the structural model. We then verify the presumption of endogeneity with a test of statistical significance (at least p-value 0.10) on the coefficient of the generalized residual.

The IV's used in this study is the presence of an extension agent in the village. There are reasons to believe the presence of extension influences the use of chemicals and can represent a convenient IV for the storage model. First, if the availability of suitable chemical is a constraint, the presence of an extension agent may convince farmers not to use farm pesticides as alternative measures. In the case of cotton, the ministry of agriculture allocates pesticide through farmer organizations. The ministry can oversee the use of pesticides thanks to agents in the field. Similarly, the presence of agents in the field favors the access to better information about recommended chemical so that farmers may limit their use of uncertified chemicals. Second, the presence of extension is exogenous because it is determined outside any farmer's decision of grain allocation. Moreover, extension agents are assigned at an administrative level and this is not influenced by the rural household.

5. Data

Data collection

The study uses data from a random survey conducted in 6 of the 12 departments in Benin. Only the choice of these departments was based on the multiple criteria of maize productivity, localization to account for regional pest infestation, and food security issues. The other steps of the survey to identify the farmers were random. Districts were randomly chosen within a given department. Counties called "Sous-prefecture" were also randomly selected in the district, followed by a random choice of villages. In the first stage, survey enumerators conducted a census of maize farmers in each selected village to identify the pool of households. In the second stage, 30 farmers were randomly chosen among these households. Each farmer interviewed was the head of the household.

Given the scope and random nature of the data collection, it can be considered as a nationally representative cross-section of farmers from the season 2011/2012. A total of 360 farmers were selected, but only 357 are considered for the analysis. One farmer was an outlier because the quantity produced was far above (51 times) the average production of other farmers. The two other removed observations are from farmers who had not stored maize that year. The data remains, however, consistent since each observation is weighted with the inverse probability of selection (Wooldridge, 2010).

The survey started with a focus group in each village. The objective of this focus group was to understand the maize production and marketing environment. This focus group helped also to obtain average sale and purchase prices from farmer perspectives. The individual survey was then implemented following the focus group discussion in the village.

The survey covered a consumption cycle for each farmer (see figure 1). It captures grain management in the household over different time periods owing to different geographical localization. The survey started in July in which the farmers from the South were at the end of the small harvest season (starting in November/December) which coincides with the beginning of big harvest period (June/July). Farmers in the North were interviewed in August, the lean season or the early beginning of the new harvest period.

To evaluate grain use in the household, harvest season was broadly considered as the beginning of maize harvest on farm until the end of storage. Post-harvest was the period the household starts sourcing its grain only from its stock or from market. This post-harvest period ends at the beginning of the new harvest (see figure 1).

Descriptive statistics of covariates

The data considered for the regression are presented in table 1. All data come from farmers' direct information, except for three generated covariates. An expected percentage of price increase between the harvest and lean season is constructed using the price differential between the two periods divided by the harvest price. When there was no maize sale for a given farmer, the community price is used as reference. To obtain the daily maize consumption per capita, the quantity of maize consumed during harvest period is divided by the duration of the harvest period and the size of the household. Expected cash during the post-harvest period was the sum of expected loan and reimbursement in the post-harvest period.

[Table 1 : Descriptive Statistics of Main Covariates of the Regression Analysis]

Farmers use four categories of equipment to store maize, namely plastic bags, traditional granaries and other technologies. The polypropylene (mostly) plastic bag and the traditional granaries dominate in the sample, as nearly 50% of respondents use each. Although these technologies are found in all regions, there is a significant regional difference. For instance, plastic bags are widespread in the North, while traditional granaries are widespread in the South. Other storage technologies include a variety of methods, such as house floor, jute bag, and plastic container.

The table 1 shows that 22% of the farmers in our sample use chemicals for storage. The nature of the chemical is mostly unidentified (63%). Recommended chemicals such as Sofagrain and Actellic represent only 23% of the chemical users. Nearly 10% of chemicals used are cotton pesticides, applied on stored maize.

Though the expected losses ratio is about 8% (see table 1), there are statistically significant differences depending on region and the type of technology. For instance, farmers who use chemicals have a lower expected losses ratio (p-value 5%). In the south the mean expected losses is close to 11 % and can reach more than 50%.

Grain uses during harvest period

Farmers allocate grain among four uses, and storage represents the biggest proportion (see table 2). The rate of storage is higher in the North than the South, while the rate of sale is higher in the South than the North. The regional differences in rate of storage and sales are statistically significant.

[Table 2: Household Grain Allocation During Harvest period by Regions]

Data indicate that nearly 30% of farmers were net maize sellers in the harvest period. Stephens and Barett (2011) find similar results in Kenya.

Grain uses during post-harvest period

Consumption dominates grain use during the post-harvest period, but with different patterns depending on the region. Nearly 52 % of grain is allocated to consumption followed by sales. Consumption is pronounced in the South whereas sales dominate in the Center. There is little difference between consumption and sales in the North.

[Table 3: Household Grain Allocation During Post-Harvest Period by Regions]

Loss during post-harvest period depends on farmers' technology of storage. The rate of loss is 8 % on average and approximates 11.5 % in the South. Storage losses seem to increase from the South to the North. Farmers who apply chemical report a lower average rate of loss (around 6% mean) than the other farmers (8.5%). This difference was statistical significant (p-value, t test, less than 1%).

Three categories of farmer risks with respect to food consumption and sales status are observed through grain management in post-harvest period (see table 4). From the classical definition of farmers' net food status (see Barett, 2008; De Janvry and Sadoulet, 2011), period of market transactions (sale and purchase) is considered to account for price variation effects. That is an early period transaction entails a lower income or cost contrary to a late period transaction. There is a category of "secured farmers", net food sellers, whose sale prices are greater than purchase price. Instead, some net sellers who are early post-harvest sellers, receive low price and become later high price buyer, because they are unable to store grain over an extended period. Although those farmers are net sellers with respect to quantity marketed, they remain unsecured because of the high purchase cost. Thus, this category of net sellers along with net buyers whose purchase price is always higher sale revenues, constitute a second group called “unsecured farmers”. In this group is also found farmers whose net seller status is equal zero, but undergo high purchase cost. The last category represents a group of “neutral farmers” whose net food status equals to zero with no difference in transaction prices. Data reveal that 35 % of the household are unsecured for maize consumption, of which almost 35% are net harvest sellers.

[Table 4 Grain Management & Net Food Status]

The data reveal a relationship between farmer risks and some grain management practices. Only 21% of unsecured farmers spray chemical. Consequently, they have a greater rate of expected loss (p value for t test, 5%), and rate of sale during harvest period (p value for t test, 5%). Data reveals that unsecured farmers, on the average, store less maize, and undergo more loss during the post-harvest period (see table 4). Their dependence on purchase for food consumption is nearly 35%, nearly 8 times the dependence ratio of secured farmers.

Data also suggest a strong relationship between the risk level and the storage goal (p value for Chi^2, 1%). Almost 95 % of secured farmers claim sale motives in the storage objective, while 55% of unsecured farmers indicate consumption only as the main motive of storage.

6. Econometric results

Table 5 presents the average partial effect (APE) of variables that affect the probability of chemical use. The table provides evidence that the presence of an extension agent in the village reduces the probability that a household uses chemicals by 21.9 percentage points, with a highly significant coefficient (p value, t test, less than 1%). The negative coefficient of this covariate suggests that farmers who use chemical might employ inappropriate protectants. Therefore extension agents may provide important information about the dangers of using uncertified chemicals. The probability of chemical use is 31 percentage points lower, when the head of household is female. Even if the highly significant effect (p value less than 1%) of female using fewer chemicals may be due to women having limited access to chemicals, it could be that women have better access to information, since they interact frequently in the markets. Similarly, the possession of a cell phone is highly significant and lowers the probability of chemical use.

Table 5 provides other insights about the probability of chemical use. As expected, farmers who produce cash crops (cotton, palm oil, pineapple and cashew) have a significant probability to use chemical protectant, with p value of (0.00). This result supports the assumption that it could be that pesticides from cash crop are used to preserve grain. Likewise, table 5 suggests that farmer can access chemicals through input dealers in the village, or membership in an organization, the latter being highly significant with p value of (0.00). This result confirms findings from Adegbola (2010) underlining the effect of membership to an association to explain storage innovations. The probit estimation suggests also that the traditional protectant methods are highly significant to decrease he probability of chemical use, with p value less than 1% (0.00). Estimation obtained from APE indicates that the use of traditional method reduces the probability of chemical application by 23.3 percentage points. In addition, farmers whose motives include consumption and sale are likely to use chemical protectant.

[Table 5: Determinants of Chemical Use]

Although the IV, the presence of extension agent, was highly significant in the probit estimation of table 5, we fail to confirm endogeneity of chemical use. The coefficient of the generalized residual obtained from the probit regression in table 5, was not statistical significant (p value less than 46%), when introduced in the storage model to account for the control function (see column 3 & 4 of table 6). We therefore conclude that the storage model can safely be estimated with an OLS regression.

[Table 6: Determinants of the quantity stored from harvest/Control function & OLS]

The column 1) and 2) presents the results of OLS regression of the storage model. The large R square is mainly due to the significant effect of household production quantity and carry-over stock. These covariates can be considered conditionally exogenous, because they are predetermined before the household's storage decision is made (Saha, 1994). The estimate on quantity produced is highly significant, with p value lower than 1%, and indicates that an increase of 1 Kg of maize production increases the mean stored quantity by 0.86 Kg. The carry-over stock has a smaller effect on the quantity stored, since a 1 kg increase in maize production increases the mean stored quantity by only 0.029 kg. The coefficient is however significant with p value less than 5%.

Results from table 6 shows that only one variable among the storage technology covariates is highly significant. The coefficient for plastic bags is negative and significant at p value less than 5%. In other words, farmers who use polypropylene bags stored less grain. This result makes sense, as bags are used for multi-purposes such as transporting grain to market rather than storing for later in the year. Chemical use has the expected positive sign on the quantity stored, and the results are marginally significant (p value less than 13%). The coefficient indicates that farmers who use storage protectant increase quantity of maize stored by nearly 196 kilograms on average. Since the average amount stored by a respondent in our survey is about 2000 kilograms, the use of storage chemicals increases quantity stored by about 10 percent.

Table 6 also demonstrates that a household's expectation of the quantity that they will lose is storage due to insect pests decreases the quantity that they store. This is what we would expect, however the effect is not statistically significant. The reason for the lack of statistical significance on expected quantity loss could be because the average household's expected price increase between harvest and lean season greatly outweighs the quantity they expect lose form pests between harvest and lean season. Indeed, the covariate for the expected price increase is highly significant, with p value less than 1%. Results show that a 1% increase in the percentage of the expected price variation increases the mean quantity stored by 8.4 kg. This covariate might outweigh expected rate losses because percentage price increase was almost 10 times larger than the expected losses (see table 1). As the loss rate and post-harvest price interact in the storage decision (see equation 14), a substantial price increase might therefore mitigate the effect of expected losses, allowing farmers to compensate quantity losses by return on sales. Hence, we might assume that seasonal price increase so far exceeds key harvest decision variables such as prevailing interest rate (Stephens and Barett, 2011) and expected losses. Although this result supports the argument that maize is becoming a cash crop (Baco et al., 2011), the overall influence of price increase might also be due to the large number farmers (65% of the sample) who claim sales as a storage motive.

Storage motives are not jointly significantly to explain the quantity stored from harvest. This result might suggest different decision process depending on the storage motive. For instance, the causal effects of the main covariates change, when we consider OLS regression under different storage motive schemes-not presented. Removing motive for storage goals causes chemical use to be highly significant, at p value less than 5%. But the effects of price increase and the use of plastic bags are unchanged. In addition, OLS regression yields different results when we undertake separated regression for storage motives to account for difference in price risk aversion. For instance, the expected price increase becomes significant only for farmers whose motives include sale. These results confirm that profit maximization is insufficient to explain holding grain for subsistence farmers. These farmers hold grain as a price hedge against price risk (Park, 2006). Although no storage technologies are significant for subsistence farmers, they seem to be more sensitive to expected losses and therefore reduce more the quantity stored. Table 4 indicates, indeed, that unsecured farmers have greater expected losses and inversely lower storage rates.

Besides, column 1) and 2) of table 6 support the idea that liquidity affects farmers 'decision to store grain. Farmers' financial wealth determines the quantity stored, since the amount of saving at the beginning of harvest period is significant with p value less than 10%. An increase of 1000 F CFA (around $ 2) of saving augments the mean quantity stored by nearly 600 g on average. Although the coefficient on the loan amount is marginally significant (p vale less than 14%), results indicate that more access to loan might trigger positive grain storage. The results are consistent to the extent that liquidity during harvest period allows farmers to cope with major family cost like school expenditures during harvest period (Adegbola, 2010). Farmers with better financial wealth can therefore take advantage of seasonal price increases.

Some other variables related to personal farm characteristics and social network are significant. Among farmer characteristics only age is significant with an increasing marginal effect. This result suggests that the quantity stored decreases with age until 51 years old, the turning point. Likewise, households where at least one member belongs to association store less grain, as these households may be more market oriented and rely on social network as buffer against cash and food needs.

7. Conclusions and policy implications

A storage behavior is modeled in this paper to determine the effect of the storage losses and technology on the quantity stored from harvest. The essay builds on the previous literature of storage economics by integrating specifically storage losses and technology to examine maize storage decision. The implications of this analysis are important, as the effectiveness of the storage technology conditions farmers' ability to insure the seasonal transfer of maize and therefore meet income and food consumption needs.

We find that access to storage chemicals increases the average amount stored by 196 kilograms with results approaching statistical significance. Farmers who use plastic bags store 293 kilograms less grain on average, likely because bags are used for transport to market in addition to storage. Results show however that in the absence of effective storage technology, farmers seem benefit from pronounced price variation to mitigate the effect of expected losses. However, farmers rely on seasonal price increase as a shield only if their storage motives include sale. In addition, farmers having better physical and financial wealth during harvest period might smooth grain use between seasons by storing more at harvest. In contrast, low physical and financial assets observed in subsistence farms might accentuate aversion for storage losses and subsequently jeopardize maize consumption in post-harvest period. While the evidence presented in this study is based on Benin farmers, the findings are relevant for smallholder farmers in other regions who undergo destructive storage pests and large price fluctuations between seasons.

We also find evidence that farmers may be using chemical storage technologies inappropriately. For example, 10% of chemical users in our sample apply cotton pesticide to their maize stocks, and 63% employ unidentified chemical most likely uncertified. In addition, households in villages with extension agents are significantly less likely to use storage chemicals, as are farmers with cell phones. These findings suggest that better connected farmers with access to information are less likely to use storage chemicals inappropriately.

The results of this study point to the need for programs that facilitate access to effective storage inputs, to improve storage rate among farmers. However, these programs must consider different market price incentives to make the technology available to small farmers in SSA. In addition, complementary investments in correct use of storage technologies are essential for increasing adoption rates and protecting health and food safety.

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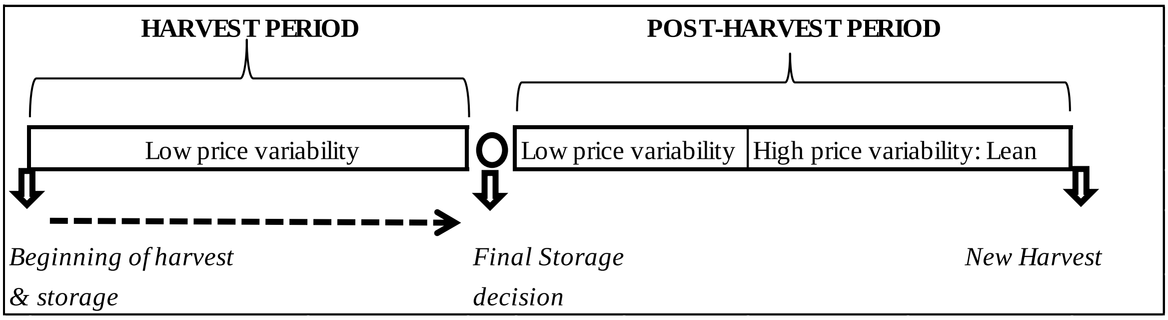
FIGURES

Figure 1

Maize Consumption Cycle



TABLES

Table 1

Descriptive Statistics of Main Covariates of the Regression Analysis

Variables	**Mean**	**Median**	**Std. Dev.**
Dependent Variable			
Quantity of maize stored from harvest (Kg)	1,973.00	1,000.00	3,070.00
Covariates			
Tested variables			
Expected grain losses (%)	7.92	3.70	10.79
=1 if chemical used	0.22	-	0.42
=1 if Polyethylene Plastic bag used	0.48	-	0.50
=1 if Traditional granaries used	0.49	-	0.50
=1 if Ceiling used	0.06	-	0.24
=1 if other technology used	0.08	-	0.27
Theoretical variables			
Expected price increase (%)	99.89	100.00	18.62
Daily consumption per head (Kg/head)	0.74	0.36	1.82
Saving amount (x 1000 F CFA)	78.72	-	232.10
Loan amount (x 1000 F CFA)	18.44	-	76.93
Expected cash (x 1000 F CFA)	24.12	-	78.50
Production (Kg)	2,328.00	1,275.00	3,436.00
Carry over stock (Kg)	375.30	-	2,818.00
Household Characteristics			
Age	42.41	40.00	13.12
Household size	10.22	9.00	6.02
=1 if HH head is female	0.10	-	0.29
=1 if formal education	0.37	-	0.48
=1 if goal sale	0.02	-	-
=1 if goal consumption & sales	0.64	-	-
= 1 if sale goal consumption only	0.34	-	-
Other control variables			
=1 if traditional protectant used	0.17	-	0.37
=1 if good quality of the road	0.34	-	0.47
=1 if Presence of input dealer	0.16	-	0.37
=1 if possess cell phone	0.52	1.00	0.50
Number of year of technology used	14.01	10.00	11.87
=1 if cash crop produced	0.32	-	0.47
=1 if Membership to an association	0.50	1.00	0.50
IV: =1 if Presence of extension agent	*0.58*	*1.00*	*0.49*

Note: N = 357; *1 US $ = 512 Francs CFA at the time of the survey*

Regional dummies are not shown in the table

Table 2

Household Grain Allocation During Harvest period by Regions

	Values (Kg)		Ratio over total Sources (%)							
			Total		South		Center		North	
	Mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Maize Sources										
Production	2,327.54	3,436.39	90.48	0.19	90.94	20.19	80.38	25.72	94.91	9.43
Carry Over Stock	375.32	2,817.85	9.17	0.19	8.66	20.28	18.86	26.17	5.02	9.46
Purchase	5.85	29.99	0.35	0.02	0.41	1.85	0.76	2.28	0.07	0.42
Maize Uses										
Consumption	169.73	205.71	10.64	8.96	12.63	9.38	8.28	7.87	8.84	8.19
Sale	267.41	945.84	8.21	17.94	10.47	21.05	9.94	18.60	3.91	10.12
Other uses	42.17	143.14	1.24	5.20	0.96	5.61	0.26	1.28	2.16	5.66
Storage	***2,228.78***	***4,256.76***	***79.74***	***19.06***	***75.63***	***21.26***	***81.51***	***19.71***	***85.09***	***12.87***

Note : (Sd) denotes standard deviation

Table 3

Household Grain Allocation During Post-Harvest Period by Regions

	Values (Kg)		Ratio over total Sources (%)							
			Total		South		Center		North	
	Mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Maize Sources										
Production	2,229.00	4,257.00	79.80	19.05	75.75	21.27	81.51	19.71	85.09	12.87
Carry Over Stock	78.09	160.00	9.67	16.78	16.09	20.07	3.72	7.52	2.97	9.47
Maize Uses										
Consumption	656.70	563.90	51.85	31.40	61.09	29.55	33.75	23.24	47.04	32.81
Sale	1,417.00	3,662.00	36.95	31.19	25.56	27.43	55.60	25.55	44.76	32.37
Other uses	44.40	172.60	1.40	6.77	0.96	7.44	1.99	5.35	1.78	6.36
Stock rest	77.39	352.60	2.93	8.43	2.69	8.78	1.97	4.74	3.78	9.30
Losses	111.50	184.90	7.86	9.78	11.45	11.54	7.07	6.20	2.82	4.84

Note: The rate of losses is specially defined over the quantity stored at the end of harvest season; (Sd) denotes standard deviation

Table 4

Grain Management and Net Food Status

		Harvest Decision (%)			Post harvest grain Management (%)					Characteristics	
		Expected Losses	Sales	Storage	Purchases	Consumption	Sale	Losses	External Food Dependence	Area (Ha)	Production (Kg)
Secured	Mean	6.97	5.57	86.09	1.45	30.42	59.08	6.07	4.27	4.63	3,412
	Sd	10.06	11.70	12.99	4.36	19.50	21.48	8.58	15.82	4.798	4,311
Neutral	Mean	6.67	12.06	70.90	-	80.12	-	8.77	-	2.768	1,205
	Sd	9.56	24.10	22.78	-	22.81	-	11.15	-	1.725	1,062
Unsecured	Mean	9.80	10.74	73.72	25.47	73.34	17.62	10.20	34.47	2.217	1,127
	Sd	12.03	22.06	21.83	19.82	24.97	22.06	10.44	22.09	1.684	1,443

Table 5
Determinants of Chemical use (Probit Estimation)

	Dep. Var: =1 if Household uses Chemical for storing Maize	
Covariates	**Coeff**	**P Value**
IV: =1 if Presence of extension agent	***-0.219****	***(0.001)***
Tested covariates		
Expected grain losses (%)	-0.006**	(0.012)
=1 if Polyethylene Plastic bag used	0.047	(0.543)
=1 if Traditional granaries used	-0.090	(0.216)
=1 if Ceiling used	-0.051	(0.615)
=1 if other technology used	-0.003	(0.972)
Theoretical Variables		
Expected price increase (%)	0.000	(0.885)
Daily consumption per head (Kg/head)	-0.009	(0.565)
Saving amount (x 1000 F CFA)	0.000	(0.775)
Loan amount (x 1000 F CFA)	-0.001*	(0.133)
Expected cash (x 1000 F CFA)	0.000	(0.927)
Production (Kg)	0.000	(0.32)
Carry over stock (Kg)	0.000*	(0.089)
=1 if goal sale	0.137	(0.25)
=1 if goal consumption & sales	0.192***	(0.000)
Household characteristics		
Age	0.023**	(0.017)
Age square	0.000**	(0.016)
=1 if formal education	0.029	(0.535)
=1 if HH head is female	-0.310***	(0.000)
Household size	-0.007	(0.12)
Control variables for technologies		
=1 if Presence of input dealer	0.254*	(0.087)
=1 if traditional protectant used	-0.233***	(0.000)
=1 if possess cell phone	-0.134***	(0.005)
=1 if good quality of the road	0.120*	(0.097)
=1 if cash crop produced	0.114*	(0.057)
Number of year of technology use	0.004*	(0.15)
=1 if Membership to an association	0.135***	(0.001)
N	**357**	
Pseudo R^2	**0.29**	

Note : *, **, ***, indicate that corresponding coefficients are statistically significant at the 15%, 5 %, and 1% level respectively; coefficients are Average Partial Effects (APE) estimated via the *margins* command in stata ; *1 US $ = 512 Francs CFA at the time of the survey*; Department dummies are not shown in the table

Table 6. Determinants of the Quantity Stored From Harvest

Dep. Var: =Quantity of Maize stored from harvest (Kg)				
	OLS		**Control function**	
Covariates	**Coeff (1)**	**P Value (2)**	**Coeff (3)**	**P Value (4)**
Generalized Residuals			***-139.412***	***(0.463)***
Tested Covariates				
Expected grain losses (%)	-2.429	(0.587)	-1.592	*(0.713)*
=1 if household use chemical	195.868*	(0.126)	417.058	*(0.250)*
=1 if Polyethylene Plastic bag used	-292.758**	(0.044)	-303.911**	*(0.033)*
=1 if Traditional granaries used	40.451	(0.781)	48.806	*(0.748)*
=1 if Ceiling used	-244.882	(0.198)	-238.082	*(0.212)*
=1 if other technology used	-70.443	(0.664)	-78.329	*(0.625)*
Theoretical variables				
Expected price increase (%)	8.362***	(0.010)	8.482***	*(0.010)*
Daily consumption per capita (Kg/Capita)	*-29.215*	(0.224)	*-28.569*	*(0.228)*
Saving amount (x 1000 F CFA)	0.590*	(0.096)	0.608*	*(0.096)*
Loan amount (x 1000 F CFA)	0.637*	(0.139)	0.812*	*(0.146)*
Expected cash (x 1000 F CFA)	-0.525	(0.414)	-0.594	*(0.373)*
Production (Kg)	0.862***	(0.000)	0.861***	*(0.000)*
Carry over stock (Kg)	0.029**	(0.030)	0.022	*(0.177)*
=1 if goal sale	-14.149	(0.932)	-39.036	*(0.826)*
=1 if goal consumption & sales	96.330	(0.342)	59.340	*(0.642)*
Household characteristics				
Age	-45.047***	(0.009)	-50.468**	*(0.018)*
Age square	0.440**	(0.014)	0.497**	*(0.027)*
=1 if formal education	-115.179	(0.403)	-118.334	*(0.397)*
=1 if HH head is female	90.358	(0.403)	138.751	*(0.235)*
Household size	-14.679	(0.403)	-13.885	*(0.414)*
Control variables for technologies				
=1 if Presence of input dealer	40.036	(0.843)	46.637	*(0.816)*
=1 if traditional protectant used	32.851	(0.746)	79.292	*(0.561)*
=1 if possess cell phone	40.707	(0.606)	61.759	*(0.461)*
=1 if good quality of the road	*240.192***	(0.021)	*232.083***	*(0.024)*
=1 if cash crop produced	84.229	(0.613)	60.862	*(0.699)*
Number of year of technology used	4.604	(0.299)	4.049	*(0.382)*
=1 if Membership to an association	-237.458*	(0.101)*	-265.435*	*(0.116)*
Constant	201.340	(0.693)	310.512	*(0.580)*
N	**357**		**357**	
R^2	**0.95**		**0.95**	

Note: *, **, ***, indicate that corresponding coefficients are statistically significant at the 15%, 5 %, and 1% level respectively; *1 US $ = 512 Francs CFA at the time of the survey*; Department dummies are not shown in the table.