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**UPDATING EX-ANTE ECONOMIC ANALYSES FOR PURDUE
IMPROVED CROP STORAGE (PICS) BAGS IN SUB-SAHARAN
AFRICA: THE CASES OF SENEGAL, KENYA, AND GHANA**

by

Michael S. Jones and Jess Lowenberg-DeBoer

Working Paper #14-5

June 2014

Department of Agricultural Economics

Purdue University

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UPDATING EX-ANTE ECONOMIC ANALYSES FOR PURDUE IMPROVED CROP STORAGE (PICS) BAGS IN SUB-SAHARAN AFRICA: THE CASES OF SENEGAL, KENYA, AND GHANA

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Abstract

Small producers throughout sub-Saharan Africa struggle to protect crops from an array of pests during medium or long-term storage before market sale or home consumption. Storage technologies like hermetic (airtight) Purdue Improved Crop Storage (PICS) bags are proven to provide long-term, reliable protection against many grains and grain legumes pests, without the need for chemical pesticides. However, even if technical efficacy of PICS bags is established, the local market conditions for crop storage should be favorable to encourage sustainable adoption. This may vary by crop and geographic region. Recognizing this need for continued localized analysis before widespread implementation, this report builds on two previous working papers investigating PICS storage profitability. Price data from Senegal, Kenya, and Ghana are analyzed. Importantly, conversions of retail and wholesale price data to producer prices are performed on a dynamic monthly basis instead of assuming a single marketing margin for the entire year. Results indicate highest potential profitability of PICS bags for groundnut and maize storage in Senegal, common beans in Kenya, and long-term maize storage in Ghana. Kenyan maize storage profitability varies significantly by year and region, but is also positive for most markets.

Keywords: hermetic storage, technology adoption, post-harvest losses, storage economics

JEL Classification: Q16, Q13, O33

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Introduction

Triple-layer Purdue Improved Crop Storage (PICS) bags were originally developed for chemical-free hermetic storage of cowpea in West and Central Africa (Baributsa et al., 2010). PICS bags work by simply allowing insects to exhaust the available oxygen supply in the closed environment until insects either perish or enter prolonged dormancy (Murdock et al., 2012). With support from the Bill and Melinda Gates Foundation, large-scale technology dissemination and supply chain building efforts have contributed to over 2 million bags being locally-manufactured and sold in 10 countries. In subsequent efforts, laboratory and field testing of the technology has been extended to storage of maize, beans, sorghum, and groundnuts and to several eastern and southern African countries such as Kenya, Rwanda, and Malawi.

Questions remain on the economic potential for PICS with new crops and regions of Africa, which the present work attempts to address to a limited scope. Ex-ante storage profitability analysis is investigated for Senegalese maize and groundnut producers, Kenyan maize and common bean producers, and Ghanaian maize producers. The selection of countries was based on the quality of limited data available and commodities were selected based on project interest within each country.

This analysis builds on previous economic assessments of Purdue Improved Crop Storage (PICS) bags for small producers marketing grains and legumes in sub-Saharan Africa (Lowenberg-DeBoer and Jones, 2010; Jones et al., 2011a,b). Following previous PICS economic analyses, a simple household financial model is constructed. Financial and economic rates of return to storage are outlined under varying rates of opportunity cost of capital (or, the time value of money). This simplified approach, outlined in Jones, Alexander, and Lowenberg-DeBoer (2014), is meant to increase accessibility of this analysis to audiences with and without economics training.

Senegal

Within Senegal, both maize and groundnut merit storage profitability exploration. Technical efficacy of PICS bags has already been proven for both crops, and the question of economics remains. Regional profitability as well as prioritization of maize vs. groundnut extension programming is investigated in this section. While groundnuts are considered to be a ‘consumable cash crop’, maize is a more traditional cereal crop (FEWSNET, 2013). Therefore, the general objective for storage of groundnuts may be oriented more towards the market and cereals more towards household consumption.

Senegal has one major harvest season, occurring after the rainy season in roughly October and November as outlined in figure 1. Some early harvesting may occur in September. With very dry conditions, maize grain may thus be available for marketing in October or November, reflected in real price trends. The southern region of Senegal is long recognized to have a longer rainy season, resulting in later national harvest periods in November (Rousseau, 1954). This southern Casamance region, including Zinguichor and Kolda, would thus have more grain ready to market by December or early January. This is reflected by distinct price trends in these two markets which are lowest in December and January. Groundnuts are harvested in the months just after maize harvest (Rousseau 1954, FAO 1996). Groundnut price trends also reflect this pattern, with lowest prices in November.

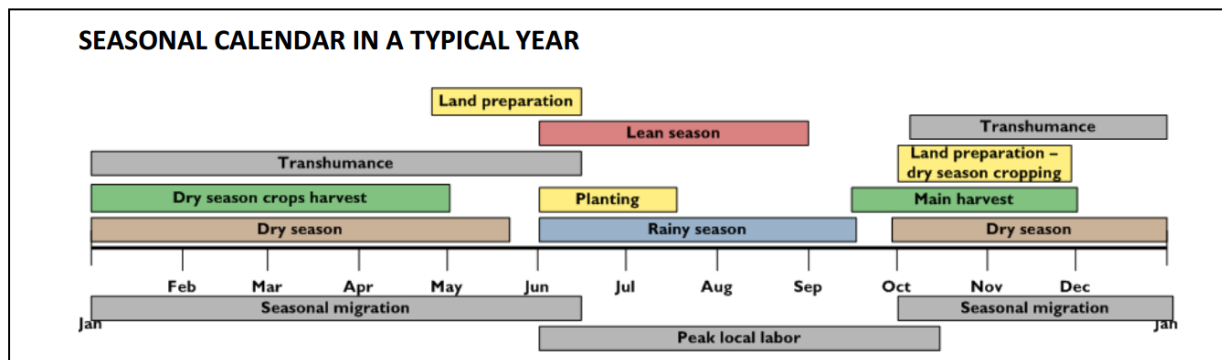


Figure 1: Senegal FEWSNET Agricultural Calendar
Source: FEWSNET, 2013

Important Trends When Converting Retail Prices to Producer Prices

Monthly price data for Senegal were downloaded online¹ from the Système d'Information des Marchés/Commissariat à la Sécurité Alimentaire (SIM/CSA) [Market Information System/Food Security Commission]. All prices recorded are for provincial capitals, which range greatly in size and connectivity to the rest of the country, as displayed in figure 2. Data were converted to real (inflation-adjusted) prices with a base month of January 2012 through the monthly harmonized Global CPI index downloaded online² from the Agence Nationale de la Statistique et la Démographie.

¹ Website: <http://csa.sn/site/>. Publications → Bulletins SIM → Specify Year

² Website: http://www.ansd.sn/IHPC_mensuel.html

SIM/CSA price data are available in sufficient detail for analysis for seven (7) markets, listed in table 1. Dakar is not considered. Retail price data are available for all markets, while three markets also have “producer” price data tracked.

Table 1: Senegal Market Data Availability

Markets with sufficient data for analysis	Maize		Groundnuts (shelled)	
	Retail price data	“Producer” price data	Retail price data	“Producer” price data
Diourbel	Yes	No	Yes	No
Fatick	Yes	Yes	Yes	Yes
Kolda	Yes	No	Yes	No
Kaolack	Yes	Yes	Yes	Yes
Louga	No	No	Yes	No
Matam	Yes	No	Yes	No
St. Louis	Yes	No	Yes	No
Tambacounda	Yes	Yes	Yes	Yes
Thiès	No	No	Yes	No
Ziguinchor	Yes	No	Yes	No



Figure 2: Senegal Market Map
Base Map Source: National Geographic

Both retail and producer price data are tracked simultaneously in Fatick, Kaolack, and Tambacounda markets. By analyzing the producers’ proportion of retail prices, it is possible to derive a Retail-to-Producer margin estimate for the remaining markets. While many analyses traditionally use a standard or constant margin conversion, this may be inherently flawed. Retail-to-producer margin trends change over time, as illustrated by Kaolack market in figure 3, with the lowest margins in immediate harvest periods

of low prices and high sales volumes and the highest margins in “lean” months of high prices, grain scarcity, and generally lower producer sales volumes. If this fluctuation in margins over time is not recognized, then a constant conversion margin to interpret secondary retail or wholesale price data for the producers’ perspective will undoubtedly underestimate storage profitability.

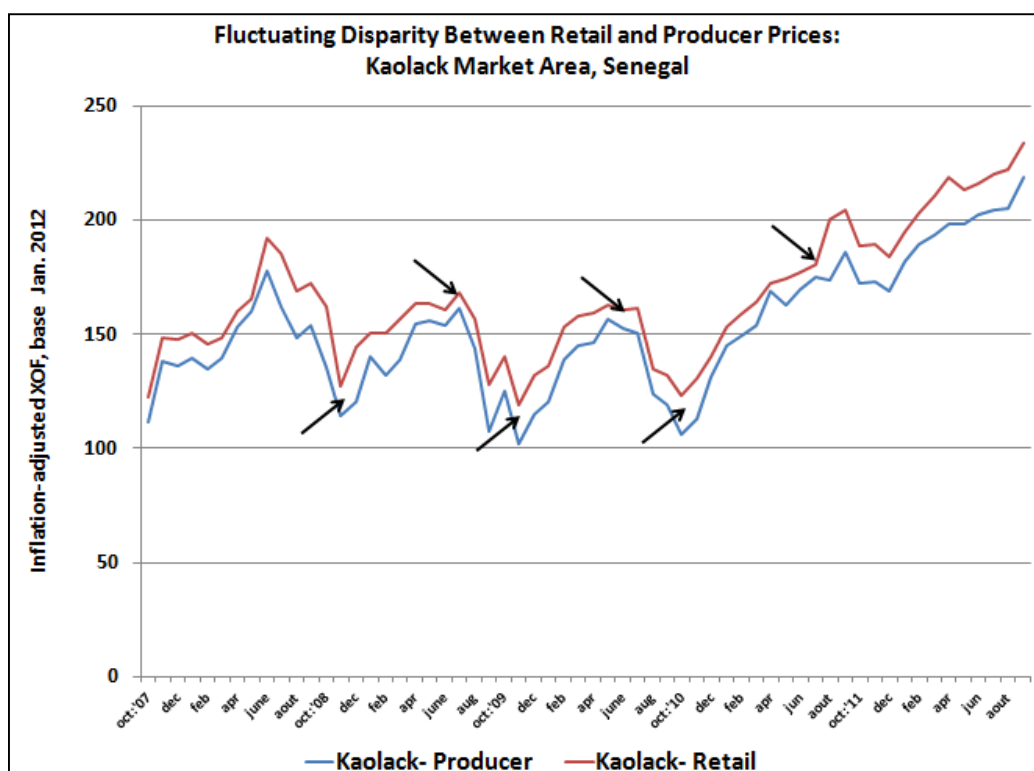


Figure 3: Fluctuating Disparity Between Retail and Producer Maize Prices: Kaolack Market Area, Senegal

Source: SIM/CAN Maize Prices

Dynamic Monthly Maize Producer-to-retail Margin

Across all three maize markets, the average producer-to-retail margin in the October (2007-2011) immediate post-harvest period is 81.9% and rises through the year to an average July (2008-2012) maximum of 91.7%. This is a statistically significant 9.8% average increase across the nine month period (two tailed t-test; $p=0.001$).

Without consideration for fluctuations over time, the average global margins would have simply been 88.6%. Fatick and Kaolack would be 91.1% and 91.7%, respectively, and Tambacounda would have been 83.1%.

Located only 45km from each other, producers in Fatick and Kaolack face similar trends in marketing margins. Margins at harvest are not statistically different (Mean difference t-test, $p=0.288$).

Tambacounda, located 279km from Kaolack towards the interior of the country, has notably lower

producer-to-retail margins and much more pronounced increase in the harvest to lean season margin. Harvest margins are statistically distinct and lower than Kaolack ($p=0.006$) and Fatick ($p=0.036$). In July, the month with the highest average producer-to-retail margin, Fatick and Kaolack continue to be statistically identical ($p=0.938$), while Tambacounda is still significantly lower than Fatick ($p=0.042$) and Kaolack ($p=0.054$). An accompanying table with producer-to-retail margin values is found in Appendix 1.

The initial drop in the average margin through August and September may be derived from the first harvests, as well as sales of green maize which interact with the maize grain market. These effects are also visible as maize prices first drop. Notably, the lowest average maize prices occur in November.

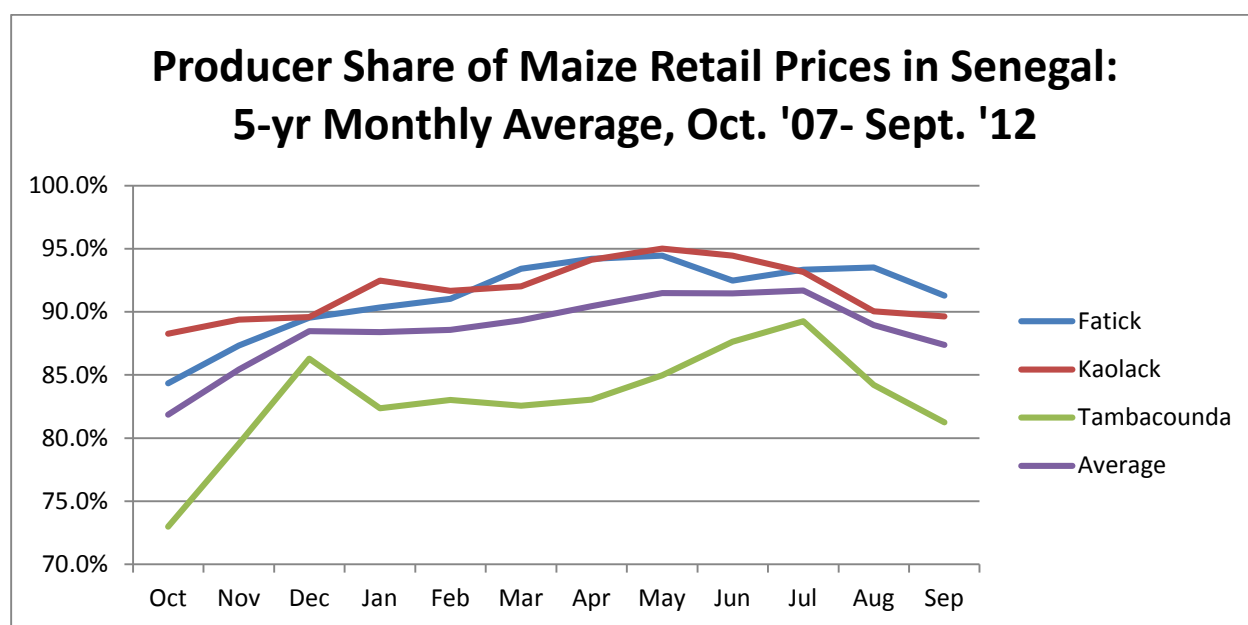


Figure 4: Producer Share of Maize Retail Prices in Senegal: 5-yr Monthly Average

Dynamic Monthly Groundnut Producer-to-Retail Margin

Figure 5 illustrates that groundnut margins are clearly lowest in November, one month after maize, at 76.1%. Margins appear to rebound quickly after the immediate harvest period, peaking in August at 89.0%. This is a statistically significant 12.9% average increase across nine months ($p=0.000$). Geographic differences appear to make little statistical impact, contrasting with maize.

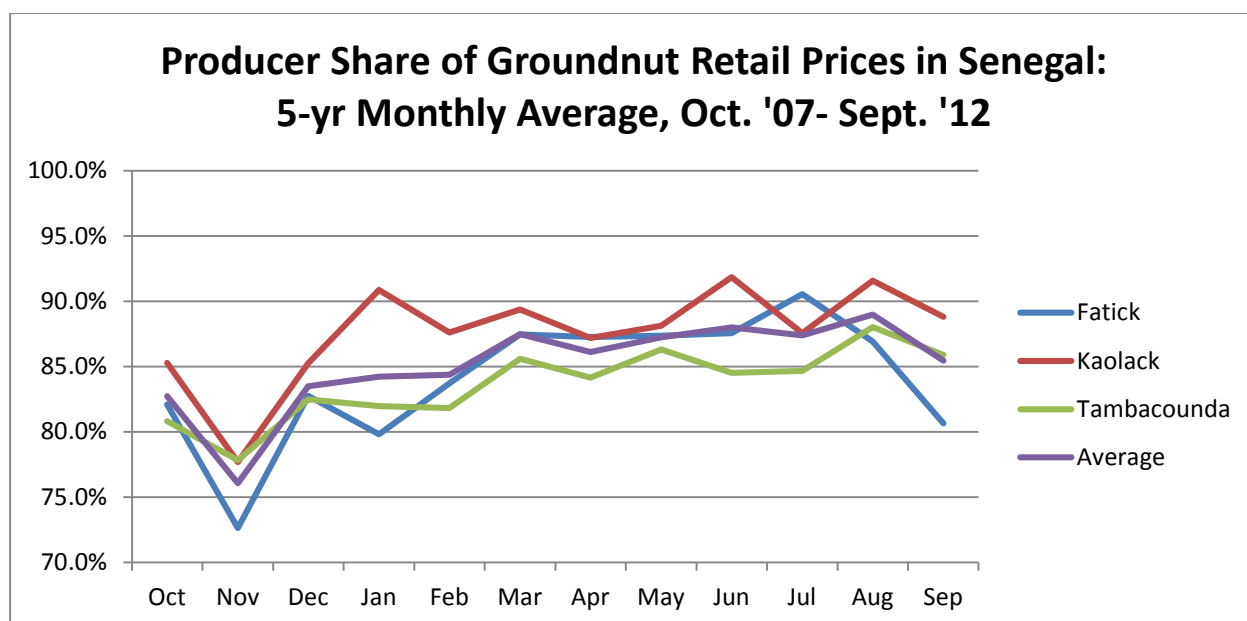


Figure 5: Producer Share of Groundnut (shelled) Retail Prices in Senegal: 5-yr Monthly Average

Since many storage profitability analyses are necessarily performed with secondary data, generally wholesale or retail prices, adjustments are crucial to more closely reflect prices received by producers. The statistically significant 9.8% maize margin increase and 12.9% groundnut margin increase from the harvest to lean season are key parameters for an accurate storage analysis. This “average” adjustment consideration will be applied when converting the remaining markets to producer prices³.

Maize Storage Profitability

Due to harvest months which fluctuate slightly by year and by geographic area, the “early” marketing month immediately after harvest is judged as the lower price month between October and November. Three scenarios for long-term storage are modeled. The first is “optimal” storage until the high (real) price month after between 6 to 10 months of storage. Hitting the “optimal” marketing point every year is not realistic, but this simply serves as a maximum ceiling for possible returns. The next two scenarios follow the example of the maize storage return analysis in Jones et al. (2011a,b) and model fixed storage periods of six and eight months.

³ Note: A detailed methodology is not included in the SIM/CAN website regarding where producers were interviewed to collect price data or whether grain quality was standardized. It is assumed here that grain quality is standard and that this represents farmers in the immediate market area who are bringing grain on market day. More remote farmers who sell to farther middle men would most likely receive a lower percentage of market retail prices, though the pattern of margin fluctuation over time should logically be similar.

Table 2 displays that the top three markets with greatest seasonal price fluctuations are Kolda, Kaolack, and Tambacounda. When storing between six and ten months, the highest average real price increases range from 26.7% in Zinguinchor to 51.0% in Kolda, with a global average of 42.0%. Producers logically see prices continue to rise from six to eight months of storage, with an average 28.2% and 36.7% increase, respectively.

Real immediate post-harvest (October or November) prices are XOF 141 ± 35 (Real Jan '12 XOF, mean \pm SD)⁴. This results in a national average value increase for a 100kg bag of maize under optimal storage scenarios of XOF 5,868. Under fixed six and eight month storage, this 100kg value increase is XOF 3,946 and XOF 5,062, respectively.

Table 2: Senegal Maize 5-yr Average Real Price Increases (2007 harvest – 2011 harvest)

Market	“Optimal” Storage	6 mo. Fixed Storage	8 mo. Fixed Storage
Diourbel	34.0%	23.0%	27.6%
Fatick	34.1%	23.6%	32.3%
Kolda	54.4%	47.2%	53.1%
Kaolack	48.0%	40.7%	45.3%
Matam	37.0%	23.5%	38.0%
St Louis	45.7%	22.8%	32.7%
Tambacounda	57.7%	35.9%	49.0%
Zinguinchor	43.9%	28.6%	34.8%
Average	44.6%	30.9%	39.4%

Analysis of storage technology profitability follows the procedures outlined in Jones, Alexander, and Lowenberg-DeBoer (2014). Profitability is first measured through the simple financial rate of return. This follows the form of Equation 1:

$$\%R = \frac{p_t q_t - (p_0 q_0 + c)}{p_0 q_0 + c} \quad [1]$$

where (p_0) and (q_0) are the price received and quantity sold in the immediate post-harvest month, (p_t) and (q_t) are the price received and quantity sold (t) months after the immediate post-harvest month ($t=0$), and (c) is the cost of the storage technology. Recent research across West Africa has demonstrated that naturally infested PICS-stored maize had no statistically significant increase in either maize weight loss or percent of grains with insect damage from the grain's initial condition (Baoua et al., 2014). In this analysis, parameters assumed for PICS efficacy reflect this unchanged grain quality.

PICS sacks have the highest profitability in markets with the highest price fluctuations, namely Tambacounda, Kolda, and Kaolack market regions. High eight-month returns between 40-50% in Kolda

⁴ In Jan '12, the XOF to USD exchange rate is 508:1

and Tambacounda contrast with lower returns of 25.8% in Diourbel. Average financial rates of return for fixed eight months storage regimen are higher for each of the nine markets, compared to six month storage.

Table 3: Senegal Maize 5-yr Average Financial Rates of Return (2007 harvest - 2011 harvest)

Market	“Optimal” Storage	6 mo. Fixed Storage	8 mo. Fixed Storage
Diourbel	31.8%	21.5%	25.8%
Fatick	32.0%	22.1%	30.3%
Kolda	50.6%	43.9%	49.4%
Kaolack	44.4%	37.7%	41.9%
Matam	36.9%	22.2%	35.8%
St Louis	42.9%	21.4%	30.8%
Tambacounda	53.0%	32.8%	44.8%
Ziguinchor	41.7%	27.1%	33.0%
Average	41.7%	28.8%	36.8%

As price seasonality and thus profitability can fluctuate from year to year, inconsistent returns may deter producers from adopting new technologies. Another barrier to adoption may be high opportunity costs of capital (OCC) faced by poorer, capital-constrained populations. The OCC is an annual discount rate to determine if an investment has reached a “threshold” profitability, acknowledging the time value of money and the fact that other investment possibilities exist for farmers. If returns for 25% OCC are above zero, this means the investment exceeds returns for an alternative investment with an annual return of 25% (or a loan with an annual interest rate of 25%). Convention follows that poorer farmers generally have greater opportunity costs of capital. If economic returns are negative, it means this theoretical producer’s OCC is too high to allow for economic profits in storage and farmers should sell early after harvest and invest this money elsewhere.

The economic rate of return builds on Equation 1 to form Equation 2:

$$\%R = \frac{p_t q_t - [1+r_t](p_0 q_0 + c)}{p_0 q_0 + c} \quad [2]$$

where r_t is the corresponding time-adjusted rate of OCC.

An average Senegalese producer with an OCC of 25% would see economic profits in every year and storage length scenario in 2007-2011, with an average economic return of 16.3%. Producers with a higher OCC of 50% would see positive economic returns in 2007, 2008, 2009 and 2010 with six month storage, and only 2007, 2009, and 2010 with eight months of storage. Global average yearly returns for Senegalese markets are outlined in Table 4.

Table 4: Yearly Average Economic Returns for Senegalese Maize Markets

Year	OCC*	Storage Period		
		“Optimal”	6 mo.	8 mo.
2007	25%	41.3%	28.5%	34.8%
	50%	24.4%	16.0%	18.2%
2008	25%	17.4%	12.8%	14.5%
	50%	0.4%	0.3%	-2.1%
2009	25%	22.0%	15.5%	18.2%
	50%	5.8%	3.0%	1.6%
2010	25%	32.1%	22.9%	27.5%
	50%	13.3%	10.4%	10.9%
2011	25%	10.7%	3.2%	5.4%
	50%	-7.6%	-9.3%	-11.2%

*Annual Rate of Opportunity Cost of Capital

Figure 6 incorporates investment risk concerns, as price seasonality is naturally different each year. The concept of “market-years” is employed to examine how frequently farmers in these market regions would hit each profitability threshold. For example, if five markets each have data for five years, then this represents 25 market years. The data set available for Senegalese maize contains 39 market years. Results indicate that farmers would never have a negative cash flow storing maize as an investment in PICS bags, as financial rates of return (0% OCC) for the modeled years are always positive. Fixed storage at six or eight months produces roughly equal percentages of market-years with positive economic returns at the 25% and 50% level of OCC. About 90% of market-years exceed the 25% threshold and just over 50% exceed the 50% threshold.

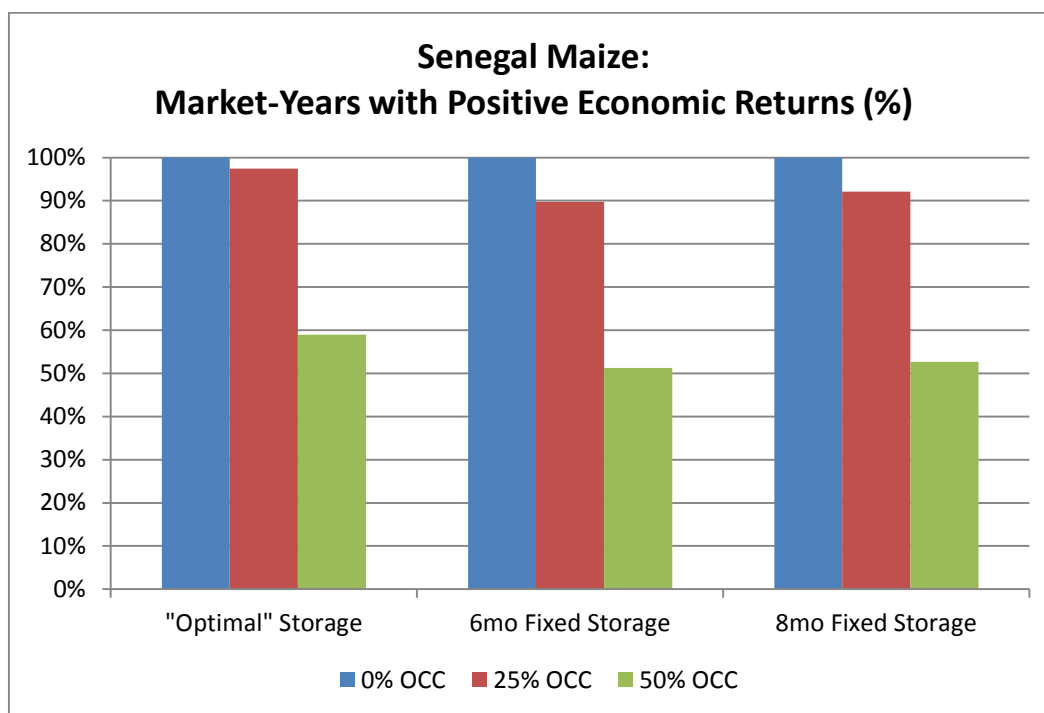


Figure 6: Senegal Maize: Market-Years with Positive Economic Returns (%)

Senegal Maize: Comparison of PICS vs. non-PICS Storage Treatments

There are many storage treatment possibilities which Senegalese farmers may employ. Chemical treatment may include Actellic, Actellic Super, and Malathion among many product options. Botanical treatments exist as well, which may not carry explicit costs but may also be considerably less effective. To accommodate the broad range of possible treatment options, this analysis compares PICS bags to generalized treatments with certain costs and effectiveness. Total costs for alternative treatments are evaluated seasonally, and include the cost of “organizing” maize (i.e. a polypropylene woven bag). Product effectiveness affects storage profitability since insect damage is known to carry an economic penalty— price reductions.

To be conservative, this analysis looks at two different marketing scenarios which farmers face, namely volumetric sales and sales by weight (with a scale). When traders do not bring scales, a bowl or standardized volumetric measurement may be used. If selling by volume, insect damage would not carry a penalty for “weight” loss that does not reduce volume. Only price loss is incorporated, drawn from the most conservative estimates in West African market research, with a 0.75% discount for each 1% damaged grains (Compton et al., 1998). If selling by weight, both dry weight loss and visible grain damage levels would penalize farmers through revenue components of quantity and price, respectively. Farmers selling by weight are therefore more heavily penalized for insect damage, *ceteris paribus*.

Therefore, alternative technologies which may be cheaper than PICS bags must perform better for weight vs. volumetric marketers for the alternative technology to maintain the same level of profitability as PICS.

Figure 7 illustrates equivalent profitability of PICS and each “generalized” storage product in six-month storage (all markets). Break-even levels indicate the even free treatment methods must remain within 3.9 – 4.4% insect-damaged grains of PICS efficacy to be as profitable. That is, if PICS-stored grain had 1% grain damage, then an alternative treatment must keep damage under 5.4% to be equally profitable for farmers selling by volume⁵. At \$0.50 USD, roughly the cost of a new woven 100kg bag, damage could not be greater than 3.1% over PICS. At \$0.75 per season, roughly the cost of a woven bag depreciated for two years of use plus the cost of brand-name insecticides, damage levels could not exceed 2.5% over PICS efficacy. These breakeven points are slightly more stringent for farmers selling by weight.

Research suggests that alternative technologies have little chance of remaining within these damage rates. ICIPE research in Kenya records maize damage rates exceeding 20% after 3 months with infested grain, even when Actellic Super Dust is applied (Njoroge et al., 2014).

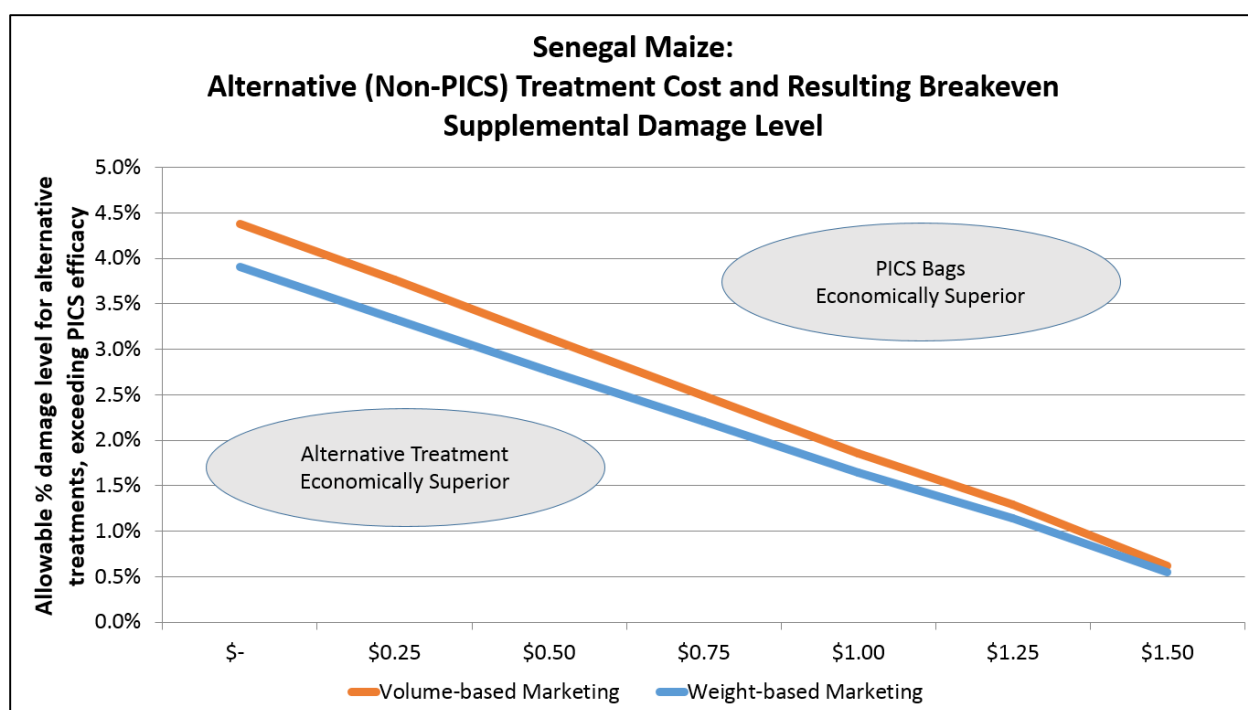


Figure 7: Alternative Treatment Breakeven Costs and Supplemental Damage Levels

⁵ Evidence suggests there are damage thresholds before traders may discount grain. In Compton et al. (1998) this was estimated at 5-7% damage. In Jones et al. (2013), only about 75% of traders still discounted at 5% insect-damaged maize. This analysis assumes that an alternative technology resulted in damage which was recognized and penalized. If this supplemental damage remained under the threshold, however, there would be no discount and the cheaper technology would dominate.

Groundnuts Storage Profitability

Groundnut harvesting typically occurs just after the main maize harvest in Senegal (FAO 1996) and average prices are logically at their lowest in November, one month after maize's lowest average prices. Therefore, the modeled "harvest period groundnut availability" period is shifted one month later than maize—November or December. Casamance region markets are shifted accordingly later as well, with early marketing months in December and January. Storage returns are modeled after fixed six and eight months of storage, as well as the "optimal" storage strategy which demonstrates the ceiling on profitability.

Table 5 outlines real price increases across the period of data availability. Six and eight month fixed-period storage coincides with the highest average price increases in Kaolack, Kolda, and Tambacounda, ranging from 61.8% to 64.8%. The lowest price increases, ranging from 23.5% to 34.7% are found in Matam, St. Louis, Fatick, and Louga. Average seasonal price increases exceed 40% for six month storage and 50% for eight month storage.

Table 5: Senegal Groundnut 5-yr Average Real Price Increases (2007 harvest - 2011 harvest)

Market	"Optimal" Storage	6 mo. Fixed Storage	8 mo. Fixed Storage
Diourbel	62.7%	54.0%	52.8%
Fatick	46.4%	33.8%	42.7%
Kolda	76.9%	63.2%	62.1%
Kaolack	80.2%	60.1%	64.8%
Matam	63.8%	23.5%	45.9%
St Louis	47.7%	31.7%	38.7%
Tambacounda	74.4%	41.3%	61.8%
Zinguinchor	60.1%	52.2%	52.1%
Louga	47.1%	34.7%	40.3%
Thies	61.1%	52.5%	40.7%
Average	62.3%	44.9%	50.2%

Ranking financial rates of return follows ranking of price seasonality, as displayed in table 6. The national average seasonal return on investment for six-month storage is 43.5% and this rises slightly to 48.6% for eight months of storage. Average returns exceeding 50% are found in Kaolack, Kolda, Tambacounda, Diourbel, Thies, and Zinguinchor.

Table 6: Senegal Groundnuts 5-yr Average Financial Rates of Return (2007 harvest - 2011 harvest)

Market	"Optimal" Storage	6 mo. Fixed Storage	8 mo. Fixed Storage
Diourbel	60.8%	52.4%	51.2%
Fatick	44.9%	32.6%	41.3%
Kolda	74.1%	61.0%	60.0%
Kaolack	76.7%	57.5%	61.9%
Matam	62.0%	22.8%	44.7%
St Louis	46.5%	30.9%	37.7%
Tambacounda	71.8%	39.8%	59.6%
Ziguinchor	58.7%	51.0%	50.8%
Louga	45.6%	33.6%	39.1%
Thies	59.3%	51.0%	39.5%
Average	60.3%	43.5%	48.6%

Yearly analysis in Table 7 of economic returns at the 25% and 50% OCC levels indicate average positive returns under almost all storage scenarios. Only eight month average returns in 2007 and 2008 did not surpass the 50% OCC threshold.

Table 7: Yearly Average Economic Returns for Senegalese Groundnut Markets

Year	OCC*	Storage Period		
		"Optimal"	6 mo.	8 mo.
2007	25%	29.3%	19.8%	15.0%
	50%	14.9%	7.3%	-1.7%
2008	25%	33.7%	26.3%	16.4%
	50%	19.4%	13.8%	-0.3%
2009	25%	35.8%	19.8%	28.5%
	50%	18.1%	7.3%	11.8%
2010	25%	69.5%	49.9%	55.0%
	50%	52.0%	37.4%	38.4%
2011	25%	56.0%	41.2%	45.9%
	50%	40.3%	28.7%	29.2%

*Annual Rate of Opportunity Cost of Capital

Figure 8 incorporates investment risk concerns, as price seasonality is naturally different each year. The concept of “market-years” is employed to examine how frequently farmers in these market regions would hit each profitability threshold. Results indicate that farmers would never explicitly lose money in six-month regimented storage, and over 95% of market-years have positive financial returns for eight-month storage. At a 25% and 50% OCC, six-month and eight-month storage have roughly equivalent frequencies of market-years with positive economic returns. Almost 90% of market-years exceed the 25% threshold and about 70% exceed the 50% threshold.

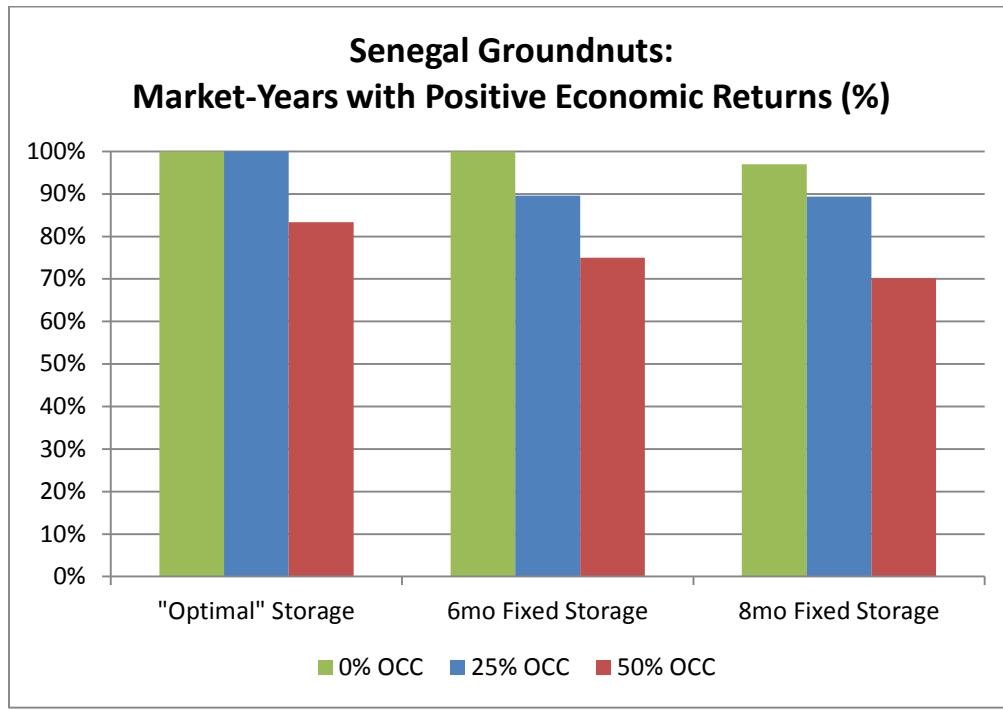


Figure 8: Senegal Groundnuts: Market-Years with Positive Economic Returns (%)

Kenya

Maize Storage Profitability

The Republic of Kenya is a large maize producing country in East Africa with well-documented difficulty in long-term maize storage. Kenyan Ministry of Agriculture statistics document 3.57M metric tons of maize produced in 2011. Figure 9 illustrates that the top ten counties produce nearly 60% of the country's grain. While much of the country has two notable growing seasons, the largest producing counties in the Western "grain basket" have only one major season.

The Larger Grain Borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), is prevalent in many areas and poses particular challenges to post-harvest loss prevention. Sightings are widely recorded, including the Western grain basket region (Nang'ayo et al., 1993; Nang'ayo, 1996; Omondi et al., 2011).

Costs of storage and storage pest protection vary widely by scale of production and desired storage length. A study through USAID's Post-Harvest Handling and Storage (PHHS) Kenya project found that farmers frequently store in large external buildings, rather than within rooms of the house. The present economic analysis with PICS bags assumes that storage structures have already been constructed with sunk costs, and the current decision is between shelled maize storage with current practices vs. shelled maize storage with PICS bags.

Top 10 Maize Production Counties (2011)

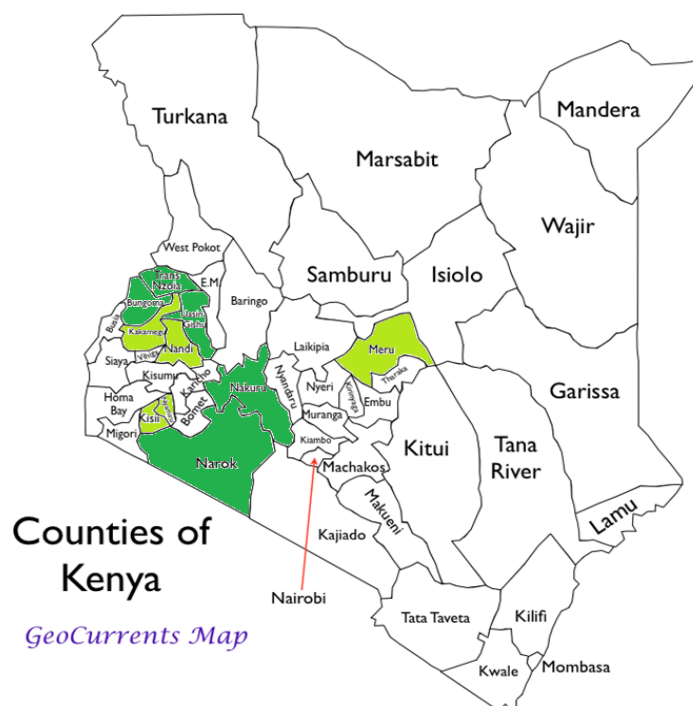


Figure 9: Kenya Top Maize Producing Counties Map
Base Map Graphic Credit: GeoCurrents

Note: Dark green indicates rank 1-5 maize producing counties; light green indicates rank 6-10 counties

Table 8: Kenya Top Maize Producing Counties (Data Table)

Province	County	Ha	Production (90kg bags)	% N'nl Prod	Rank
Rift Valley	Trans Nzoia	97,740	4,546,831	11.5%	1
Rift Valley	Uasin Gishu	83,602	3,095,075	7.8%	2
West	Bungoma	103,408	2,856,524	7.2%	3
Rift Valley	Nakuru	91,835	2,437,286	6.1%	4
Rift Valley	Narok	86,775	2,237,476	5.6%	5
Eastern	Meru	118,594	1,926,249	4.9%	6
Rift Valley	Nandi	75,075	1,882,643	4.7%	7
West	Kakamega	76,539	1,869,519	4.7%	8
Nyanza	Nyamira	63,825	1,358,241	3.4%	9
Nyanza	Kisii	58,290	1,338,702	3.4%	10
Top 10 Counties		855,683	23,548,546	59.4%	-

Source: Kenyan Ministry of Agriculture (2013)

Harvest months in Kenya vary widely by geographic region, and regional harvest months may also vary somewhat each year. Following interviews with researchers at the Nairobi-based Tegemeo Institute of Agricultural Policy and Development, harvest months were outlined for each market region with available historical price data. In Nakuru, Kisumu, and Eldoret this was the low-price month between November and December. In Kisii and Busia, this was the primary season in August or September. In Taveta, Machakos, and Kitui, this was the low-price month in the primary season of February and March.

Wholesale price data were provided by the Kenyan Ministry of Agriculture and range from January 2007 to December 2012. Farm-gate to wholesale conversions were assessed at a margin of 92% (Ariga, Jayne, Njuki, 2010). Constant farm-gate price conversions were used, contrasting with evidence that margins are dynamic and most likely lowest in the immediate post-harvest period and highest in the lean season (i.e. producers' seasonal price fluctuations are greater than wholesale traders'). Therefore, this represents a very conservative assessment due to the lack of data for farmgate-wholesale dynamic margins, and the author believes storage is likely to be more profitable for producers than this analysis is able to report. PICS bags are modeled at \$2.50 USD per unit, depreciated for two seasons of use. The cost of an additional woven bag for marketing purposes (\$0.50 USD) is assessed for the first seasons of PICS use. Prices are all real January 2012 USD, adjusted through indices provided by the Kenyan Bureau of Statistics, with a Jan. 2012 KES exchange rate of 83.6:1.

For Kenyan maize, three storage scenarios are modeled for each of two regions. Each region is modeled with an "optimal" storage period, from harvest to the season-specific high price month. Hitting the high price month every year is not realistic, but this simply serves as a maximum ceiling on returns. The next two scenarios for each region follow the example of the maize storage return analysis in Jones et al. (2011a,b) and model fixed storage periods. Fixed periods modeled are four, six or eight months, depending upon frequency of rainy seasons and realistic regional storage periods. When the model is allowed to pick the local maximum price month, "optimal" storage periods in Taveta, Machakos, and Kitui are an average 4.0 - 4.6 months over 2007-2011. For Western market regions, "optimal" storage periods are logically longer, varying between 5.6 and 9.0 months of storage. Western Kenyan markets are thus modeled for fixed storage periods of six and eight months. Eastern and Central market regions are modeled for shorter storage periods of four and six months.

Table 9 displays that maize price seasonality is strongest in Nakuru, Eldoret, and Busia. This coincides with the market regions of highest PICS storage profitability, outlined in Table 10. For fixed six month storage, average returns for PICS-stored maize range from 23.0% to 66.6%. For eight months of storage in the Western market regions, average returns range from 42.1% to 89.3%.

Table 9: Kenya Maize 5-yr Average Real Price Increase (2007 main harvest – 2011 main harvest)

Market	"Optimal" Storage	4 mo. Fixed	6 mo. Fixed	8 mo. Fixed
Nakuru	96.7%	*	66.6%	89.3%
Kisumu	69.0%	*	41.8%	59.6%
Eldoret	89.6%	*	61.8%	82.1%
Kisii	85.2%	*	23.0%	42.1%
Busia	127.4%	*	50.1%	87.8%
Taveta	38.5%	27.5%	28.7%	*
Machakos	47.7%	33.0%	37.9%	*
Kitui	77.9%	53.4%	62.3%	*

*storage period not modeled for this market

Table 10: Kenya Maize 5-yr Average Financial Rates of Return (2007 main harvest - 2011 main harvest)

Market	"Optimal" Storage	4 mo. Fixed	6 mo. Fixed	8 mo. Fixed
Nakuru	81.0%	*	55.4%	74.1%
Kisumu	60.7%	*	36.5%	52.0%
Eldoret	77.1%	*	53.3%	70.2%
Kisii	75.6%	*	20.9%	37.5%
Busia	106.6%	*	41.5%	72.8%
Taveta	34.6%	24.7%	25.7%	*
Machakos	41.8%	29.1%	33.0%	*
Kitui	68.7%	39.8%	54.7%	*

*storage period not modeled for this market

It is convenient for analysis to examine the Eastern and Western Kenya regions separately. This is also pertinent to differentiate due to probable upcoming divisions in the PICS product supply chain. Table 11 breaks down economic storage returns by year, with thresholds at 25% and 50% opportunity cost of capital (OCC).

For Western markets, years 2007, 2008, and 2010 have positive returns for all modeled storage patterns. However, the harvest in 2009 (stored into 2010) was a very poor year for storage investment in Kenya as well as the East African region. Storing the 2011 harvest only had positive returns when evaluated at 25% OCC.

Table 11: Yearly Average Economic Storage Returns for Western Kenyan Maize Markets (2007-2011)

Year	OCC*	Storage Period		
		“Optimal”	6 mo.	8 mo.
2007	25%	95.9%	67.0%	94.3%
	50%	80.8%	54.5%	77.6%
2008	25%	34.0%	26.0%	28.2%
	50%	19.8%	13.5%	11.6%
2009	25%	-23.5%	-32.6%	-45.5%
	50%	-35.1%	-45.1%	-62.1%
2010	25%	220.3%	85.0%	160.7%
	50%	202.0%	72.5%	144.0%
2011	25%	12.7%	7.8%	3.3%
	50%	-3.1%	-4.7%	-13.4%

*Opportunity cost of capital

Figure 9 incorporates investment risk concerns, as price seasonality is naturally different each year. The concept of “market-years” is employed to examine how frequently farmers in these market regions would hit each profitability threshold⁶. Under fixed storage regimens, storage has positive financial rates of return (0% OCC) in 75% of market-years. As seen in Table 11 above, harvests in 2009 and 2011 (marketing in 2010 and 2012) posed difficult periods for maize storage investment, resulting in 25% of market-years with negative returns. The 2010 year saw particularly flat or decreasing maize prices across storage periods in many regional markets, with Malawi as another notable example (Jones, Alexander, and Lowenberg-DeBoer, 2014). A six-month storage strategy results in a somewhat higher percentage of positive economic returns at the 50% OCC level.

⁶ i.e., if a market has five years of data, then this represents five market-years. This analysis incorporates a total of 38 market-years for Kenyan maize price data and 36 market-years for bean price data. Sometimes monthly data is missing, such as the “eighth” month in a fixed storage period, and therefore it is not exactly 40 market-years (8 markets x 5 years).

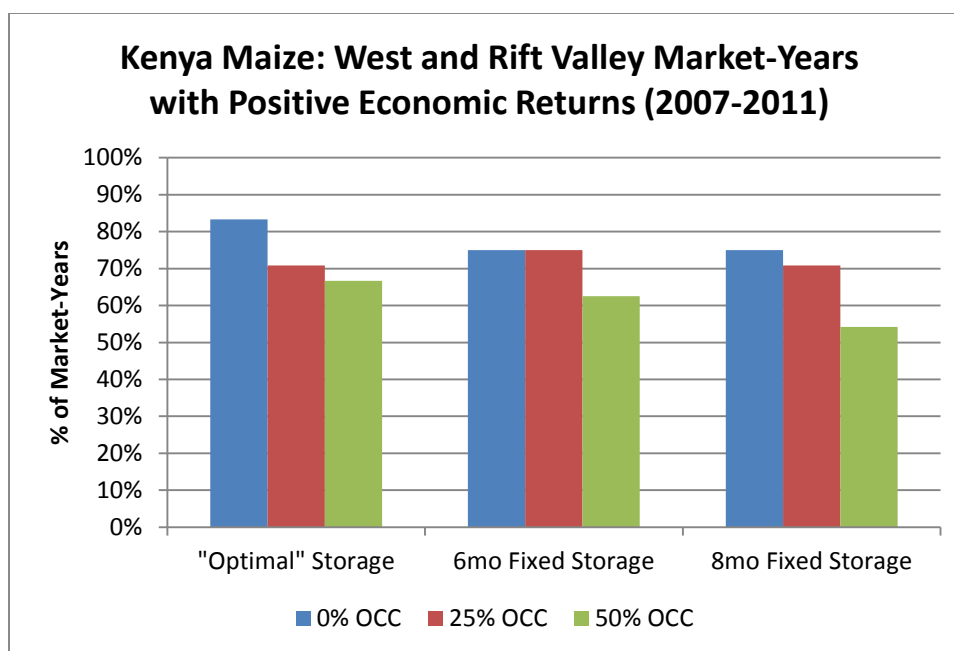


Figure 10: Kenya Maize: West and Rift Valley Market-Years with Positive Economic Returns (%)

For Eastern markets, outlined in Table 12, positive economic returns at the 25% and 50% OCC level are present in all storage scenarios for 2007 and 2010. The year 2011 had positive returns only at the 25% OCC level. However, years 2008 and 2009 were not profitable for the market region group, on average, under any modeled fixed storage scenarios.

Table 12: Yearly Average Economic Storage Returns for Eastern Kenyan Maize Markets (2007-2011)

Year	OCC*	Storage Period		
		"Optimal"	4 mo.	6 mo.
2007	25%	66.2%	42.7%	59.1%
	50%	53.1%	34.4%	46.6%
2008	25%	8.9%	-2.3%	-8.7%
	50%	2.6%	-10.6%	-21.2%
2009	25%	-15.5%	-26.8%	-39.8%
	50%	-20.4%	-35.1%	-52.3%
2010	25%	108.6%	91.8%	93.0%
	50%	98.2%	83.4%	80.5%
2011	25%	12.3%	6.9%	0.7%
	50%	3.9%	-1.5%	-11.8%

Figure 11 illustrates that farmers would explicitly earn income in about 80% of market-years. Fixed storage of four-months seems to be a more stable strategy, with explicitly profitable years generally breaking the annual return threshold of 25%. Results are roughly equivalent under 50% OCC between four and six month storage strategies.

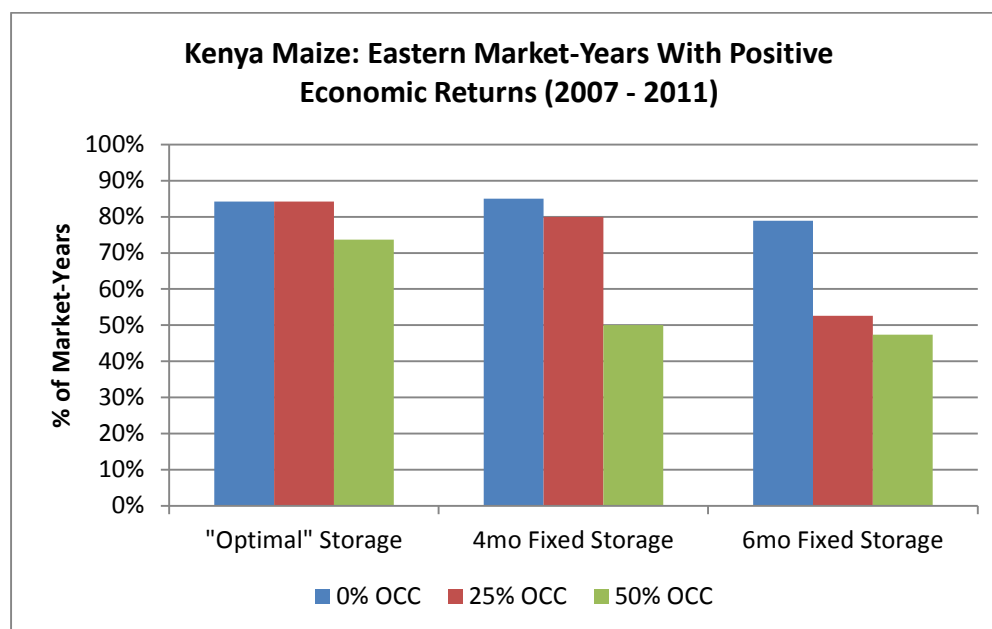


Figure 11: Kenya Maize: Eastern Market-Years with Positive Economic Returns (%)

Kenya Maize: Comparison of PICS vs. non-PICS Storage Treatments

There are a myriad of storage treatment possibilities which Kenyan farmers employ. Chemical treatment may include Actellic, Actellic Super, and Malathion among many product options. Botanical treatments exist as well, which may not carry explicit costs but also may be considerably less effective. To accommodate the broad range of possible treatment options, this analysis compares PICS bags to generalized treatments with certain costs and effectiveness. Total costs for alternative treatments are evaluated seasonally, and include the cost of “organizing” beans (i.e. a woven bag). Product effectiveness affects storage profitability since insect damage is recorded to carry an economic penalty— price reductions. To be conservative, this analysis assumes volumetric sales, common in Kenya according to USAID and Tegemeo Institute researchers, which would not carry a penalty for “weight” loss that does not reduce volume. Only price loss is incorporated, drawn from the most conservative estimates in African market research, with 0.75% discount for each 1% damaged grains (Compton et al., 1998).

Figure 11 illustrates equivalent profitability of PICS and each generalized storage product in six-month storage (all markets).

Break-even levels indicate the even zero-cost treatment methods must remain within 4% insect-damaged grains of PICS efficacy to be as profitable. That is, if PICS-stored grain had 1% grain damage, then an

alternative treatment must keep damage under 5% to be equally profitable⁷. At \$0.50 USD, roughly the cost of a new woven 90kg bag, damage could not be greater than 3.2% over PICS. At \$0.75 per season, roughly the cost of a woven bag depreciated for two years of use plus the cost of Actellic Super, damage levels could not exceed 2.8% over PICS efficacy.

If the damage discount per 1% insect-damaged grains increased to 1.13%, a higher discount recently found in Rwanda (Jones et al., 2013), then a treatment at \$0.75 per season must prevent damage to within 2.1% of PICS efficacy. With zero-cost, a technology would then still be required to keep damage within 3.8% of PICS results. Research suggests that alternative technologies have little chance of remaining within these damage rates, as a common dry weight loss of 5% translates to about 22% damaged grains when the larger grain borer is the primary pest (Holst, Meikle, and Markham, 2000). ICIPE research in Kenya records maize damage rates exceeding 20% after 3 months with infested grain, even when Actellic Super dust is applied (Njorore et al., 2014).

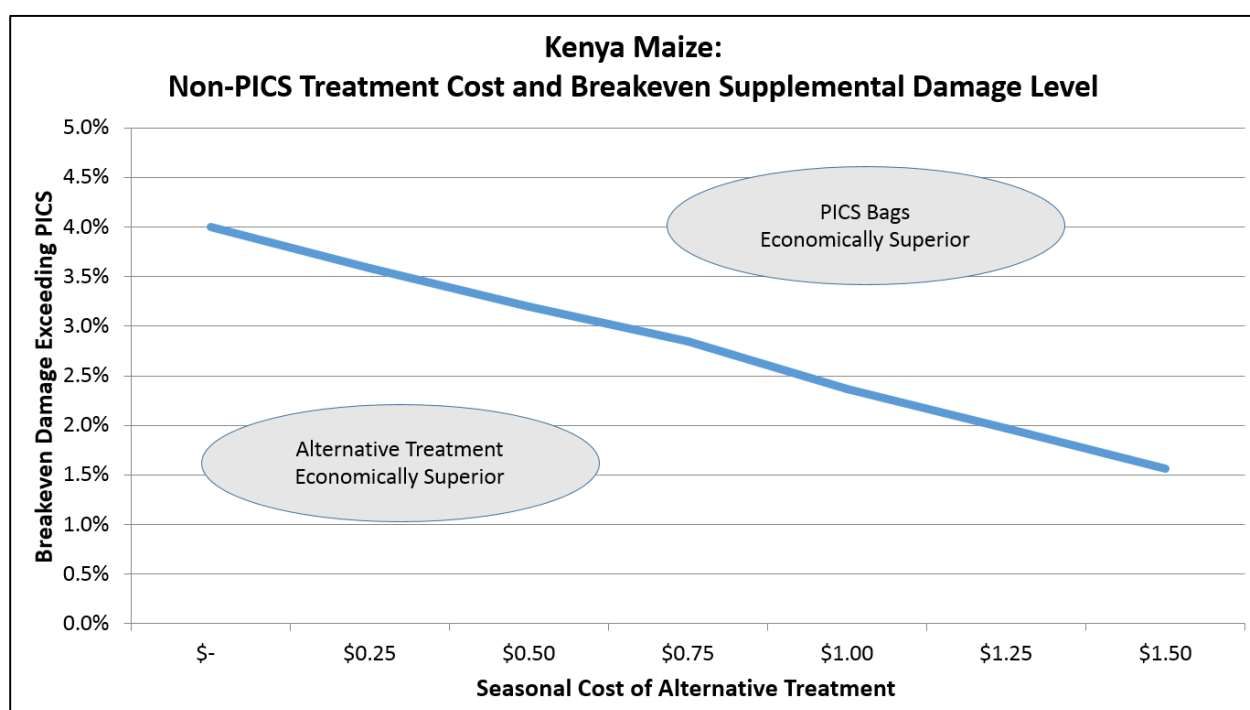


Figure 12: Kenya Maize: Non-PICS Alternative Technology Break-Even Analysis

⁷ Evidence suggests there are damage thresholds before traders may discount grain. In Compton et al. (1998) this was estimated at 5-7% damage for Ghanaian traders. In Jones et al. (2013), about 75% of Rwandan traders still reported discounting at 5% insect-damaged maize. This analysis assumes that an alternative technology resulted in damage which was recognized and penalized by a trader. If this damage remained under some threshold, however, there would be no discount and the cheaper technology would dominate.

Common Bean Storage Profitability

Kenya is the largest national producer of common beans in Africa (FAOSTAT, 2013). Illustrated in figure 13 and accompanying data table 13, the Kenyan Ministry of Agriculture estimates that domestic production in 2011 exceeded 577,000 metric tons. Common pests include the bean weevil (*Acantholeodes obtectus*) and the Mexican bean weevil (*Zabrotes subfasciatus*). Damage rates over time vary greatly in the literature, with some records of 11% after four months (Songa and Rono, 1998) and 40% after four months (Paul et al, 2009). Grain damage in bean storage is extensive in Eastern Africa and a summary may be found in Jones et al. (2011b).

Top 10 Dry Bean Production Counties (2011)

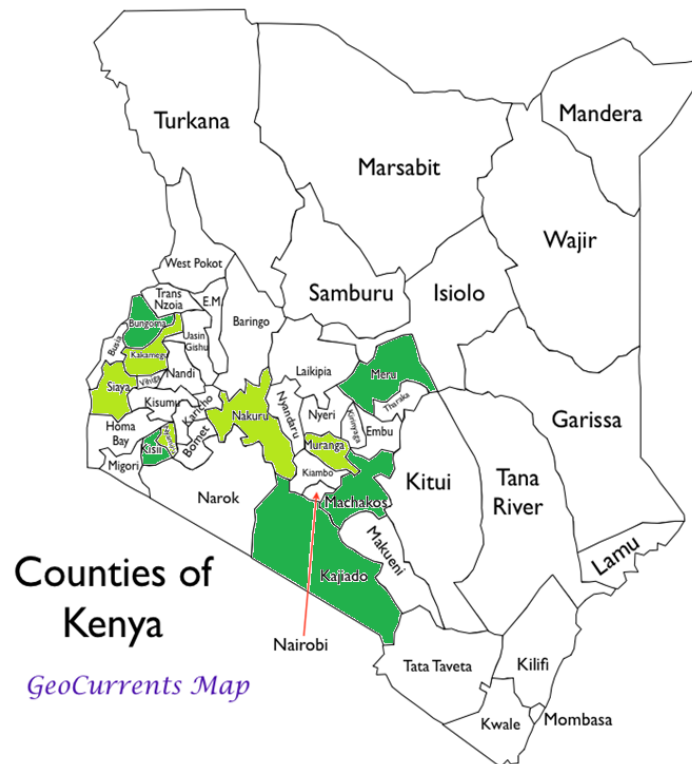


Figure 13: Kenya Top Common Bean Producing Counties Map
Base Map Graphic Credit: GeoCurrents

Note: Dark green indicates rank 1-5 maize producing counties; light green indicates rank 6-10 counties

Table 13: Kenya Top Common Bean Producing Counties (Data Table)

Province	County	Ha	Prod (90kg Bags)	% N'nl Prod	Rank
Rift Valley	Kajiado	46,105	569,880	8.9%	1
Eastern	Meru	72,291	558,918	8.7%	2
West	Bungoma	69,684	385,290	6.0%	3
Nyanza	Kisii	41,688	343,931	5.4%	4
Eastern	Machakos	73,710	330,740	5.2%	5
Nyanza	Nyamira	38,055	326,920	5.1%	6
West	Kakamega	59,075	281,705	4.4%	7
Rift Valley	Nakuru	47,905	251,267	3.9%	8
Central	Murang'a	38,475	242,392	3.8%	9
Nyanza	Siaya	39,104	231,410	3.6%	10
Top 10 County Total		526,092	3,522,453	54.9%	-

Source: Kenyan Ministry of Agriculture (2013)

For Kenyan common beans, three storage scenarios are modeled for each of two regions. The first is “optimal” storage until the high (real) price month. Hitting the high price month every year is not realistic, but this simply serves as a maximum ceiling. The next two scenarios follow the example of the dry bean storage return analysis in Jones et al. (2011b) and model fixed storage periods. Fixed periods modeled are either four and six months or six and eight months, depending upon frequency of rainy seasons and realistic storage periods. Beans are harvested 1-2 months before maize and this was accounted for in determining the first months for marketable grain availability.

Nakuru, Kisumu, and Eldoret each have one distinct main harvest, necessitating longer storage. In Kisii and Busia, both in zones with a second harvest season, short term storage of four months for marketing purposes does not appear very profitable in these two zones and is not considered in detail. Long term storage does appear profitable and is investigated. Taveta, Machakos, and Kitui are all located in dual harvest zones. Long term storage for marketing purposes appears less feasible or attractive in these market regions, and thus shorter storage periods are analyzed in detail.

For common beans: In Nakuru, Kisumu, and Eldoret, the first month of grain availability was designated as the low-price month between August and September. In Kisii and Busia, this was the primary season in July or August. In Taveta, Machakos, and Kitui, grain availability was assessed for the primary season of January and February.

Table 14 details 5-year seasonal real price increases, where the greatest fluctuations occur in Western and Rift market regions of Eldoret, Nakuru, and Busia. Table 15 illustrates that financial rates of return with PICS storage bags follow intensity of market price seasonality. In Western Kenya, fixed six-month storage patterns results in average returns of 13.6% to 53.9%. Eight-month average returns range from 23.3% to 92.0%.

Table 14: Kenya Beans 5-yr Average Real Price Increase (2007 main harvest – 2011 main harvest)

Market	"Optimal " Storage	4 mo. Fixed	6 mo. Fixed	8 mo. Fixed
Nakuru	75.1%	*	46.6%	64.3%
Kisumu	62.9%	*	36.6%	44.6%
Eldoret	114.5%	*	58.2%	98.8%
Kisii	30.6%	*	14.3%	24.4%
Busia	70.0%	*	40.3%	61.3%
Taveta	26.4%	22.5%	14.2%	*
Machakos	34.4%	22.1%	27.9%	*
Kitui	30.9%	21.0%	27.5%	*

*Not modeled for this market area

Table 15: Kenya Beans 5-yr Average Financial Rates of Return (2007 main harvest - 2011 main harvest)

Market	"Optimal " Storage	4 mo. Fixed	6 mo. Fixed	8 mo. Fixed
Nakuru	69.6%	*	43.4%	59.3%
Kisumu	59.7%	*	34.6%	42.4%
Eldoret	106.6%	*	53.9%	92.0%
Kisii	29.3%	*	13.6%	23.3%
Busia	65.7%	*	37.6%	57.4%
Taveta	25.2%	21.4%	13.5%	*
Machakos	32.9%	21.2%	26.7%	*
Kitui	29.6%	17.2%	26.4%	*

*Not modeled for this market area

It is convenient for the aggregated analysis to examine the Eastern and Western Kenya regions separately. This is also pertinent to differentiate due to probable upcoming divisions in the PICS product supply chain. Table 16 breaks down economic storage returns for the Western markets by year, with thresholds at 25% and 50% opportunity cost of capital (OCC). All average economic returns are positive, indicating that PICS could be a strong investment in these market regions, on average, under all modeled storage time patterns.

Table 16: Yearly Average Economic Storage Returns for Western Kenyan Bean Markets (2007-2011)

Year	OCC*	Storage Period		
		“Optimal”	6 mo.	8 mo.
2007	25%	99.9%	69.3%	101.4%
	50%	84.2%	66.1%	97.2%
2008	25%	19.6%	21.7%	24.4%
	50%	1.7%	16.7%	17.7%
2009	25%	27.2%	35.3%	41.6%
	50%	15.2%	29.1%	33.2%
2010	25%	88.2%	32.2%	63.1%
	50%	68.6%	27.2%	56.4%
2011	25%	24.5%	13.4%	29.4%
	50%	7.8%	8.4%	22.7%

Figure 14 incorporates investment risk concerns, as price seasonality is naturally different each year. The concept of “market-years” is employed to examine how frequently farmers in these market regions would hit each profitability threshold. Results indicate that farmers would never have a negative cash flow if investing with their own funds in PICS bean storage in 2007-2011, as 100% of markets have positive returns with 0% OCC (financial rate of return). Over 95% of market-years break the 25% OCC threshold and 70% break the 50% threshold. Eight month storage of beans with PICS seems to be a relatively low-risk and potentially high earning investment. Six-month fixed storage periods would provide positive returns in over 95% of market-years at 0% OCC. Economic returns are slightly lower than eight month storage with 25% OCC and roughly equivalent with 50% OCC.

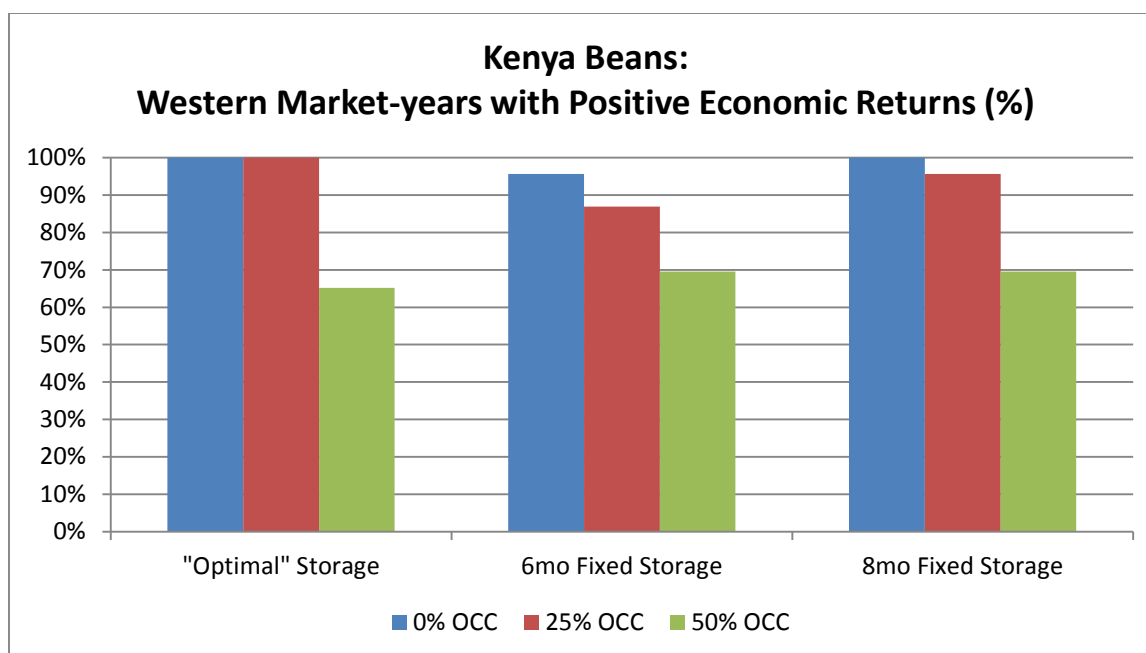


Figure 14: Kenya Beans (West): Market-Years Reaching Threshold Profitability Levels (%)

In the Eastern markets of Taveta, Machakos, and Kitui, profitability varied somewhat more intensely, outlined in Table 17. In 2008 and 2009, these markets have average negative economic returns at the 25% and 50% level of OCC for fixed storage periods. Figure 15 demonstrates that despite this variability, farmers in these market regions would not have explicitly lost money storing beans. Slightly more market-years for six-month fixed storage exceed the 25% OCC threshold; however, this is reversed at the 50% OCC threshold. Overall, PICS bean storage in the west is a more profitable and consistent investment than the east, while both regions hold promise for potential adoption.

Table 17: Yearly Average Economic Storage Returns for Eastern Kenyan Bean Markets (2007-2011)

Year	OCC*	Storage Period		
		"Optimal"	4 mo.	6 mo.
2007	25%	27.2%	13.5%	15.2%
	50%	14.7%	5.1%	2.7%
2008	25%	11.4%	-2.2%	-0.9%
	50%	1.0%	-10.6%	-13.4%
2009	25%	10.2%	4.0%	-3.7%
	50%	1.1%	-4.3%	-16.2%
2010	25%	29.5%	26.0%	16.4%
	50%	23.3%	17.7%	3.9%
2011	25%	18.6%	18.7%	13.5%
	50%	9.3%	10.4%	1.0%

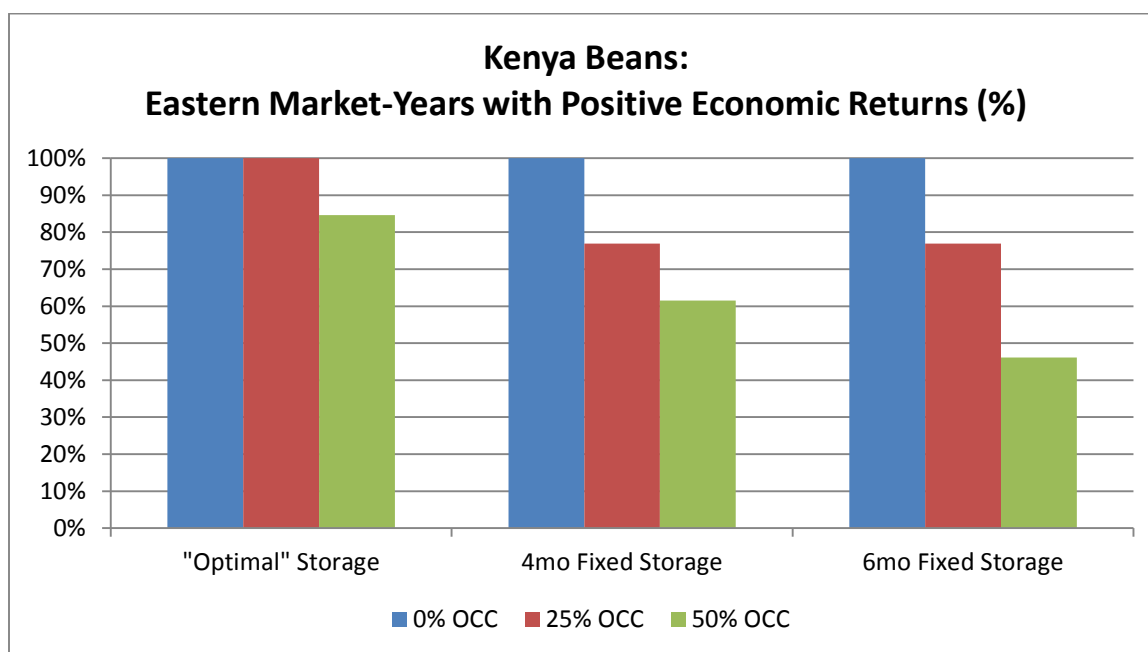


Figure 15: Kenya Beans (East): Market-Years Reaching Threshold Profitability Levels (%)

Kenya Beans: Comparison of PICS vs. non-PICS Storage Treatments

Many treatment possibilities exist for bean storage in Kenya, including chemical and botanical options. To accommodate the broad range of possible treatment options, this analysis compares PICS bags to generalized treatments with certain costs and effectiveness. Total costs for alternative treatments are evaluated seasonally, and include the cost of “organizing” beans (i.e. a woven bag). Product effectiveness affects storage profitability since insect damage is recorded to carry an economic penalty— price reductions. To be conservative, this analysis assumes volumetric sales, common in Kenya according to USAID and Tegemeo Institute researchers, which would not carry a penalty for “weight” loss. Only price loss is incorporated, drawn from the most conservative estimates in neighboring Rwandan market research, with 0.36% discount for each hole in 100 seeds (Jones et al., 2013).

Figure 16 illustrates equivalent profitability of PICS and each generalized storage product in six-month storage (all markets).

Break-even levels indicate that even zero-cost storage technologies would have to maintain damage within 4.3 holes per 100 seeds of PICS efficacy for equivalent profitability. That is, if PICS-stored grain had one hole per 100 seeds after six months, then a free alternative technology could not exceed 5.3 holes per 100 seeds and still be as profitable. At \$0.50 USD, roughly the cost of a new woven 90kg bag, damage could not be greater than 3.0 holes per 100 seeds over PICS. At \$0.75 per season, roughly the cost of a woven bag depreciated for two years of use plus the cost of Actellic Super, damage levels could not exceed 2.4 holes greater than PICS.

If the damage discount per hole is increased to 2.3% discount per hole in 100 grains, a higher retail discount found in Tanzania (Mishili et al., 2011), then a treatment at \$0.75 per season must hold damage to within 0.4 holes of PICS efficacy (and zero-cost treatment must remain within 0.7 holes of PICS efficacy).

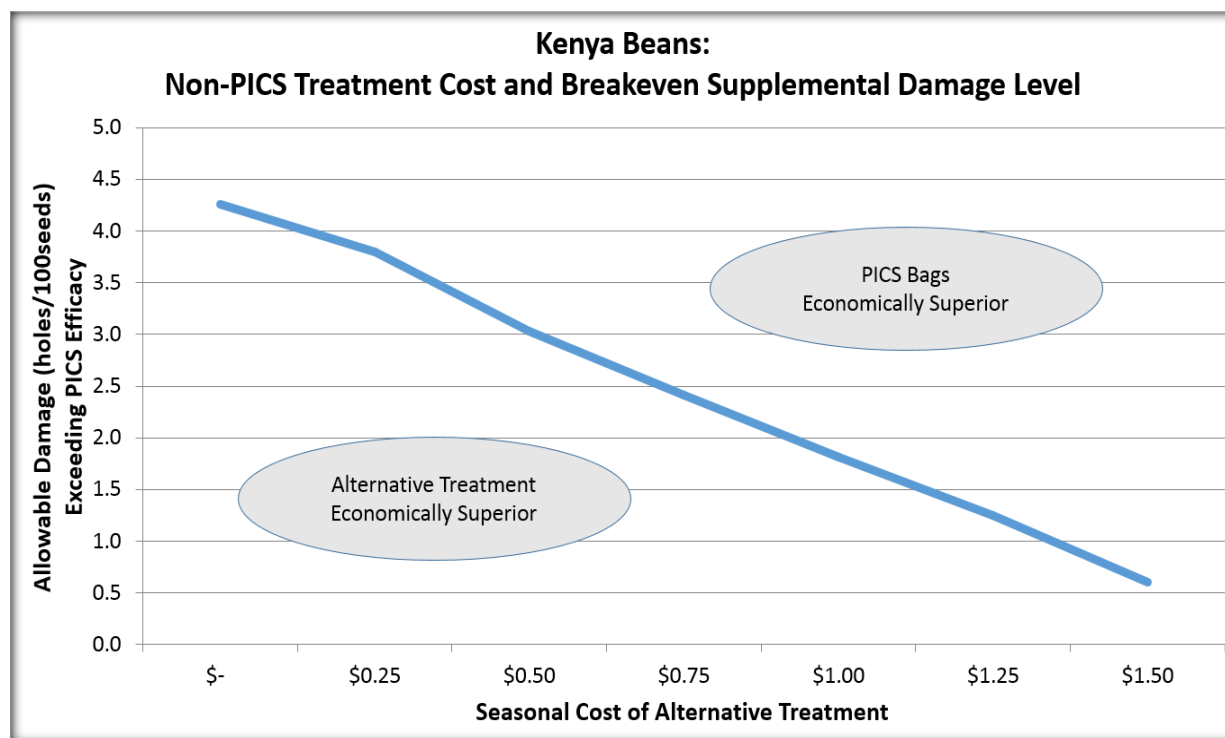


Figure 16: Kenya Beans: Non-PICS Alternative Technology Break-Even Analysis

Ghana

Maize Storage Profitability

Background

Ghana is a maize-dependent country in West Africa which faces significant post-harvest constraints. Based on 2011 and 2012 production data, the largest maize producing provinces of the country are Brong-Ahafo in the central zone (capital: Sunyani) and Eastern province in the southeast (capital: Koforidua). Provincial production data are further illustrated in Figure 17. By overlaying 2010 census data, it is clear that the largest provincial per capita annual maize production is found in Brong-Ahafo (217.5 kg/p/year), Eastern (146.1 kg/p/year), and the Upper West province (150.8 kg/p/year). Per capita production in these three provinces significantly exceeds all others. Naturally, the Greater Accra area has the lowest per capita production at about 1.1 kg/p/year.

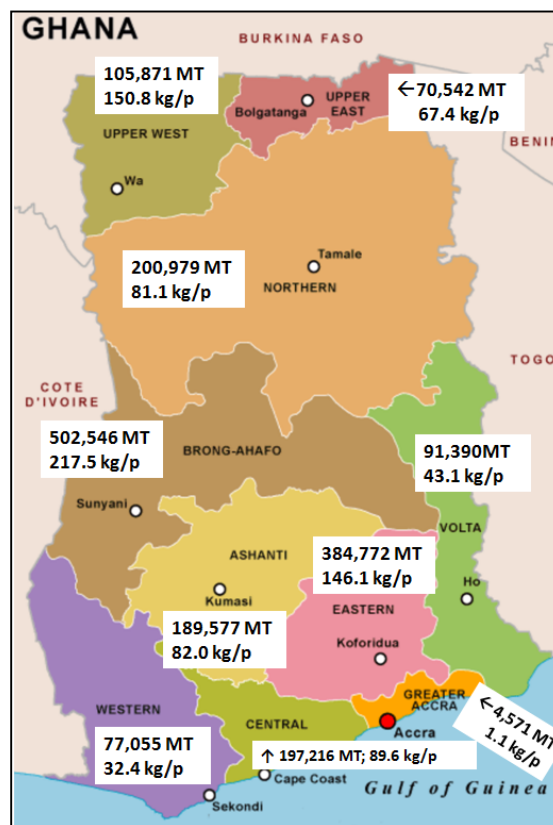


Figure 17: Ghana Maize: Average 2011 & 2012 total and per capita production, by region

Note: Metric ton (MT); Kilograms per Person (kg/p)

Sources: Production- Statistics, Research and Info. Directorate (SRID), Min. of Food & Agriculture;
Population- 2010 Ghanaian National Census

Maize storage is a challenge due to both mold and insect infestation. Aflatoxin contamination is a concern complicated by rains during and after the major harvest months, in which farmers struggle to bring grain moisture down to safe storage levels. Proper drying is a prerequisite for any effective grain storage and will remain a concern for all post-harvest management programs in Ghana. Once dried, grain faces the second challenge of storage pest infestation. With widely present larger grain borer (LGB) infestation, it is not unusual to find dry weight losses in excess of 10-15% in untreated stocks (Boxall, 2002). Producers are known to even use harsh and inappropriate chemicals on stored grain in an attempt to protect stocks from these threats (Hodges, 2003). In addition to dry weight losses, marketing producers additionally face price discounts for insect-damaged grain, exacerbating economic storage losses due to insects. These price discounts, summarized in Figure 18, have been recorded at about a 1% discount per 1% damaged grain immediately after harvest and softening slightly to a 0.75% discount per 1% damage as grain becomes more scarce in “lean” season (Compton et al., 1998). Thresholds exist before discounts are applied, with a tolerance up to about 5-7% in the mid- and lean season.

Availability of maize on the market	Maize given top price (% damaged grains)	Price of highly damaged maize (> 90% damaged grains)	Simplified damage-price equation and suggested standard deviation for single grain sample ^a
Plentiful (after harvest)	0–5%	Unlikely to sell	$P = 100 - D \pm 15$
Moderate (mid-season)	0–5%	Unlikely to sell	$P = 100 - 0.85D \pm 15$
Scarce (lean season)	0–7%	25%	$P = 100 - 0.75D \pm 15$
Very scarce (bad years)	0–10%	30%	$P = 100 - 0.65D \pm 15$

^aD = percent damaged grains as defined in text. P = price as percent of top price. After calculating P, it can be multiplied by the mean price of good-quality grain to get the expected cash price for a given damaged batch of maize.

Figure 18: Ghana Maize Discount Schedules by Post-Harvest Period

Source: Taken from table 4 in Compton et al., 1998

Ghana has two notable harvest periods, with the major harvest collected in July to August and the minor harvest collected in about January to February. To accommodate necessary drying periods, the model identifies the month of first dry-grain availability for the major harvest season as the low price month between August and September. The minor harvest season is modeled starting with the low price month between February and March.

Monthly wholesale maize price data for twelve major markets are synthesized from Ghanaian Ministry of Food and Agriculture (MoFA) records⁸. Wholesale prices are converted to farm-gate prices using dynamic monthly margins. These margins were computed through supplementary data from Ghanaian MoFA records with suitably complete “average farm-gate prices” for a limited number of markets, including Tamale, Techiman, Ejura, Mankessim, and Sunyani. The dynamic monthly farm-gate/wholesale margins show clear local minimums at major and minor harvest periods, at an average of 65% and 70%, respectively. This margin peaks at 81% in May, when grain is most scarce. Therefore, this analysis corrects for overly conservative profitability estimates which are based on fixed wholesale/farm-gate margins. Data for average monthly margins in Ghana may be found in Appendix 4.

⁸ Historical commodity prices may be found online at http://mofa.gov.gh/site/?page_id=8803 (as of June '14)

PICS bags are modeled at \$2.50 USD per unit, depreciated for two seasons of use. The cost of an additional woven bag for marketing purposes (\$0.50 USD) is assessed for the first seasons of PICS use. Prices are all real January 2012 USD, adjusted through CPI records provided by the Ghana Statistical Service⁹, with a January 2012 Cedi exchange rate of 1.62:1.

Major Harvest Storage Profitability

Storage of the major harvest is modeled under four scenarios, with an “optimal” storage period to the annual high price month and three fixed storage periods of four, eight, and ten months. The optimal storage period was between eight and ten months, with a national average of 8.9 months. The four month fixed period represents storage up to the months immediately prior to the minor harvest. Eight and ten month fixed storage periods represent storage eclipsing the minor harvest until the period of greatest annual grain scarcity.

Table 18 displays that maize price seasonality is greatest in Mankessim, Koforidua, Ejura, and Sunyani. These are also the market regions of highest PICS storage profitability, further elaborated in Table 19. Storage of the major harvest for four months results in wide ranging average returns of 0.3% to 42.3%. Fixed storage of eight months, to the period of greatest annual grain scarcity, results in average returns of 14.0% to 81.5%. Storing the main harvest further to ten months slightly increases average returns in 10 of 12 markets, with returns ranging from 17.9% to 62.5%.

Table 18: Ghana Maize Average Real Price Increase of Major Harvest (2009 major harvest -2011 major harvest)

Market	“Optimal” Storage	4 mo. Fixed	8 mo. Fixed	10 mo. Fixed
Mankessim	86.5%	44.9%	86.5%	57.6%
Tema	45.8%	9.0%	36.5%	37.4%
Koforidua	76.5%	21.3%	51.9%	55.8%
Ho	52.9%	22.1%	29.0%	47.7%
Obuasi	43.6%	15.4%	28.2%	40.0%
Kumasi	51.4%	9.7%	18.6%	51.4%
Ejura	88.6%	33.0%	59.7%	69.1%
Sunyani	78.5%	17.6%	78.5%	62.2%
Techiman	41.0%	0.4%	22.7%	31.2%
Tamale	43.1%	4.5%	26.9%	30.5%
Wa	27.8%	5.4%	15.3%	19.6%
Bolgatanga	37.7%	5.7%	16.6%	25.7%

⁹ Historical CPI data in Ghana may be found at http://www.statsghana.gov.gh/cpi_release.html

Table 19: Ghana Maize Average Financial Rates of Return on Storing Major Harvest (2009 major harvest -2011 major harvest)

Market	“Optimal” Storage	4 mo. Fixed	8 mo. Fixed	10 mo. Fixed
Mankessim	81.5%	42.3%	81.5%	54.2%
Tema	43.3%	8.5%	34.5%	35.4%
Koforidua	71.6%	20.0%	48.9%	52.2%
Ho	49.5%	20.8%	27.1%	44.6%
Obuasi	41.5%	14.6%	26.9%	38.0%
Kumasi	48.2%	9.1%	17.5%	48.2%
Ejura	79.9%	29.9%	53.4%	62.5%
Sunyani	71.3%	16.1%	71.3%	56.5%
Techiman	37.4%	0.3%	20.7%	28.5%
Tamale	39.2%	4.0%	24.7%	27.5%
Wa	25.4%	5.0%	14.0%	17.9%
Bolgatanga	34.3%	5.1%	15.1%	23.2%

Economic storage returns at an OCC of 25% and 50% annually help compare fixed storage periods of four, six, and eight months. The highest and most consistently positive average economic returns are with eight months of storage. On average, positive returns at an OCC of 25% are possible under each year and storage scenario except for 2009 for ten months. When OCC is modeled at 50%, representing farmers with greater capital constraints, storage for four months only has positive economic returns in 2011. At 50% OCC, storage for eight and ten months has positive average economic returns in both 2010 and 2011.

Table 20: Yearly Avg. Economic Storage Returns for Ghana Maize Markets (Major Harvest; 2009-2011)

Year	OCC*	Storage Period			
		“Optimal”	4 mo.	8 mo.	10 mo.
2009	25%	14.5%	3.8%	11.6%	-1.9%
	50%	-3.5%	-4.5%	-5.1%	-22.7%
2010	25%	47.0%	8.1%	20.9%	39.4%
	50%	27.5%	-0.2%	4.2%	18.6%
2011	25%	43.4%	23.7%	32.3%	26.9%
	50%	25.2%	15.4%	15.6%	6.1%

*annual rate of opportunity cost of capital

Analysis using 36 market-years per storage scenario allows for some scrutiny of risk in PICS maize storage profitability. When storing the major harvest for a fixed period of eight or ten months, farmers have a positive cash flow in 92% of modeled national market-years. This drops slightly to 86% for fixed four month storage. When the opportunity cost of capital is considered, profitability exceeds a 25%

annualized return in 75% of market-years for four and ten month storage and 80% of market-years for eight month storage. Storage only exceeds a 50% annual OCC threshold for about half of market-years in four month storage, but up to 64% of market-years in ten month storage.

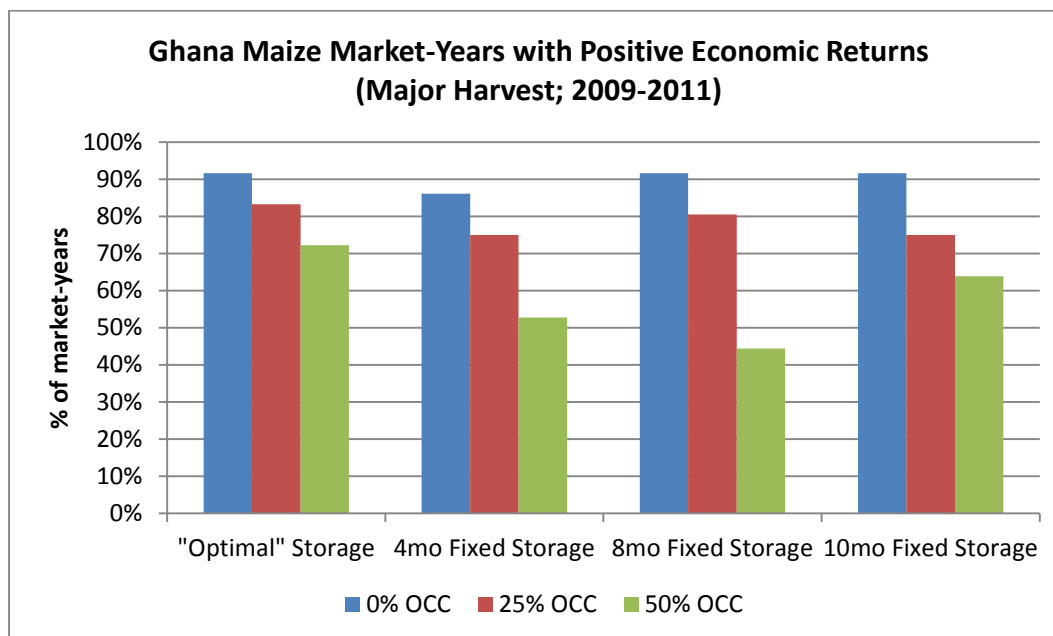


Figure 19: Ghana Maize Market-Years with Positive Economic Returns (Major Harvest 2009-2011)

Minor Harvest Storage Profitability

Storage of the minor maize harvest is largely not as lucrative as the major harvest, despite reports that the minor harvest is traditionally stored longer before marketing (Armah and Asante, 2006). There is significant variance in regional price seasonality as displayed in Table 21, with the most "optimal" marketing scenarios resulting in an average real stock value appreciation of between 7.8% and 32.3%. Fixed storage of four months closely mirrors optimal timing of marketing. Table 22 outlines the financial rates of return in each market region, with the strongest returns in Kumasi, Koforidua, and Techiman under a fixed four month storage regimen. Wa and Mankessim have the lowest average returns.

Table 21: Ghana Minor Harvest Maize Average Real Price Increase (2009 minor harvest – 2012 minor harvest)

Market	“Optimal” Storage	4 mo. Fixed
Mankessim	7.8%	7.3%
Tema	16.4%	16.4%
Koforidua	28.8%	22.5%
Ho	28.7%	27.8%
Obuasi	11.4%	8.8%
Kumasi	25.8%	25.8%
Ejura	28.4%	24.4%
Sunyani	23.5%	22.8%
Techiman	32.3%	28.5%
Tamale	21.6%	18.2%
Wa	10.1%	4.3%
Bolgatanga	15.1%	15.1%

Table 22: Ghana Minor Harvest Maize Average Financial Rates of Return (2009 minor harvest – 2012 minor harvest)

Market	“Optimal” Storage	4 mo. Fixed
Mankessim	7.5%	6.4%
Tema	15.6%	10.8%
Koforidua	27.3%	21.7%
Ho	27.0%	18.8%
Obuasi	10.9%	10.5%
Kumasi	24.3%	23.7%
Ejura	26.2%	19.6%
Sunyani	21.9%	16.8%
Techiman	29.6%	22.1%
Tamale	20.0%	15.1%
Wa	9.3%	6.6%
Bolgatanga	14.1%	13.1%

When evaluated at 25% OCC, there are positive economic returns to storage in 2009, 2011, and 2012. When increasing this threshold to 50% OCC, farmers would only have positive economic returns in 2011 and 2012. Though admittedly basic in analysis, this compares less favorably to average economic returns in fixed four, eight, and ten month storage of the major harvest.

Table 23: Yearly Avg. Economic Storage Returns for Ghana Maize Markets (Minor Harvest; 2009-2011)

Year	OCC*	Storage Period	
		“Optimal”	4 mo.
2009	25%	6.0%	1.0%
	50%	-1.6%	-7.3%
2010	25%	-1.9%	-11.7%
	50%	-10.1%	-20.1%
2011	25%	30.4%	28.3%
	50%	21.9%	20.0%
2012	25%	12.8%	11.7%
	50%	4.5%	3.3%

*annual rate of opportunity cost of capital

Basic risk analysis results indicate that 77% of market-years had positive cash flows under fixed four months of storage. Risk results are quite similar for four month fixed storage of the minor and major season crop, though slightly favoring the major season. Even if storing to the “optimal” high-price month every year, long term storage of the major season is somewhat less risky for all OCC levels modeled. This is especially true for producers with 50% OCC.

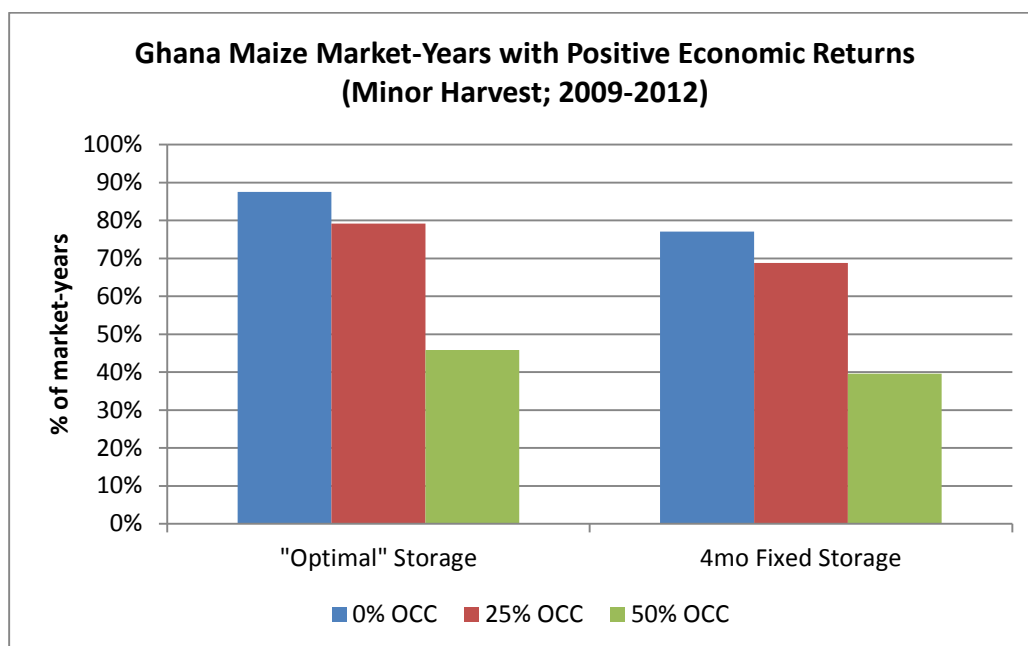


Figure 20: Ghana Maize Market-Years with Positive Economic Returns (Minor Harvest 2009-2011)

Ghana Maize: Comparison of PICS vs. non-PICS Storage Treatments

This analysis also compares PICS bags to generalized treatments with certain costs and effectiveness, measured as the percentage of maize grains with visible insect damage. Total costs for alternative treatments are evaluated seasonally, including the cost of a standard woven polypropylene bag. Grain sales are modeled under both volume-based and weight-based methods. Volume-based marketing assumes that physical weight loss, which inevitably accompanies visible grain damage, does not affect overall revenue loss from insect infestation. In weight-based marketing, the quantity is reduced by insect damage as well as price penalties from grain damage, assumed at 0.75% price reduction per 1% grain damage (Compton et al., 1998). Since the price discount work in Ghana does not make a clear distinction, this analysis assumes price discounts are the same in volume- and weight-based marketing.

Even if farmers had a free form of protection, revenue losses from infestation require that alternative treatments remain within 3.58% of PICS efficacy for equivalent profitability in volume-based marketing. This drops considerably to a 2.81% grain damage differential with weight-based marketing. At \$0.75 per season, roughly the cost of a woven bag depreciated for two years of use plus the cost of Actellic Super, damage levels could not exceed 2.04% and 1.60% in volume and weight-based marketing, respectively, for equivalent profitability with PICS. Increasing the dosage of insecticide past recommended levels, anecdotally common among risk-averse marketing producers, requires increasingly tighter damage differentials.

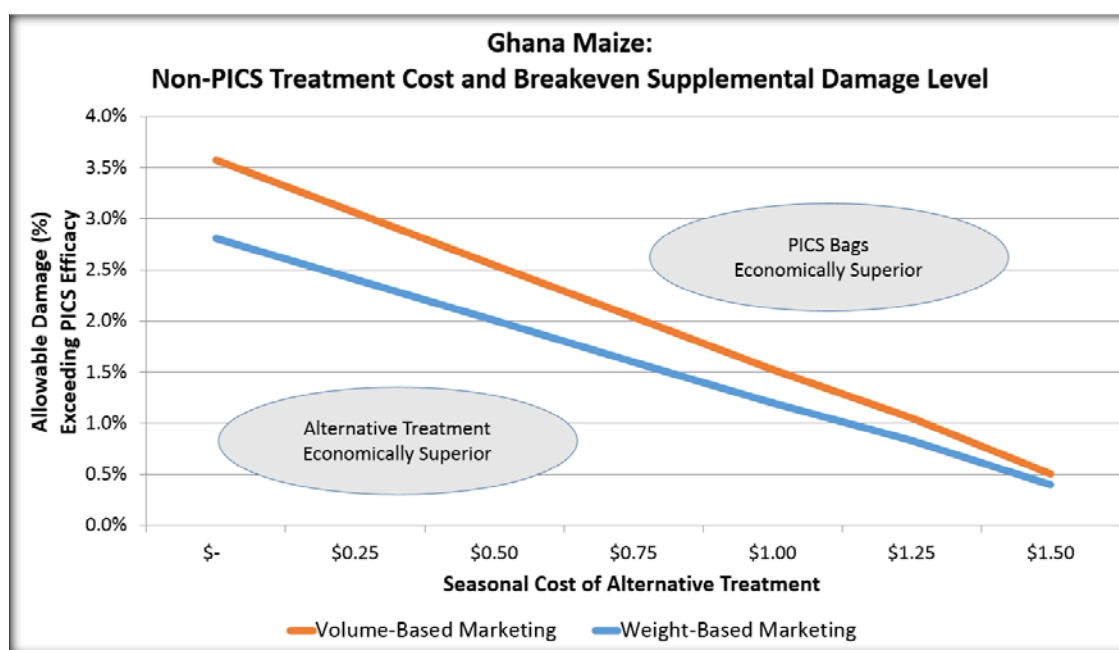


Figure 21: Ghana Maize: Non-PICS Alternative Technology Break-Even Analysis

Conclusion

Ex-ante profitability analysis indicates that PICS bags could provide strong returns in many market regions of the countries evaluated. Dynamic monthly farmgate-retail and farmgate-wholesale margins help to better contextualize price movement across the storage season from a producer's perspective. This method is seriously lacking in current literature, most likely due to inadequate data availability. This analysis is able to incorporate dynamic margins for Senegalese maize and groundnuts as well as maize in Ghana.

Overall, significant variance in storage profitability with PICS (and any storage method) exists between crops and geographic area. Assuming PICS bags retain the same efficacy found in lab and field experiments, systematic variance in storage profitability will occur due to annual changes in price seasonality. Basic risk-analysis provided greater insight into this variance for marketing producers using grain storage as an income generating activity. Results for each country are briefly outlined below.

Senegalese maize and groundnut storage both appear to have strong promise for PICS application. Nearly 90% of 87 market-years analyzed for both crops have positive economic returns at a level of 25% OCC. Groundnut storage is more lucrative than maize storage, with 70% vs. 50% market-years resulting in economic profits when assuming 50% OCC.

Analysis for Kenyan markets is necessarily overly conservative due to lack of data to incorporate dynamic farmgate-wholesale margins. This is considered conservative because data from Ghana and Senegal indicate that farmgate prices increase more dramatically from the immediate post-harvest period to the lean season than wholesale prices. From the data available, maize storage for six or eight months in the Western and Rift Valley market regions had positive cash flows in 70-75% of market-years. Economic returns are generally positive with 25% OCC whenever there are positive cash flows. In the Eastern market regions, four and six month storage have positive cash flows in 80-85% of market-years. Economic returns are positive more frequently with 25% OCC in four month storage, however, indicating this is most likely the more strategic regional storage regimen. Nationally, maize storage in the Eastern market regions is more consistently profitable than the West and Rift Valley, while maize storage in Western and Rift Valley market regions has much better returns to storage when there are positive cash flows. Therefore, Western and Rift Valley producers with the financial capacity to wait may appreciate a storage technology which provides the technical ability to store through the following year until prices are more favorable.

Kenyan bean storage carries significantly less risk of negative cash flows compared to maize storage. Nearly all bean market-years modeled in both the Western and Eastern markets have positive cash flows, even considering the conservative nature of fixed farmgate-wholesale margins. Over 75% of fixed four and six month storage regimens in Eastern markets had positive economic returns under 25% OCC. This increases to 85% and 95% of Western markets with six and eight month storage, respectively.

In Ghana, maize storage was modeled with both short and long-term storage of the major crop and short-term storage of the minor crop. In four month fixed storage of the major crop (marketing just before the minor crop harvest), positive cash flows were possible in 85% of market-years. This increased slightly to 91% of market-years in eight and ten month fixed storage periods. Explicit returns are highest for eight

month fixed storage regimens overall when marketing the major crop. Storing the minor crop is less profitable than long-term storage of the major crop with the current data and modeled storage costs. Four month fixed storage resulted in positive economic returns in about 70% of market-years with 25% OCC. This drops significantly to only 40% of market-years with a 50% OCC.

Comparisons in breakeven storage revenue were made with alternative technologies which may be cheaper and less effective. Cost savings for cheaper, less effective storage technologies are quickly lost when damaged grain reduces prices and/or the quantity sold. Results show that alternative technologies may not exceed PICS grain damage rates by more than 3.5% to 4.5%, depending on crop value and damage penalties, for equivalent profitability. When producers are marketing grain by weight (with a scale), it becomes even more profitable to employ a storage technology like PICS with slightly higher costs but better performance protecting grain.

Where storage is profitable and insect pressure high, there will be increased demand for improved storage technologies such as PICS bags. This analysis should contribute to the targeting of PICS technology dissemination and extension messages customized for each market region in Senegal, Kenya, and Ghana. Additional detail is available in the accompanying annexes with yearly output for each market area. Risk of negative cash flow should be strongly considered when promoting storage as a means of income generation, and caution exercised when few market-years have positive economic returns under 25% or 50% OCC. However, where storage returns are high and consistent with target crops, these markets regions could provide prime expansion points for the highly effective storage technologies.

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Appendices

Appendix 1: Senegal Producer to Retail Margins

Senegal producer share (%) of retail maize prices. Oct 2007 – Sep 2012.

Source: SIM/CNA

Market: Maize	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Fatick	84.3	87.3	89.5	90.4	91.0	93.4	94.2	94.4	92.5	93.3	93.5	91.3
Kaolack	88.3	89.4	89.6	92.5	91.7	92.0	94.1	95.0	94.5	93.2	90.0	89.6
Tambacounda	73.0	79.6	86.3	82.4	83.0	82.6	83.0	85.0	87.6	89.3	84.2	81.2
Average	81.9	85.4	88.5	88.4	88.6	89.3	90.5	91.5	91.5	91.7	89.0	87.4

Senegal producer share (%) of retail shelled groundnut prices. Oct 2007 – Sep 2012.

Source: SIM/CAN

Market: Groundnuts	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Fatick	82.1	72.6	82.8	79.8	83.7	87.5	87.3	87.4	87.5	90.6	86.9	80.6
Kaolack	85.3	77.7	85.2	90.9	87.6	89.4	87.2	88.1	91.8	87.6	91.6	88.8
Tambacounda	80.8	77.8	82.5	82.0	81.8	85.6	84.2	86.3	84.5	84.7	88.0	85.9
Average	82.7	76.1	83.5	84.2	84.4	87.5	86.1	87.3	88.0	87.4	89.0	85.4

Appendix 2: Senegal Maize Yearly Analysis Breakdown

Real Price Increases, “Optimal” Storage Period between 6-10 months

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	29.2%	26.5%	47.4%	33.0%	34.0%
Fatick	40.5%	31.4%	27.7%	44.3%	26.8%	34.1%
Kolda	59.6%	42.7%	64.3%	64.3%	40.9%	54.4%
Kaolack	60.0%	41.1%	54.3%	65.4%	19.0%	48.0%
Matam	58.2%	29.0%	43.4%	31.3%	23.3%	37.0%
St Louis	70.5%	56.9%	29.8%	49.8%	21.5%	45.7%
Tambacounda	95.5%	30.5%	58.3%	61.3%	42.9%	57.7%
Ziguinchor	55.4%	32.6%	24.1%	71.8%	35.8%	43.9%
Average	62.8%	36.7%	41.1%	54.5%	30.4%	44.6%

Real Financial Rates of Return, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	27.3%	24.7%	44.1%	31.3%	31.8%
Fatick	37.8%	29.5%	26.1%	41.3%	25.3%	32.0%
Kolda	55.2%	39.8%	59.1%	60.1%	38.8%	50.6%
Kaolack	55.5%	38.1%	50.0%	60.3%	18.0%	44.4%
Matam	54.4%	27.4%	41.0%	29.5%	22.3%	34.9%
St Louis	66.0%	53.0%	28.2%	47.0%	20.6%	42.9%
Tambacounda	86.7%	28.4%	52.6%	56.3%	40.8%	53.0%
Ziguinchor	52.3%	31.0%	23.0%	68.0%	34.4%	41.7%
Average	58.3%	34.3%	38.1%	50.8%	28.9%	41.7%

Real Price Increases, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	20.9%	16.2%	41.1%	13.8%	23.0%
Fatick	34.7%	22.3%	19.7%	30.5%	10.7%	23.6%
Kolda	59.6%	42.6%	48.7%	53.5%	31.6%	47.2%
Kaolack	38.0%	36.5%	54.3%	59.5%	15.1%	40.7%
Matam	31.2%	10.6%	31.1%	21.5%	23.3%	23.5%
St Louis	23.2%	45.0%	10.9%	18.5%	16.3%	22.8%
Tambacounda	68.6%	20.1%	46.3%	38.7%	5.9%	35.9%
Ziguinchor	54.1%	18.9%	14.7%	40.4%	14.8%	28.6%
Average	44.2%	27.1%	30.2%	38.0%	16.4%	30.9%

Real Financial Rates of Return, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	19.6%	15.1%	38.3%	13.1%	21.5%
Fatick	32.4%	20.9%	18.6%	28.5%	10.2%	22.1%
Kolda	55.2%	39.7%	44.7%	50.0%	29.9%	43.9%
Kaolack	35.1%	33.9%	50.0%	54.9%	14.4%	37.7%
Matam	29.1%	10.0%	29.3%	20.3%	22.3%	22.2%
St Louis	21.7%	41.9%	10.3%	17.5%	15.6%	21.4%
Tambacounda	62.3%	18.8%	41.8%	35.5%	5.6%	32.8%
Ziguinchor	51.1%	17.9%	14.0%	38.3%	14.2%	27.1%
Average	41.0%	25.3%	28.0%	35.4%	15.7%	28.8%

Real Price Increases, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	29.2%	24.4%	37.2%	19.8%	27.6%
Fatick	31.5%	31.4%	27.7%	44.3%	26.8%	32.3%
Kolda	59.1%	39.3%	64.3%	61.8%	40.9%	53.1%
Kaolack	60.0%	41.1%	48.0%	60.1%	17.2%	45.3%
Matam	48.2%	29.0%	43.4%	31.3%	n/a	38.0%
St Louis	45.8%	44.4%	24.2%	34.3%	14.9%	32.7%
Tambacounda	94.5%	30.5%	51.0%	58.7%	10.4%	49.0%
Ziguinchor	49.6%	21.8%	18.4%	51.6%	32.5%	34.8%
Average	55.5%	33.3%	37.7%	47.4%	23.2%	39.4%

Real Financial Rates of Return, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	n/a	27.3%	22.8%	34.6%	18.7%	25.8%
Fatick	29.4%	29.5%	26.1%	41.3%	25.3%	30.3%
Kolda	54.8%	36.6%	59.1%	57.7%	38.8%	49.4%
Kaolack	55.5%	38.1%	44.1%	55.5%	16.4%	41.9%
Matam	45.1%	27.4%	41.0%	29.5%	n/a	35.8%
St Louis	42.9%	41.3%	22.9%	32.4%	14.3%	30.8%
Tambacounda	85.8%	28.4%	46.0%	53.9%	9.9%	44.8%
Ziguinchor	46.8%	20.7%	17.6%	48.9%	31.2%	33.0%
Average	51.5%	31.2%	34.9%	44.2%	22.1%	36.8%

Appendix 3: Senegal Groundnuts Yearly Analysis Breakdown

Real Price Increase, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	73.0%	42.8%	50.0%	66.8%	81.2%	62.7%
Fatick	26.8%	32.8%	51.6%	74.5%	n/a	46.4%
Kolda	83.2%	64.2%	67.1%	110.7%	59.1%	76.9%
Kaolack	15.2%	156.2%	45.1%	100.4%	84.1%	80.2%
Matam	66.1%	32.9%	54.8%	101.2%	n/a	63.8%
St Louis	47.6%	39.2%	61.2%	49.4%	40.8%	47.7%
Tambacounda	29.8%	20.2%	55.4%	134.2%	132.2%	74.4%
Ziguinchor	39.0%	53.0%	48.9%	91.7%	67.7%	60.1%
Louga	24.7%	13.8%	59.1%	92.0%	45.5%	47.1%
Thies	42.7%	45.8%	61.4%	79.8%	75.8%	61.1%
Average	44.8%	50.1%	55.5%	90.1%	73.3%	62.3%

Real Financial Rates of Return, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	71.1%	41.4%	48.1%	64.4%	79.2%	60.8%
Fatick	26.2%	31.9%	49.5%	72.0%	n/a	44.9%
Kolda	80.1%	61.6%	64.7%	106.5%	57.6%	74.1%
Kaolack	14.8%	146.7%	43.3%	96.5%	82.0%	76.7%
Matam	64.6%	32.2%	53.2%	98.2%	n/a	62.0%
St Louis	46.5%	38.2%	59.4%	48.1%	40.1%	46.5%
Tambacounda	28.9%	19.5%	53.0%	128.8%	128.5%	71.8%
Zinguinchor	38.1%	51.6%	47.7%	89.3%	66.5%	58.7%
Louga	24.2%	13.4%	57.0%	88.8%	44.6%	45.6%
Thies	41.7%	44.6%	59.1%	77.1%	74.2%	59.3%
Average	43.6%	48.1%	53.5%	87.0%	71.6%	60.3%

Real Price Increases, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	73.0%	42.8%	40.7%	41.1%	72.5%	54.0%
Fatick	21.2%	12.2%	36.7%	64.9%	n/a	33.8%
Kolda	67.4%	64.2%	22.2%	92.1%	49.9%	59.2%
Kaolack	15.2%	121.6%	30.3%	51.5%	81.9%	60.1%
Matam	25.2%	16.3%	-3.7%	56.0%	n/a	23.5%
St Louis	31.0%	33.9%	51.4%	31.0%	11.2%	31.7%
Tambacounda	12.1%	20.2%	37.9%	82.0%	54.3%	41.3%
Zinguinchor	39.0%	37.3%	41.8%	89.2%	53.7%	52.2%
Louga	18.5%	9.9%	40.6%	58.8%	45.5%	34.7%
Thies	29.7%	45.8%	37.1%	79.8%	70.3%	52.5%
Average	33.2%	40.4%	33.5%	64.6%	54.9%	44.9%

Real Financial Rates of Return, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	71.1%	41.4%	39.1%	39.6%	70.7%	52.4%
Fatick	20.8%	11.9%	35.2%	62.7%	n/a	32.6%
Kolda	64.9%	61.6%	21.4%	88.6%	48.7%	57.1%
Kaolack	14.8%	114.2%	29.1%	49.5%	79.9%	57.5%
Matam	24.6%	15.9%	-3.6%	54.3%	n/a	22.8%
St Louis	30.3%	33.1%	49.9%	30.2%	11.0%	30.9%
Tambacounda	11.7%	19.5%	36.3%	78.7%	52.7%	39.8%
Zinguinchor	38.1%	36.3%	40.8%	86.8%	52.8%	51.0%
Louga	18.1%	9.6%	39.2%	56.8%	44.6%	33.6%
Thies	29.0%	44.6%	35.7%	77.1%	68.8%	51.0%
Average	32.3%	38.8%	32.3%	62.4%	53.7%	43.5%

Real Price Increases, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	43.9%	30.7%	41.6%	66.8%	81.2%	52.8%
Fatick	16.4%	32.8%	48.3%	73.3%	n/a	42.7%
Kolda	74.8%	n/a	32.5%	82.8%	58.3%	62.1%
Kaolack	2.0%	128.5%	36.8%	100.4%	56.5%	64.8%
Matam	39.3%	32.4%	45.1%	66.9%	n/a	45.9%
St Louis	47.6%	23.4%	61.2%	25.9%	35.1%	38.7%
Tambacounda	18.9%	7.1%	50.7%	106.4%	125.6%	61.8%
Ziguinchor	23.7%	42.3%	48.9%	79.5%	65.8%	52.1%
Louga	19.2%	9.6%	55.2%	79.9%	37.8%	40.3%
Thies	39.3%	3.5%	47.5%	61.0%	52.2%	40.7%
Average	32.5%	34.5%	46.8%	74.3%	64.1%	50.2%

Real Financial Rates of Return, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Diourbel	42.7%	29.7%	40.0%	64.4%	79.2%	51.2%
Fatick	16.1%	31.9%	46.4%	70.9%	n/a	41.3%
Kolda	72.0%	n/a	31.4%	79.7%	56.9%	60.0%
Kaolack	1.9%	120.7%	35.4%	96.5%	55.1%	61.9%
Matam	38.5%	31.6%	43.7%	64.9%	n/a	44.7%
St Louis	46.5%	22.8%	59.4%	25.2%	34.5%	37.7%
Tambacounda	18.4%	6.9%	48.6%	102.2%	122.1%	59.6%
Ziguinchor	23.2%	41.2%	47.7%	77.4%	64.6%	50.8%
Louga	18.8%	9.3%	53.2%	77.1%	36.9%	39.1%
Thies	38.3%	3.4%	45.7%	59.0%	51.2%	39.5%
Average	31.7%	33.1%	45.1%	71.7%	62.6%	48.6%

Appendix 4: Kenya Maize Yearly Analysis Breakdown

Real Price Increase, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	171.1%	42.2%	-18.6%	261.6%	27.3%	96.7%
Kisumu	113.2%	4.0%	6.3%	190.0%	31.2%	69.0%
Eldoret	93.1%	61.8%	-5.8%	271.0%	27.7%	89.6%
Kisii	n/a	60.5%	-8.7%	269.5%	19.6%	85.2%
Busia	165.0%	100.9%	-30.4%	351.0%	50.5%	127.4%
Taveta	58.2%	21.7%	19.1%	79.5%	13.7%	38.5%
Machakos	115.1%	13.0%	-24.3%	119.3%	15.2%	47.7%
Kitui	104.0%	n/a	-25.3%	193.1%	39.6%	77.9%
Average	117.1%	43.4%	-11.0%	216.9%	28.1%	78.8%

Real Financial Rates of Return, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	131.5%	38.3%	-17.1%	226.2%	25.8%	81.0%
Kisumu	92.3%	3.7%	5.8%	172.0%	29.9%	60.7%
Eldoret	75.1%	55.2%	-5.3%	234.4%	26.2%	77.1%
Kisii	n/a	54.7%	-8.1%	237.3%	18.7%	75.6%
Busia	126.4%	90.0%	-28.3%	297.6%	47.3%	106.6%
Taveta	49.8%	20.2%	17.0%	73.1%	13.0%	34.6%
Machakos	96.2%	12.0%	-22.4%	108.7%	14.5%	41.8%
Kitui	87.2%	n/a	-23.1%	173.0%	37.5%	68.7%
Average	94%	34%	-10%	190%	27%	66.3%

Real Price Increases, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	133.2%	40.9%	-28.0%	167.1%	19.9%	66.6%
Kisumu	88.9%	-0.2%	-19.2%	108.4%	31.2%	41.8%
Eldoret	71.5%	61.1%	-14.8%	163.7%	27.7%	61.8%
Kisii	n/a	33.2%	-8.7%	39.2%	18.2%	20.5%
Busia	95.6%	81.7%	-31.2%	72.8%	15.7%	46.9%
Taveta	58.2%	7.6%	-16.0%	67.3%	12.7%	26.0%
Machakos	101.9%	2.8%	-38.4%	118.4%	4.8%	37.9%
Kitui	90.2%	n/a	-30.7%	162.0%	27.7%	62.3%
Average	91.4%	32.4%	-23.4%	112.4%	19.8%	45.7%

Real Financial Rates of Return, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	102.4%	37.2%	-25.7%	144.5%	18.9%	55.4%
Kisumu	72.5%	-0.2%	-17.7%	98.1%	29.9%	36.5%
Eldoret	57.7%	54.6%	-13.5%	141.6%	26.2%	53.3%
Kisii	n/a	30.0%	-8.1%	34.5%	17.4%	18.5%
Busia	73.2%	72.9%	-29.0%	61.7%	14.7%	38.7%
Taveta	49.8%	7.0%	-14.2%	61.9%	12.0%	23.3%
Machakos	85.2%	2.6%	-35.4%	107.9%	4.6%	33.0%
Kitui	75.6%	n/a	-28.0%	145.1%	26.2%	54.7%
Average	73.8%	25.5%	-21.4%	99.4%	18.7%	38.3%

Real Price Increases, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	171.1%	32.8%	-41.5%	261.6%	22.3%	89.3%
Kisumu	113.0%	-4.2%	-28.6%	190.0%	19.4%	57.9%
Eldoret	93.1%	61.8%	-22.1%	271.0%	6.9%	82.1%
Kisii	n/a	60.5%	-20.2%	109.1%	18.9%	42.1%
Busia	165.0%	100.9%	-36.2%	166.1%	43.4%	87.8%
Average	135.5%	50.4%	-29.7%	199.6%	22.2%	73.1%

Real Financial Rates of Return, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	131.5%	29.8%	-38.1%	226.2%	21.1%	74.1%
Kisumu	92.1%	-3.9%	-26.3%	172.0%	18.6%	50.5%
Eldoret	75.1%	55.2%	-20.1%	234.4%	6.6%	70.2%
Kisii	n/a	54.7%	-18.6%	96.1%	18.1%	37.5%
Busia	126.4%	90.0%	-33.7%	140.8%	40.7%	72.8%
Average	106.3%	45.2%	-27.4%	173.9%	21.0%	62.0%

Real Price Increases, 4 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Taveta	45.5%	0.6%	14.5%	63.5%	13.7%	27.5%
Machakos	69.9%	10.6%	-31.9%	101.7%	14.7%	33.0%
Kitui	64.0%	n/a	-38.4%	165.0%	23.1%	53.4%
Average	59.8%	5.6%	-18.6%	110.1%	17.2%	36.9%

Real Financial Rates of Return, 4 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Taveta	38.9%	0.5%	12.8%	58.4%	13.0%	24.7%
Machakos	58.5%	9.8%	-29.4%	92.7%	14.0%	29.1%
Kitui	53.6%	n/a	-35.0%	147.8%	21.8%	47.1%
Average	50.3%	5.2%	-17.2%	99.6%	16.3%	32.7%

Appendix 5: Kenya Common Beans Yearly Analysis Breakdown

Real Price Increase, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	150.0%	25.4%	32.9%	120.1%	47.1%	75.1%
Kisumu	103.6%	43.7%	n/a	72.8%	31.6%	62.9%
Eldoret	137.6%	63.2%	43.6%	244.9%	83.1%	114.5%
Kisii	n/a	30.4%	34.5%	33.7%	24.1%	30.6%
Busia	117.8%	35.2%	115.8%	55.1%	26.2%	70.0%
Taveta	36.2%	12.3%	16.4%	40.8%	n/a	26.4%
Machakos	44.5%	33.3%	26.3%	36.1%	31.7%	34.4%
Kitui	45.5%	n/a	17.5%	34.6%	26.0%	30.9%
Average	90.7%	31.6%	41.0%	79.8%	38.6%	57.6%

Real Financial Rates of Return, “Optimal” Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	134.3%	24.1%	31.2%	113.1%	45.5%	69.6%
Kisumu	96.4%	41.7%	n/a	70.1%	30.8%	59.7%
Eldoret	122.5%	59.2%	41.3%	229.4%	80.6%	106.6%
Kisii	n/a	28.9%	32.7%	32.1%	23.4%	29.3%
Busia	108.7%	33.8%	107.8%	52.9%	25.5%	65.7%
Taveta	34.0%	11.8%	15.7%	39.3%	n/a	25.2%
Machakos	42.1%	31.8%	25.1%	34.7%	30.7%	32.9%
Kitui	43.0%	n/a	16.8%	33.4%	25.3%	29.6%
Average	83.0%	33.1%	38.6%	75.6%	37.4%	54.2%

Real Price Increases, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	84.2%	20.1%	30.9%	50.9%	47.1%	46.6%
Kisumu	73.5%	43.7%	n/a	11.0%	18.3%	36.6%
Eldoret	83.3%	47.8%	40.9%	103.8%	14.9%	58.2%
Kisii	n/a	10.9%	24.4%	22.3%	-0.4%	14.3%
Busia	77.6%	18.5%	80.6%	9.4%	15.2%	40.3%
Taveta	19.9%	3.2%	2.1%	21.3%	n/a	11.6%
Machakos	35.3%	33.3%	8.0%	34.7%	28.2%	27.9%
Kitui	33.1%	n/a	17.5%	34.2%	25.4%	27.5%
Average	58.1%	25.4%	29.2%	35.9%	21.3%	34.0%

Real Financial Rates of Return, 6 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	75.3%	19.1%	29.3%	47.9%	45.5%	43.4%
Kisumu	68.4%	41.7%	n/a	10.6%	17.9%	34.6%
Eldoret	74.2%	44.8%	38.8%	97.2%	14.5%	53.9%
Kisii	n/a	10.3%	23.1%	21.3%	-0.4%	13.6%
Busia	71.6%	17.8%	75.0%	9.0%	14.8%	37.6%
Taveta	18.7%	3.1%	2.0%	20.5%	n/a	11.1%
Machakos	33.3%	31.8%	7.6%	33.4%	27.3%	26.7%
Kitui	31.2%	n/a	16.8%	32.9%	24.7%	26.4%
Average	53.3%	24.1%	27.5%	34.1%	20.6%	32.0%

Real Price Increases, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	150.0%	24.7%	32.9%	84.5%	29.2%	64.3%
Kisumu	66.7%	37.5%	n/a	42.6%	31.6%	44.6%
Eldoret	131.6%	55.0%	41.8%	183.9%	81.8%	98.8%
Kisii	n/a	23.6%	29.7%	27.3%	17.0%	24.4%
Busia	117.8%	23.2%	108.1%	31.1%	26.2%	61.3%
Average	116.5%	32.8%	53.1%	73.9%	37.2%	60.8%

Real Financial Rates of Return, 8 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Nakuru	134.3%	23.5%	31.2%	79.6%	28.2%	59.3%
Kisumu	62.1%	35.7%	n/a	41.0%	30.8%	42.4%
Eldoret	117.2%	51.5%	39.6%	172.3%	79.3%	92.0%
Kisii	n/a	22.4%	28.2%	26.1%	16.6%	23.3%
Busia	108.7%	22.3%	100.6%	29.8%	25.5%	57.4%
Average	105.6%	31.1%	49.9%	69.8%	36.1%	56.8%

Real Price Increases, 4 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Taveta	36.2%	12.3%	5.0%	36.4%	n/a	22.5%
Machakos	15.5%	1.0%	26.3%	36.1%	31.7%	22.1%
Kitui	17.8%	n/a	7.6%	34.5%	24.1%	21.0%
Average	23.2%	6.7%	12.9%	35.7%	27.9%	21.9%

Real Financial Rates of Return, 4 month Fixed Storage Period

Market	<u>2007</u>	<u>2008</u>	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Taveta	34.0%	11.8%	4.7%	35.0%	n/a	21.4%
Machakos	14.6%	1.0%	25.1%	34.7%	30.7%	21.2%
Kitui	16.8%	n/a	7.3%	33.3%	23.4%	20.2%
Average	21.8%	6.4%	12.4%	34.3%	27.1%	21.0%

Appendix 6: Ghana maize yearly analysis breakdown

Ghana producer share (%) of wholesale maize prices. Jan 2009 – Dec 2012.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tamale	76.2	80.2	78.0	75.3	90.9	72.6	76.0	68.0	84.2	88.1	79.6	78.3
Techiman	62.9	65.2	78.9	74.9	74.6	75.8	76.8	72.0	73.9	73.9	74.9	68.8
Ejura	74.4	73.0	85.6	75.5	83.4	79.8	69.8	60.0	91.2	78.5	75.0	82.0
Mankessim	64.9	68.1	66.2	72.2	75.0	72.5	74.2	60.1	74.4	88.0	77.9	70.4
Sunyani	71.8	82.8	79.9	88.9	80.6	78.7	76.0	65.6	76.5	72.2	79.5	79.2
Average	70.0	73.9	77.7	77.4	80.9	75.9	74.5	65.2	80.0	80.2	77.4	75.7

Major Harvest: Real Price Increase, “Optimal” Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	99.7%	69.1%	88.6%	85.8%
Tema	10.1%	50.0%	75.6%	45.2%
Koforidua	64.0%	69.1%	94.3%	75.8%
Ho	33.2%	60.4%	63.5%	52.4%
Obuasi	15.6%	62.0%	51.7%	43.1%
Kumasi	9.0%	72.4%	71.0%	50.8%
Ejura	93.5%	91.7%	78.3%	87.9%
Sunyani	38.2%	122.9%	72.3%	77.8%
Techiman	27.3%	62.5%	31.6%	40.4%
Tamale	-1.3%	76.9%	52.2%	42.6%
Wa	-2.2%	53.4%	30.7%	27.3%
Bolgatanga	-13.5%	84.4%	40.7%	37.2%

Major Harvest: Real Financial Rates of Return, “Optimal” Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	94%	65%	85%	81.5%
Tema	10%	47%	72%	43.1%
Koforidua	59%	65%	90%	71.6%
Ho	31%	57%	61%	49.4%
Obuasi	15%	59%	50%	41.3%
Kumasi	8%	68%	68%	48.1%
Ejura	83%	84%	74%	80.4%
Sunyani	35%	112%	68%	71.7%
Techiman	25%	57%	30%	37.4%
Tamale	-1%	70%	49%	39.2%
Wa	-2%	49%	29%	25.3%
Bolgatanga	-13%	77%	38%	34.3%

Major Harvest: Real Price Increases, 4 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>2012</u>	<u>Average</u>
Mankessim	82.1%	36.8%	42.0%	16.5%	44.4%
Tema	-9.5%	7.6%	43.1%	-6.9%	8.6%
Koforidua	19.5%	25.2%	26.6%	12.2%	20.9%
Ho	10.4%	24.3%	29.2%	22.6%	21.6%
Obuasi	13.8%	15.1%	49.3%	-18.5%	14.9%
Kumasi	16.7%	-1.7%	41.9%	-19.7%	9.3%
Ejura	52.3%	10.9%	54.4%	12.5%	32.5%
Sunyani	5.2%	30.8%	38.2%	-5.4%	17.2%
Techiman	5.4%	2.6%	18.7%	-26.7%	0.0%
Tamale	-8.9%	26.5%	10.5%	-11.6%	4.1%
Wa	-7.2%	9.5%	12.9%	4.9%	5.0%
Bolgatanga	-24.4%	21.7%	33.8%	-9.9%	5.3%

Major Harvest: Real Financial Rates of Return, 4 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	77%	35%	40%	50.8%
Tema	-9%	7%	41%	13.1%
Koforidua	18%	24%	26%	22.4%
Ho	10%	23%	28%	20.1%
Obuasi	13%	14%	48%	25.1%
Kumasi	16%	-2%	40%	18.1%
Ejura	47%	10%	51%	35.9%
Sunyani	5%	28%	36%	22.9%
Techiman	5%	2%	18%	8.4%
Tamale	-8%	24%	10%	8.6%
Wa	-7%	9%	12%	4.7%
Bolgatanga	-23%	20%	32%	9.5%

Major Harvest: Real Price Increases, 8 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	99.7%	69.1%	88.6%	85.8%
Tema	10.1%	50.0%	48.0%	36.0%
Koforidua	27.7%	32.1%	94.3%	51.3%
Ho	25.5%	21.4%	38.6%	28.5%
Obuasi	11.9%	26.0%	45.2%	27.7%
Kumasi	5.7%	11.8%	36.8%	18.1%
Ejura	93.5%	39.5%	44.3%	59.1%
Sunyani	38.2%	122.9%	72.3%	77.8%
Techiman	27.3%	19.9%	19.4%	22.2%
Tamale	-1.3%	28.4%	52.2%	26.4%
Wa	-2.2%	23.4%	23.3%	14.9%
Bolgatanga	-13.5%	31.8%	30.3%	16.2%

Major Harvest: Real Financial Rates of Return, 8 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	94%	65%	85%	81.5%
Tema	10%	47%	46%	34.3%
Koforidua	26%	30%	90%	48.7%
Ho	24%	20%	37%	26.9%
Obuasi	11%	25%	44%	26.6%
Kumasi	5%	11%	35%	17.2%
Ejura	83%	36%	42%	53.7%
Sunyani	35%	112%	68%	71.7%
Techiman	25%	18%	18%	20.5%
Tamale	-1%	26%	49%	24.6%
Wa	-2%	22%	22%	13.8%
Bolgatanga	-13%	29%	29%	14.9%

Major Harvest: Real Price Increases, 4 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	57.4%	64.7%	48.8%	57.0%
Tema	2.3%	45.9%	62.4%	36.9%
Koforidua	45.8%	56.6%	63.1%	55.2%
Ho	29.7%	53.8%	57.8%	47.1%
Obuasi	8.1%	62.0%	48.3%	39.5%
Kumasi	9.0%	72.4%	71.0%	50.8%
Ejura	61.6%	69.3%	74.3%	68.4%
Sunyani	18.4%	107.5%	58.8%	61.6%
Techiman	14.7%	58.8%	18.6%	30.7%
Tamale	-10.3%	76.9%	23.5%	30.0%
Wa	-12.7%	47.5%	22.7%	19.2%
Bolgatanga	-28.9%	70.8%	33.7%	25.2%

Major Harvest: Real Financial Rates of Return, 4 month Fixed Storage Period

Market	<u>2009</u>	<u>2010</u>	<u>2011</u>	<u>Average</u>
Mankessim	54%	61%	47%	54.1%
Tema	2%	44%	60%	35.2%
Koforidua	42%	53%	60%	52.1%
Ho	28%	50%	55%	44.4%
Obuasi	8%	59%	47%	37.8%
Kumasi	8%	68%	68%	48.1%
Ejura	55%	64%	70%	62.8%
Sunyani	17%	98%	55%	56.7%
Techiman	13%	54%	18%	28.4%
Tamale	-10%	70%	22%	27.5%
Wa	-12%	44%	21%	17.7%
Bolgatanga	-27%	65%	32%	23.0%