POST HARVEST HANDLING AND STORAGE (PHHS) PROJECT

FINAL REPORT

ANNEX II: MAIZE POST-HARVEST PRACTICES, REVISED LOSS ESTIMATES AND TRAINING NEEDS SEASONS A AND B, 2012

PROJECT # EEM-I-00-07-00006-00
Task Order 09

DISCLAIMER

The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

CONTENTS

EXECUTIVE SUMMARY 3
SAMPLING SUMMARY 8
KEY BASE PRODUCTION AND SUPPLY PARAMETERS 9
MAIZE PURCHASING 11
MARKET OUTLETS 11
HARVESTING CONDITIONS, PRACTICES, AND LOSSES 13
SEASON B 2012 QUESTIONNAIRE HARVEST LOSS RESULTS 14
SEASON A 2013 PILOT FIELD VERIFICATION RESULTS 16
DRYING PRACTICES 19
MAIZE SHELLING 20
MAIZE STORAGE 22
STORAGE FOR CONSUMED MAIZE 22
STORAGE OF MARKETED MAIZE 24
PROTECTANT USE IN STORAGE 26
STORAGE LOSSES (SEASON B ONLY) 29
TRAINING BY SUBJECT AND PROVINCE 32
APHLIS POST HARVEST LOSSES 34
COMPARISON OF POST-HARVEST LOSS ESTIMATES FROM APHLIS VS. MINAGRI SURVEYS 36
COMPARATIVE INCORPORATION OF FIELD MEASURED “HARVEST/DRYING LOSSES” TO BACK-CAST PREVIOUS SEASONS 38
SHIFTS IN SEASON B 2012 POST-HARVEST LOSSES IF EXCLUDING THE NORTHERN PROVINCE 39
SUMMARY AND EXTENSION RECOMMENDATIONS 41
GENERAL 41
TRAINING 41
POST-HARVEST LOSSES MODEL PARAMETER ESTIMATIONS 42
REFERENCES 43
LIST OF TABLES 44

EXECUTIVE SUMMARY

Following the completion of the first baseline survey of postharvest handling and storage of maize in 2011, MinAgri and USAID's Post-Harvest Handling and Storage (PHHS) - Rwanda undertook two national post-harvest assessments in Season A and Season B of 2012. The Season A survey was administered from May 14-25, 2012 with a total of 637 national surveys. The Season B survey was administered Oct 9-17, 2012 with a total of 416 surveys (in two versions). A third pilot exercise was conducted in 9 districts with 54 farmers in Season A 2013 to verify harvest and drying loss estimates with Season B 2012 questionnaire results.

In Season A, general data were taken on environmental conditions at harvest as well as post-harvest technology use and marketing practices, very similar to data collected in 2011. Post-harvest loss estimates were made for Season A using general parameters and formatting from the African Post-Harvest Losses Information System (APHLIS).

In Season B, this assessment was expanded to gather more detailed information about practices, marketing, grain quality, and farmers' losses at several key stages of the post-harvest process.

These key stages investigated in Season B 2012 include 1) Harvesting/Field Drying, 2) Further Drying [APHLIS notes 'platform drying'], and 3) On-farm storage. This was a cross-sectional survey in which farmers recalled events and condition of grain at certain end-use points, aided by a wide range of visual cues in grain damage samples. Five visual samples of maize per enumerator were utilized, with 0, 5, 10, 20, and 30% grain damage. Loss parameters from this survey were targeted to contextualize the APHLIS parameters to the Rwandan environment and serve as better local estimators of post-harvest losses. Recognizing the imperfect nature of cross-sectional data collection for this purpose, the data at a minimum serves to identify key zones of disparity between APHLIS and MinAgri estimates to prioritize the next step of in-depth field data collection.

Both Season A and B surveys note various training courses farmers have taken, which can then be cross-tabulated with technology use and post-harvest practices to note potential influences of extension education.

The Season A 2013 pilot field validation was a physical measurement of discarded and damaged maize during the harvest/drying period. Physical measurement of losses was not possible in the Season B 2012 survey due to late survey timing. Results provide loss estimates for farmers with rainy harvest periods and farmers with dry harvest periods. The validation served to compare methodologies of simple questionnaire (2012B) vs. physical measurement with balances (2013A).

<u>Major findings for each report section are as follows:</u>

Base production, supply parameters, and purchasing

Maize is grown on 78.0% - 98.3% consolidated land primarily as a cash crop. In Season A, 86.7% of national maize grown was marketed and 83.4% was marketed in Season B. At the individual level, 75.1% of farmers sell some maize in Season A and 77.8% in Season B. Farmers generally sell maize locally,

either bringing to markets, selling directly to traders, or selling to neighbors. Cooperatives become important or dominant outlets in the South year round and Kigali in Season A.

At the provincial level, maize is stored an average of 2.9 - 4.8 months in Season A, with a national average of 4.1 months. In Season B, maize was stored between 2.7 - 3.9 months, with a national average of 3.2 months. Most marketed maize is sold within three months of harvest, the quantity considered by the APHLIS system to be "sold soon after harvest", totaling 66% of all maize sold in Season A and 89% in Season B. Farmers report saving maize for consumption as well, with an average of 22.3kg per household member in Season A and 18.9kg per member in Season B.

Nationally, 31.7% of households buy some form of maize in Season A and 45.9% in Season B. Kigali farmers are more likely to buy than any other province. Purchasing in the Eastern province is very uncommon in Season A (3.3%) but quite common in Season B (65.9%). Flour is the dominant exclusive form purchased (85.4% and 64.2%), though grain purchase (or 'both') is increases significantly in Season B.

Harvesting Conditions and Practices

Farmers experience more rain at harvest in Season A (56%) than Season B (12%). This has strong implications for post-harvest losses in the harvest and drying stages. Season B survey data go deeper into loss implications. When there is rain at harvest, 40.0% of farmers discard at least some cobs at harvest, while without rain this drops to 25.7%. Farmers in Kigali were more affected (71.4%) while Eastern province farmers had a much lower incidence (9.6%).

Season B 2012 questionnaire data reported farmers discarding a national average of 8.3% of cobs (weighted by provincial production). Provincial averages range from 4.9% in Western Province to 12.6% in the North. When rain is present at harvest, the provincial average quantity of cobs left is consistently higher than in non-rainy conditions. Nationally weighted by provincial production, this totals 9.6% with rain at harvest and 7.8% without. These two parameters are the first utilized in "Harvest/Field Drying" contextualized APHLIS measurements.

The Season A 2013 field verification provided very different parameter estimates than the questionnaire methodology. The questionnaire method asked farmers to recall specific data several months after harvest activities in an imperfect format, while the field verification methodology brought MinAgri agents to farmers' homes to physically measure damaged and undamaged cobs with a balance. The accuracy of the physical measurement approach is much more reliable and also ultimately judged to more accurately reflect the Rwandan ground realities.

Farmers evaluating combined harvest/drying losses discarded 3.1% of maize cobs in rainy harvest zones and 0.9% in drier harvest zones. The field measurement thus drives a much different overall post-harvest loss estimate than APHLIS, as this general model provides estimates of 16.3% in rainy harvest zones and 6.4% in dry harvest zones.

Losses in the harvest/drying period in rainy harvest regions of the Northern Province at 6.3% were double the national average. Encouragingly, farmers in rainy harvest zones who received training had more than 50% lower harvest/drying losses than producers who did not receive training. This is a very

positive sign for education impact and it is recommended to focus harvest/drying education in the rainy harvest zones for maximum future impact.

Drying Practices

Farmers use diverse mechanisms to dry maize, varying greatly by geographic region. In Season A and B, the most common methods were suspended (35% and 28%), on a plastic sheet (30% and 20%), and drying rack or covered platform (27% and 18%). When there is no rain at harvest, farmers report almost no losses (0.4%), however when there is rain this rises considerably (3.7%). These parameters are taken for use in the "Platform Drying" part of the APHLIS model. At the provincial level, this ranges from 0.0% reported losses to 8.3%.

Maize Shelling

Shelling practices remain diverse as well. In both seasons, about half of Rwandan producers use only their hands. This rate is consistently high in the Western Province (76.6% and 90%). Producers receiving training were much more likely to use a mechanical hand sheller (16% compared to 36% in Season A, and 11% to 30% in Season B). Training seems to provide exposure and/or facilitated access to this technology. There is some, albeit weak, evidence that farmers engage less in "beating to shell in sack", with 7% compared to 3% in Season A and 2% compared to 1% in Season B.

Maize Storage

Maize is more likely to be stored as grain vs. cob when destined for the market in both seasons (83 and 94.6% vs. 72.9 and 81.5%). This corresponds with higher usage of polypropylene sacks for storage. Season B data delves deeper into storage practices. Polypropylene sacks are generally used "new", however, for both consumed and marketed maize storage, there are groups in the South (18% and 8.2%) and West (13% and 6.5%) who re-use old untreated sacks. This may be an opportunity for further extension education. As well, rates of palette use are consistently lower in the Northern and Western province than others – not just associated with suspended storage. That stated, the North and West are the dominant locations for suspended maize cob storage.

The majority of Rwandan farmers do not use storage protectants. National rates of application are 44.5% in Season A and 38.3% in Season B. This varies tremendously by province and season. In Season A, 80.2% of Eastern province farmers applied while 18.5% did so in the Western province. In Season B, 58.1% of Eastern farmers applied while only 16.7% did in the West. In Season A, farmers receiving training in pesticide application to stores or grain have a large and statistically significant greater application rate (80.0%) than those not receiving education (39.5%). In Season B, 37.5% with training applied while 27.3% without training applied, though the difference is not statistically significant. Training seems particularly responsive in the Western province, where, in Season A, 100% of farmers receiving training applied while only 13.1% without training applied protectants. Malathion is by far the most common storage protectant used, employed by 45.3% and 65.8% of farmers in Season A and B who applied some form of protectant. As Malathion is referred to as "DDT" by many untrained farmers, this market share may be as high as 66.8% in Season A and 75.7% in Season B. Insecticide application may be associated with a slight increase in storage before sale, however less than one week.

This study found storage losses in maize which were higher than those predicted by the APHLIS model. To estimate physical (weight) losses, visual samples were used with nine possible quality specifications (including "between" displayed sample levels). While APHLIS predicts zero losses in less than four months of storage, the weighted national average was 4.9% losses in on-farm storage. This parameter is the third and final used in a revised format of the APHLIS losses model.

Within this 4.9% loss, rats composed 2.9%, while insects averaged 1.3% and molds 0.7%. The highest storage losses reported are in Northern (7.6%) and Western (6.2%) provinces, driven primarily by rats. This highlights an important point, as rats rarely receive attention in post-harvest extension education programs. The South reported the highest losses from insects (1.9%), followed by Western province (1.5%). Kigali province actually did report no losses in storage, possibly driven by quick sales of most of the harvest and use of storage protectants. Average damage rates in sold maize (1.1%) were considerably lower than average rates for consumed maize (4.8%). This undoubtedly reflects very rapid sales. There is some evidence that use of insecticide is related to lower damage rates in sold maize (2.0% vs. 0.5%) and consumed maize (5.7% vs. 2.5%).

Extrapolating loss rates with national production, it is estimated that the economic impact of maize storage losses in Season B 2012 alone are between RWF 1.78 – 2.58 Billion. While considerable variance is present, farmers receiving storage training had 28.6% lower storage losses. This reflects a potential benefit of storage education in Season B 2012 of about RWF 300 Million.

Training

About half of farmers reported education in harvesting (50.8 and 49.7%), drying (50.0 and 45.9%), and shelling (42.3 and 41.0%). This average masks great provincial diversity, however, as few to no producers in Kigali province report receiving training. While populations and production are small in Kigali, this is also the province with the highest reported incidence of rain in harvest periods and highest APHLIS loss estimates, and may be a point of attention for education regimens.

Training is particularly low in use of pesticides on grain (11.3 and 11.7%) and use of pesticides on structures (10.2 and 6.1%). As rates of storage protectant application were a significant 40% higher among trained farmers, this could serve as a useful point of attention.

APHLIS Post-Harvest Losses Calculation and comparison with new MinAgri parameter estimates

The national average post-harvest losses, according to the APHLIS system, were 21.1% in Season A and 17.5% in Season B. The increased losses in Season A are driven by higher incidence of rain at harvest as well as breaking the "4 month" storage threshold, at which point modeled APHLIS storage losses increase from 0% to 2.6%. The total APHLIS-calculated losses for the year 2012 is 19.8%.

Parameters from the most accurate MinAgri physical loss evaluations suggest significantly lower losses. With field-measured harvest/drying losses and storage losses assessed through questionnaires and grain samples as visual aids, maize post-harvest losses for Season B 2012 are estimated at 9.1% (±.1.0%). When APHLIS predicts 16.3% total losses for areas without rain at harvest, contextualized Rwandan parameters predict 8.8% (±0.9%). When APHLIS predicts 25.0% for rainy harvest regions,

contextualized parameters predict 10.8% (±1.7%). Lower Rwandan estimations are primarily driven by lower losses in the harvest and drying periods.

Table i-1: APHLIS vs. MinAgri parameter comparison for 2012 National Post-Harvest Losses

Post-Harvest Loss Parameter	APHLIS		Only MinAgri / PHHS Season B 2012 Survey		Proposed Correction With Field Verification of Harvest/Drying Loss Parameter + Season B 2012 Survey Storage Loss Parameter	
	No Rain	Rain at Harvest	No Rain	Rain at Harvest	No Rain	Rain at Harvest
Harvesting/ field drying	6.4%	16.3%	7.8% (1.3)	9.6% (2.5)	0.9% (0.2)	3.1% (1.0)
'Platform' Drying	4.0%	4.0%	0.4% (0.2)	3.7% (2.3)		
Threshing and Shelling	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
Transport to farm	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
Farm storage	0.0%	0.0%	4.9% (0.9)	4.9% (0.9)	4.9% (0.9)	4.9% (0.9)
Transport to market	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Market storage	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Increment Total*	16.3%	25.0%	15.4% (2.8)	19.8% (9.2)	8.8% (0.9)	10.8% (1.7)
Season B 2012 Total+	17.5%		15.9% (± 3.6%)		9.1% (1.0)	

(standard errors)

*The total is not simply the summation of parameters, but a continual adjustment process based on remaining grain stocks after each stage.

+ With weighted regions of 'rain at harvest'

SAMPLING SUMMARY

Farmers in 2012A were randomly selected from Ministry of Statistics household records.

Farmers in 2012B were also randomly selected from Ministry of Statistics household records. Questionnaires in 2012B have been divided into Version 1, to concentrate on the pre-storage post harvest steps, and Version 2 which covered storage and beyond. The reason for this division was the level of detail desired, considered unreasonable for each farmer to respond for the entire post-harvest process. The number of questionnaires answered varies according to province. In 2012A, the Northern Province had the highest number of questionnaires (210/637) and in 2012B the Southern Province had the highest number 69/209 questionnaires of Version 1 and 70/207 questionnaires of Version 2.

The questions covered mainly the quantity of maize harvested, sold and consumed; the postharvest techniques used in different postharvest steps; where and when maize was marketed; what and which quantity of protectants used; the training received and what kind of government support received for postharvest handling operations.

The pilot field verification of harvest losses conducted in Season A 2013 had a total of 54 farmers, six randomly selected farmers from nine randomly selected districts within participants of the Season A 2012 post-harvest questionnaire.

Table 0-1: Geographic distribution of Surveys

Province	Maize: Season A 2012			Maize: Season B 2012					
				Survey Version 1: Harvest, Drying, Shelling			Survey Version 2: Storage and Marketing		
	No. districts	No. villages	No. surveys	No. districts	No. villages	No. surveys	No. districts	No. villages	No. surveys
East	5	40	91	6	32	52	6	36	44
Kigali	3	23	59	2	7	14	3	8	16
North	5	98	210	5	27	33	5	22	29
South	7	70	129	8	44	69	8	40	70
West	7	77	148	6	21	41	7	33	48
Total	27	308	637	27	131	209	29	139	207

Province	Maize: Field Verification for Harvest Losses, Season B 2013
	No. surveys
East	12
Kigali	6
North	12
South	12
West	12
Total	54

KEY BASE PRODUCTION AND SUPPLY PARAMETERS

Nationally, average area of maize cultivation is quite similar for Season A and B, at 0.73 and 0.67 hectares, respectively. Almost all farmers are cultivating on consolidated land. In Season A, only the Eastern and Western province drops below 80% consolidated land production. In Season B, only Kigali province drops below 90%. Green maize is harvested by nearly half of national farmers in both seasons, though farmers may have an incentive to under-report this quantity due to official restrictions. However, reported green maize harvested only composes a small percentage of total maize production, at 1.3 and 0.9 bags in Seasons A and B. Average households successfully harvested 1,014kg in Season A with highest productions per household in Eastern and Kigali province. In the comparatively minor Season B, households harvested 725kg, with the greatest production in Eastern province. Reported yields averaged 1,504kg/ha in 1,344kg/ha in Seasons A and B, respectively. Notable outliers in provincial yield data are Kigali province in Season A, reporting 3,050kg/Ha, and Western province in Season B, reporting 699kg/Ha.

Maize in Rwanda is largely grown as a cash crop. In Season A, households sold or intended to sell 87% of maize production, similar to nearly 84% in Season B. About two-thirds (66%) of maize sold in Season A was sold before 3 months, the period designated by the African Post-Harvest Losses Information System (APHLIS) as "soon after harvest". In Season B, maize sold "soon after harvest" increases to 89%. Notably, maize stored for market longer than 3 months composed more than half (59.6%) of maize sold by Eastern province households and just less than half (48.6%) in Southern province in Season A. In Season B, this shrinks to 15.5% in the Eastern province and 4.3% in the Southern province.

Reported maize per person retained for consumption is similar in Seasons A and B, at 22.3kg and 18.9kg, respectively. Average storage time for all maize was 4.1 and 3.2 months in Season A and B, respectively.

Table 0-1: General Background Data -- Season A

	National	East	Kigali	North	South	West
Area of maize harvested per household (Ha/HH)	0.73	1.34	0.90	0.92	0.31	0.32
% of HH cultivating maize on consolidated land	86.8%	78.0%	98.3%	86.2%	96.9%	79.7%
% HH harvesting green maize	48.5%	8.8%	0.0%	82.9%	16.3%	69.2%
Avg. no. bags of green maize harvested (bags/HH)	1.3	0.3	-	1.6	0.7	2.3
Avg. weight of maize successfully harvested (kg/HH)	1,013.6	2,033.2	2,859.8	801.0	574.5	389.1
Avg. maize yield (kg/Ha)	1,504.1	1,601.7	3,050.1	1,160.0	1,630.5	1,555.5
Avg. total quantity of maize for market (kg)	878.4	1,846.3	2,700.5	650.6	478.1	229.8
Avg. quantity of maize sold within 3 months of harvest (kg/HH)	580.4	746.5	2,683.3	334.2	366.7	204.2
Avg. quantity maize kept for household consumption (kg/HH)	131.4	161.4	115.7	137.4	100.7	137.4
Avg. number people per HH	6.1	5.9	6.4	6.0	5.8	6.6
Avg. number months maize will be held	4.1	3.5	2.9	4.5	3.7	4.8
Avg. maize kept for consumption per person	22.3	26.5	20.3	24.3	18.9	20.6

Table 0-2: General Background Data – Season B

	National	East	Kigali	North	South	West
Area of maize harvested per household (Ha/HH)	0.67	1.12	0.78	0.67	0.47	0.53
% of HH cultivating maize on consolidated land	95.7%	97.7%	81.3%	96.4%	97.1%	95.8%
% HH harvesting green maize	48.8%	32.6%	46.2%	85.7%	27.1%	72.9%
Avg. no. bags of green maize harvested (bags/HH)	0.87	0.69	*	1.72	0.36	1.39
Avg. weight of maize successfully harvested (kg/HH)	724.62	1,652.61	824.38	877.14	328.17	340.42
Avg. maize yield (kg/Ha)	1,344.32	1,420.01	1,145.66	1,605.08	1,628.96	698.64
Avg. total quantity of maize for market (kg)	608.45	1,583.11	506.25	563.11	283.88	258.42
Avg. quantity of maize sold within 3 months of harvest (kg/HH)	541.58	1,337.89	506.25	511.68	271.56	242.79
Avg. quantity maize kept for household consumption (kg/HH)	106.94	115.91	314.33	162.86	32.63	110.73
Avg. number people per HH	5.75	6.55	4.44	6.61	4.73	6.45
Avg. number months maize will be held	3.2	3.9	3.4	2.7	2.8	3.1
Avg. maize kept for consumption per person	18.90	17.04	60.82	29.17	6.76	18.54

MAIZE PURCHASING

Households purchasing maize were slightly different between Season A and B, at 31.7% and 45.9% nationally. Figures in Kigali and the East varied widely, however, changing by season from 57.1% to 100% in Kigali and from 3.3% to 65.9% in Eastern province. Of households purchasing maize, the large majority (85.4% and 64.8% in Season A and B) only bought maize in flour form. However, about one-third of households purchasing maize (33.3% and 34.5%) in Eastern and Northern provinces only bought maize as grain in Season A. As quantities purchased in each form were not reported in this survey, making it difficult to disentangle the relative importance of grain and flour in the buying habits of this category (28.4%) of farmers purchasing maize throughout Season B.

Table 0-3: Household Purchase of Maize Season A

Season A	National	East	Kigali	North	South	West
% HH buying maize	31.7%	3.3%	57.1%	28.4%	31.5%	44.6%
Of those buying maize, form bought:						
% HH buying only flour	85.4%	66.7%	100.0%	62.1%	97.4%	92.4%
% HH buying only grain	13.6%	33.3%	-	34.5%	2.6%	7.6%
% HH buying both grain and flour	1.0%	-	-	3.4%	-	-

Table 0-4: Household Purchase of Maize Season B

Season B	National	East	Kigali	North	South	West
% HH buying maize	45.9%	65.9%	100.0%	17.9%	27.1%	54.2%
Of those buying maize, form bought:						
% HH buying only flour	64.2%	82.8%	25.0%	60.0%	84.2%	53.8%
% HH buying only grain	7.4%	3.4%	-	20.0%	15.8%	7.7%
% HH buying both grain and flour	28.4%	13.8%	75.0%	20.0%	-	38.5%

MARKET OUTLETS

About three quarters of Rwandan farmers are marketing at least some of their maize production. Though market outlets vary in importance by province, local markets and local traders are accessed nationally by 75.8% and 68.1% of producers in Seasons A and B, respectively. Cooperative outlets are minor overall, but an important outlet for farmers in the Southern province in both seasons, as well as Kigali province in Season A. Neighbors are another minor outlet overall, with notable elevated importance in the Western province in Season A.

Table 0-5: Maize Market Outlets Season A

Season A	Selling Maize	Market Outlet						
		Co-operatives	Local market	Local trader	National trader	Neighbor	RADA	Market outside Rwanda
National	75.1%	16.3%	54.9%	20.9%	-	13.4%	4.3%	0.2%
East	83.0%	13.3%	65.3%	21.3%	-	-	-	-
Kigali	91.1%	39.2%	5.9%	54.9%	-	-	-	-
North	78.1%	0.7%	79.3%	15.2%	-	16.6%	0.7%	-
South	69.8%	36.0%	29.3%	16.0%	-	10.7%	24.0%	-
West	64.9%	14.7%	55.8%	14.7%	-	28.4%	-	1.1%

Table 0-6: Maize Market Outlets Season B

Season B	Selling Maize	Market Outlet						
		Co-operatives	Local market	Local trader	National trader	Neighbor	RADA	Market outside Rwanda
National	77.8%	28.6%	38.8%	29.3%	4.1%	6.1%	2.0%	-
East	90.9%	15.0%	42.5%	37.5%	5.0%	2.5%	-	-
Kigali	81.3%	-	100.0%	-	-	-	-	-
North	67.9%	-	50.0%	50.0%	-	16.7%	-	-
South	77.1%	64.8%	20.4%	9.3%	-	1.9%	3.7%	-
West	70.8%	3.6%	46.4%	46.4%	7.1%	14.3%	3.6%	-

HARVESTING CONDITIONS, PRACTICES, AND LOSSES

Harvest conditions, confirming common knowledge, were much wetter for farmers in Season A 2012 (56%) than Season B 2012 (12%). In Season A, rain at harvest was a particular problem for farmers in Kigali, Southern, and Western provinces. In Season B, farmers in Kigali and Western provinces had higher relative rates of rain at harvest.

The expanded loss survey for Season B allows some analysis of reported affects of rain at harvest. Estimating harvesting losses simply through the Season B questionnaire was difficult, however, requiring farmers to recall fairly precise data from a harvest period four months prior. Therefore, a pilot field-measured validation of the original farmer-reported harvest losses was conducted in Season A 2013. In this validation, "good" maize and "bad" maize were separated physically weighed with a balance by extension agents. "Bad" maize cobs were those with mold damage sufficient to simply feed animals or outright reject. This pilot yielded considerably different results than original Season B questionnaire results regarding losses with and without rainy harvest conditions. With precise physical measurements at the time of harvest, this is ultimately judged to be a much more accurate report of harvest losses.

Table 0-1: Comparison of Harvest Loss Assessment Methods in Season B 2012 and Pilot Field Verification in Season A 2013

	Season B 2012 PHL Questionnaire: "Harvest and Drying" Version	**Season A 2013 (Pilot) Field Verification**
# of Farmers Surveyed	209	54
# of Districts Surveyed	27	9
Average Surveys Per District	7.7	6
Method Employed	Questionnaire only, due to the survey implementation in October 2012 and harvest periods ending by July/August. Farmers asked to recall: 1) Average # of cobs per stalk 2) Of 10 stalks, # of cobs discarded in the harvest period	Randomly selected farmers (drawn from Season A 2012 sample) were provided with many sacks before harvest and requested to separate "good" and "bad" cobs at the point where pre-shelling selection occurs (during harvest, before drying, or after drying). Post-Harvest Task Force agents visited farmer residences after selection occurred and physically weighed the "good" maize, "bad" maize destined for animals, and "bad" maize to be discarded.

Comments	Recall data for losses were much higher than MinAgri field experience suggested would be reasonable. While recall data is certainly imperfect, this method was the only option at the survey implementation period. Verification through direct field measurement was decided to compare with recall data.	Direct field measurement of harvest losses is a much more precise way to approach harvest losses. Delay in reporting of initial survey results resulted from this verification since the harvest period for Season A extends into April, however this appears justified since this methodology is much more trustworthy. A pilot to trial the methodology was implemented since this was a new methodology. A more comprehensive sample will be taken in the future when deemed necessary.

SEASON B 2012 QUESTIONNAIRE HARVEST LOSS RESULTS

Two metrics are discussed; the first is whether farmers reported leaving (not harvesting) at least some cobs in the field and the second is a reported estimation of the quantity of cobs not harvested. Reliability of reporting is thought to be much higher for the binary choice of "whether cobs were left" vs. the continuous estimation of quantities left. However, this estimation may give a reasonable indication of harvesting losses more specific to the Rwandan environment, contextualizing beyond the general East and Southern African "harvesting/field drying" figure presented by current APHLIS estimates.

Sole attention to the national average may disguise the diversity between provinces. The global average of farmers not harvesting at least some cobs was 27.3%, with much higher percentages in Kigali and Northern provinces. Very few farmers (9.6%) in Eastern report harvesting losses in Season B. However, the national average of producers leaving some cobs in the field when reporting rain at harvest was 40.0%. This contrasts with only 25.7% of producers not experiencing rain at harvest. While the sample size of those with rain at harvest (n=25) results in a wide confidence interval not producing stastically significant differences, the disparity in the results should not be overlooked.

While important, rain appeared to not be the only cause of losses at harvest, as in Kigali and Northern provinces 60.0% and 44.8% of producers are still reporting some harvesting losses. Interestingly and contrary to expectations, a greater percentage of Western province farmers report leaving at least some cobs in the field when there is no rain than when there was rain at harvest. However, the same Western province farmers reported removing a greater absolute percentage of cobs during rainy periods. This is one contradictory result from simple recall data which prompted calls for a verification field measurement in Season A 2013.

The second metric to evaluate post-harvest losses during the harvesting period is the quantity of cobs left in the field. Completed data on this metric was significantly lower than the binary choice of whether any cobs were left, at 46.4%. However, respondents with data indicate that, nationally, about 8.5% of cobs were not harvested. It is important to note that the national figure is adjusted by the provincial maize production weights in Season B. The highest losses in this category were in the north, where farmers estimate that 12.6% of cobs were left or discarded in the harvesting process. While some provinces show large differences in harvest losses whether rain was present or not, the weighted national averages only slightly differ. This may suggest other variables besides rain influence harvest losses, or that issues in data collection necessitate more direct and precise field measurement.

When cobs are left in the field, 61.4% of farmers simply feed their animals in the field. The remainder is left in the field to rot, with isolated cases selling as green maize.

Table 0-2: Rain incidence at harvest and farmers rejecting some cobs

Province	Season A	Season B			
	Rain at Harvest	Rain at Harvest	Leaving any cobs		
			Global average	Only if **rain**	Only if **no rain**
National	56%	12.0%	27.3%	40.0%	25.7%
East	35%	11.5%	9.6%	33.3%	6.7%
Kigali	95%	28.6%	71.4%	100.0%	60.0%
North	40%	12.1%	45.5%	50.0%	44.8%
South	67%	1.4%	23.2%	-	23.5%
West	67%	24.4%	26.8%	20.0%	29.0%

Table 0-3: Season B Harvest period expansion: Harvest/Field Losses when cobs rejected

Quantity of Cobs Left in Field, i.e. Field and Harvesting Loss	% cobs left in field	When rain at harvest: % cobs left	When no rain at harvest: % cobs left
Simple Full Survey Average	8.5%	10.6% ± 2.6%	7.9% ± 1.3%
Weighted National*	8.3%	9.6% ± 2.5%	7.8% ± 1.3%
East	9.3%	10.0%	9.0%
Kigali	6.2%	9.2%	5.0%
North	12.6%	20.0%	11.9%
South	8.7%	**	7.9%
West	4.9%	6.7%	4.5%
Blanks (no response)	*53.6%*		
*National average adjusted by provincial production		** No data in this category	

Table 0-4: Alternative uses for field rejected cobs

What Done with cobs left in field	National
Animal feed*	61.4%
Left to rot in field	36.8%
Sold later as green maize	1.8%
Blanks (no response)	0.0%

*The APHLIS model currently considers use of maize as animal feed to be a 100% loss.

SEASON A 2013 PILOT FIELD VERIFICATION RESULTS

Discriminate analysis shows important effects of rain and training on harvest losses, though increasing the sample size will increase confidence in future statements.

Rain at harvest was previously measured as "any rain at harvest". This restriction in practice was regarded as excessive, not even allowing one day of rain in a median 21 harvest days. Eleven (11) farmers had zero days of rain at harvest, while an additional five (5) farmers saw one day of rain. While zero days of rain had average losses of 1.24% ± 0.2%, one day of rain had 0.23% ± 0.23%. Combining one day of rain with the "rainy at harvest" category thus dramatically increased the variance of the "rainy" coefficients and downwardly biased the reality of rain's effect on harvest losses. Two days of rain (n=7) was much higher, at 3.66% ± 3.36%. Therefore, one day of rain was judged to not be "adverse conditions" for farmers, and only two days of rain or greater at harvest was considered "rainy" conditions.

When there are two or more rainy days in the harvesting period, average losses arrive at 3.08% ± 1.03%, which is statistically significantly higher than 0.92% ± 0.19% with one or no rainy days. Training appears to have a large effect on losses in rainy zones, as a statistically significant reduction of 3.80% ± 2.28% at the 90% confidence interval (Ha: diff>0; p=0.054). In non-rainy zones, a very slight increase in losses is seen, while this is almost surely not driven by any training and may be attributable to extremely low sample sizes in this sub-set (n=7 and n=9).

Among non-trained farmers, there is a large statistically significant difference 5.21% ± 3.47% between producers in rainy and non-rainy zones (though sub-sample size is small). When farmers are trained, the harvest loss differences are less than 1% and not statistically significant. The stark difference here suggests that vulnerable producers in rainy zones see tangible benefits from harvesting and drying extension trainings.

Table 0-5: Physical losses after harvesting and drying under different climate conditions and training: Discriminate Analysis

	Training in Harvesting/Drying	No Training in Harvesting/Drying	Total: Rain	Signif.
Two or more rainy days in harvest period	2.08% ± 0.75%	5.87% ± 3.28%	3.08% ± 1.03%	(*)
	(n=28)	(n=10)	(n=38)	
One or no rainy days in harvest period	1.25% ± 0.24%	0.67% ± 0.27%	0.92% ± 0.19%	(*)
	(n=7)	(n=9)	(n=16)	
Total: Training	1.91% ± 0.60%	3.41% ± 1.79%	2.44% ± 0.74%	(-)
	(n=35)	(n=19)	(n=54)	
Signif.	(-)	(*)	(*)	

Significant row or column difference at *90%, **95%, ***99% confidence level
(-) means no statistical significance

Results from the harvest loss verification show larger differences with the recall data. The source of these differences could be related to the manner in which the question was posed in the previous survey. The approach attempted to provide a reasonable manner for recall estimation but in practice forced a non-zero answer to be in increments of 5% loss (max of 2 cobs per stalk and the question asked "of ten stalks, how many cobs removed?"). Therefore over-estimation is possible when a farmer remembered there were "some" cobs removed. The multiple-month time lapse between the harvest and survey period no doubt compounded the difficulty for farmers to accurately estimate. Additionally, farmer rates of training were higher in the field verification than previous 2012 surveys. However, even the non-trained farmers in the verification had an average of 3.41% losses, indicating that the overall disparity is not simply due to this fact.

No questionnaire can typically replace the accuracy of field measurements. The field verification results are judged to be a much more accurate reflection of the field reality.

Further implications come from the fact that nearly all farmers reported separating "good" from "bad" cobs after drying. Only an isolated group (n=6) from Burera district of the Northern Province reported separating before drying (farmers there continue to dry for an additional month after a late harvest period, so a follow-up was not conducted for the pilot). Since the field verification group by default overwhelmingly covered both "harvest" losses and "drying" losses in the same coefficient, they are presented together. When this loss exercise is continued in the future in Rwanda, it is recommended that coefficients should be presented together and farmers separating both before and after drying should receive a second data collection visit to accommodate possible additional losses.

Table 0-6: Comparison of Harvest/Drying Loss Parameter Results from Questionnaire and Field Verification

Comparison Between Studies	Questionnaire (recall) Data for Harvest Period conditions and losses		Pilot Field Verification in Season A 2013
	Season A 2012	Season B 2012	
"Rain" at Harvest	56%	12%	77%
Farmers Receiving Harvest or Drying Training	51%	50%	64.8%
Two or more days of rain in harvest period– judged proxy for "*rainy* at harvest"	-	-	70.4%
"Harvest Period" + "Drying Period" losses **with** rain(y) harvest	-	9.6% ± (2.5%) + 3.7% ± (2.3%) = 13.0% ± (11.7%)Ŧ	3.1% ± (1.0%)
"Harvest Period" + "Drying Period" losses **without** rain(y) harvest	-	7.8% ± (1.3%) + 0.4% ± (0.2%) = 8.2% ± (3.5%)	0.9% ± (0.2%)

(-) Not measured in that particular survey

Ŧ Combined losses is (Harvest Loss)+(1-Harvest Loss)*(Drying Loss). Combined standard error is $\sqrt{SE_1^2 + SE_2^2 + 2 * Cov_{b_1,b_2}}$

DRYING PRACTICES

Farmers employed many different drying methods across the country. In Season A, the most common methods were drying racks, on plastic sheets, and suspended from the house. Similarly in Season B, platforms, plastic sheets, and suspension from sticks were most popular. "Dangerous" or "sub-optimal" drying practices were not extremely common, with 'on ground without sheeting' (1%), 'outside on platform without roof' (11%), and 'suspended from sticks and uncovered' (4%). Only isolated cases in the North dried on the ground, but between 5-14% of producers throughout the provinces dried on platforms without roofs. Uncovered suspension from sticks was concentrated in the East (12%) and a small percentage in the South (4%).

Table 0-1: Drying Practices, Season A

Season A	National	East	Kigali	North	South	West
Drying floor (no sheet)	3%	2%	2%	5%	-	5%
Drying Ground	3%	-	-	9%	-	-
Drying Rack	27%	26%	-	17%	55%	26%
Drying Shelter	-	-	-	-	-	1%
On mat	3%	-	-	3%	-	7%
On plastic sheet	30%	57%	98%	14%	21%	16%
Suspended from house	35%	14%	-	53%	24%	45%
Blank (no response)	**3%**	**0%**	**9%**	**2%**	**5%**	**2%**

*Non-blank answers total to 100%

Table 0-2: Drying Practices, Season B

Season B	National	East	Kigali	North	South	West
Dried on a mat	1%	-	-	-	-	2%
On roof	1%	-	-	-	1%	-
On ground without sheeting	1%	-	-	3%	-	-
On plastic sheet	20%	21%	50%	3%	26%	10%
Outside on a platform WITH roof	18%	14%	29%	27%	3%	37%
Outside on a platform WITHOUT roof	11%	14%	14%	12%	12%	5%
In house (unspecified)	17%	16%	-	27%	4%	37%
Drying Hanging (unspecified)	2%	-	-	-	4%	-
Suspended from sticks and COVERED	28%	23%	7%	27%	45%	10%
Suspended from sticks and UNCOVERED	4%	12%	-	-	4%	-
Blank (no response)	**4%**	**17%**	**0%**	**0%**	**0%**	**0%**

*Non-blank answers total to 100%.

Table 0-3: Losses in Drying Process: Questionnaire Method

Season B Drying Losses	Global Average	No Rain at Harvest	Rain at Harvest
National*	1.0%	3.7%	0.4%
East	0.2%	0.0%	0.2%
Kigali	1.3%	4.4%	0.0%
North	1.7%	8.3%	0.7%
South	0.5%	0.0%	0.5%
West	1.5%	5.0%	0.3%

*Weighted by provincial production

MAIZE SHELLING

Shelling practices were also quite diverse and showed some variation depending on training received. In both Season A and B, about half of producers only used hands to shell. The rate was particularly high in both seasons in the West (76.6% and 90%) and, during Season B, Kigali (85.7%) and the North (75.8%).

In both Season A and B, simple hand shellers (18.2% and 18.8%) and mechanical hand shellers (24.4% and 17.4%) were the next widely reported. Among producers received training, mechanical hand sheller use increased from 16% to 36% in Season A and from 11% to 30% in Season B, the most dramatic disparity between producers trained and non-trained in shelling practices.

In Season A, some decrease in the damaging practice of "beating in sacks" is seen after training, yet the practice does persist in spite of clear advice against. It is notable that the East, North, and West show large decreases in the practice with training, yet Southern province farmers have higher percentages in trained populations. In Season B, beating in sacks is very infrequent nationally and largely isolated to the North.

Table 0-1: General Shelling Methods, Season A

Season A	National	East	Kigali	North	South	West
Beat in Sack	5.4%	3.3%	-	8.1%	6.3%	4.1%
Beat in Sack and Hand Sheller	0.2%	-	-	0.5%	-	-
Hand Sheller	18.2%	11.0%	49.1%	27.3%	14.8%	0.7%
Hand and Knife	0.2%	-	-	0.5%	-	-
Maize not shelled	0.6%	-	-	1.0%	-	1.4%
Mechanical Hand Sheller	24.4%	63.7%	-	13.4%	33.6%	16.6%
Motorized Mech Sheller	0.8%	5.5%	-	-	-	0.0%
Hands and Hand sheller	1.1%	-	-	2.9%	-	0.7%
Hands only	49.2%	16.5%	50.9%	46.4%	45.3%	76.6%
Blanks	**2%**	**0%**	**9%**	**0%**	**1%**	**2%**

Shelling Methods with Training Considered	National		East		Kigali		North		South		West	
	Tr[1]	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr
Beat in Sack	3%	7%	1%	9%	**	-	2%	11%	10%	3%	1%	7%
Beat in Sack and Hand Sheller	-	-	-	-	**	-	2%	-	-	-	-	-
Hand Sheller	16%	20%	9%	18%	**	49%	42%	21%	17%	13%	-	1%
Hand and Knife	-	-	-	-	**	-	2%	-	-	-	-	-
Maize not shelled	-	1%	-	-	**	-	-	1%	-	-	-	3%
Mechanical Hand Sheller	36%	16%	72%	36%	**	-	6%	16%	45%	24%	21%	12%
Motorized Mech. Sheller	2%	-	7%	-	**	-	-	-	-	-	-	-
Hands and Hand Sheller	3%	-	-	-	**	-	10%	-	-	-	1%	-
Hands only	40%	56%	10%	36%	**	51%	37%	50%	28%	60%	77%	76%

** no data available

[1]Tr = Training ; No Tr = No Training

Table 0-2: General Shelling Methods, Season B

Season B	National	East	Kigali	North	South	West
Beat maize with stick in sack	1.4%	2.0%	-	6.1%	-	-
Only hands	52.2%	30.0%	85.7%	75.8%	27.5%	90.2%
Only hands, beat maize with stick in sack	0.5%	-	-	3.0%	-	-
Hand shelling with ring	9.2%	16.0%	14.3%	-	10.1%	4.9%
Hand shelling (mechanical)	18.8%	44.0%	-	3.0%	23.2%	-
Mechanical Shelling (powered)	17.4%	8.0%	-	9.1%	39.1%	4.9%
Not yet shelling	0.5%	-	-	3.0%	-	-

Table 0-3: Shelling methods with training considered, Season B

Season B with training considered	National		East		Kigali		North		South		West	
	Tr[1]	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr	Tr	No Tr
Beat maize with stick in sack	1%	2%	-	6%	-	-	6%	6%	-	-	-	-
Only hands	37%	63%	31%	28%	100	85%	88%	65%	12%	42%	75%	92%
Only hands, beat maize with stick in sack	-	1%	-	-	-	-	-	6%	-	-	-	-
Hand shelling with ring	10%	8%	13%	22%	-	15%	-	-	15%	6%	-	5%
Hand shelling with rotating level	30%	11%	56%	22%	-	-	6%	-	21%	25%	-	-
Mechanical Shelling (powered)	21%	15%	-	22%	-	-	-	18%	52%	28%	25%	3%
Not yet shelling	-	1%	-	-	-	-	-	6%	-	-	-	-

[1] Tr = Training ; No Tr = No Training

MAIZE STORAGE

STORAGE FOR CONSUMED MAIZE

Maize retained for consumption purposes is largely stored as grain in Season A (72.9%) and Season B (81.5%). Cob storage is most common in the West and especially the North in both seasons. This correlates strongly with, but is not isolated to, the practice of storing suspended cobs in the roof of the house.

Grain form storage is generally in tandem with polypropylene (PP) sacks or jute bags, which are used by 83.9% and 90% of farmers in seasons A and B, respectively. In Season B, more in-depth information was gathered on PP sack quality. About 81% of farmers using PP sacks used new bags, ranging provincially from 67-100%. In the South and West, 18% and 13% of producers (respectively) used old, possibly contaminated, sacks without washing or pesticide treatment. Use of pallets was also wide spread, with lowest rates in the North and West. Much of non-use of pallets is simply related to practices of cob suspension from roofs; however, there are some cases where jute and PP sacks are utilized without elevation from the ground.

Table 0-1: Maize form in storage, Season A (consumed)

Season A	National	East	Kigali	North	South	West
Cobs with sheath	8.2%	12.2%	2.4%	5.5%	11.3%	9.0%
Cobs without sheath	18.3%	-	-	30.5%	10.4%	23.4%
Flour	0.3%	-	-	1.0%	-	-
Flour and Grain	0.2%	-	-	0.5%	-	-
Grain	72.9%	87.8%	97.6%	62.5%	78.3%	67.6%

Table 0-2: Maize form in storage, Season B (consumed)

Stored Grain Form	National	East	Kigali	North	South	West
Cobs with sheath	2.1%	-	-	3.7%	-	4.3%
Cobs without sheath	14.4%	3.2%	-	51.9%	3.6%	10.6%
Cobs without sheath, grain	1.4%	3.2%	-	3.7%	-	-
Grain	81.5%	93.5%	92.3%	40.7%	96.4%	85.1%

Table 0-3: Storage Containers, Season A (consumed)

Season A	National	East	Kigali	North	South	West
Baskets	4.2%	1.3%	-	1.5%	6.1%	9.3%
Jerry Cans	2.1%	-	-	-	-	8.6%
Jute sacks	7.7%	28.2%	21.4%	0.5%	10.5%	-
Pitcher	0.2%	-	-	-	-	0.7%
On Ground	0.2%	-	-	-	-	0.7%
Placed on roof	0.3%	-	-	-	-	1.4%
PP sacks	76.2%	70.5%	78.6%	81.8%	81.6%	66.4%
PP sacks, woven big basket	0.2%	-	-	0.5%	-	-
Pot	0.2%	-	-	-	-	0.7%
Hung on Rack	0.2%	-	-	-	-	0.7%
Suspended in House	8.4%	-	-	15.2%	1.8%	11.4%
Suspended in house, PP sacks	0.2%	-	-	0.5%	-	-

Table 0-4: Storage Containers, Season B (consumed)

Season B-- Storage Method	National	East	Kigali	North	South	West
Jerry Cans	2%	-	-	-	-	6%
None	1%	-	-	-	-	4%
On the ground	1%	-	-	5%	-	-
Polypropylene Sacks	90%	97%	100%	75%	100%	83%
Polypropylene Sacks, baskets	1%	3%	-	-	-	-
Suspended in house	5%	-	-	20%	-	6%

Table 0-5: Polypropylene sack type, Season B (consumed)

HH Consumption: If using sacks, what was the condition	National	East	Kigali	North	South	West
new sacks	81%	100%	100%	91%	71%	67%
old sacks washed	3%	-	-	-	11%	-
old sacks, treated with pesticide	7%	-	-	-	-	21%
old sacks, untreated	9%	-	-	-	18%	13%
old sacks, untreated and new sacks	1%	-	-	9%	-	-

Table 0-6: Use of palettes (consumed)

Palletting (consumed)	Season A	Season B
National	90.4%	81.8%
East	97.5%	84.8%
Kigali	100.0%	100.0%
North	92.6%	58.3%
South	93.0%	86.4%
West	78.6%	78.6%

STORAGE OF MARKETED MAIZE

Maize stored for marketing purposes was stored as grain at slightly higher rates, at 83% in Season A and 94.6% in Season B. Storage in PP and jute sacks is similarly higher, at 90.5% and 95%. For producers storing in PP sacks, provincial "new sacks" use averages 77.4-100% with a national rate of 89.2%. Use of untreated and unwashed old sacks is found in low levels in the East (3.0%), North (7.1%), South (8.2%) and West (6.5%).

Table 0-7: Maize form in Storage, Season A (sold)

Season A	National	East	Kigali	North	South	West
Cobs (unspecified)	17%	-	-	22%	11%	34%
Grain	83%	100%	100%	78%	89%	66%

Table 0-8: Maize form in storage, Season B (sold)

Season B	National	East	Kigali	North	South	West
Cobs with sheath	0.7%	-	-	-	-	2.9%
Cobs without sheath	4.1%	-	-	25.0%	-	5.7%
Cobs without sheath, grain	-	-	-	-	-	-
Grain	94.6%	100.0%	100.0%	68.8%	100.0%	91.4%
Cobs (unspecified)	0.7%	-	-	6.3%	-	-

Table 0-9: Storage Methods, Season A (sold)

Season A	National	East	Kigali	North	South	West
Baskets	3.1%	-	-	-	5.9%	9.0%
Jerry Cans	1.0%	-	-	-	1.0%	4.0%
Jute sacks	8.9%	26.1%	23.4%	-	13.9%	-
Pitcher	0.2%	-	-	-	-	1.0%
On Ground	0.2%	-	-	-	-	1.0%
Placed on roof	0.2%	-	-	-	-	1.0%
PP sacks	81.4%	73.9%	76.6%	91.7%	79.2%	74.0%
Hung on Rack	0.2%	-	-	-	-	1.0%
Suspended in House	3.1%	-	-	3.6%	-	9.0%
Suspended in house, PP sacks	1.6%	-	-	4.8%	-	-

Table 0-10: Storage methods, Season B (sold)

Season B	National	East	Kigali	North	South	West
Jerry Cans	1%	-	-	-	-	3%
Jute Cans	1%	-	-	-	-	3%
None	2%	-	-	-	-	8%
Polypropylene Sacks	94%	100%	100%	93%	100%	82%
Pot	1%	-	-	-	-	3%
Suspended by house	1%	-	-	7%	-	-
Tank	1%	-	-	-	-	3%

Table 0-11: Polypropylene Sack type, Season B (sold)

For Sale: If using sacks, what was the condition	National	East	Kigali	North	South	West
new sacks	89.2%	97.0%	100.0%	85.7%	91.8%	77.4%
old sacks washed	-	-	-	-	-	-
old sacks, treated with pesticide	3.8%	-	-	-	-	16.1%
old sacks, untreated	6.2%	3.0%	-	7.1%	8.2%	6.5%
old sacks, untreated and new sacks	0.8%	-	-	7.1%	-	-

Table 0-12: Use of palettes (sold)

Palletting (SOLD maize)	Season A	Season B
National	80.9%	85.9%
East	100.0%	93.1%
Kigali	100.0%	100.0%
North	71.3%	66.7%
South	85.0%	87.5%
West	73.3%	85.7%

PROTECTANT USE IN STORAGE

Nationally, the rate of protectant application, chemical or otherwise, was 44.5% in Season A and 38.3% in Season B. In both Season A and B, the Western province had the lowest levels of application at 18.5% and 16.7%, respectively. In Season B, the North was similarly low. In contrast, rates of application are higher in Eastern province. This region of lower elevation has a warmer climate which is generally related to greater storage pest threat.

Among those applying protectants, Malathion dominates the storage protection regimen at 45.3% and 65.8% in Seasons A and B. Many times farmers use Malathion but do not know the proper name of the chemical, confusion which was recorded separately in this survey. Inclusion of unknown chemicals could potentially increase Malathion up to 69.1% and 75.4% in Seasons A and B. Kelorine has an appreciable market presence in the North, while SuperGuard use is generally isolated to Kigali province in both seasons. Natural storage protectant use is rare, under 4%, and includes black pepper and ash.

It is important to note that training is particularly low for pesticide treatment of grain and stores, between 6.7 and 11.1% nationally (discussed in detail in training section). Much higher education rates are found in Eastern province than any other (which may be a natural response to greater relative need), while no respondents from Kigali province had received training in this area.

There is also some evidence that insecticide application is related to longer storage before marketing, though the difference is slight and not stastically significant. This suggests that insect threat may be only one of several factors which would limit storage period before sale (i.e. credit constraints).

It appears training in this subject area is important and related to higher application rates. Training would also certainly contribute to more effective and possibly safer application procedures. In Season A, there is a stastically significant 40.5% difference between pesticide application rates of farmers receiving and not receiving insecticide training[1]. While there is a 10.2% difference in national application rates in Season B, it is not statistically significant and provinces differences are more ambiguous.

Table 0-13: Use of storage protectants [including training], Season A

Season A Use of Storage Protectants	Trained on pesticide with maize grain	Protectant use (All farmers)	Use when receiving training in pesticide	Use with no training
National	11.3%	44.5%	80.0%	39.5%
East	34.1%	80.2%	93.5%	72.7%
Kigali	0.0%	67.3%	n/a	67.3%
North	11.0%	42.8%	64.0%	39.9%
South	8.5%	44.0%	60.0%	42.6%
West	4.7%	18.5%	100.0%	13.1%

[1] While the difference is consistent in the provinces during Season A, due to low training rates it is not possible to conclude statistical significance for application rate differences in provincial trained/non-trained respondents.

Table 0-14: Use of storage protectants [including training], Season B

Season B Use of Storage Protectants	Trained on pesticide with maize grain	Protectant use (All farmers)	Use when receiving training in pesticide	Use with no training
National	11.7%	38.3%	37.5%	27.3%
East	8.3%	58.1%	50.0%	58.5%
Kigali	0.0%	50.0%	n/a	50.0%
North	24.7%	25.0%	37.5%	20.0%
South	13.4%	44.3%	42.9%	44.4%
West	9.0%	16.7%	28.6%	14.6%

Table 0-15: Storage Protectants Specified, Season A

Season A	National	East	Kigali	North	South	West
Malathion	45.3%	60.9%	5.7%	28.7%	68.5%	70.0%
Unknown white powder	23.8%	18.8%	31.4%	28.7%	24.1%	5.0%
Metiano	0.8%	1.4%	-	1.1%	-	-
Actellic	4.9%	13.0%	-	4.6%	-	-
Kelorine	9.4%	2.9%	-	26.4%	-	-
Phostoxin	0.8%	2.9%	-	-	-	-
SuperGuard	7.5%	-	57.1%	-	-	-
Ikinini	0.8%	-	5.7%	-	-	-
Skana	1.9%	-	-	5.7%	-	-
Thiod	0.4%	-	-	1.1%	-	-
Ngirire	0.4%	-	-	-	-	5.0%
Pyrethrum and Sikombe	0.4%	-	-	-	-	5.0%
Sikombe	0.4%	-	-	-	-	5.0%
Pepper and ash	3.4%	-	-	3.4%	7.4%	10.0%
Blanks in farmers using protectants	**3%**	**0%**	**2%**	**3%**	**3%**	**5%**

***Non-blank sum to 100%**

Table 0-16: Storage Protectants Specified, Season B

Season B	National	East	Kigali	North	South	West
Malathion	65.8%	45.0%	-	57.1%	100.0%	50.0%
Actellic	-	-	-	-	-	-
Unknown chemical	9.6%	20.0%	14.3%	28.6%	-	-
Kelorine	4.1%	10.0%	-	14.3%	-	-
Super Skana	4.1%	15.0%	-	-	-	-
Durspan	1.4%	5.0%	-	-	-	-
D6	1.4%	5.0%	-	-	-	-
Super Guard	8.2%	-	85.7%	-	-	-
Simikombi	2.7%	-	-	-	-	25.0%
Natural: (unspecified)	2.7%	-	-	-	-	25.0%

Table 0-17: Season B: Marketing of Maize (timing, marketed before survey period)

Percent Marketed After (weeks)	**Total**	**Using Insecticide**	**Not Using Insecticide**
2	9%	7%	12%
4	40%	35%	48%
6	19%	22%	13%
8	23%	27%	16%
10	5%	3%	9%
12	2%	3%	2%
14	2%	3%	0%
Season B: Avg. weeks before marketing	5.8	6.1	5.4

STORAGE LOSSES (SEASON B ONLY)

Storage losses can be measured in dry weight loss (quantity loss) and the percentage of maize grains damaged (quality loss). Both are important metrics and have been quantitatively linked in academic literature (Holst, Meikle, and Markham, 2000). To estimate storage losses, visual scale samples were utilized to identify grain quality at each end use (consumption, sale, or grain state in storage at time of survey). Visual scales have been used in some exemplary postharvest losses research to decrease the reliance on farmer quantification, which is generally poor (Adams and Hartman, 1977). Visual scale samples ranged from 0%, 5%, 10%, 20%, and 30% grain damage, as well as quality "in-between" each sample. Through conversion factors in Holst, Meikle, and Markham (2000), these levels of grain damage constitute 0%, 1.0%, 2.1%, 4.5%, and 7.1% dry weight loss.

Rats appear to be the largest cause of storage losses at 2.9% nationally, with particularly high levels of concern in Northern and Western provinces. Insect losses only exceeded rat losses in the Southern province. Mold in storage appear to be a relatively isolated issue in the North and West, nationally averaging 0.7%. Insect losses are estimated nationally at 1.3%, though this might be a slight underestimation as a few months remained in the storage period at the time of the survey. With low to zero stock levels generally found, however, the difference is unlikely to be high.

Table 0-18: Storage Losses and components, Season B

Est. TOTAL dry weight storage losses (quantity)	Est. Total Storage Losses	By Individual Components		
		Insects	Molds	Rats
National	4.9%	1.3%	0.7%	2.9%
East	2.4%	1.1%	0.0%	1.3%
Kigali	0.0%	0.0%	0.0%	0.0%
North	7.6%	0.7%	2.0%	4.9%
South	2.7%	1.9%	0.0%	0.8%
West	6.2%	1.5%	0.8%	3.9%

While economic losses at this time are too difficult to estimate for the whole post-harvest system, farm storage losses, evaluated at post-storage October 2012 (survey period) average prices, show national storage losses between RWF 1.7 – 2.6 billion. More conservative economic estimates at September 2012 prices show very little difference. This is caused by rats, insects, and molds. As extension material currently focuses more on insects and molds, greater inclusion of rat prevention strategies will be very beneficial to reducing storage losses. Additionally, greater mold storage losses in the North due to wet conditions pose a greater challenge to storage training for loss reduction, which should be considered in promotion of grain vs. green maize form consumption and marketing.

Table 0-19: Season B 2012 Maize Storage Economic Loss Estimates

Region	Some Training in Storage	By Individual Components			Est. Total Farm Storage Losses	Est. Total Quantity Loss (MT)	Est. Economic Loss (Oct'12, RWF)	Est. Economic Loss (Sep'12, RWF)
		Insects	Molds	Rats				
National	34.3%	1.3%	0.7%	2.9%	4.9%	8,166	2,178,244,878 (±400,085,794)	2,121,887,878 (±389,734,431)
East	56.8%	1.1%	0.0%	1.3%	2.4%	1,066	266,659,329	229,372,758
Kigali	6.3%	0.0%	0.0%	0.0%	0.0%	0	0	0
North	64.3%	0.7%	2.0%	4.9%	7.6%	2,842	745,144,810	742,119,925
South	18.6%	1.9%	0.0%	0.8%	2.7%	629	166,456,058	156,400,306
West	29.2%	1.5%	0.8%	3.9%	6.2%	3,701	999,984,681	993,995,367

Training in some realm of storage, received by 34.3% of farmers, reduced losses from 5.60% (±1.3) to 4.03% (±1.2) storage losses. While not statistically significant, this could translate to a roughly 300M RWF benefit just from storage training for Season B alone.

Table 0-20: Season B 2012 Maize Storage Training Benefit Estimation

National (Seas. B)	Farmers trained in storage	Storage losses if trained	Storage losses if not trained	Economic losses if no farmers trained (Oct prc, RWF)	National benefit with storage training (Oct prc, RWF)	Economic losses if no farmers trained (Sep prc, RWF)	National benefit with storage training (Sep prc, RWF)
	34.3%	4.03% (±1.2)	5.60% (±1.3)	2,489,422,718 (±577,901,702)	311,177,840	2,425,014,236 (±562,949,733)	303,126,358

*Estimates not statistically significant and primarily meant to illustrate process for determining benefit

Comparisons with the Tropical Savanna small-holder "Farm Storage" section of the APHLIS model show this study's estimates are higher than averages of other sub-Saharan African studies (used to compute APHLIS estimates). This study strongly suggests through visual scale measurements that a non-zero loss estimate is more appropriate for Rwanda's average 3.2 months of storage.

Overall, this suggests storage losses are much higher than the APHLIS model would predict. However, estimates of non-rat storage losses average nationally at 2.0%, which is much closer to the predicted four (4) month APHLIS storage loss.

Table 0-21: APHLIS specifications for storage losses with respect to time stored

APHLIS Model Specification in Maize "Farm Storage"*	APHLIS Est. Total Storage Losses	MinAgri Survey (avg. 3.2 mo. Storage)
Avg. Storage < 4 months	0.0%	4.9%
Avg. Storage =/> 4 mo and < 7 mo	2.6%	**
Avg. Storage =/> 7 mo	5.3%	**

*Specifying Rwanda's absence of the Larger Grain Borer (Prostephanus truncatus),
**Insufficient data due to short storage times and timing of survey at roughly 4 months of storage
a particularly destructive grain storage pest in many surrounding countries.
Source: Downloadable APHLIS Post-Harvest Losses Calculator

Storage losses from insects were computed through visual scales with unique pre-coded "% grain damage" levels. Broken down by storage losses for each end-use of grain, damage levels in household consumed maize are much higher than maize previously sold. The very low average of grain damage in marketed maize is most likely due to an average storage period of 5.4 weeks, with nearly 50% of maize sold within one month and 90% within two months. Damage rates were four times higher in untreated marketed maize than treated, but the absolute difference is small.

Consumed grain has a national average damage rate (weighted by provincial production) of 4.8%. The damage rate is twice as high in untreated maize than treated. In the North, South, and West there is a particularly high difference in damage rates with respect to treatment use. Grain remaining in house was evaluated by the MinAgri extension agent rather than the farmer only. This grain was not specified to be for consumption or sale, as future use may be unpredictable (or both uses from same bag). Global loss rates compare closely with consumed maize loss rates, however provincial estimates are much more ambiguous between treatment use.

Table 0-22: Maize damage level, previously marketed grain

Est. Maize Damage Levels (not weight loss) of PREVIOUSLY MARKETED GRAIN	Total: Damage Level	Total: Derived Weight Loss
Total	1.1%	0.22%
Farmers Using Insecticide	0.5%	0.10%
Farmers Not Using Insecticide	2.0%	0.41%

Table 0-23: Maize damage level, previously consumed grain

Est. Maize Grain Damage Levels (not weight losses) of PREVIOUSLY CONSUMED GRAIN	Damage Rates			Derived Est. Weight Loss		
	Total	Farmers Using Insecticide	Farmers Not Using Insecticide	Total	Farmers Using Insecticide	Farmers Not Using Insecticide
National	4.8%	2.5%	5.7%	0.98%	0.51%	1.18%
East	4.2%	3.7%	5.0%	0.86%	0.76%	1.03%
Kigali	0.0%	0.0%	0.0%	0%	0%	0%
North	2.4%	0.4%	3.1%	0.49%	0.08%	0.63%
South	5.9%	0.8%	6.7%	1.22%	0.16%	1.39%
West	6.6%	2.5%	7.1%	1.37%	0.51%	1.48%

Table 0-24: Maize damage level, grain remaining in home

Est. Maize Grain Damage Levels (not weight losses) of REMAINING GRAIN IN HOUSE	Damage Rates			Derived Est. Weight Loss		
	Total	Farmers Using Insecticide	Farmers Not Using Insecticide	Total	Farmers Using Insecticide	Farmers Not Using Insecticide
National	4.7%	4.2%	4.9%	0.97%	0.86%	1.01%
East	5.4%	6.1%	4.6%	1.12%	1.26%	0.95%
Kigali	n/a	n/a	n/a	n/a	n/a	n/a
North	2.5%	1.9%	2.8%	0.51%	0.39%	0.57%
South	4.1%	0.8%	4.8%	0.84%	0.16%	0.98%
West	6.0%	5.0%	6.3%	1.24%	1.03%	1.31%

TRAINING BY SUBJECT AND PROVINCE

Roughly half of Rwandan farmers have received some form of post-harvest training. Provincial rates of training are slightly ambiguous between respondents of each season, but consistently show higher rates of training in the East. Training rates for each link in the post-harvest process are roughly similar for Seasons A and B respondents at the national level. For both seasons, the most frequently reported training areas are in harvesting (50.8 and 49.7%), drying (50.0% and 45.9%), and shelling (42.3% and 41.0%). Less frequently reported training are in "use of pesticide on maize grain" (11.3% and 11.7%), "use of pesticide on store structures" (10.2% and 6.1%), and transport from store to market (9.4% and 7.4%).

Table 0-1: Training received, Season A 2012

Season A	Harvesting	Drying	Shelling	Transport field to store	Good types of store	Good storage hygiene	Use of pesticide on maize grain	Use of pesticide on store structures	Sorting to improve quality	Transport from store to market
National	50.8%	50.0%	42.3%	16.1%	26.4%	22.6%	11.3%	10.2%	22.0%	9.4%
East	79.1%	79.1%	75.8%	48.4%	47.3%	42.9%	34.1%	34.1%	35.2%	34.1%
Kigali	13.8%	-	-	-	-	-	-	-	-	-
North	34.8%	34.8%	29.5%	7.1%	32.4%	28.6%	11.0%	9.0%	25.7%	7.6%
South	68.2%	69.0%	46.5%	13.3%	20.2%	16.3%	8.5%	7.8%	9.3%	7.8%
West	55.4%	56.8%	52.7%	17.6%	20.9%	16.2%	4.7%	3.4%	28.4%	2.0%

Table 0-2: Training received, Season B 2012

Season B	Harvesting	Drying	Shelling	Transport field to store	Good types of store	Good storage hygiene	Use of pesticide on maize grain	Use of pesticide on store structures	Sorting to improve quality	Transport from store to market
N'nl	49.7%	45.9%	41.0%	22.8%	26.1%	26.0%	11.7%	6.1%	24.1%	7.4%
East	70.8%	67.7%	67.7%	20.8%	28.1%	42.7%	8.3%	5.2%	16.7%	6.3%
Kigali	33.3%	20.0%	13.3%	-	3.3%	-	-	-	-	-
North	52.5%	52.5%	49.2%	22.9%	41.1%	31.2%	24.7%	11.5%	29.7%	6.6%
South	45.3%	45.3%	40.5%	40.0%	23.0%	22.8%	13.4%	7.9%	30.9%	12.7%
West	33.7%	24.7%	14.6%	9.0%	25.8%	19.1%	9.0%	4.5%	27.0%	5.6%

APHLIS POST HARVEST LOSSES

Losses are calculated using the African Post Harvest Losses Information system, a general modeling tool for East and Southern Africa developed by the National Research Institute (NRI). The model functions as a meta-analysis of a wide range of post-harvest losses studies across Africa. Unfortunately, no parameter-contributing studies have yet been produced in Rwanda. With the absence of local data, APHLIS can provide an evidence-based estimate to inform discourse. Limitations of the model stem from its generality, as this calculator only takes into consideration three main parameters: rain at harvest, period of storage and the production marketed immediately after harvest. Therefore, individual farmer characteristics, practices, or training levels cannot be considered. In this calculation, rain at harvest is weighted by percentage incidence to avoid only a binary "yes" or "no" generalization for the province, while other parameters are held constant.

Under APHLIS specifications, Season A provincial losses range from 19.8% to 24.9%, with a national average of 20.1%. In Season B, due to significantly less incidences of rain at harvest, provincial loss estimates range from 13.8% to 17.7%. The national average in Season B is 15.4%. APHLIS estimates that the full 2012 year weighted average post-harvest losses would be 18.4%.

Table 0-1: APHLIS Losses by Province, Season A

Season A 2012	East		Kigali		North		South		West		National	
Rain at Harvest	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Production Share (MT)	6,302	6,031	3,733	325	37,180	56,899	38,994	19,555	62,424	60,943	148,633	143,753
Months Stored (Consumed And Marketed)	4.2		3.6		4.5		3.8		4.3		4.2	
Marketed "at Harvest" or within 3-months of harvest (production) %	41.6%		90.8%		42.1%		62.6%		51.3%		58.7%	
Post Harvest Loss (APHLIS) %	25.1%	16.3%	25.6%	16.8%	25.1%	16.3%	24.6%	15.7%	25.3%	16.4%	25.4%	16.6%
Season Weighted Average Loss %	20.8%		24.9%		19.8%		21.6%		20.9%		21.1%	

Table 0-2: APHLIS Losses by Province, Season B

Season B 2012	East		Kigali		North		South		West		National	
Rain at Harvest	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Production Share (MT)	5,224	39,178	531	1,328	4,533	32,861	338	22,966	14,559	45,131	25,184	141,465
Months Stored (Consumed And Marketed)	3.9		3.4		2.7		2.8		3.1		3.2	
Marketed "at Harvest" or within 3-months of harvest (production) %	81.0%		61.4%		58.3%		82.7%		71.3%		74.7%	
Post Harvest Loss (APHLIS) %	25.2%	16.4%	24.6%	15.7%	24.5%	15.6%	25.3%	16.5%	24.9%	16.1%	25.0%	16.3%
Season Weighted Average Loss %	17.4%		18.2%		16.7%		16.6%		18.2%		17.5%	

Table 0-3: APHLIS Losses By Province, Year 2012

Total APHLIS Post-Harvest Losses for 2012					
East	Kigali	North	South	West	National
18.2%	22.8%	18.9%	20.2%	20.0%	19.8%

COMPARISON OF POST-HARVEST LOSS ESTIMATES FROM APHLIS VS. MINAGRI SURVEYS

This current Season B 2012 survey attempted to gain local context for post-harvest loss parameters through farmer-reported data. The variables in question to contextualize were 1) Harvesting/Field Drying, 2) Further Drying, and 3) Farm Storage. Some study results were quite similar to APHLIS estimates, while others differed. APHLIS parameters themselves are built from averages of many study parameters, most of which vary considerably within each category. Therefore, it would not be unusual for this study's parameters to deviate somewhat from APHLIS "average" parameter estimates.

The APHLIS parameter for "Harvesting/Field Drying" with and without 'rain at harvest' comes from a Swaziland study in the early 1990s (Rick Hodges, personal communication, 2012). MinAgri-determined parameters are slightly higher than APHLIS without rain at harvest (6.4 to 7.8%), a relative difference of 21.8% greater and an absolute difference of 1.4%. With rain at harvest, MinAgri estimates are much below APHLIS (16.3 to 9.6%), with a relative difference of 41.1% less and an absolute difference of 6.7%.

The title of 'platform drying' to describe the drying process would only apply to a select group of farmers in this sample (see drying section), however the vocabulary of APHLIS is maintained. While the MinAgri estimate with 'rain at harvest' was quite close to the APHLIS parameter, without rain there is little to no reported loss.

The APHLIS parameter "Farm Storage" simply returns zero (0.0%) losses if storage is less than four months. However, this study suggests a non-zero on-farm storage loss for an average storage period of 3.2 months; ultimately this was a national production-weighted average of 4.9%. This measurement was not just farmer-reported estimations, but also through the use of visual scales and agent evaluation of present stocks.

Overall, the end resulting "total post-harvest losses" are quite similar. Compared to APHLIS estimates, the final estimates when weighting for regions with and without 'rain at harvest' are 17.5% to 16.1%. This represents a relative difference of 8.0% and an absolute difference of 1.4%.

Notably, key parameter differences are canceled out in a slightly disguising way. This difference would be more exaggerated if there was 1) a greater instance of 'rain at harvest' [i.e. Season A], or 2) longer maize storage periods on-farm.

Interestingly with the current model format, the disparity decreases if less maize is marketed within three months of harvest. This is because less marketed maize signifies larger stores on-farm, which raises the MinAgri parameter loss estimate (since APHLIS maintains a zero 'farm storage' coefficient for less than 4 months storage).

Table 0-1: APHLIS vs. new MinAgri Parameters: Summary of Season B 2012 Physical Losses

Post-Harvest Loss Parameter	APHLIS		Only MinAgri / PHHS Season B 2012 Survey		Proposed Correction With Field Verification of Harvest/Drying Loss Parameter + Season B 2012 Survey Storage Loss Parameter	
	No Rain	Rain at Harvest	No Rain	Rain at Harvest	No Rain	Rain at Harvest
Harvesting/ field drying	6.4%	16.3%	7.8% (1.3)	9.6% (2.5)	0.9% (0.2)	3.1% (1.0)
'Platform' Drying	4.0%	4.0%	0.4% (0.2)	3.7% (2.3)		
Threshing and Shelling	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
Transport to farm	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
Farm storage	0.0%	0.0%	4.9% (0.9)	4.9% (0.9)	4.9% (0.9)	4.9% (0.9)
Transport to market	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Market storage	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Total*	16.3%	25.0%	15.4% (2.8)	19.8% (9.2)	8.8% (0.9)	10.8% (1.7)
Season B 2012 Total+	17.5%		15.9% (± 3.6%)		9.1% (± 1.0%)	

*The total is not simply the summation of parameters, but a continual adjustment process. Download the APHLIS post-harvest losses calculator online for a detailed explanation (458kb): http://www.aphlis.net/index.php?form=downloads

+ With weighted regions of 'rain at harvest

COMPARATIVE INCORPORATION OF FIELD MEASURED "HARVEST/DRYING LOSSES" TO BACK-CAST PREVIOUS SEASONS

In light of new harvest/drying and storage loss parameter estimates which have been contextualized for Rwanda, it becomes necessary to address past post-harvest loss estimations made only with general model parameters. While revised estimates are made for harvest/drying and storage (the most impactful parameters which needed Rwandan context), it should be noted that the other four APHLIS loss "categories" are still taken from the general model parameters. The revision reveals post-harvest losses which were most likely lower than previous estimates suggested.

Harvest/Drying and Storage loss parameters were chosen for verification because they have the largest impact on losses in the APHLIS model. As the remaining variables are investigated to get Rwanda-specific parameters, overall post-harvest losses will most likely continue to change. Back-casting will be an important way to track losses over time without mixing methodologies. The large difference in overall post-harvest loss estimates for Season B 2012 between methodologies, presented in Table 9.1, underscores this point.

Table 0-1: Back-casting Post-Harvest Losses with New Field Measurements

	2011 A	**2011 B**	**2012 A**	**2012 B**
Rain at Harvest (%)	65%	34%	56%	12%
Est. Post-Harvest Losses*	10.25% (1.5)	9.76% (1.3)	9.85% (1.3)	9.14% (1.1)
Total quantity reported produced (MT)	341,479	166,644	406,389	166,649
Est. total quantity lost during post-harvest (MT)**	35,000	16,264	40,029	15,231

(standard errors)

*Weighted by provincial production and rain at harvest

**Based on production estimation methodology of measuring in the field prior to harvest. If production was estimated from farmer questionnaires, then harvest and drying losses of dried grain would be excluded.

SHIFTS IN SEASON B 2012 POST-HARVEST LOSSES IF EXCLUDING THE NORTHERN PROVINCE

Some discussion has centered on whether or not it is strategic to recommend that the Northern Province shift away from dry maize production, give the high post-harvest losses in this region. Table 11-1 and 11-2 illustrate that in Season A and Season B 2012, national post-harvest losses would have decreased by 0.9% and 0.3%, respectively. These correspond to a 9.0% and 3.3% relative reduction, respectively, in each season. Due to variance in the model, this difference is not statistically significant. The greater impact in Season A is because of heavier harvest-period rainfall, and the Northern Province has about double the national average harvest/drying losses during rainy harvests. The greater impact excluding Northern Province would be seen when harvests are particularly rainy. Losses in areas of "rainy" harvest periods are an absolute 3.5% higher (and relatively 32.1% higher) in the Northern Province than the national average.

Table 0-1: Projected Shifts in Season A 2012 Post-Harvest Losses if Excluding the Northern Province

Stage	Region	Season B 2012 Post-Harvest Losses Questionnaire			Following Harvest Losses Field Verification		
		Rain	No Rain	All	Rain	No Rain	All
Harvest and Drying Losses	North Prov.	26.7% (19.5)	12.5% (4.4)	18.2% (10.4)	6.3% (2.6)	0.9%* (0.2)	3.1% (1.2)
	Total Country	13.0% (11.7)	8.2% (3.5)	10.9% (8.1)	3.1% (1.0)	0.9% (0.2)	2.1% (0.7)
	Country w/o North	8.9% (11.3)	7.0% (2.3)	8.2% (8.1)	1.6% (0.8)	0.9%* (0.2)	1.3% (0.6)
On-Farm Storage Losses**	North Prov.			7.6% (2.2)			
	Total Country			**4.9% (0.9)**			
	Country w/o North			4.2% (1.5)			
	Absolute Net Country Change			**-0.7%**			
All Post-Harvest Stages (not shown: other non-measured APHLIS loss parameters)	North Prov.	33.0% (15.4)	20.1% (3.5)	25.3% (8.3)	14.4% (2.2)	9.5% (2.2)	11.5% (2.2)
	Total Country	19.8% (9.2)	15.4% (2.8)	17.9% (6.4)	10.9% (1.7)	8.8% (0.9)	10.0% (1.3)
	Country w/o North	16.0% (8.9)	14.3% (1.9)	15.4% (6.4)	9.3% (1.5)	8.7% (1.5)	9.1% (1.5)
	Absolute Net Country PHL	**-3.8%**	**-1.1%**	**-2.5%**	**-1.6%**	**-0.1%**	**-0.9%**

	Change						
	Percent Country PHL Change	**-19.2%**	**-7.1%**	**-14.0%**	**-14.7%**	**-1.1%**	**-9.0%**

*Use of other province data for proxy since all Northern Province farmers in Season A 2013 verification had more than one day of rain in harvest period.
**Parameters from questionnaire, where visual samples aided farmers' damage level identification

Table 0-2: Projected Shifts in Season B 2012 Post-Harvest Losses if Excluding the Northern Province

Stage	**Region**	**Season B 2012 Post-Harvest Losses Questionnaire**			**Following Harvest Losses Field Verification**		
		Rain	**No Rain**	**All**	**Rain**	**No Rain**	**All**
Harvest and Drying Losses	**North Prov.**	26.7% (19.5)	12.5% (4.4)	14.2% (6.2)	6.3% (2.6)	0.9%* (0.2)	1.6% (0.5)
	Total Country	13.0% (11.7)	8.2% (3.5)	8.8% (4.5)	3.1% (1.0)	0.9% (0.2)	1.2% (0.3)
	Country w/o North	8.9% (11.3)	7.0% (2.3)	7.2% (3.3)	1.6% (0.8)	0.9%* (0.2)	1.0% (0.3)
On-Farm Storage Losses**	**North Prov.**			7.6% (2.2)			
	Total Country			**4.9% (0.9)**			
	Country w/o North			4.2% (1.5)			
	Absolute Net Country Change			**-0.7%**			
All Post-Harvest Stages (not shown: other non-measured APHLIS loss parameters)	**North Prov.**	33.0% (15.4)	20.1% (3.5)	21.6% (4.9)	14.4% (2.2)	9.5% (2.2)	10.1% (2.2)
	Total Country	19.8% (9.2)	15.4% (2.8)	15.9% (3.6)	10.9% (1.7)	8.8% (0.9)	9.1% (1.0)
	Country w/o North	16.0% (8.9)	14.3% (1.9)	14.5% (2.7)	9.3% (1.5)	8.7% (1.5)	8.8% (1.5)
	Absolute Net Country Change	**-3.8%**	**-1.1%**	**-1.4%**	**-1.6%**	**-0.1%**	**-0.3%**
	Percent Country PHL Change	**-19.2%**	**-7.1%**	**-8.8%**	**-14.7%**	**-1.1%**	**-3.3%**

*Use of other province data for proxy since all Northern Province farmers in Season A 2013 verification had more than one day of rain in harvest period.
**Parameters from questionnaire, where visual samples aided farmers' damage level identification

SUMMARY AND EXTENSION RECOMMENDATIONS

GENERAL

1) Maize continues to primarily be a cash crop, with 87% of production sold in Season A and 84% in Season B.
2) Maize is stored longer in Season A than Season B, at 4.1 months vs. 3.2 months. This correlates with higher production in Season A.
3) Post-Harvest losses in Season A 2012 are estimated to be higher than Season B 2012, at 9.85% and 9.14%, respectively, due to greater Season A incidence of rain at harvest.
4) Most maize destined for the market is sold very quickly after harvest. In Season B, nearly 50% was sold within one month and 90% sold within two months. Mostly due to shorter holding periods, insect damage in marketed maize is a low average 1.1% compared to 4.8% in consumed maize.
5) If farmers desire to increase this period of storage before sale, careful attention must be paid to their dominant constraints—financial or technical ability to store.
    a. If technical ability to store is the dominant constraint, the Post-Harvest Task Force can help to increase knowledge about grain preservation technologies and proper structures.
    b. If the dominant constraint is financial, credit support is a more crucial focus.

TRAINING

Many farmer post-harvest practices have notable differences depending on training received.

1) Trained farmers in areas with rainy harvests have significantly lower harvest/drying losses. Harvest/Drying education seems to make little impact in areas with dry harvest periods. Therefore, expansion of harvest/drying training programs will have a greater impact on reducing post-harvest losses if concentrated on areas within provinces with rainy harvest periods.
2) Farmers trained in shelling practices and exposed to new technologies have notably higher adoption rates of more sophisticated shelling equipment.
3) Training in storage protectant use is the lowest of all post-harvest activities. There is a greatly elevated and statistically significant rate of storage protectant adoption among limited farmers who have received training. This category should be pursued in training regimens.
4) Rats are the largest reported contributor to on-farm storage losses, yet training on rat prevention techniques is largely absent from current curriculum. Rats should receive a greater focus in future post-harvest training.
5) The Western province is behind other provinces in many categories. The West has consistently higher usage of old and untreated sacks, low palette use, and simple technology utilization. This could be a region to particularly focus expansion of post-harvest education.

POST-HARVEST LOSSES MODEL PARAMETER ESTIMATIONS

1) Farmer-reported estimates in this study are meant to start a constructive discourse about contextualizing APHLIS parameters to Rwandan conditions, while maintaining the APHLIS calculation format.
2) A questionnaire should not be used to estimate harvest/drying losses. Instead, agents should use the simple methodology from the field verification to measure damaged and undamaged maize with balances. While the questionnaire method resulted in estimates somewhat close to the APHLIS general model parameters, the field verification loss parameters are significantly lower. A larger sample size for subsequent harvest/drying loss studies would help expand analysis on training and rain impact.
3) There are large differences between storage losses from this study and the APHLIS general model parameters. This Rwandan study suggests a non-zero parameter is much more appropriate for losses when storing for less than 4 months.
4) It is recommended to continue refining post-harvest loss parameters from the general model to the Rwandan context. The next most impactful parameters to contextualize are transport to farm (2.4% loss) and market storage (2.7% loss).

REFERENCES

Adams, J. M. and Harman G.W. (1977). The evaluation of losses in maize stored on a selection of small farms in Zambia with particular reference to the development of methodology. *Rep. Trop. Prod. Inst.* G109, xi + 149.

Holst, N., Meikle, W.G., and Markham, R.H. (2000). Grain Injury Models for *Prostephanus truncatus* (Coleoptera: Bostrichidae) and *Sitophilus zeamais* (Coleoptera: Curculionidae) in Rural Maize Stores in West Africa. *Journal of Economic Entomology.* 93(4):1338-1346.

LIST OF TABLES

Table i-1: APHLIS vs. MinAgri parameter comparison for 2012 National Post-Harvest Losses 7
Table 1-1: Geographic distribution of Surveys 8
Table 2-1: General Background Data -- Season A 10
Table 2-2: General Background Data – Season B 10
Table 2-3: Household Purchase of Maize Season A 11
Table 2-4: Household Purchase of Maize Season B 11
Table 2-5: Maize Market Outlets Season A 12
Table 2-6: Maize Market Outlets Season B 12
Table 3-1: Comparison of Harvest Loss Assessment Methods in Season B 2012 and Pilot Field Verification in Season A 2013 13
Table 3-2: Rain incidence at harvest and farmers rejecting some cobs 15
Table 3-3: Season B Harvest period expansion: Harvest/Field Losses when cobs rejected 15
Table 3-4: Alternative uses for field rejected cobs 16
Table 3-5: Physical losses after harvesting and drying under different climate conditions and training: Discriminate Analysis 17
Table 3-6: Comparison of Harvest/Drying Loss Parameter Results from Questionnaire and Field Verification 18
Table 4-1: Drying Practices, Season A 19
Table 4-2: Drying Practices, Season B 19
Table 4-3: Losses in Drying Process: Questionnaire Method 20
Table 5-1: General Shelling Methods, Season A 20
Table 5-2: Shelling Methods with Training Considered, Season A ..... **Error! Bookmark not defined.**
Table 5-3: General Shelling Methods, Season B 21
Table 5-4: Shelling methods with training considered, Season B 22
Table 6-1: Maize form in storage, Season A (consumed) 23
Table 6-2: Maize form in storage, Season B (consumed) 23
Table 6-3: Storage Containers, Season A (consumed) 23
Table 6-4: Storage Containers, Season B (consumed) 23
Table 6-5: Polypropylene sack type, Season B (consumed) 24
Table 6-6: Use of palettes (consumed) 24
Table 6-7: Maize form in Storage, Season A (sold) 24
Table 6-8: Maize form in storage, Season B (sold) 24
Table 6-9: Storage Methods, Season A (sold) 25
Table 6-10: Storage methods, Season B (sold) 25
Table 6-11: Polypropylene Sack type, Season B (sold) 25
Table 6-12: Use of palettes (sold) 25
Table 6-13: Use of storage protectants [including training], Season A 26
Table 6-14: Use of storage protectants [including training], Season B 27
Table 6-15: Storage Protectants Specified, Season A 27
Table 6-16: Storage Protectants Specified, Season B 28

Table 6-17: Season B: Marketing of Maize (timing, marketed before survey period) 28
Table 6-18: Storage Losses and components, Season B 29
Table 6-19: Season B 2012 Maize Storage Economic Loss Estimates 30
Table 6-20: Season B 2012 Maize Storage Training Benefit Estimation 30
Table 6-21: APHLIS specifications for storage losses with respect to time stored 30
Table 6-22: Maize damage level, previously marketed grain 31
Table 6-23: Maize damage level, previously consumed grain 31
Table 6-24: Maize damage level, grain remaining in home 32
Table 7-1: Training received, Season A 2012 33
Table 7-2: Training received, Season B 2012 33
Table 8-1: APHLIS Losses by Province, Season A 35
Table 8-2: APHLIS Losses by Province, Season B 35
Table 8-3: APHLIS Losses By Province, Year 2012 35
Table 9-1: APHLIS vs. new MinAgri Parameters: Summary of Season B 2012 Physical Losses 37
Table 10-1: Back-casting Post-Harvest Losses with New Field Measurements 38
Table 11-1: Projected Shifts in Season A 2012 Post-Harvest Losses if Excluding the Northern Province 39
Table 11-2: Projected Shifts in Season B 2012 Post-Harvest Losses if Excluding the Northern Province 40