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Measuring Postharvest Losses at the Farm Level in Malawi

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ABSTRACT

Reducing food loss and waste are important policy objectives prominently featured in the United Nation's Sustainable Development Goals. To optimally design interventions targeted at reducing losses, it is important to know where losses are concentrated between the farm and fork. This paper measures farm-level postharvest losses for three main crops—maize, soy, and groundnuts—among 1,200 households in Malawi. Farmers answered a detailed questionnaire designed to learn about losses during harvest and transport, processing, and storage and which measures both total losses and reductions in crop quality. The findings indicate that fewer than half of households report suffering losses conditional on growing each crop. In addition, conditional on losses occurring, the loss averages between 5 and 12 percent of the farmer's total harvest. Compared to nationally representative data that measure losses using a single survey question, this study documents a far greater percentage of farmers experiencing losses, though the unconditional proportion lost is similar. We find that losses are concentrated in harvest and processing activities for groundnuts and maize; for soy, they are highest during processing. Existing interventions have primarily targeted storage activities; however, these results suggest that targeting other activities may be worthwhile.

Keywords: Malawi, postharvest loss, agricultural production

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1. INTRODUCTION

Sustainable Development Goal 12 (SDG12), agreed to by the world's governments, aims to "ensure sustainable consumption and production patterns." This goal implies an effort to reduce waste and losses in the production and consumption of goods—in particular, in the food system. A specific target of SDG12 is to reduce food losses along production and supply chains, including postharvest losses. Yet to do so, it is important to know the magnitude and timing of waste or loss within specific supply chains, so that solutions for reducing waste or loss can be applied when it is cost-effective to do so. In this paper, working with smallholders in Malawi, we use a specialized survey module designed to estimate postharvest losses and study correlates with those losses.

Postharvest losses, and food loss more generally, have regained prominence since the global food price crisis of 2007–2008. From the consumer's perspective, the presence of food loss along the value chain leads to higher food prices. From a macro perspective, for poorer countries dependent on agriculture, lower postharvest losses can reduce the need to import food, freeing scarce foreign exchange. Storage technologies to reduce postharvest losses were prominent in the 1970s and 1980s, when state-run grain marketing boards purchased most of the grain in Africa south of the Sahara. However, after the liberalization of grain markets in the 1990s, the World Bank (2011) argued that price and quality risks have been passed on to farmers. As a result, incentives to use postharvest technologies may have declined over time. Yet, there is little detailed information about how bad such losses are, either in quantity or quality of crops being produced.

To meet the SDG12 target, farmers must be provided with the tools they need to limit postharvest losses. Yet, a major challenge is that little is systematically known about where along agricultural value chains food loss and waste occur, particularly in developing countries.[1] One reason is that postharvest losses can occur at one of several different stages between the farm and food consumption. For example, losses may take place before the farmer sells or consumes the crop, during the primary processing phase, while in storage by the processor, while the product is being marketed, or after purchase by the consumer. A key issue with the literature on food loss and waste is that definitions vary from study to study (Schuster and Torero 2016). Research definitions of postharvest loss are not consistent, even at specific stages between the farm and food consumption. Even at the farm level, different surveys may ask about crop losses in different ways, which can result in mistargeted interventions to reduce such losses. Given the expense of potential strategies for loss reduction, accurate and consistent measurement is an important input when weighing the cost of solutions against the value of reduced losses (Parfitt, Bartel, and MacNaughton 2010; Rosegrant et al. 2015).

A 2011 FAO report provides estimates of food loss worldwide, separated by region and food type. In general, estimated losses are quite high. In Africa south of the Sahara, total losses for cereals are estimated to be more than 20 percent, and 8 percent in the postharvest handling and storage period (FAO 2011). However, these estimates are not based on surveys; rather, they rely on several assumptions. Another source of estimates of postharvest losses is the African Postharvest Losses Information System (APHLIS), a multistakeholder monitoring system that dates to 2009. However, like the FAO estimates, estimates from APHLIS may be inaccurate for several reasons. First, when new estimates of postharvest losses are generated, APHLIS largely depends on parameters from the academic literature. Yet, of the 79 references listed on the APHLIS website, only 16 had been published since 2000. Thus, if postharvest losses have changed in the past two decades, the estimates will be outdated. Second, APHLIS splits loss estimates into seven grain crops but only three climate types (tropical savannah, arid desert, or warm temperate). As such, only 21 grain-climate profiles are used to extrapolate losses when data are not available (APHLIS 2014). Third, when survey data are available, it is not clear what methods are used to estimate postharvest losses, nor is it clear whether the same methods are used across different papers.

[1] When losses are quantified, they have typically been quantified in terms of weight or calories but often neglect nutritional or visual quality (see, for example, APHLIS 2014; Kummu et al. 2012).

A meta-analysis conducted by Affognon et al. (2015) echoed the above concerns about the APHLIS system. They found that most estimates in Africa south of the Sahara are unpublished, and the research is generally of poor quality. In addition, the research is perhaps too focused on maize, which is represented in 43 percent of the 213 documents reviewed. Fewer than half of the documents (37 percent) used household surveys to estimate postharvest losses, they largely focused on West Africa, and they tended to neglect crop quality.

For these reasons, international organizations such as the United Nations Food and Agriculture Organization (FAO) and CGIAR have begun to systematize information being collected on postharvest losses (FAO 2011; Aulakh and Regmi 2013; Schuster and Torero 2016). Through a more systematic understanding of these losses, interventions to reduce food loss and waste can be better targeted by both crop and intervention type. For example, if quantity losses are shown to be low prior to food leaving the farm, interventions should target other parts of the value chain if overall losses are high. This paper is part of this systematic endeavor; future papers coming from this effort will use the same survey modules to gather information.

The survey modules used in this study are adapted from farmer surveys being used as part of the larger effort to examine postharvest losses among producers and processors (see, for example, Schuster and Torero 2016). The survey specifically asks farmers to self-report whether losses occurred during three particular activities between harvest and sale into the value chain: harvest and transport from the field to home, processing, and postprocessing storage. Moreover, the instrument carefully elicits both quantity and quality losses to better understand how losses are occurring.

This study measures postharvest losses and their determinants among smallholder farms in farmer groups in Malawi for three crops: maize, soy, and groundnuts. The postharvest loss survey modules were added to the second follow-up survey for a cluster randomized controlled trial studying the impact of individualized extension services and capital transfers. Doing so allows us to relate losses during the follow-up to household and farm characteristics collected over three rounds of surveys. The detail available in the survey modules helps pinpoint when postharvest losses occur. Moreover, the existence of recently collected, nationally representative data allows us to compare the farmers in our sample with a representative sample of farmers both nationwide and in the districts in which the intervention took place. Finally, because the nationally representative survey includes a single question on postharvest losses, we can study the differences between asking a single question and the more systematic body of questions included in our survey.

This paper is also related to a recent paper on postharvest losses that focuses on measuring on-farm losses using nationally representative data, including data collected in Malawi. Kaminski and Christiaensen (2014) used the Living Standards Measurement Surveys in Malawi, Tanzania, and Uganda to estimate postharvest losses at the farm level for maize. They find losses of only between 1.4 and 5.9 percent. The estimate of 1.4 percent is for Malawi, casting doubt on the need for on-farm technologies such as metal silos promoted through the Effective Grain Storage Project (Maliro and Kandiwa 2015).

Our results contribute to the existing literature in several ways. First, across crops, fewer than half of households report losses (conditional on growing that crop). Conditional on experiencing a loss, losses vary across crops: 5 percent for maize, 8 percent for soy, and 12 percent for groundnuts. Although the maize estimates are small relative to FAO (2011) estimates, they are comparable to other recent studies examining staple crops in Africa south of the Sahara (Kaminski and Christiaensen 2014; Minten, Engida, and Tamru 2016; Abdoulaye et al. 2016). Losses in our sample are concentrated in harvest and processing activities; for soy, they are highest during processing. Most interventions have targeted storage activities; however, our results suggest that targeting other activities might also be effective. Furthermore, the findings indicate that large losses tend to be concentrated on a few farmers.[2]

Second, we compare our results to those from the most recent available data of the nationally representative Integrated Household Survey (IHS), which relies on a single question to measure

[2] Groundnuts are the exception—20 percent of farmers report losses equivalent to 20 percent or more of total production.

postharvest losses. Although we find considerably higher incidence of postharvest losses using our detailed approach, we find fairly similar unconditional proportions of lost production estimates.

Third, we move beyond measuring the incidence of losses to consider the determinants of losses across activities and crops. We find broadly consistent patterns across the three different crops examined and across the different activities, as well as for quantity and quality losses separately. Wealthier households, smaller households, and households with a female farmer group member are better equipped to avoid crop loss. Further, individuals who are less risk averse are less likely to experience losses. This last finding is robust to using either a self-reported scale measure or an incentivized experimental measure of risk aversion. Fourth, after examining the impact of our individualized extension support program (relative to group-based extension), we find suggestive evidence that two years of exposure reduces postharvest losses.

Finally, we measure postharvest losses for maize, soybean, and groundnuts at the farm level. Although the literature shows other estimates of maize losses, there are only two estimates of groundnut losses from Ghana (Affognon et al. 2015), and there appear to be no estimates of soy losses anywhere in Africa south of the Sahara. Therefore, this paper both serves as a complement to Kaminski and Christiaensen (2014) in maize and provides new estimates for other crops underrepresented in the literature.

The paper proceeds as follows: The next section describes the data. Section 3 describes the incidence of postharvest losses in the sample. Section 4 describes determinants of postharvest losses in the data. Section 5 concludes with a summary of results and a discussion of the implications for both policy and intervention design related to postharvest losses.

2. DATA

This paper uses data collected from three waves of a randomized controlled trial conducted by IFPRI in Malawi spanning 120 distinct farmer clubs. The project, conducted over two seasons, evaluates the impact of capital transfers (in cash or in kind) and intensive agricultural extension. All interventions were conducted by the National Smallholder Farmers' Association of Malawi (NASFAM), which is the largest smallholder-owned organization in Malawi that provides both commercial and development services to member farmers. The transfers were conducted in the first season only (2014/2015), and the intensive extension was conducted in both years (2014/2015 and 2015/2016). The transfer and extension treatments were cross randomized. In addition, in the second year, the intensive extension treatment was re-randomized such that one-quarter of farmers received two years of services, one-quarter received services in the first year only, one-quarter received services in the second year only, and one-quarter were in a control group. More details are available in Ambler, de Brauw, and Godlonton (2017).

The sample comprises farmers in NASFAM farmer clubs in the Dowa and Ntchisi districts in central Malawi. Because one goal of the project is to encourage farmers to adopt cash crops other than tobacco, selection criteria excluded clubs focused on tobacco production. The study sample consisted of the 120 newest clubs in these two districts. The project focus crops were groundnuts and soy; project services (including a seed replication program and extension advice) were concentrated on, but not completely limited to, these two crops. Almost all farmers also grow maize, the main staple crop in Malawi.

A project baseline conducted in August and September 2014 included demographic and socioeconomic information, as well as detailed questions on agricultural production and practices among many other modules. Two full follow-up surveys were conducted following the first and second seasons of implementation, in August/September of 2015 and in August/September 2016. In almost all cases, the respondent for these surveys was the member of the NASFAM farmer club, not necessarily the household head. The surveys included similar information as the project baseline, as well as additional outcome measures. The second follow-up survey in 2016 also included an extensive module on postharvest losses. Therefore, the sample of interest for this paper is all farmers who completed the second follow-up, including both original sample members and farmers who had joined the club since the project began. Of the 1,118 households in the second follow-up sample, 965 had completed the baseline survey, and 969 had completed the first follow-up.[3] While the postharvest loss data collected in the second follow-up will be used to construct the main variables of interest, data from baseline and the first follow-up will also be used in the analysis of predictors of postharvest losses.

The postharvest loss module in this survey is designed to measure losses incurred by smallholder producers up to the point at which crops are sold. We adapt the methodology developed from Schuster and Torero (2016) for surveys conducted among producers in Guatemala, Honduras, Peru, and Ethiopia, among other countries, and apply it to maize, groundnuts, and soy. Although self-reported postharvest losses have been measured in Malawi in the nationally representative IHS, our method is innovative in that it measures both losses in crop quality and complete crop loss. We also differentiate by activity and measure losses at different points in the production process. Such detailed information is important for policy makers designing interventions to mitigate postharvest losses.[4]

Farmers are first asked to identify the activities they engaged in for each target crop (maize, groundnuts, and soy) that they had reported growing earlier in the survey. The three activities are harvest

[3] Missing data for the baseline and first follow-up are largely due to new club members who were surveyed during the second follow-up: 100 observations are new farmers. The other discrepancies are instances in which a household was not available at baseline or at first follow-up but was found during the second follow-up.

[4] It is worth noting that farmers may not recall losses or may misreport losses. The advantage of the method used here is that a relatively large battery of questions was used to ask about losses in different ways; therefore, farmers' memory could be catalyzed from several different angles. The methods are consistent with those used in the remainder of this data collection effort.

and transport, processing, and postprocessing storage.[5] For each activity, they are asked to indicate the amount of the crop that was damaged but not completely lost and the amount that was completely lost. Additional questions collect information on the severity of crop damage, the causes of the damage and complete loss, and the uses of damaged crops. Throughout this paper, the term *damaged* refers to crops that suffered a reduction in quality and complete loss to crops that were completely lost. The term *loss* refers generally to either damage or complete loss.

Table 2.1 presents summary statistics describing the sample and compares the sample to the nationally representative sample from the 2013 round of the IHS. Given the policy relevance of understanding the extent of postharvest losses, it is important to know how close our sample is to a representative sample of Malawians. One particular concern is that, given NASFAM farmers' involvement with cash crops, our households may be somewhat better off than the average household. The first column in Table 2.1 presents statistics for all rural households in the IHS. The second column limits the sample to Dowa and Ntchisi districts, where our surveys were conducted. The third column presents statistics from our surveys of NASFAM farmers. The fourth column shows the p-value for a t-test on the equality of columns 2 and 3.

Table 2.1 Summary statistics and sample comparison

	(1)	(2)	(3)	(4)
Demographic characteristics	**IHS (All rural)**	**IHS (Dowa/Ntchisi)**	**NASFAM farmer sample**	**p-value for equality of columns 2 and 3**
Household size	5.1	4.9	5.7	0.000
Age of household head	43.3	41.6	47.0	0.000
Household head is female	0.24	0.17	0.17	0.966
Household head is polygamous	0.07	0.09	0.10	0.683
Education of household head				
No schooling	0.19	0.14	0.19	0.079
Some primary	0.45	0.54	0.59	0.206
Completed primary	0.15	0.16	0.09	0.004
Some secondary	0.13	0.12	0.09	0.238
Completed secondary +	0.08	0.05	0.03	0.073
Agricultural Production				
Number of crops	2.1	2.0	4.9	0.000
Land area (Acres)	2.6	2.9	4.1	0.000
Total Sales Revenue (Kwacha)	27,002	52,893	174,310	0.000
Household planted maize	0.97	0.99	0.99	0.365
Land area planted for maize (Acres)	1.5	1.7	1.8	0.870
Production of maize (Kgs)	821	1,394	1,414	0.904
Household planted groundnuts	0.33	0.55	0.81	0.000
Land area planted for groundnuts (Acres)	0.8	1.1	0.9	0.142
Production of groundnuts (Kgs)	292	295	351	0.271
Household planted soy	0.09	0.30	0.78	0.000
Land area planted for soy (Acres)	0.8	1.1	0.9	0.123
Production of soy (Kgs)	268	376	255	0.036

[5] Processing activities varied slightly by crop and were defined as follows: maize—removing husks, drying, shelling, cleaning, chemical application and packaging, storage related to processing; groundnuts—plucking, drying, shelling, cleaning, chemical application and packaging, storage related to processing; and soy—drying, threshing, cleaning, chemical application and packaging, storage related to processing.

Table 2.1 Continued

	(1)	(2)	(3)	(4)
Demographic characteristics	**IHS (All rural)**	**IHS (Dowa/Ntchisi)**	**NASFAM farmer sample**	**p-value for equality of columns 2 and 3**
Postharvest losses				
Reports loss: Maize	0.10	0.06	0.36	0.000
Proportion of production lost: Maize	0.03	0.02	0.02	0.217
Reports loss: Groundnuts	0.04	0.04	0.47	0.000
Proportion of production lost: Groundnuts	0.02	0.02	0.05	0.030
Reports loss: Soy	0.02	0.04	0.42	0.000
Proportion of production lost: Soy	0.01	0.04	0.03	0.733

Source: Authors' calculations from the NASFAM farmer surveys and the 2013 round of the Malawi IHS panel survey.
Note: IHS = integrative household survey; NASFAM = National Smallholder Farmers' Association of Malawi.

Households in our sample have an average size of 5.7 members. Household heads are 47 years old on average; 17 percent of household heads are women, and 10 percent are polygamous. Education levels are low: almost 80 percent of household heads have not completed primary school. On average, these NASFAM households are larger and household heads are older and somewhat less educated than IHS households in Dowa and Ntchisi. Even though many of these differences are statistically significant, the magnitudes of the differences are fairly small.

Comparison of agricultural measures is also important, as shown in the third panel of Table 2.1. Farmers in the NASFAM sample grow an average of 4.9 crops on 4.1 acres of land, which is significantly larger than the same numbers for the Dowa and Ntchisi IHS sample (2.0 and 2.9, respectively) and is indicative of the involvement of NASFAM farmers in a higher level of commercial agriculture. Indeed, the sales revenue in our sample is almost three times the average in Dowa and Ntchisi.[6] Maize production, the main staple crop in Malawi, is remarkably similar. Maize is grown by almost all rural households in Malawi, and our sample is no exception. Maize land area and total maize production are also similar and not statistically different from the IHS numbers for Dowa and Ntchisi (although both of these numbers are higher than the national average). Given the project focus on groundnuts and soy, it is unsurprising that NASFAM farmers grow these crops at much higher rates than the population (rates are around 80 percent for both crops, compared to 55 percent for groundnuts and 30 percent for soy in the IHS). However, conditional on growing the crop, production is similar between the IHS and our sample. Overall, the farmers in the sample considered in this paper appear to be representative of other farmers in the region, particularly those who grow groundnuts or soy.

[6] These figures are, of course, from different seasons. The IHS numbers refer to the 2011/2012 season, and the numbers for the NASFAM sample refer to the 2015/2016 season. Thus, some of the difference may be due to seasonal variation.

3. DESCRIPTION OF POSTHARVEST LOSSES

This section describes the incidence of postharvest losses in our sample for maize, which the main staple crop in Malawi, and for soy and groundnuts, the two focus crops of the project. One issue with collecting data on crop losses is that crops are sensitive to climatic factors that may vary across time. Although we collect detailed data on postharvest losses only in our second follow-up survey, we do have information on whether farmers report a loss *prior* to harvest in all three years of data. We present this information, along with information on production of main crops, in Table 3.1. The table considers the three crops for which we have information on postharvest losses (maize, groundnuts, and soy), as well as the next most commonly grown crops in our sample (tobacco, sweet potato, pumpkins, and tomato). Table 3.1 reports the proportion of farmers planting each crop; the conditional mean of kilograms produced; the standard deviation and the 25th, 50th, and 75th percentiles; and whether farmers reported a loss prior to harvest for that crop, for 2014, 2015, and 2016.

Table 3.1 Production and loss of major crops over time

			Quantity produced (Kg) (if planted)					Reports	Reports loss
Crop	Year	Proportion planting	Mean	SD	25th	Median	75th	loss prior to harvest	during or after harvest
	2014	0.99	1,171	1,089	400	900	1,500	0.34	-
	2015	0.99	1,020	1,541	300	600	1,200	0.82	-
Maize	*2016*	1.00	1,408	2,173	540	1,000	1,620	0.78	0.36
	2014	0.91	253	402	50	105	300	0.53	-
	2015	0.82	228	339	50	125	289	0.91	-
Groundnuts	*2016*	0.80	423	492	108	270	563	0.67	0.47
	2014	0.66	206	329	50	100	250	0.34	-
	2015	0.75	222	315	80	150	250	0.90	-
Soy	*2016*	0.79	333	462	105	234	400	0.69	0.43
	2014	0.53	319	440	100	200	400	0.44	-
	2015	0.47	298	447	100	200	330	0.81	-
Tobacco	*2016*	0.48	640	4,815	120	260	480	0.66	-
	2014	0.15	261	290	100	150	300	0.24	-
	2015	0.12	330	367	90	200	400	0.62	-
Sweet potato	*2016*	0.23	468	629	180	360	525	0.52	-
	2014	0.50	354	352	125	250	500	0.17	-
	2015	0.23	131	285	0	50	150	0.74	-
Pumpkins	*2016*	0.53	202	361	29	96	239	0.46	-
	2014	0.04	175	196	50	100	200	0.21	-
	2015	0.12	119	354	25	50	100	0.55	-
Tomato	*2016*	0.20	136	462	18	40	120	0.28	-

Source: Authors' calculations from the baseline (2014), first follow-up (2015), and second follow-up (2015) of the NASFAM farmer study.
Note: NASFAM = National Smallholder Farmers' Association of Malawi.

The statistics presented in Table 3.1 show that, across crops, both quantity produced and reporting of preharvest losses vary widely across time. For example, 2015 was a particularly bad year in terms of amounts harvested and reported preharvest losses; 2016 was the best year for production for all crops, even though reports of preharvest losses were still at a relatively high level compared to 2014. The last column of Table 3.1 shows the percentage of farmers reporting any loss (damage or complete loss) during harvest or postharvest in 2016 for the three crops. The incidence of postharvest losses is lower on the extensive margin than preharvest losses. Given the limited data available here, however, it is not possible to say much about how postharvest losses relate to preharvest losses. Although postharvest losses are lower than reported losses preharvest, the crop for which preharvest losses are highest (maize) has the lowest incidence of postharvest losses. Given that climatic factors are expected to be a large determinant of both pre- and postharvest losses and that weather can vary through the growing season, it might be expected that pre- and postharvest losses are not strongly correlated.

Incidence of Postharvest Losses

Table 3.2 presents detailed statistics describing postharvest losses for the 2015/2016 growing season for the three crops of interest. The proportion of households growing maize, groundnuts, and soy in 2016 is 99.6 percent, 80 percent, and 79 percent, respectively. Panel A shows the percentage of households engaged in each activity considered (harvest and transport, processing, and storage) conditional on growing that crop. Across crops, most farmers report participating in all activities, with the lowest percentage being the 85 percent of households that report storing maize.

Table 3.2 Postharvest losses of targeted crops (if crop planted)

	Maize			Groundnuts			Soy		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
A. Engaged in activity									
Harvest and transport	1.00	0.06	1,112	0.99	0.07	901	1.00	0.07	873
Processing	0.96	0.19	1,112	0.95	0.21	901	0.95	0.22	873
Storage	0.85	0.36	1,112	0.91	0.29	901	0.89	0.32	873
B. Proportion reporting losses									
Any quality loss	0.28	0.45	1,112	0.37	0.48	901	0.29	0.46	874
Any total loss	0.26	0.44	1,112	0.33	0.47	901	0.34	0.47	874
Any quality or total loss	0.36	0.48	1,110	0.47	0.50	899	0.42	0.49	874
C. Severity of loss (if loss reported)									
Very little damage	0.30	0.38	396	0.31	0.38	420	0.22	0.34	369
Some damage	0.06	0.17	396	0.09	0.21	420	0.05	0.15	369
Extensive damage	0.21	0.27	396	0.20	0.27	420	0.21	0.26	369
Complete loss	0.43	0.37	396	0.40	0.37	420	0.52	0.37	369
D. Timing of losses (% in each activity)									
Harvest and transport	0.43	0.43	396	0.49	0.44	420	0.36	0.42	369
Processing	0.37	0.42	396	0.35	0.42	420	0.58	0.44	369
Storage	0.21	0.37	396	0.16	0.33	420	0.05	0.18	369

Table 3.2 Continued

	Maize			Groundnuts			Soy		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
E. Mean quantity lost (kgs)									
Harvest and transport	8.9	35.9	1,110	7.1	21.8	899	3.7	16.8	874
Processing	4.9	35.5	1,110	3.4	11.0	899	4.2	18.2	874
Storage	2.8	15.6	1,110	1.1	6.3	899	0.2	1.1	874
Total	**16.6**	**54.7**	**1,110**	**11.7**	**26.8**	**899**	**8.1**	**25.2**	**874**
F. Mean quantity lost if any loss (kgs)									
Harvest and transport	24.8	56.7	398	15.2	29.8	421	8.7	24.9	370
Processing	13.7	58.3	398	7.3	15.2	421	9.9	26.9	370
Storage	7.8	25.3	398	2.4	9.0	421	0.5	1.6	370
Total	**46.3**	**83.5**	**398**	**24.9**	**34.7**	**421**	**19.1**	**36.0**	**370**
G. % of Total production lost									
Harvest and transport	0.01	0.04	1,109	0.04	0.12	899	0.02	0.07	873
Processing	0.00	0.02	1,109	0.01	0.05	899	0.02	0.05	873
Storage	0.00	0.02	1,109	0.00	0.02	899	0.00	0.01	873
Total	**0.02**	**0.05**	**1,109**	**0.05**	**0.14**	**899**	**0.03**	**0.09**	**873**
H. % of Total production lost if any loss									
Harvest and transport	0.03	0.07	398	0.08	0.17	421	0.04	0.10	370
Processing	0.01	0.03	398	0.03	0.07	421	0.04	0.08	370
Storage	0.01	0.03	398	0.01	0.04	421	0.00	0.01	370
Total	**0.05**	**0.08**	**398**	**0.12**	**0.18**	**421**	**0.08**	**0.12**	**370**
I. Total value of postharvest losses (Kwacha) if any loss									
Total	**8,375**	**15,716**	**398**	**8,898**	**14,722**	**421**	**4,886**	**10,512**	**370**

Source: Authors' calculations from the second follow-up of the NASFAM farmer study.
Note: NASFAM = National Smallholder Farmers' Association of Malawi. Base sample by crop in Panel A is all farmers who reported planting that crop during the second follow-up of the NASFAM farmer study.

Panel B shows the percentage of farmers (conditional on growing a certain crop) that report a loss in quality or a total loss: 28 percent of households report a quality loss for maize, 26 percent report a total loss, and 36 percent report a loss of any kind. These numbers are higher for groundnut production (37 percent report loss in quality, 33 percent report a total loss, and 47 percent report a loss of any kind) and for soy (29 percent, 34 percent, and 42 percent, respectively). These numbers indicate that the losses are affecting a meaningful number of farmers but are not close to universal.

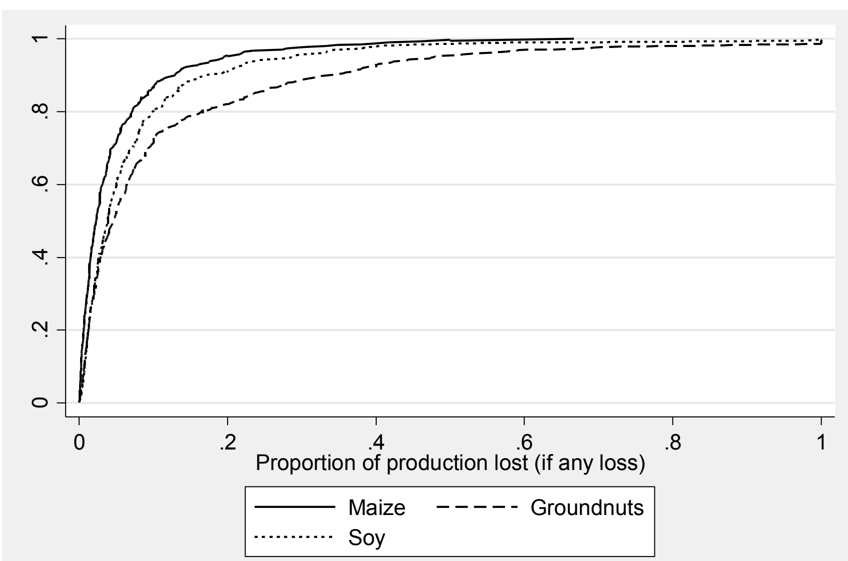
Panel C examines the percentage of the total quantity lost that falls into different quality categories as reported by farmers. These categories are “very little damage,” “some damage,” “extensive damage,” and “complete loss.” This distribution is similar for maize and groundnuts, with about 30 percent of the harvest in the “very little damage” category, 6–9 percent in “some damage,” 20 percent in “extensive damage,” and 40 percent in “completely lost.” The percentage of soy crop completely lost is somewhat higher, at 52 percent, with only 22 percent reporting “very little damage.” These numbers show that both complete loss and crop damage are important components of postharvest losses. For the rest of the paper, we will generally combine damage and complete loss in our analysis and focus on differentiation by activity.

Panel D reports the percentage of losses (by amount lost) attributable to each production stage. In these data, the harvest and transport stage and the processing stage incur the most losses. For maize, 43 percent of losses occur at harvest and 37 percent during processing, while those numbers for groundnuts are 49 percent and 35 percent, respectively. Processing is relatively more important for soy, at 58 percent, compared with 36 percent for harvest. Storage losses are relatively low: 21 percent for maize, 16 percent for groundnuts, and 5 percent for soy. Storage is often considered one of the most important components of postharvest losses; yet, in our sample, those losses are somewhat low. Given that our survey is conducted relatively soon after harvest, we have likely underestimated the losses due to storage as they will continue to accumulate over time.[7] However, for a crop such as soy, which is grown primarily for sale and may not be stored for long, it makes sense to see low losses during storage by producers.

Panels E and F report the quantity lost in kilograms for the full sample growing that crop (Panel E) and the sample reporting a loss (Panel F). These losses as a proportion of total harvest are reported in Panels G (unconditional) and H (conditional). The unconditional proportions lost across the three activities are 2 percent for maize, 5 percent for groundnuts, and 3 percent for soy; the conditional proportions lost are 5 percent, 12 percent, and 8 percent, respectively. Similar to Kaminski and Christiaensen (2014), our findings are well below the FAO estimates. However, the number of farmers experiencing loss is significant, and the conditional losses on the order of 5–12 percent may represent significant amounts for some farmers.

To further understand the distribution of losses, the cumulative distribution function of the conditional proportion lost for each crop is presented in Figure 3.1. All three distributions are concentrated at low proportions of the crop being lost, with long right tails. In addition, the curve for soy is clearly to the right of maize, and groundnuts to the right of soy. Overall, Figure 3.1 shows that most people who report losses report low levels of loss, with a small minority reporting larger losses. However, this statement is somewhat less true for groundnuts, where 20 percent of the sample reports losing 20 percent or more of their groundnut harvest.

Figure 3.1 Cumulative distribution function of proportion of production lost

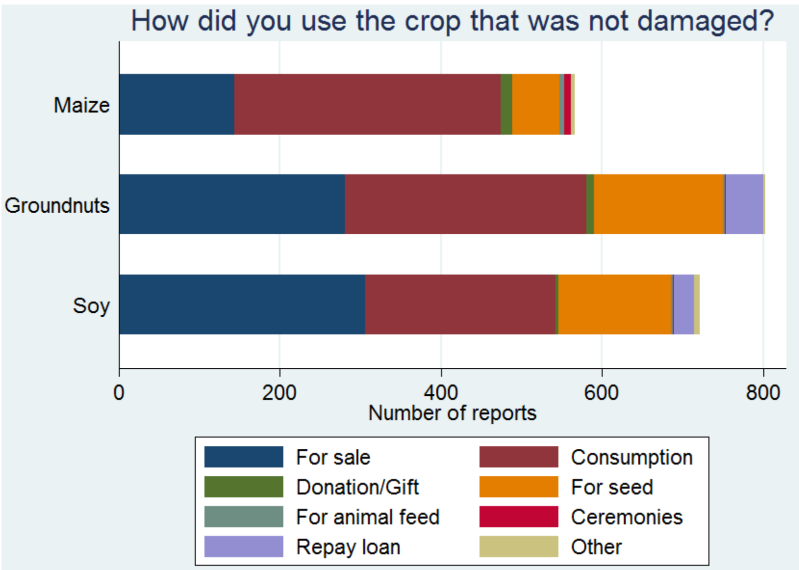


Source: Authors.
Notes: By crop, sample is all respondents reporting any loss for that crop.

[7] To better understand how the timing of our survey may have affected the estimation of losses during storage, we analyze losses by week of survey. The survey spanned an eight-week period. We do not observe differential losses by week of survey in our data. However, it is important to note that, for maize, the survey was conducted approximately four to six months after harvest. Soy and groundnuts were harvested later, and the harvest timing varied more across farmers. Therefore, the time postharvest is shorter, and there is higher variance for groundnut and soy as compared with maize.

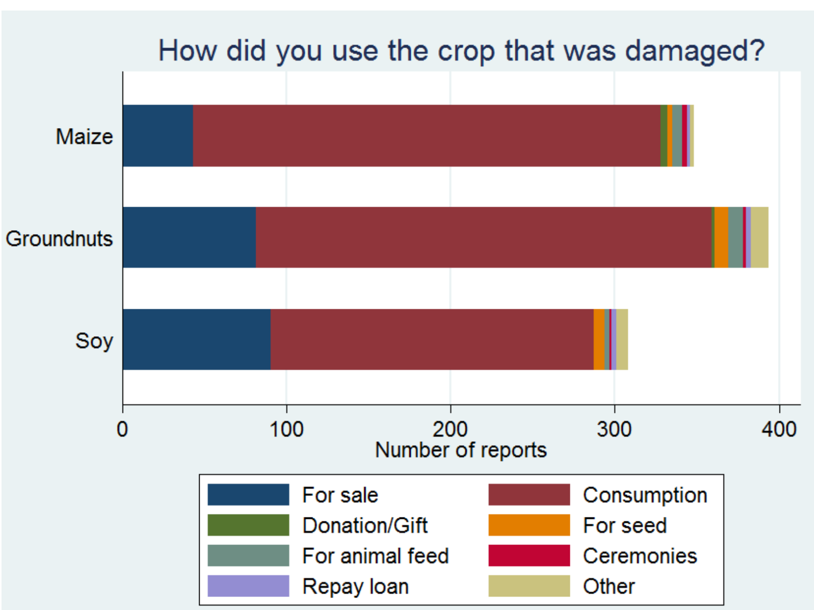
To understand the impact of crop loss on farmers, we include questions on how crops are used, separately, for damaged and nondamaged crops. Figure 3.2a presents the count, by crop, of how farmers reported using crops that were not damaged. Figure 3.2b presents how farmers reported using damaged crops. Because farmers could list more than one use, the numbers reported add up to more than the total number of farmers. Figure 3.2a shows that nondamaged crops are used primarily for consumption and sales, as well as for seed. Figure 3.2b shows that, proportionally, damaged crops are much more likely to be consumed by the family, instead of sold or used for seed.

Figure 3.2a Reported uses of nondamaged crops



Source: Authors.

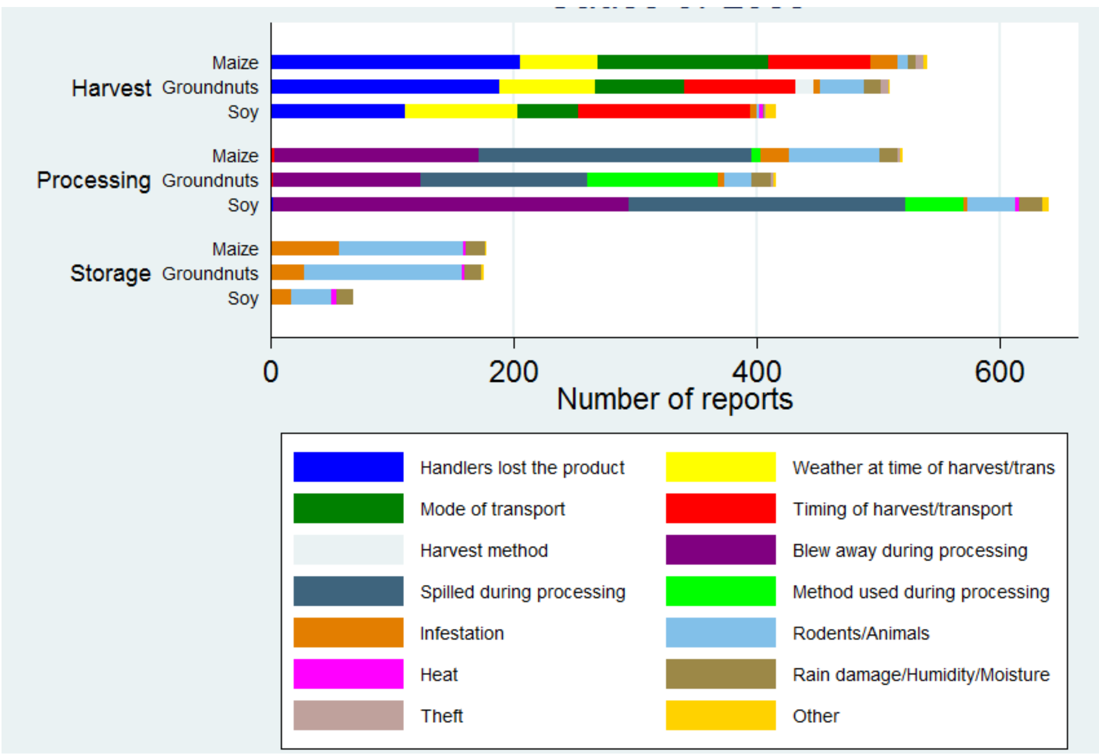
Figure 3.2b Reported uses of damaged crops



Source: Authors.
Notes: Sample is all reports of use from farmers who report any loss for that crop.

Beyond careful measurement of crop loss, understanding its root causes is important for any policy aimed at loss reduction. Our survey collected detailed information, by crop and activity, on the causes of damage and total loss. Figure 3.3 shows the numbers of farmers reporting a certain cause for each crop and activity. Because farmers could list more than one cause, the numbers reported add up to more than the total number of losses. For harvest and transport, the most important causes of loss are loss of product by handlers, weather, mode of transport, and timing of activity. During processing, the most important causes are crop blowing away (particularly for soy), crop being spilled, the processing method, and rodents or other animals. During storage, the main causes are infestation or rodents and animals. While many policy recommendations have focused on storage technologies, these data suggest that technologies or better training that could lead to less waste during harvest and processing may be beneficial.

Figure 3.3 Reported cause of crop loss



Source: Authors.
Note: By crop, sample is all respondents who report any loss for that crop.

Comparison to the Integrated Household Survey

Given that our methodology departs from previous self-reported measures through a detailed collection of loss by activity and a differentiation of quality loss and complete loss, it is instructive to compare our estimates to the estimates collected in the IHS through a less detailed methodology. The IHS data were collected with a single question for each crop, asking how much of the harvest was "*lost* to rotting, insects, rodents, theft, etc. in the *postharvest period*?" The bottom panel of Table 2.1 provides comparison of the percentage reporting loss and the proportion of production lost for the three crops of interest between the IHS and our sample. The most striking result is the large discrepancy between the percentage of people reporting loss in the IHS compared to our sample. In the IHS, only 6, 4, and 4 percent of households report loss for maize, groundnuts, and soy, respectively, compared to 36 percent, 47 percent, and 42 percent in our sample. The IHS numbers for maize are similar to those reported by Kaminski and Christiaensen (2014), who used the 2010/2011 round of the IHS.

A number of things may account for these differences. First, whereas our survey specifically asks about damage and total loss, the IHS lacks specificity and refers more generally to complete loss. Given that a significant proportion of damaged crops are rated as having “extensive damage” and even low levels of damage can affect a crop’s suitability for sale and export, collecting this additional information is important. However, the numbers in Panel B of Table 3.1 show that even when just considering total losses, the estimates from this survey still far exceed the IHS estimates. It is therefore evident that the detailed questions and differentiation by activity are important to the collection of this information. For example, the IHS question does not specifically refer to harvest and transport or processing activities, which account for the bulk of losses in our analysis. By focusing on causes related to storage, the IHS is missing important information about other activities carried out by producers.

Interestingly, even though the incidence of losses is so much higher in the NASFAM sample, the unconditional proportion of lost production is similar for maize and soy and is only somewhat higher for groundnuts (2 percent compared to 5 percent). Indeed, the conditional proportions lost in the IHS data are much higher—above 20 percent for maize. Beyond measurement differences, the most likely explanation for this discrepancy is the recall period. As noted earlier, our survey will underestimate losses due to storage because it takes place soon after harvest, when crops have not been in storage for long. The IHS, conducted in 2013, asked the loss question about the 2011/2012 rainy season in order to fully account for these storage losses; Kaminski and Christiaensen (2014) then adjusted the data based on the collection time before coming up with their estimate for postharvest losses. We can assume that any storage losses, although infrequent, are more important when they occur than they seem to be in our data, at least for maize. Because households are less likely to store large amounts of groundnuts and soy for the year, our estimates are more likely to be accurate for those crops.[8]

Overall, the analysis of the incidence of postharvest losses in our sample suggests that losses at the producer level in our sample are small compared to many previous estimates being used to advocate for policy interventions aimed at loss reduction (FAO 2011). Even using a more detailed methodology that expands beyond maize and carefully accounts for losses by activity and damage level, as well as total loss, our average results are consistent with the estimates for Malawi, Uganda, and Tanzania in Kaminski and Christiaensen (2014). Although our methods substantially raise the percentage of farmers who report losses, the proportion of the crop lost remains low overall, on average.

[8] Moreover, the proportion of farmers growing these crops in the IHS is quite low. Given the low levels of reported losses, there are not sufficient data to reliably compare the two data sources.

4. DETERMINANTS OF POSTHARVEST LOSSES

The rich household survey data available in our project provides the opportunity to go beyond simply describing the incidence of postharvest losses to also study their determinants. This section explores whether it is possible to predict the incidence of losses using a variety of household and climate characteristics; it further examines whether these determinates vary by activity.[9] Our regression analysis uses ordinary least squares regressions in which the outcome variable is an indicator variable for incurring any loss or the proportion of harvest lost. In certain specifications, we also use the inverse hyperbolic sine of the value of the loss.[10] In regressions, robust standard errors are clustered by farmer club.

Regressions include a variety of potential predictor variables. First, we examine variables related to agricultural output, the inverse hyperbolic sine of crop production (in kilograms) and of the gross value of agricultural output. Next, we include a set of variables to proxy for household wealth, the inverse hyperbolic sine of the total value of household assets and of land area owned. We also include a set of demographic variables including household size, age of the NASFAM member, gender of the NASFAM member, and whether the NASFAM member is reported as the household head. The number of years the NASFAM member has been in the farmer club is included as a proxy for agricultural experience and for access to agricultural advice and other services. We further control for risk preferences through a simple survey question that asks respondents, on a scale from 1 to 10, whether they generally see themselves as a person who is fully prepared to take risks.[11] Finally, we include control variables for the education level of the NASFAM member, though we do not show this variable in the results.

Crop production and demographic variables are measured during the second follow-up. Wealth measures, gross value of agricultural production, and risk preferences are measured during the first follow-up, as they may have been affected by recent crop loss. Marital status is measured at baseline. Dummy variables are included to control for missing values and participation in the first follow-up. We do not intend to interpret any of the multivariate analysis causally; rather, the intention is to provide some understanding of the characteristics that are associated with crop loss, holding other factors constant.

Finally, because crop losses are related to climatic factors—specifically, humidity and temperature—we include mean precipitation preharvest (November–March) and during harvest and postharvest (April–September). Rainfall prior to harvest should be indicative of overall production, as well as a proxy for humidity patterns. Excess rainfall during the harvest/postharvest period can directly cause losses, particularly during harvest and processing. The precipitation data come from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data source. The GPS coordinates in our data match 33 unique cells in the CHIRPS data. We additionally control for long-term average precipitation and average maximum temperature[12] but do not show these coefficients in the results.[13] This specification of precipitation and temperature follows the model used by Kaminski and Christiaensen (2014) in their investigation of determinants of losses in Tanzania.

We begin by exploring losses aggregated across activities. Table 4.1 presents the results across all crops (columns 1 and 2), maize (columns 3 and 4), groundnuts (columns 5 and 6), and soy (columns 7 and 8). For each category, we examine conditional correlations with two outcome variables: an indicator for any loss occurring and the proportion of harvest lost. For the analysis across crops, we cannot calculate proportion of harvest lost and instead examine the inverse hyperbolic sine of the value of the loss in column 2.

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[9] We also examine determinants by type of loss—that is, by quality loss and total loss of each crop—and find similar results.

[10] The inverse hyperbolic sine is similar to the log but is defined at zero. It is defined as $\log(y_i + (y_i^2 + 1)^{1/2})$. As is clear from the formula, the inverse hyperbolic sine collapses to a simple transformation of $\log(y)$ for most values of y.

[11] A 1 indicates someone who avoids risks, while a 10 indicates high willingness to take risks.

[12] We do not have access to the most recent temperature data.

[13] The historical data are monthly averages at approximately 1-km resolution from WorldClim.

Table 4.1 Determinants of postharvest losses

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Maize, groundnuts, and soy		Maize		Groundnuts		Soy	
Variable	Any loss	Inv hyp sine value of loss	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost
Inv hyp sine production quantity: Maize (kgs)	0.026*	0.319**	0.057***	-0.008***				
	(0.015)	(0.147)	(0.017)	(0.003)				
Inv hyp sine production quantity: Groundnuts (kgs)	0.019***	0.181***			0.056***	-0.030***		
	(0.006)	(0.060)			(0.018)	(0.007)		
Inv hyp sine production quantity: Soy (kgs)	0.008	0.096					0.034*	-0.016***
	(0.007)	(0.066)					(0.018)	(0.006)
Inv hyp sine of gross value of agricultural output	0.005	-0.016	-0.012	-0.003	-0.021	0.004	-0.014	0.002
	(0.021)	(0.206)	(0.021)	(0.003)	(0.023)	(0.010)	(0.024)	(0.004)
Inv hyp sine of total household asset value	-0.020*	-0.199*	-0.008	-0.000	-0.028**	-0.009	-0.016	-0.001
	(0.012)	(0.108)	(0.014)	(0.001)	(0.013)	(0.007)	(0.013)	(0.002)
Inv hyp sine of total land area owned (acres)	-0.051	-0.318	-0.082*	-0.004	0.031	-0.001	-0.021	-0.007
	(0.043)	(0.405)	(0.042)	(0.004)	(0.040)	(0.014)	(0.053)	(0.009)
Household size	0.023***	0.221***	0.005	0.001	0.020**	0.007**	0.017*	0.000
	(0.007)	(0.068)	(0.008)	(0.001)	(0.008)	(0.003)	(0.009)	(0.001)
Age of NASFAM member	-0.002	-0.020*	-0.003**	-0.000*	-0.001	0.000	-0.001	0.000
	(0.001)	(0.012)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
NASFAM member is female	-0.089**	-0.752*	-0.018	-0.004	-0.006	0.015	-0.085*	-0.014
	(0.045)	(0.429)	(0.045)	(0.004)	(0.055)	(0.013)	(0.047)	(0.010)
NASFAM member is polygamous	0.053	1.007	-0.036	-0.004	0.110	0.010	0.047	0.034
	(0.071)	(0.708)	(0.071)	(0.005)	(0.080)	(0.012)	(0.072)	(0.030)
Years in NASFAM club	0.002	0.041	0.001	0.001	-0.003	0.002	-0.002	-0.000
	(0.006)	(0.054)	(0.007)	(0.001)	(0.007)	(0.002)	(0.007)	(0.001)
Member is head of household	-0.006	0.044	0.013	-0.002	0.057	0.011	-0.000	-0.006
	(0.046)	(0.442)	(0.044)	(0.005)	(0.049)	(0.013)	(0.045)	(0.008)
Risk score (1-10)	-0.014**	-0.121**	-0.019***	-0.000	-0.002	0.002	-0.010*	-0.001
	(0.006)	(0.054)	(0.005)	(0.001)	(0.007)	(0.002)	(0.006)	(0.001)
Mean precipitation preharvest	-0.008**	-0.068**	-0.006**	-0.000	-0.002	0.001	-0.013***	-0.000
	(0.003)	(0.028)	(0.003)	(0.000)	(0.004)	(0.001)	(0.003)	(0.001)

Table 4.1 Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Maize, groundnuts, and soy		Maize		Groundnuts		Soy	
Variable	**Any loss**	**Inv hyp sine value of loss**	**Any loss**	**Proportion of harvest lost**	**Any loss**	**Proportion of harvest lost**	**Any loss**	**Proportion of harvest lost**
Mean precipitation postharvest	0.047**	0.460**	0.029	0.001	0.029	0.003	0.059**	0.003
	(0.021)	(0.198)	(0.019)	(0.002)	(0.026)	(0.006)	(0.024)	(0.004)
Observations	1,112	1,109	1,107	1,106	896	896	872	871
R-squared	0.056	0.066	0.051	0.043	0.044	0.105	0.053	0.051
Mean of dependent variable	0.614	7981	0.359	0.0182	0.468	0.0547	0.423	0.0324

Source: Authors.

Note: NSAFAM = National Smallholder Farmers' Association of Malawi. Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. Regressions also control for NASFAM member education (indicator variables for some primary, completed primary, some secondary, and completed secondary plus) and the 1960-1990 average precipitation and temperature. Missing values of independent variables due to missing first follow-up are set to zero and an indicator for missing the first follow-up is included. Additional missing values are also set to zero and indicator variables are included to control for each missing value. The risk score is the answer to the survey question: "How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?" 10 indicates a person who is very willing to take risks. Preharvest precipitation covers November–March and harvest/post-harvest precipitation covers April–September. *** p<0.01, ** p<0.05, * p<0.1.

Across all specifications, the production quantity is an important predictor of crop loss. Increased production of a crop increases the probability of experiencing any loss but decreases the proportion of harvest lost. Because these results make intuitive sense, they are useful to suggest validation of our measures of postharvest losses. The more a farmer has produced, the more opportunity there is to experience loss; however, because the farmer produced a larger amount, that loss is a smaller percentage of the overall harvest. The prior year gross value of agricultural output is not significantly associated with crop loss.

Some evidence suggests that wealth is negatively associated with experiencing loss. In particular, total household asset value is negatively associated with experiencing any loss and the value of that loss (columns 1 and 2), statistically significant at the 10 percent level. This negative relationship is consistent in the crop-level regressions as well, though not usually statistically significant. This evidence suggests that wealthier households are better equipped to avoid crop loss, either because they have more resources or because they have access to better information.

The demographic variables are generally not predictive, with two exceptions. Household size is positively associated with experiencing any loss and total loss value. It could be that the larger the household, the more diffuse the responsibility for ensuring proper handling of crop production; alternatively, it could be that households have had to acquire more diffuse plots to feed the household, and therefore there is more chance of loss. This relationship is repeated on the crop level for groundnuts for both any loss and proportion of harvest lost and for soy for any loss. One additional household member is associated with a 2-percentage point increase in the probability of experiencing a loss. The results further suggest that female NASFAM members are less likely to experience loss than male members, a result that is significant across crops and for soy. Although not directly comparable, Kaminski and Christiaensen (2014) found that female-headed households are less likely to incur losses in Tanzania. Because females are in charge of meal preparation, if fully in control of the farm, they are perhaps more likely to ensure that postharvest crop losses are minimized.

The final survey measure to exhibit a significant relationship with loss incidence is the respondent's risk score. Respondents who are less risk averse (that is, more likely to take risks) are somewhat counterintuitively less likely to experience any loss, a result that is statistically significant across crops and for maize and soy. A 1-percentage point increase in the risk score is associated with a 1- to 2-percentage point increase in the probability of experiencing any loss. There does not appear to be an association with risk preferences and the proportion of harvest lost, though there is a strong association with the total value of the loss. Because the survey module related to risk is about risks in general, these questions are not focused on understanding risk solely in the context of agriculture. Our analysis cannot definitively explain why this correlation between risk aversion and postharvest losses exists. One possibility is that decisions made by farmers more willing to take risks include adapting technologies or practices that contribute to lower postharvest losses.[14] Risk aversion may also be a proxy for other, unobserved farmer characteristics. It is also possible that risk aversion affects a farmer's perception of losses and, consequently, his or her responses to our survey questions. For example, farmers categorized as risk taking might perceive postharvest losses as lower because they do not consider the small amounts of crops lost in transporting or processing as materially important until those losses get large.

Finally, the precipitation data show that climate variations are important in determining losses. Preharvest precipitation has a negative effect on losses (statistically significant in columns 1, 2, 3, and 7). More rain during the growing season should be indicative of a better quality harvest that is less likely to be damaged or completely lost, save problems with flooding. Conversely, postharvest rainfall has a positive effect on the incidence of losses (significant in columns 1, 2, and 7). Damp, humid weather after the harvest can lead crops to spoil or mold in storage, as well as making harvest and processing more difficult. It is also interesting to note that while precipitation in both periods is predictive, the size of the

[14] This relationship could be general or specific to the climate conditions of the 2015/2016 agricultural season.

coefficients for postharvest rainfall is much larger than for preharvest rainfall. These results are similar to those in Kaminski and Christiaensen (2014), although in Tanzania, they did not find a relationship with preharvest rainfall. The role of weather suggests that all households, not just a certain set, are susceptible to losses in bad years, making targeted solutions difficult. Perhaps the most interesting conclusion to be drawn from the regression results is that patterns, for the most part, seem to be similar across crops, despite the three very different crops considered.

The results in Table 4.1 investigate the determinants of losses aggregated across activities. Next, we perform this analysis separately for each activity and crop. Table 4.2a presents the results for maize; Table 4.2b, the results for groundnuts; and Table 4.2c, the results for soy. In each table, columns 1 and 2 examine harvest and transport, columns 3 and 4 examine processing, and columns 5 and 6 examine storage. Unfortunately, the disaggregation of the results leads to a reduction in statistical power, making the identification of any trends difficult. In general, however, patterns by activity appear to be similar to those identified in aggregate. Finally, for groundnuts and soy, the impacts of precipitation postharvest seem to be entirely concentrated on the processing stage.

One of the most interesting results from Table 4.1 is that people who are more inclined to take risks are less likely to experience losses. To test the robustness of this result, we replicate Table 4.1 but replace the survey risk measure with an incentivized measure (also scaled 1 to 10) collected during a lab-in-the-field experiment conducted during fieldwork for the first follow-up (Ambler, Godlonton, and Recalde 2017). Participants were given an endowment and were asked to decide how much of that endowment they wanted to keep and how much they wanted to invest. Investments would quadruple with 50 percent probability and be lost with 50 percent probability (Table 4.3). The incentivized measure gives similar results as the survey measure, supporting the association between risk and loss incidence.

Finally, we examine the relationship between access to agricultural training and postharvest losses. As described in Section 2, these data were collected as part of a project that randomized implementation of an intensive agricultural extension program. This intensive program included at least three one-on-one visits from a professional extension worker, a farm management plan, and additional group activities. Control group farmers received standard extension services in which extension is disseminated largely through trained farmers leading demonstrations. Although the intensive extension program did not focus specifically on postharvest losses, it did touch on all aspects of production and could have affected loss incidence. The results are presented in Table 4.4, which shows the three treatment indicators (year 1 treatment, year 2 treatment, and treatment in both years). The regressions also control for the capital transfers and all other variables included in Table 4.1. When examining the aggregate measures of any loss and value of loss in columns 1 and 2, these results suggest that being exposed to two years of intensive extension lowers the probability that a farmer will incur a loss (these results are significant at the 10 percent level). There is no evidence that one year of extension has any impact, and the sample appears to be underpowered to detect any crop-level impacts of training. These results, however, suggest that quality extension programs can play a part in reducing postharvest losses but that one season of training is likely not sufficient.

Table 4.2a Determinants of postharvest losses by activity: Maize

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Harvest and transport		Processing		Storage	
	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost
Inv hyp sine production quantity: Maize (kgs)	0.029*	-0.005***	0.033*	-0.002	-0.007	-0.002
	(0.017)	(0.002)	(0.017)	(0.001)	(0.014)	(0.001)
	-0.010	-0.002	-0.004	0.000	0.010	-0.002
Inv hyp sine of gross value of agricultural output	(0.018)	(0.003)	(0.016)	(0.001)	(0.018)	(0.002)
Inv hyp sine of total household asset value	-0.002	-0.001	-0.007	-0.000	-0.018	0.001
	(0.011)	(0.001)	(0.011)	(0.000)	(0.012)	(0.001)
Inv hyp sine of total land area owned (acres)	-0.047	-0.002	-0.038	-0.002	-0.004	0.000
	(0.035)	(0.004)	(0.035)	(0.002)	(0.030)	(0.002)
Household size	0.005	0.001	0.008	0.000	-0.007	-0.000
	(0.007)	(0.000)	(0.006)	(0.000)	(0.005)	(0.000)
Age of NASFAM member	-0.001	-0.000*	-0.001	-0.000	-0.001	-0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
NASFAM member is female	-0.036	-0.004	-0.042	-0.003	0.014	0.004
	(0.039)	(0.003)	(0.037)	(0.002)	(0.035)	(0.003)
NASFAM member is polygamous	0.040	-0.001	-0.138***	-0.004***	0.002	0.001
	(0.071)	(0.004)	(0.045)	(0.001)	(0.054)	(0.002)
Years in NASFAM club	0.002	0.002	-0.006	-0.000	0.020***	-0.000
	(0.006)	(0.001)	(0.005)	(0.000)	(0.006)	(0.000)
Member is head of household	0.006	-0.003	0.027	0.000	-0.006	0.002
	(0.034)	(0.004)	(0.034)	(0.001)	(0.032)	(0.003)
Risk score (1-10)	-0.009**	-0.000	-0.009*	-0.000	-0.004	0.000
	(0.005)	(0.001)	(0.005)	(0.000)	(0.004)	(0.000)
Mean precipitation preharvest	-0.004	0.000	-0.004*	-0.000*	-0.002	0.000
	(0.003)	(0.000)	(0.002)	(0.000)	(0.003)	(0.000)
Mean precipitation postharvest	0.014	-0.001	0.022	0.001	0.024	0.000
	(0.018)	(0.002)	(0.017)	(0.001)	(0.020)	(0.001)

Table 4.2a Continued

Variable	(1) Harvest and transport: Any loss	(2) Harvest and transport: Proportion of harvest lost	(3) Processing: Any loss	(4) Processing: Proportion of harvest lost	(5) Storage: Any loss	(6) Storage: Proportion of harvest lost
Observations	1,103	1,103	1,067	1,067	941	941
R-squared	0.039	0.033	0.042	0.031	0.044	0.038
Mean of dependent variable	0.201	0.0103	0.214	0.00451	0.143	0.00417

Source: Authors.
Note: NASFAM = Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. Regressions also control for NASFAM member education (indicator variables for some primary, completed primary, some secondary, and completed secondary plus) and the 1960–1990 average precipitation and temperature. Missing values of independent variables due to missing first follow-up are set to zero and an indicator for missing the first follow-up is included. Additional missing values are also set to zero and indicator variables are included to control for each missing value. The risk score is the answer to the survey question: "How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?" 10 indicates a person who is very willing to take risks. Pre-harvest precipitation covers November–March and harvest/postharvest precipitation covers April–September. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.2b Determinants of postharvest losses by activity: Groundnuts

Variable	(1) Harvest and transport: Any loss	(2) Harvest and transport: Proportion of harvest lost	(3) Processing: Any loss	(4) Processing: Proportion of harvest lost	(5) Storage: Any loss	(6) Storage: Proportion of harvest lost
Inv hyp sine production quantity: Groundnuts (kgs)	0.009	-0.021***	0.025	-0.009***	0.015	-0.001
	(0.017)	(0.007)	(0.020)	(0.003)	(0.014)	(0.002)
Inv hyp sine of gross value of agricultural output	-0.010	-0.001	-0.005	0.008	-0.001	-0.003
	(0.019)	(0.007)	(0.020)	(0.007)	(0.019)	(0.003)
Inv hyp sine of total household asset value	-0.017	-0.008	-0.019	-0.000	-0.026**	-0.001
	(0.012)	(0.007)	(0.013)	(0.001)	(0.012)	(0.001)
Inv hyp sine of total land area owned (acres)	-0.000	0.004	0.036	-0.007	0.005	0.003
	(0.039)	(0.012)	(0.047)	(0.008)	(0.036)	(0.002)
Household size	0.022***	0.006**	0.002	0.000	0.009	0.001
	(0.008)	(0.003)	(0.008)	(0.001)	(0.007)	(0.001)
Age of NASFAM member	-0.001	0.000	-0.001	0.000	0.001	-0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
NASFAM member is female	0.005	0.012	-0.001	0.002	-0.031	0.000
	(0.047)	(0.010)	(0.055)	(0.006)	(0.038)	(0.003)

Table 4.2b Continued

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Harvest and transport		Processing		Storage	
	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost
NASFAM member is polygamous	-0.011	0.009	0.079	0.004	-0.032	-0.002**
	(0.072)	(0.012)	(0.082)	(0.007)	(0.052)	(0.001)
Years in NASFAM club	0.004	0.001	-0.004	0.001	0.006	-0.000
	(0.006)	(0.001)	(0.006)	(0.001)	(0.005)	(0.000)
Member is head of household	0.027	0.009	0.056	0.001	-0.017	0.001
	(0.042)	(0.012)	(0.044)	(0.005)	(0.031)	(0.005)
Risk score (1-10)	0.001	0.002	-0.003	0.001	0.001	-0.000
	(0.006)	(0.001)	(0.005)	(0.001)	(0.005)	(0.000)
Mean precipitation preharvest	0.003	0.002	-0.012***	-0.001*	-0.001	-0.000
	(0.004)	(0.001)	(0.003)	(0.000)	(0.003)	(0.000)
Mean precipitation postharvest	-0.001	-0.002	0.083***	0.005**	-0.002	0.001
	(0.027)	(0.006)	(0.025)	(0.002)	(0.016)	(0.001)
Observations	892	892	855	855	813	813
R-squared	0.033	0.091	0.083	0.062	0.050	0.031
Mean of dependent variable	0.286	0.0384	0.255	0.0127	0.156	0.00474

Source: Authors.

Note: Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. Regressions also control for NASFAM member education (indicator variables for some primary, completed primary, some secondary, and completed secondary plus) and the 1960–1990 average precipitation and temperature. Missing values of independent variables due to missing first follow-up are set to zero and an indicator for missing the first follow-up is included. Additional missing values are also set to zero and indicator variables are included to control for each missing value. The risk score is the answer to the survey question: "How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?" 10 indicates a person who is very willing to take risks. Pre-harvest precipitation covers November–March and harvest/postharvest precipitation covers April–September. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.2c Determinants of postharvest losses by activity: Soy

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Harvest and transport		Processing		Storage	
	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost
Inv hyp sine production quantity: Soy (kgs)	0.027*	-0.007**	0.034*	-0.008**	-0.007	-0.002**
	(0.016)	(0.003)	(0.017)	(0.003)	(0.010)	(0.001)
	0.004	0.001	-0.024	0.001	0.014	0.000
Inv hyp sine of gross value of agricultural output	(0.020)	(0.003)	(0.023)	(0.003)	(0.012)	(0.000)
Inv hyp sine of total household asset value	-0.014	-0.001	-0.012	-0.002	-0.011	0.000
	(0.012)	(0.002)	(0.013)	(0.001)	(0.011)	(0.000)

Table 4.2c Continued

Variable	(1) Harvest and transport: Any loss	(2) Harvest and transport: Proportion of harvest lost	(3) Processing: Any loss	(4) Processing: Proportion of harvest lost	(5) Storage: Any loss	(6) Storage: Proportion of harvest lost
Inv hyp sine of total land area owned (Acres)	0.003	-0.006	-0.015	-0.003	-0.000	-0.000
	(0.040)	(0.007)	(0.051)	(0.007)	(0.023)	(0.001)
Household size	-0.001	-0.001	0.015*	0.001	0.009	0.000*
	(0.008)	(0.001)	(0.009)	(0.001)	(0.006)	(0.000)
Age of NASFAM member	-0.001	0.000	-0.001	0.000	0.001	0.000
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
NASFAM member is female	-0.040	-0.008	-0.062	-0.001	-0.044*	-0.001
	(0.038)	(0.009)	(0.049)	(0.006)	(0.026)	(0.001)
NASFAM member is polygamous	0.073	0.036	-0.032	0.001	-0.060***	-0.002**
	(0.076)	(0.030)	(0.066)	(0.007)	(0.022)	(0.001)
Years in NASFAM club	0.006	-0.000	-0.001	-0.000	0.007	-0.000
	(0.005)	(0.001)	(0.008)	(0.001)	(0.005)	(0.000)
Member is head of household	0.039	-0.003	-0.013	0.001	-0.014	-0.001
	(0.035)	(0.006)	(0.047)	(0.005)	(0.024)	(0.001)
Risk score (1-10)	-0.004	-0.001	-0.005	0.000	-0.004	-0.000
	(0.005)	(0.001)	(0.006)	(0.000)	(0.003)	(0.000)
Mean precipitation preharvest	-0.002	0.000	-0.012***	-0.001*	0.002	0.000
	(0.003)	(0.000)	(0.003)	(0.000)	(0.002)	(0.000)
Mean precipitation postharvest	-0.007	-0.001	0.065***	0.005*	-0.006	-0.001*
	(0.019)	(0.002)	(0.021)	(0.003)	(0.014)	(0.000)
Observations	867	867	825	825	772	772
R-squared	0.045	0.043	0.052	0.047	0.039	0.049
Mean of dependent variable	0.209	0.0154	0.325	0.0170	0.0672	0.00172

Source: Authors.

Note: Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. Regressions also control for NASFAM member education (indicator variables for some primary, completed primary, some secondary, and completed secondary plus) and the 1960–1990 average precipitation and temperature. Missing values of independent variables due to missing first follow-up are set to zero and an indicator for missing the first follow-up is included. Additional missing values are also set to zero and indicator variables are included to control for each missing value. The risk score is the answer to the survey question: "How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?" 10 indicates a person who is very willing to take risks. Preharvest precipitation covers November–March and harvest/postharvest precipitation covers April–September. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.3 Determinants of postharvest losses: Incentivized risk measure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Maize, groundnuts, and soy		Maize		Groundnuts		Soy	
Variable	Any loss	Inv hyp sine	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost	Any loss	Proportion of harvest lost
Inv hyp sine production quantity: Maize (kgs)	0.024*	0.307**	0.055***	-0.008***				
	(0.015)	(0.147)	(0.017)	(0.003)				
Inv hyp sine production quantity: Groundnuts (kgs)	0.020***	0.183***			0.054***	-0.030***		
	(0.006)	(0.060)			(0.018)	(0.008)		
Inv hyp sine production quantity: Soy (kgs)	0.008	0.098					0.036**	-0.016***
	(0.007)	(0.067)					(0.018)	(0.005)
Inv hyp sine of gross value of agricultural output	0.005	-0.003	-0.014	-0.003	-0.018	0.005	-0.010	0.003
	(0.021)	(0.202)	(0.021)	(0.003)	(0.023)	(0.010)	(0.024)	(0.004)
Inv hyp sine of total household asset value	-0.021*	-0.204*	-0.010	-0.000	-0.028**	-0.008	-0.017	-0.001
	(0.012)	(0.109)	(0.014)	(0.001)	(0.013)	(0.006)	(0.013)	(0.002)
Inv hyp sine of total land area owned (acres)	-0.045	-0.265	-0.075*	-0.003	0.038	-0.003	-0.016	-0.007
	(0.044)	(0.407)	(0.043)	(0.004)	(0.039)	(0.014)	(0.053)	(0.009)
Household size	0.022***	0.214***	0.004	0.001	0.020**	0.007**	0.015*	0.000
	(0.007)	(0.067)	(0.008)	(0.001)	(0.008)	(0.003)	(0.009)	(0.001)
Age of NASFAM member	-0.002	-0.020*	-0.002**	-0.000**	-0.001	0.000	-0.001	0.000
	(0.001)	(0.012)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
NASFAM member is female	-0.092**	-0.758*	-0.022	-0.004	-0.010	0.019	-0.080	-0.012
	(0.044)	(0.429)	(0.045)	(0.005)	(0.055)	(0.013)	(0.048)	(0.011)
NASFAM member is polygamous	0.047	0.976	-0.043	-0.004	0.108	0.010	0.050	0.035
	(0.072)	(0.709)	(0.073)	(0.006)	(0.079)	(0.011)	(0.071)	(0.030)
Years in NASFAM club	0.003	0.043	0.003	0.001	-0.003	0.002	-0.001	-0.000
	(0.006)	(0.055)	(0.007)	(0.001)	(0.007)	(0.002)	(0.007)	(0.001)
Member is head of household	-0.002	0.096	0.015	-0.001	0.063	0.013	0.011	-0.005
	(0.047)	(0.446)	(0.045)	(0.005)	(0.049)	(0.014)	(0.046)	(0.008)
Incentivized risk measure	-0.011**	-0.081	-0.011**	-0.001*	-0.008	0.003*	-0.007	0.001
	(0.005)	(0.050)	(0.005)	(0.001)	(0.006)	(0.002)	(0.006)	(0.001)
Mean precipitation preharvest	-0.007**	-0.065**	-0.005*	-0.000	-0.002	0.001	-0.012***	-0.000
	(0.003)	(0.028)	(0.003)	(0.000)	(0.004)	(0.001)	(0.003)	(0.001)
Mean precipitation postharvest	0.045**	0.439**	0.028	0.001	0.027	0.003	0.056**	0.002
	(0.021)	(0.193)	(0.019)	(0.003)	(0.025)	(0.006)	(0.025)	(0.004)

Table 4.3 Continued

Variable	(1) Maize, groundnuts, and soy: Any loss	(2) Maize, groundnuts, and soy: Inv hyp sine	(3) Maize: Any loss	(4) Maize: Proportion of harvest lost	(5) Groundnuts: Any loss	(6) Groundnuts: Proportion of harvest lost	(7) Soy: Any loss	(8) Soy: Proportion of harvest lost
Observations	1,111	1,108	1,106	1,105	895	895	872	871
R-squared	0.054	0.063	0.043	0.046	0.044	0.108	0.058	0.055
Mean of dependent variable	0.614	7981	0.359	0.0182	0.468	0.0547	0.423	0.0324

Source: Authors.

Note: Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. Regressions also control for NASFAM member education (indicator variables for some primary, completed primary, some secondary, and completed secondary plus) and the 1960–1990 average precipitation and temperature. Missing values of independent variables due to missing first follow-up are set to zero and an indicator for missing the first follow-up is included. Additional missing values are also set to zero and indicator variables are included to control for each missing value. The incentivized risk measure is the results of an investment decision (normalized to 1–10) where respondents chose how much of an endowment to invest. Investments paid zero with 50% probability and were quadrupled with 50% probability. Preharvest precipitation covers November–March and harvest/postharvest precipitation covers April–September. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.4 Impact of extension treatment on postharvest losses

Variable	(1) Maize, groundnuts, and soy: Any loss	(2) Maize, groundnuts, and soy: Inv hyp sine value of loss	(3) Maize: Any loss	(4) Maize: Proportion of harvest lost	(5) Groundnuts: Any loss	(6) Groundnuts: Proportion of harvest lost	(7) Soy: Any loss	(8) Soy: Proportion of harvest lost
Received intensive extension in year 1 only	-0.001	-0.102	-0.040	0.004	0.018	-0.001	0.021	-0.003
	(0.039)	(0.398)	(0.040)	(0.006)	(0.065)	(0.015)	(0.046)	(0.007)
Received intensive extension in year 2 only	0.014	0.145	0.042	0.002	0.037	-0.007	-0.005	0.003
	(0.034)	(0.340)	(0.035)	(0.004)	(0.054)	(0.016)	(0.041)	(0.010)
Received intensive extension in years 1 and 2	-0.063*	-0.630*	-0.040	-0.004	0.006	0.003	-0.021	0.003
	(0.038)	(0.349)	(0.036)	(0.004)	(0.057)	(0.015)	(0.040)	(0.010)
Observations	1,012	1,010	1,009	1,008	815	815	796	796
R-squared	0.067	0.076	0.068	0.051	0.057	0.112	0.059	0.052
Mean of dependent variable	0.614	7981	0.359	0.0182	0.468	0.0547	0.423	0.0324

Source: Authors.

Note: Robust standard errors in parentheses are clustered by farmer club. Inclusion in regressions is conditional on growing the crop. In addition to the treatment indicators for intensive extension regressions control for the randomized capital transfer treatments and all other variables that were included in Table 3.3. *** p<0.01, ** p<0.05, * p<0.1

5. SUMMARY AND IMPLICATIONS FOR INTERVENTIONS

This paper studies the incidence and predictors of postharvest losses in Malawi, using a detailed survey module designed to pinpoint where these losses occur on the farm. Losses are, in general, quite low, consistent with findings from a much less detailed survey module described by Kaminski and Christiaensen (2014) and with those from nationally representative data analyzed in this paper. However, our methodology suggests that losses are spread across a much larger proportion of farmers. The previous work focused on total crop loss during storage; this paper, however, uses a more specific questionnaire to document that farmers report both total loss and partial (quality) loss, as well as loss during harvest and transport, processing, and storage.

A principal contribution of this paper is that it goes beyond maize to study losses in two common smallholder cash crops: groundnuts and soy. We find slightly higher losses for groundnuts and soy, as compared with maize. However, the estimates are still on the low end of estimates worldwide or publicized through sources such as APHLIS. Our detailed survey instrument allows us to identify which activities are more susceptible to crop losses for the three focus crops. Losses in our sample are concentrated in harvest and processing activities for groundnuts and maize; whereas for soy, they are highest during processing. Most interventions have been targeted toward storage activities, but our results suggest that targeting other activities might also be worth considering.

The second part of this study analyzes the predictors of postharvest losses. We find little that would inform an efficient farmer-level targeting strategy for loss-reduction technologies. However, given that more than half of farmers report experiencing some kind of postharvest loss in the three crops studies and that losses of even 5 percent of harvest can be individually significant for poor farmers, innovative policy solutions for smallholders could still have an important impact. Such solutions must be cost-effective and easy to implement. Two of our results provide guidance for possible solutions. First, we find that higher production leads to higher losses, suggesting that farmers may have the capacity and willingness to pay for technologies that can limit losses if they are properly informed about their importance. In addition, the important role of climate—in particular, precipitation during and postharvest—highlights the variability of these losses over time. Properly educating farmers about the conditions in which they should be most concerned about loss prevention will only serve to enhance the effectiveness of any prevention strategies.

The estimates in this paper and others, which that show that postharvest losses are low at the farmer level, suggest that any large investments in the reduction of food loss may be best targeted at other points in the value chain. The potential value of either policies or interventions to reduce postharvest loss further on the value chain is beyond the scope of this paper. It could be that in Malawi, postharvest losses are, on average, as high as sources such as APHLIS have suggested. If so, then targeted interventions at actors along the value chain, from middlemen to processors, could improve crop handling and therefore overall food availability. However, before such interventions are planned, it would be prudent to conduct a careful study of postharvest losses among middlemen and processors to understand whether such interventions would be cost-effective ways to increase actual crop use.

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