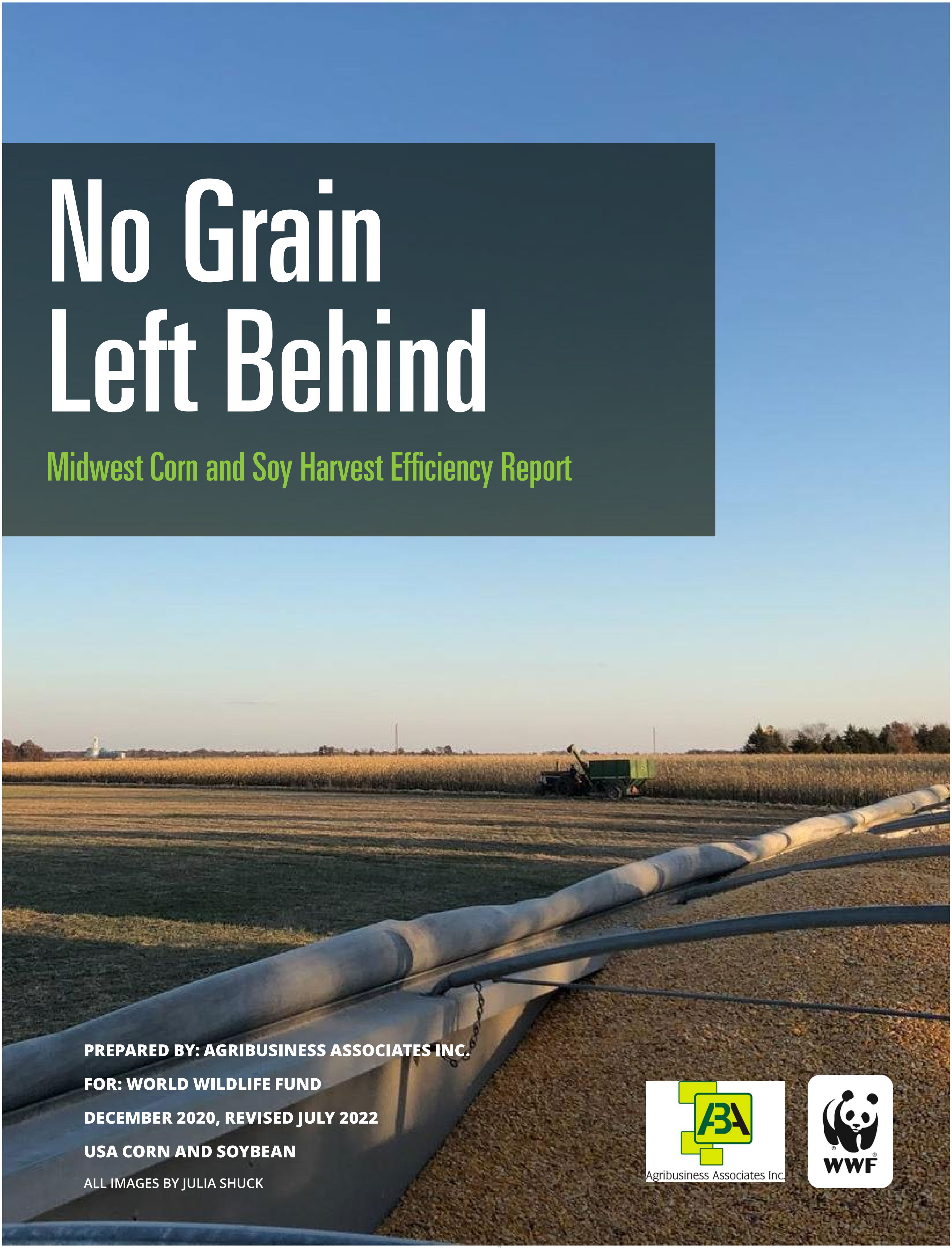

No Grain Left Behind

Midwest Corn and Soy Harvest Efficiency Report

PREPARED BY: AGRIBUSINESS ASSOCIATES INC.

FOR: WORLD WILDLIFE FUND

DECEMBER 2020, REVISED JULY 2022

USA CORN AND SOYBEAN

ALL IMAGES BY JULIA SHUCK

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WWF

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EXECUTIVE SUMMARY

Globally, one third of food is lost or wasted.[1] In developing countries, this commonly presents itself as food loss, where product does not reach the consumer, whereas in developed countries, food is typically wasted closer to the point of consumption, such as grocery stores, restaurants, and in consumers' homes. Estimates indicate that 16% of US food loss occurs at the farm level, though this is based on limited field studies.[2]

This research focuses on harvest-related losses for corn and soybeans, as these crops are commonly rotated throughout the United States and collectively represent 22% of all agricultural land.[3,4] Corn and soybean agricultural research mostly focuses on increasing yield and research on losses in the supply chain has been lacking. Proper harvesting and management of edible food at the farm level presents an opportunity to capture food early in the value chain that can potentially support Americans living in food insecure households, or also enter alternative markets for value-added products. Ironically, unavoidable food loss on farms may be preferable compared to later stages in the supply chain, where additional labor and transportation inputs and their resulting environmental effects are embedded into the product.

This research took place in 2020 with field studies being conducted in October 2020, during the global COVID-19 pandemic. The research team took precautions to reduce the risk of transmission between the research team and farmers. Farmers were asked what impact COVID-19 was having on their harvest, and other than one farmer noting the local grain elevator was operating slowly due to half of the staff being under quarantine, there were no other practical implications. That said, delayed impacts from the global pandemic have influenced soybean prices, and the global markets are still watching in anticipation of what may happen to corn prices.

This study collected baseline primary data that showed that the average field-level loss on corn farms was 4.7%, whereas farmers expected 0.65% loss. Extension agents encourage farms to have less than 1% loss. This means a loss overage of 3.7%, which when scaled to the national level, means a loss of 503 million bushels of corn worth $2.07 billion, based on 2019 production figures.[5]

Overall, soybean farmers expected 1.5 bushels of loss per acre, while they experienced an average of 2.18 bushels loss/acre. This study found the average loss was 4.5%, whereas 3% is the accepted industry loss. This means a loss overage of 1.5%, that when scaled to the national level is a loss of $0.53 billion.

This study found that 31.3% of corn farmers contribute to 74.3% of the total loss, and 27% of highest loss soy farms accounted for 44.4% of total losses. Total losses amount to a projected area of land that is four times larger than what was converted to cropland in 2018 across the Great Plains. A strategic campaign

1 http://www.fao.org/food-loss-and-food-waste/flw-data)
2 Xue, Li, et al. "Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data." Environmental Science & Technology, vol. 51, no. 12, 2017, pp. 6618–6633., doi:10.1021/acs.est.7b00401.
3 https://downloads.usda.library.cornell.edu/usda-esmis/files/j098zb09z/vx022244t/8910kf38j/acrg0620.pdf
4 https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0220.pdf

5 https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan20.pdf

to target these farmers, who are often smaller in size and have less sophisticated combine equipment, can improve future harvest efficiency rates, especially for corn. Specifically, encouraging farmers to check for losses when moving to new fields and sharing visual guides on how to do a quick check of field losses may best address gaps in understanding how to estimate harvest related losses and putting this into practice.

The location of ethanol plants and availability of government conservation programs seem to have the greatest influence on US farmer and landowner behavior to convert natural prairie, which is currently the most susceptible to land use change. This issue is of particular concern in North and South Dakota. This study illustrated the staggering amount of land that is used to produce corn and soy that is never sold, or is left behind in-field, which is projected to be four times greater than annual conversion in the Great Plains.

INTRODUCTION

The United Nations Sustainable Development Goal (SDG) 12.3 seeks to halve global food loss and waste by 2030.[6,7] Improving the overall efficiency of the global food system through reduced food loss can help address food security by increasing overall food supply, reduce pressure on the environment by decreasing the amount of land needed to produce food for the world's population, and improve profits of farmers, who often make smaller profit margins than other sectors. As World Wildlife Fund works towards fulfilling these commitments of halving global food loss and waste, this study seeks to understand corn and soy loss at the field level in the US Midwest.

The US is the world's largest producer for both corn and soybeans. About a third of America's corn is used for feeding cattle, hogs and poultry providing them carbs, while soybean provides protein. Over a third of the corn crop is used to make ethanol which serves as a renewable fuel additive to gasoline. The rest of the corn crop is used for human food, beverages and industrial uses in the US or exported to other countries for food or feed use.[8]

Approximately 98% of soybeans grown in the US are used for animal feed and soybean oil.[9] Poultry is the primary livestock consuming soybean, followed by hogs, dairy, beef, and aquaculture. Around 68% of soybean oil is used as food - vegetable oil, baking goods, salad dressings and margarines. Biodiesel makes up 25% of soybean oil used in the US. Further, 7% of soybean oil is used for creating industrial products like paints, plastics, cleaners, etc.[10]

Corn used in ethanol production spurs the food vs fuel debate. About a third (32%) of total corn becomes livestock feed in the form of distilled dried grains and solubles (DDGS).[11] On the other hand, soybean oil is separated from soybean meal that is fed to livestock, leaving a coproduct requiring an end market.[12] This allows soybeans to curtail the issue commonly faced by corn.

Of the 2.3 billion acres of total land in the US,[13] 92 million acres was planted in corn and 83.8 million acres was planted in soy in 2020.[14]Agricultural land has decreased from 63% of US land in 1949[15] to 45.5% in 2017,[16] although production continues to grow, shining a light on the industries growing rates of productivity and agricultural intensification. Concerns regarding accelerated conversion of

6 http://www.fao.org/sustainable-development-goals/indicators/1231/en/
7 Food loss occurs from the point of harvest through delivery to the markets where consumers can buy the final product. Food waste occurs at the consumer level, including supermarkets and restaurants. In developing countries, this loss tends to occur from the point of the farm to reaching the consumer. But in developed countries, like the United States, a majority of food is wasted at the consumer level.
8 Capehart, Tom and Proper, Susan. "Corn is America's Largest Crop in 2019." USDA. United States Department of Agriculture media blog, 01, Aug. 2019. Web. 15 Mar. 2020. www.usda.gov/media/blog/2019/07/29/corn-americas-largest-crop-2019
9 "Soy and Corn: Healthy Choices or Hidden Ingredients?!" Co+op, welcome to the table. Web. 24 Mar. 2020. www.welcometothetable.coop/fresh-from-the-source/soy-and-corn-healthy-choices-or-hidden-ingredients
10 Krull, Chris. "Biodiesel – uses for soybeans." USSoy.org. US Soy Advantage, 11 May, 2018. Web. 20 Mar. 2020. www.ussoy.org/uses-for-soybeans/
11 https://www.agweb.com/Understanding-the-Relationship-Between-Ethanol-and-DDGS
12 https://farm-energy.extension.org/biodiesel-and-the-food-vs-fuel-debate/#Biodiesel_is_often_made_from_animal_feed_by-products
13 https://www.ers.usda.gov/amber-waves/2012/march/data-feature-how-is-land-used/#:~:text=U.S.%20land%20area%20covers%20nearly,forestland%20has%20decreased%20more%20rapidly
14 https://downloads.usda.library.cornell.edu/usda-esmis/files/j098zb09z/vx022244t/8910kf38j/acrg0620.pdf
15 https://www.ers.usda.gov/amber-waves/2012/march/data-feature-how-is-land-used/#:~:text=U.S.%20land%20area%20covers%20nearly,forestland%20has%20decreased%20more%20rapidly
16 https://www.ers.usda.gov/data-products/major-land-uses/

grasslands and wetlands to cropland in the US western corn belt have been raised.[17] Analyzing land cover data revealed elevated rates of grassland conversion (1.0-5.4% annually) in North Dakota, South Dakota, Minnesota, Nebraska, and Iowa.[18]

This study covers harvest-related losses for corn and soybeans, as these crops are commonly rotated throughout the US and collectively represent 22% of all agricultural land. [19] This rotation provides benefits of controlling pest and disease in both crops, while the nitrogen-fixing properties of soybeans provide a boost to corn production, improving overall profitability.[20] A 28-year study comparing continuous corn, continuous soybeans and a corn-soybean rotation, in addition to six tillage systems, found that crop rotation had the greatest impact on yields, regardless of tillage systems, in the Western Corn Belt.[21] However, a 2019 Iowa State study found that soybeans leave nitrogen-rich residue, which supports good bacteria and fungi that help decompose material to improve soil organic matter, whereas corn leaves nitrogen-poor residues, which slows these organisms down. Corn triggers these beneficial bacteria and fungi to go elsewhere in search of food, decreasing decomposition in the long term, although adding a cover crop or rotating an additional crop can maintain soil health.[22]

In the US, estimates indicate 16 percent of food waste occurs at the farm level as loss, which is about 19 million tons. However, this number is based on limited field studies, which vary considerably with regional conditions.[23] A 1989 Ohio harvesting efficiency study, frequently referenced by extension agents today, found 1% losses in corn and 4% losses in soybeans.[24] APHLIS has more recent estimates for Africa, in 2019, that generally estimate losses on the continent at: 6.4% during the harvesting/field drying stage, 4% during further drying, 1.3% while threshing and shelling, and negligible losses during winnowing.[25] This totals to 11.7% in losses at the field level. APHLIS does not collect data for soy.

Journey of a seed

Figure 1 explains the journey of a seed from planting to storage or sale at the grain elevator. Understanding the journey helps in understanding the different points in the chain where losses may occur as well as the harvest process including how a combine operates.

As the warm summer growing months come to an end, corn and soybeans are fully developed

17 Rashford, Benjamin S., et al. "Economics of Grassland Conversion to Cropland in the Prairie Pothole Region." Conservation Biology, 2010, doi:10.1111/j.1523-1739.2010.01618.x.
18 Wright, C. K., and M. C. Wimberly. "Recent Land Use Change in the Western Corn Belt Threatens Grasslands and Wetlands." Proceedings of the National Academy of Sciences, vol. 110, no. 10, 2013, pp. 4134–4139., doi:10.1073/pnas.1215404110.
19 https://downloads.usda.library.cornell.edu/usda-esmis/files/j098zb09z/vx022244t/8910kf38j/acrg0620.pdf
20 https://www.farmprogress.com/corn-soybean-rotation-still-makes-sense
21 Sindelar, Aaron & Schmer, Marty & Jin, Virginia & Wienhold, Brian & Varvel, G.. (2015). Long-Term Corn and Soybean Response to Crop Rotation and Tillage. Agronomy Journal. 107. 10.2134/agronj15.0085.
22 Steven J. Hall et al. Do corn-soybean rotations enhance decomposition of soil organic matter?, Plant and Soil (2019). DOI: 10.1007/s11104-019-04292-7
23 Xue, Li, et al. "Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data." Environmental Science & Technology, vol. 51, no. 12, 2017, pp. 6618–6633., doi:10.1021/acs.est.7b00401.
24 Gliem, Joe A., Robert G. Holmes, and Randall K. Wood. Corn and Soybean Harvesting Losses. Proceedings of 1990 International Winter Meeting of The American Society of Agricultural Engineers, Hyatt Regency Chicago, Chicago. Series 1563. St. Joseph, MI: American Society of Agricultural Engineers, 1990.
25 "Value Chain: All countries - Maize – 2019." (2019). APHLIS. Accessed December 12, 2020. https://www.aphlis.net/en/page/20/data-tables#/datatables?year=20&tab=value_chain&metric=prc&crop=3

and begin to dry in preparation for dropping their seeds. Preharvest losses at this stage can occur from wildlife eating the crop, strong winds blowing stalks down or plants drying to the point that beans pop out of pods. This year, haze blowing in from the California wildfires slowed the drying process in Missouri, where rains came surprisingly regularly throughout the season.

Farmers keep a close eye on crops and the weather, looking for the sweet spot when conditions are dry enough that mud does not cause equipment to get stuck and wet plant material will not clog combines and cause losses; but not too dry that bean pods shatter open upon contact with a header and beans fall to the ground before being collected into the combine or corn ears are so brittle that kernels pop off cobs during the gathering process - both of which are types of header loss.

Once a farmer deems conditions favorable enough to harvest, given the number of acres to cover and impeding precipitation, they bring their readied combines, with disk plates sharpened and mechanical issues resolved, to the field to begin harvesting. For Western Iowa farmers, this meant starting harvest weeks earlier than usual, in early October for corn and early September for soybeans, as they experienced a drier than normal year. The start of harvest is an exciting time, with farmers full of energy to reap the bounty of decisions and efforts made earlier in the year.

During harvest, farmers pay attention to combine settings so as to reduce header losses that can be caused by driving too fast or not setting the reel low enough to collect all the soybean pods, threshing losses that leave

IMAGES 1 & 2. COMBINE OPERATOR'S POINT OF VIEW

kernels on cob chunks or beans in pods from rotor and/or cylinder settings, or separation losses due to sieve and cleaning fan settings.

Once a corn or soybean seed is cut by a header and moved into the threshing mechanism, rotating rotors and/or cylinders knock bean pods open and kernels off of ears. This mix of seed and cut plant material then goes through sieves intended to let seeds fall to the bottom to then be stored in the grain tank, while a cleaning fan blows plant material behind the machine, typically referred to as 'trash' by farmers. As the grain tank fills, a tractor pulling a grain wagon drives alongside the combine, which simultaneously harvests grain and unloads stored seed into the cart. This requires attentive tractor drivers to ensure they keep an appropriate distance from the combine and maintain pace to prevent seed loss. From there, the tractor and grain cart unload into a grain truck or semi. If the truck is filled to the brim, drivers will deploy a cover to ensure no grain is lost during transportation. Trucks then either take grain to on-farm storage, typically grain bins, or straight to market, often grain elevators for soybeans and ethanol plants for corn when possible.

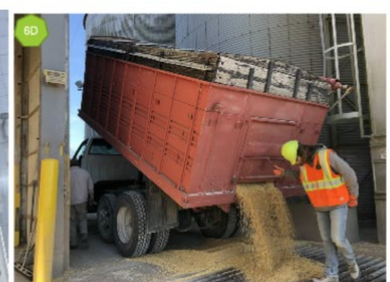
FIGURE 1. JOURNEY OF A SEED

Harvested seed is unloaded from combine into a grain cart pulled by a tractor

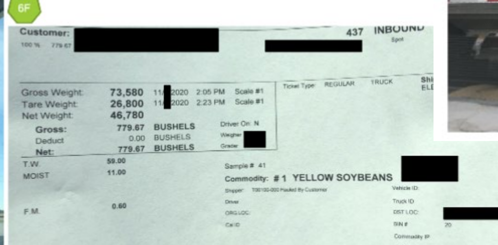
Seed from grain cart is then unloaded into a grain semi (for larger loads – on the left) or truck (for smaller loads – on the right)

Grain truck or semi leaves the field to go to take grain to first storage point

The primary end markets for corn and soy are grain ethanol plants (for corn, when available) and grain elevators



Drive grain around back and unload into concrete pit, which has an underground auger connected to many bins. Semi trucks unload from two doors on the bottom, grain trucks unload using a back door


6F

Customer: [redacted] [redacted] 437 INBOUND
100 % 779.67 Spot

Ticket Type: REGULAR TRUCK

Gross Weight: 73,580 11/[redacted]2020 2:05 PM Scale #1
Tare Weight: 26,800 11/[redacted]2020 2:23 PM Scale #1
Net Weight: 46,780
Gross: 779.67 BUSHELS Driver On: N
Deduct 0.00 BUSHELS Weigher [redacted]
Net: 779.67 BUSHELS Grader
T.W. 59.00
MOIST 11.00
F.M. 0.60

Sample # 41
Commodity: # 1 YELLOW SOYBEANS [redacted]
Shipper
Driver
ORG LOC:
Cal ID
Vehicle ID:
Truck ID
DST LOC: [redacted]
BIN # 20
Commodity IP
Trailer Type

The empty truck drives back onto the scale for a final weight reading and to collect the load ticket, which includes sample moisture content (MOIST) and presence of debris, or foreign material (F.M.)

METHODOLOGY

Scope

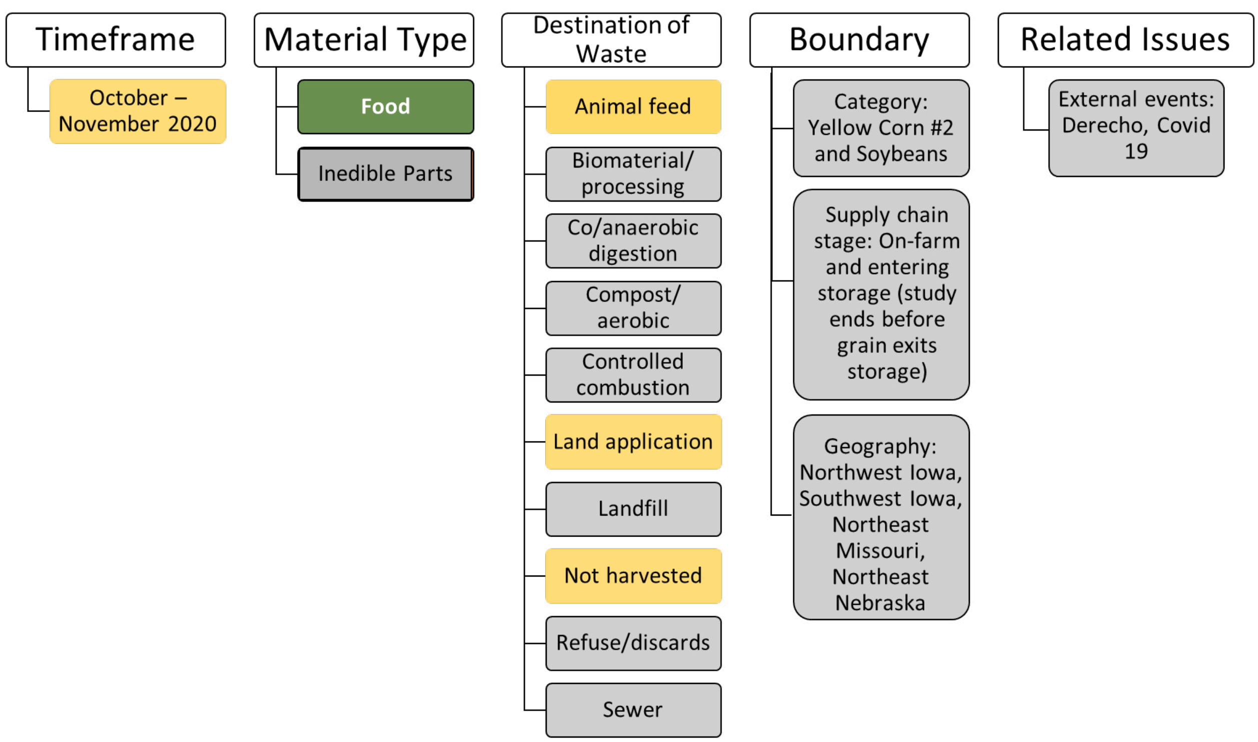
Figure 2 describes the scope of the study based on the *Food Loss and Waste Accounting and Reporting Standard*. The data reported in this study reflects the amount of loss assessed during the 2020 harvest season (October – November 2020). The study focused on the food part of corn and soybeans (seeds). The destinations investigated included: animal feed (e.g., silage fed to cattle), land application (e.g. tilling back into the soil of the organic matter left behind after harvesting like leaves, stalks etc.), and grain not harvested / plowed (e.g., tilling back into the soil of the seeds left behind after the combine had harvested the field).

This study focuses on losses that occur during harvest to the first point of storage, including seed transfer and transportation.

This study drew on the Food Loss and Waste Quantification Methods of direct weighing, counting, and surveys.[26] Direct weighing was taken in ounces for ease of conversion into bushels loss per acre. However, sometimes rain inflated the moisture content of the field samples collected or samples were too small to measure the moisture content. In this case, the Food Loss & Waste moisture content calculator was used to account for the moisture weight. This study found direct weighing results were very similar to counting results. Counting not only provided data to compare with direct weighing results, but also provided an opportunity to separate grain into categories reflective of types of harvest losses (i.e. whole seeds, split/cracked/damaged seed). Surveys provided yield data needed to calculate field-specific losses and gather information on harvesting practices from farmers to further identify where losses may have occurred.

26 https://flwprotocol.org/wp-content/uploads/2016/05/FLW_Protocol_Guidance_on_FLW_Quantification_Methods.pdf

FIGURE 2. SCOPE OF THE 2020 CORN AND SOYBEAN HARVEST EFFICIENCY STUDY



The field sample collection protocol and survey were developed based on the Commodity Systems Assessment Methodology (CSAM), a step-by-step methodology for describing and evaluating postharvest losses that includes interviews of value chain actors, observations of harvesting and handling practices along the chain, and direct measurements of quality and quantity losses along the chain.[27]

Following the protocols of CSAM, field data was collected through mixed methods, including farmer surveys, key informant interviews, field samples, photographs and observations during harvest, transportation, and delivery to the first point of storage. Questionnaires were prepared to collect data from randomly selected corn and soybean farmers. Data were collected from 15 soybean fields (14 surveys) and 16 corn fields (14 surveys). Participants were randomly selected from three different geographic areas in the Midwest: Northwest Iowa - including Northeast Nebraska for corn, Southwest Iowa, and Northeast Missouri. For 3 farms, data was collected from field samples. The number of surveys is lower than the number of farms where data was collected due to the unavailability of some farmers.

27 CSAM was developed by the Inter-American Institute for Cooperation on Agriculture (www.iica.int).

In 2019, Iowa ranked #1 in corn production in the US, and #2 in soy (Illinois was the #1 soy producing state). Nebraska was the 3rd largest producer of corn and 4th largest producer of soybeans. Missouri was the 8th largest corn producer and 6th largest soy producing state.

Iowa benefits from ideal natural resources for growing row crops and has sophisticated corn and soybean infrastructure, which serves as a benchmark for US industry standards. Missouri is also a major US corn and soybean producing state, with most production occurring in the northern half of the state and diversifies the dataset to better represent differences throughout the Midwest.

Key informant interviews were conducted with four extension agents in Iowa, one Iowa Corn Growers Association district manager, two farmers, two grain elevator managers, three combine dealers/ engineers, and one County USDA conservation program specialist.

FIGURE 3. CORN AND SOY FIELD STUDY LOCATIONS

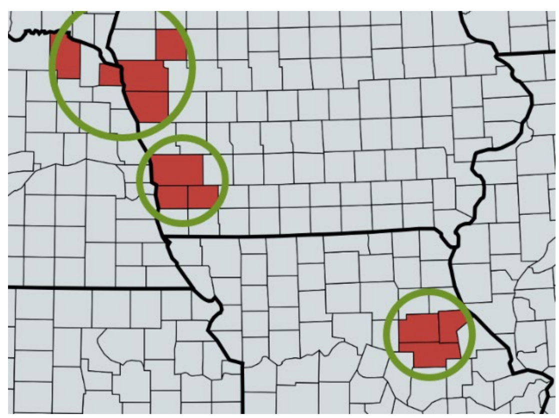


TABLE 1: CORN AND SOYBEAN DATA COLLECTED

AREA	CORN FIELDS (SURVEYS)	SOYBEAN FIELDS (SURVEYS)
NW Iowa (& NE Nebraska)	6 (5)	4 (3)
SW Iowa	5 (5)	5 (5)
NE Missouri	6 (7)	6 (6)

TABLE 2: GEOGRAPHIC DIFFERENCES BETWEEN AREAS SURVEYED

	NW IOWA	SW IOWA	NE MISSOURI
Topography & Landscape	Gently rolling plain, few trees	Rolling hills, few trees	Level prairies and river hills, forest corridors
2020 Weather Events	Water stress, typically a drier area	Water stress, strong winds in weeks prior to harvest	Weekly rains throughout summer, except 2 weeks in August
Soil Types	Wind-blown loess soils means internal drainage is quite good, allowing for good crop yields in most years.	Loess Hills – some of most productive soil in the world, good internal drainage but erosion issues so many terraces and no-till practices	Productive soils responsive to fertilizer and lime, land bordering streams is shallow and highly erodible
Image			

TABLE 3: DATA COLLECTION METHODS AT EACH POSTHARVEST STAGE & SOURCES OF UNCERTAINTY

STAGE	QUANTIFICATION METHODS USED	SOURCES OF UNCERTAINTY
Field	Direct measurement was done in one (1) field for each farmer surveyed. In each field, three (3) repetitions of 10 ft^2 plots were collected, for a total of 30 ft^2/field. Semi-structured survey interviews gathered data from farmers on: Operator experience level Acres planted/harvesting 2020 yield (to date) Combine settings End markets Contextual observations were made throughout data collection - including during interviews and field data collection. Semi-structured interviews conducted while riding in combines during harvesting (5 corn fields, 1 soybean field) provided key observations.	Plot totals include preharvest losses (weather, wildlife damage, overall stand health), header losses and mechanical losses, precluding identification of exact losses in each field. If future studies can secure commitments from farmers to participate in the study earlier, then arrangements can be made to collect data on the three types of losses. Future soybean assessments need to occur a couple weeks earlier as a drier than normal summer in Iowa meant farmers were harvesting earlier than usual. Unharvested soybeans were only observed in Missouri where wet conditions and hazy skies from California wildfires slowed natural drying processes.
Transportation to First Point of Storage	The semi-structured survey collected data on what percent of a farmer's total yield was immediately stored on-farm or sold and the percentage of harvest that went to each end market. Transportation of grain was observed while riding in a grain truck and a semi-truck hauling soybeans to a local grain elevator.	Seed loss during grain transfer from combine to grain cart to grain truck/semi to first point of storage/sale was minimal, infrequent, and highly variable. Negligible amounts of losses could not be accurately captured and measured.

Survey Adaptations

A template CSAM survey was adapted for corn and soybeans in the Midwest based on inputs from Missouri farmers and Iowa extension agents.

The Field Data Collection Protocol can be found in Annex A. The soybeans survey is in Annex B and the corn survey in Annex C.

IMAGES 3 & 4. MISSOURI FARMER TRANSFERS CORN FROM THE COMBINE TO THE GRAIN WAGON DURING HARVEST.

CORN FINDINGS

A total of 14 farmers were interviewed with 16 farms allowing for in-field measurements in three regions in Nebraska, Iowa, and Missouri during the month of October 2020 (see Table 4). Of the 14 survey respondents, 43% of plots were on land the farmer owned. 43% of surveyed farmers only produce corn and soy. 31% of farms sampled are considered small, less than 1,000 acres. Twelve respondents provided the exact amount of land planted with corn, which totaled 11,050 acres. 31% of farms were harvested by operators with more than 30 years' experience. On average 57% of harvested corn was stored immediately on farm, ranging from one farmer who stored none to one farmer who stored 100%.

TABLE 4: CORN SURVEY DEMOGRAPHIC DATA

FARM ID	AREA	LAND SAMPLED	OTHER CROPS OR LIVE-STOCK	OPERATOR EXPERIENCE (+/-30 YEARS)	FARM SIZE (ACRES)*	PLANT POPULA-TION	COMBINE SOPHISTICA-TION	% STORED ON-FARM
F1	NW	Rent	Cattle	Typical	Small	-	Flagship	100
F2	NW	Rent	No	Typical	Large	30,000	Flagship	95
F3	N/A	-	-	Expert	Small	-	-	-
F5	NW	-	-	Typical	Large	-	Flagship	-
F7	NW	Own	No	Expert	185	34,000	Midrange	-
F8	NW	Own	Livestock	Typical	67	33,200	Midrange	64
F11	SW	Rent	No	Expert	1,300	32,500	Flagship	50
F13	SW	Own	Cattle	Expert	1,600	30,500	Flagship	75
F15	SW	Rent	No	Typical	1,250	35,000	Flagship	75
F17	SW	Own	Cattle	Expert	275	34,000	Midrange	5.5
F19	SW	Rent	Cattle	Typical	4,500	36,500	Flagship	40
F21	NE		Crop	Typical	480	32,000	Midrange	75
F23	NE	Own	No	Typical	Large	30,000	Flagship	80
F26	NE	Own	Cattle, Sheep	Typical	900	29,500	Flagship	75
F28	NE	Rent	Pigs, Crop	Typical	320	32,000	Midrange	65
F30	NE	Own	Crop	-	140	27,500	Midrange	7
F32	NE	Own	No	Typical	33	32,000	Midrange	0

* Some farmers preferred not to disclose their exact acreage but did indicate if they had more or less than 1,000 acres, which was used to distinguish between small and large farms.

On Farm Measured Corn Losses

Across all 15 farmers interviewed, growers *estimated* on average 1.2 bushels per acre (approximately 0.65%) was lost in the field based on weather and combine settings. Corn extension agents who were interviewed, note that harvest loss should not be more than 1%.

Based on the 16 in-field sample measurements of remaining seeds per acre the ***measured* loss ranged from 0.5% - 18.1%.** For three growers the harvest loss was less than 1% (total loss as a percentage of grower reported yield); across all growers, the average loss was 4.7% and the median is 2.75%. Comparing the *measured* average harvest loss (4.7%) to commonly accepted industry *goals* of harvest loss (1%) shows a difference of 3.7%.

Losses were measured as whole kernels (average 3.78 bu/acre), split or cracked kernels (average 0.38 bu/ac), cob chunks (average 0.82 bu/ac), and kernels counted on whole ears remaining intact (average 3.84 bu/ac), for a total average loss of 8.8 bushels per acre (See Table 5 for detailed results).

TABLE 5: CORN LOSS

FARM ID	GROWERS ESTI-MATED HARVEST LOSSES	GROWER REPORTED YIELD	WHOLE KERNELS	CRACKED KERNELS	KERNELS ON COB CHUNKS	EAR KERNEL	TOTAL LOSS	% YIELD LOSS
			LOSS					
	(Bushels per acre)							
F1	0	170	4.02	0.21	0.35	4.86	9.44	5.6%
F2	0.1	191	2.18	0.19	0	9.02	11.39	6.0%
F3	-	191	1.29	0.24	0	0	1.53	0.8%
F5	-	191	2.02	0.35	0	0	2.37	1.2%
F7	1	210	2.1	0.1	0	0	2.19	1.0%
F8	-	185	3.53	2.05	1.13	0	6.71	3.6%
F11	3	191	1.88	0.08	0.53	2.18	4.67	2.4%
F13	1	190	0.68	0.21	0	0	0.89	0.5%
F15	1.5	175	1.87	0.21	0	0	2.08	1.2%
F17	1	200	5.94	0.13	6.1	23.98	36.15	18.1%
F19	1.5	165	5.63	0.65	3.71	18.47	28.46	17.2%
F21	2	200	19.38	0.98	0	0	20.36	10.2%
F23	1	190	0.87	0.16	0	0	1.03	0.5%
F26	1	160	1.69	0.21	0.27	3.4	5.58	3.5%
F28	2	220	2.68	0.05	1.1	0	3.82	1.7%
F32	0.5	157	5.4	0.34	0	0	5.74	3.7%
Average	1.2	186	3.78	0.38	0.82	3.84	8.82	4.7%
Loss as % of yield	0.65%	-	2%	0.20%	0.40%	2.10%	4.70%	

*Economic loss calculated at $4.11/bushel

Types of Corn Losses

There are four distinct types of corn loss found in the team's field measurements. Whole kernel losses are standalone intact kernels, caused most commonly by dry or low moisture content, fan speed, and disc plate alignment that exacerbates butt shelling. Whole kernel loss contributed on average 3.78 bushels per acre of on-farm corn losses and approximately 2% average overall bushels of yield.

Cracked kernel losses are distinguished by split or broken standalone kernels, contributing 0.38 or 0.2% average bushels per acre. Cracked kernels can be attributed to tight sieve settings, insect damage, and dry or low moisture content.

Kernel loss from chunks of cob are losses found as broken pieces of cob with kernels remaining intact, which indicates the ear was taken into the combine but the kernels were improperly threshed, and likely caused by thresher settings (e.g., rotor speed, concave clearance).

Kernel loss from whole ear are distinctly whole ears with fully intact kernels that never entered the combine, most likely caused by combine operation (e.g., alignment, ground speed, deck plates) or non-harvesting factors such as dryness or low moisture, wildlife damage, or wind. Whole ear loss contributed on average 3.84 bushels per acre, or 2.1% of total measured harvest losses. Total corn loss was calculated at 8.8 bushels per acre on average, or 4.7% of total yield. The two greatest areas of loss were whole kernels and whole ears. Whole ears left behind quickly increase total loss per acre, as each ¾ lb. ear per 1/100 acre equates to an estimated loss of 1 bushel/acre.[28] Stalks may lodge (stand at an angle, instead of upright) due to wind damage (a major issue with the Derecho storm), wildlife damage, or overall stand health (level land with consistent drainage, sufficient nutrients to ensure stalk strength, etc.). Combine operation can also leave ears behind if the header deck plates are not accurately adjusted, the operator is not driving in straight alignment, etc. Farmers noted the importance of having the same operator who planted the crop to also harvest the crop as they will have a better feel for the field and recall of crop placement. Individual whole kernel loss, when not attached to or near a cob, can be more closely attributed to harvesting and combine operations, including harvesting when the crop is too dry and ears enter the header at an angle, which can be due to combine management or natural factors.

28 Univ Georgia protocol

TABLE 6: TYPES OF CORN LOSS

TYPE OF LOSS	WHOLE KERNEL LOSS	CRACKED KERNEL LOSS	CHUNK OF COB KERNEL LOSS	WHOLE EAR KERNEL LOSS	TOTAL LOSS
Average loss (bushels/acre)	3.78	0.38	0.82	3.84	8.82
Average % loss (bushels of loss/ bushels of yield)	2%	0.20%	0.40%	2.10%	4.70%
Causes	Butt shelling caused by disk plates, dry/low moisture content, fan speed	Tight sieve settings, insect damage, dry/ low moisture content. Cracked kernels lower grain quality and can be docked when sold.	Threshing settings (rotor speed, concave clearance)	Combine operation (alignment, ground speed, deck plates), dry, wildlife damage, wind	

Levels of Loss

A 1989 study of 53 corn fields in Ohio, frequently cited by extension agents, found corn losses to range from 0 to 5 bushels per acre, with an average loss of 1.5 bushels/acre, or 1% of estimated yield. Of this, 40% of corn fields had less than 1 bushel/acre loss.[29]

This research similarly found that 43.8% of corn farms had low levels of loss - around 1% or 4 bushels/acre loss. The remaining 25% of corn farms had an average level of loss at 3% of yield, or 4-8 bushels/acre loss, and 31.3% of corn farms had high levels of loss, averaging above 11% or 9 bushels/acre (Figure 4). 44% of farms, with low levels of loss, accounted for 9.8% of total loss in the study, whereas the 34% of farms with medium loss accounted for 15.9% of total loss, and the 31% of farms with the highest loss accounted for 74.3% of total grain loss.

While it may seem that losses have increased from the 1989 study till now, the context of increasing yield should be kept in mind. The average corn yield in the 1989 study was 150 bushels/acre vs the average yield in this study is 186 bushels/acre.

29 Gliem, Joe A., Robert G. Holmes, and Randall K. Wood. Corn and Soybean Harvesting Losses. Proceedings of 1990 International Winter Meeting of The American Society of Agricultural Engineers, Hyatt Regency Chicago, Chicago. Series 1563. St. Joseph, MI: American Society of Agricultural Engineers, 1990.

Other Factors Impacting Corn Harvest

Corn field data was cross-analyzed with farm-specific survey data to identify any trends that may indicate key factors influencing harvest-related losses.

Farmers were interviewed to elicit qualitative factors impacting harvesting losses. Operator experience levels were divided into two categories of “Average” (<30 years harvesting) and “Expert” (>30 years). Combine sophistication was categorized as “Midrange” meaning the equipment has comparatively fewer auto settings, or “Flagship”, which include advanced sensor technology that provides real time harvest information presented on a digital screen, including grain moisture content and kernel expulsion, and can automatically adjust deck plates and threshing settings.

As shown in Table 7, combine operators with more than 30 years of harvesting experience have less loss in this study, as do farms using technologically sophisticated flagship combine models. Although, the combine model has a more significant impact on reducing loss than

TABLE 7. OPERATOR EXPERIENCE AND COMBINE SOPHISTICATION IMPACT ON CORN LOSSES

OPERATOR EXPERIENCE LEVEL	FLAGSHIP COMBINE	MIDRANGE COMBINE	AVERAGE TOTAL LOSS (BU/ACRE)
Typical (<30 years experience)	2.2	2.91	2.44
Expert (>30 years experience)	1.55	2.57	2.23
Total	2.04	2.72	2.35

operator experience, indicating the ability of modern farming equipment to potentially compensate for human error, which many farmers noted as the main cause of error in harvesting.

Economic Loss

Market prices remained moderately high the year measurement occurred despite the impact of COVID-19 on global food systems and supply chains, and partially bolstered by the Derecho storm that greatly reduced yields across the middle of Iowa.[30] Average market price for the month of October was $4.11 per bushel.

Economic losses were calculated based on the average price of corn for the month ($4.11 per bushel) multiplied by average loss for each farmer, ranging from $4.24 per acre to $148.57 per acre. The average economic loss across all 16 corn farms was calculated at $36.23 per acre (see Table 8). The average loss was 4.7%, whereas extension agents encourage less than 1% loss. This means a loss overage of 3.7%, which when scaled to the national level, means a loss of 503 million bushels of corn worth $2.07 billion, based on 2019 production figures.[31]

30 Thiesse, Kevin. "USDA Report Increases Corn and Soybean Yields." Morning Ag Clips. August 20, 2020. Accessed December 08, 2020. https://www.morningagclips.com/usda-report-increases-corn-and-soybean-yields/.

31 https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan20.pdf

TABLE 8: CORN ECONOMIC LOSS

FARM ID	GROWERS ESTIMATED HARVEST LOSSES	GROWER REPORTED YIELD	BUSHEL LOSS PER ACRE	ECONOMIC LOSS PER ACRE
F1	0	170	9.44	$ 38.81
F2	0.1	191	11.39	$ 46.81
F3	-	191	1.53	$ 6.30
F5	-	191	2.37	$ 9.75
F7	1	210	2.19	$ 9.02
F8	-	185	6.71	$ 27.58
F11	3	191	4.67	$ 19.17
F13	1	190	0.89	$ 3.65
F15	1.5	175	2.08	$ 8.55
F17	1	200	36.15	$ 148.57
F19	1.5	165	28.46	$ 116.97
F21	2	200	20.36	$ 83.68
F23	1	190	1.03	$ 4.24
F26	1	160	5.58	$ 22.94
F28	2	220	3.82	$ 15.71
F32	0.5	157	5.74	$ 23.61
Average	1.2	186	8.82	$ 36.23
Loss as a % of yield	0.65%	-	4.70%	

Transporting Grain from Field to Storage or Selling Immediately

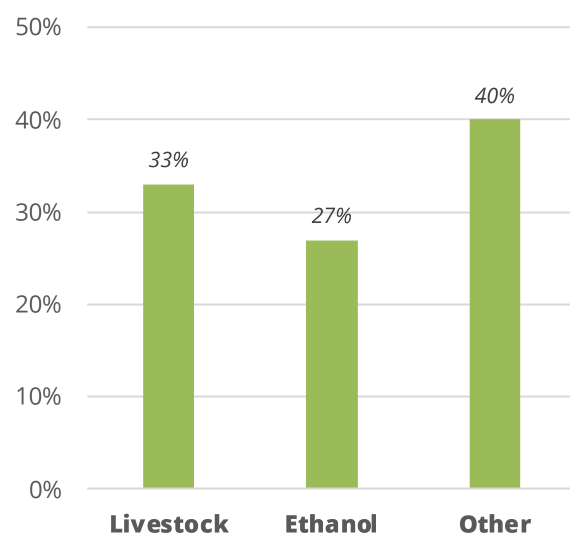
On-farm storage (i.e., grain bins or field grain bags) is an investment that farmers choose to engage in so that they are not forced to sell product at the date of harvest when prices tend to be low. In 2019 farmer participants stored corn from March to September, with the average holding period of 9.5 months. Markets for corn include ethanol plants, cooperatives, grain elevators, feed mills, or using grains for farmers' own cattle feed. Farmers prefer to sell to ethanol plants, if within near enough proximity because the price tends to be higher and the quality standards are lower. In this study, 87% of the growers chose to store at least partial harvest on-farm, and 73% of farmers sold corn for ethanol as the first end market (see Table 9).

This study found that farmers prefer selling their corn to ethanol plants, when possible, as ethanol plants accept corn at 17% moisture before docking prices, whereas grain elevators begin docking farmers at 15.5% moisture content and this reduction in price per bushel significantly impacts farmers' bottom line. This highlighted farmers' frustrations with the docking system at grain elevators, as grain elevators blend docked grain with high quality grain, diluting any impurities. Farmers did not typically mention that grain standards are set by USDA or that well-enforced docking systems encourage farmers in mass to meet quality standards, preventing large-scale quality issues.

Most farmers in this study stored some amount of corn – all respondents except one used grain bins for on-farm storage, whereas the one farmer used grain bags. Overall, the data indicates that 2020 is a typical year in terms of grain storage.

The above end markets in Table 9 are the first point of storage for farmers coming off field. From there corn in the US is used for the following purposes: livestock, ethanol production, exports, processing, distiller's dried grains with solubles (DDGS), etc.

FIGURE 4. US CORN END MARKETS



* Other includes (exports, processing, DDGS, etc.)

TABLE 9: CORN FROM FIELD TO FIRST POINT OF STORAGE

	IMMEDIATELY AFTER HARVEST		ANY TIME AFTER HARVEST - WITHIN 12 MONTHS					
FARM ID	% STORED ON-FARM	% SOLD OFF-FARM	END MARKET 1	% TOTAL YIELD	END MARKET 2	% TOTAL YIELD	END MARKET 3	% TOTAL YIELD
F1	100	0	Own farm feed	100				
F2	95	5	Ethanol	100				
F23	80	20	Ethanol	100				
F13	75	25	Ethanol	25	Elevator	70	On farm feed	5
F15	75	25	Ethanol	80	Elevator	20		
F21	75	25	Ethanol	100				
F26	75	25	Ethanol	67	Feed mill	33		
F28	65	35	Ethanol	83	Elevator	15.5	On farm feed	1.5
F8	64	36	Ethanol	12	Elevator	24	On farm feed	64
F11	50	50	Cooperative	50	Ethanol	50		
F19	40	60	Ethanol	100				
F30	7	93	Ethanol	100				
F17	5.5	94.5	Cooperative	94.5	On farm feed	5.5		
F32	0	100	Ethanol	100				
F7	0	100	Cooperative	100				

SOYBEAN FINDINGS

A total of 14 farmers were interviewed with 15 farms allowing for in-field measurements in three regions across Iowa and Missouri during the month of October 2020. Market prices had significantly increased the year measurement occurred due to a weaker U.S. dollar combined with dry Midwest weather conditions, the reopening of meat-processing plants following COVID-19 closures, strong Chinese demand, and a lower perception of swine fever in China[32] that greatly incentivized growers to sell their harvest immediately without storing.

Field plot tests occurred on 54% of land owned by the farmer and 46% on rented land. Of the 14 survey respondents, 35% were solely producing row crops. Of the remaining 65% of respondents who had diversified farms, half grew other crops and half had livestock, primarily cattle with two farmers also raising hogs. Thirteen (13) farmers shared how much land they planted with soybeans, totaling 13,628 acres.

32 Saefong, Myra P. "Why Soybeans May Be Headed for Their Highest Price in 6 Years." MarketWatch. September 18, 2020. Accessed December 08, 2020. https://www.marketwatch.com/story/why-soybeans-may-be-headed-for-their-highest-price-in-6-years-11600450312.

TABLE 10:DEMOGRAPHIC SURVEY DATA FOR SOYBEAN FARMS

FARM ID	AREA	LAND SAMPLED	OTHER CROPS OR LIVESTOCK	OPERATOR EXPERIENCE (YEARS)	FARM SIZE (ACRES)*	PLANT POPULATION PER ACRE	ROW SPACING (INCHES)	COMBINE SOPHISTICATION	DRAPER HEADER
F4	NW	Rent	No	Expert	153	144,000	15	Midrange	No
F6	NW	Own	No	Expert	155	140,000	30	Midrange	Yes
F9	NW	Own	Few	Typical	108	132,500	30	Midrange	No
F10	NW	-	-	Typical	Large	-	-	Flagship	Yes
F12	SW	-	No	Expert	1350	160,000	15	Flagship	Yes
F14	SW	-	Livestock	Expert	1800	140,000	10	Flagship	Yes
F16	SW	Rent	No	Typical	1900	130,000	30	Flagship	Yes
F18	SW	Own	Livestock	Expert	300	150,000	15	Midrange	No
F20	SW	-	Livestock	Typical	4000	150,000	30	Flagship	Yes
F22	NE	Rent	Crop	Typical	1500	160,000	15	Flagship	Yes
F24	NE	Own	Crop	Typical	Large	150,000	15	Flagship	Yes
F25	NE	Own	Crop	Expert	720	162,000	15	Midrange	No
F27	NE	Rent	Livestock	Typical	950	135,000	30	Flagship	No
F29	NE	Rent	Livestock, Crop	Typical	650	130,000	15	Midrange	No
F31	NE	Rent	No	Typical	42	145,000	30	Midrange	No

* Some farmers preferred not to disclose their exact acreage but did indicate if they had more or less than 1,000 acres, which was used to distinguish between small and large farms.

On Farm Measured Soy Losses

Across all 15 farms assessed, growers *estimated* on average 1.56 bushels per acre (approximately 3%) of soybeans were lost in the field based on weather and combine settings. Actual *measured* losses ranged from 1 - 5.2 bushels per acre, for a total average loss of 2.3 bushels per acre or 4.5% of harvested yield, a difference of 1.5% overage loss.

In soybeans, whole beans and beans in pod loss can occur preharvest (wildlife, high winds, dry conditions) or during gathering, threshing or cleaning. Split beans are directly linked with rotor/cylinder and concave settings.

The 1989 Ohio study of 69 soybean fields found soy losses ranged from 0.2 to 4.1 bushels/acre, with an average of 1.4 bushels/acre, or 4% of estimated yield. Approximately 41% of soy fields had less than 1 bushel/acre loss.[33] Due to large ranges in yield, percent loss can vary widely in terms of bushels/acre so data is presented as percent loss only.

33 Gliem, Joe A., Robert G. Holmes, and Randall K. Wood. Corn and Soybean Harvesting Losses. Proceedings of 1990 International Winter Meeting of The American Society of Agricultural Engineers, Hyatt Regency Chicago, Chicago. Series 1563. St. Joseph, MI: American Society of Agricultural Engineers, 1990.

TABLE 11. SOYBEAN FIELD LOSSES

FARM ID	2020 YIELD	WHOLE BEANS	SPLIT BEANS	BEANS IN PODS	TOTAL BEANS	LOSS*	% YIELD LOSS
	Bu/acre	Per foot^2				Bu/acre	
F4	42	7.1	0.8	1.8	9.1	1.9	4.5%
F6	69	17.3	1.6	6.2	25.1	5.2	7.5%
F9	60	10.4	0.5	6.9	17.8	3.7	6.2%
F10	57	5.8	1.0	2.4	8.8	1.8	3.2%
F12	57	1.9	0.2	2.8	4.8	1.0	1.8%
F14	50	8.7	1.0	0.7	10.1	2.1	4.2%
F16	56	12.0	1.0	1.4	13.8	2.9	5.1%
F18	58	8.5	0.2	2.0	10.1	2.1	3.6%
F20	47	9.9	0.6	2.3	12.8	2.7	5.7%
F22	50	4.1	0.3	0.9	5.3	1.1	2.2%
F24	49	13.8	1.4	2.2	17.4	3.6	7.4%
F25	55	1.4	1.0	2.9	5.3	1.1	2.0%
F27	40	4.6	0.3	0.6	5.4	1.1	2.8%
F29	55	24.2	2.0	52.3	65.4	1.8	3.4%
F31	44	6.3	0.7	8.3	15.3	3.2	7.2%
Average	53	9.4	0.9	6.7	16.2	2.3	4.5%

* Bushel loss/acre was calculated using the average of 210,000 beans/bushel

For soy, extension agents expect an average loss of 3% while the data collected by this study showed a loss of 4.5%. The efficiency of growers was categorized into three levels: low levels of loss ranged from 1.8 - 2.8%, average levels of loss ranged 3.2 - 5.7% loss, and high levels of loss ranged 6.3 - 7.5%

Research found that 27% of soybean farms had low levels of loss - around 2.2%, while 46% of soybean farms had an average level of loss at 4.2% of yield, and 27% of farms had high levels of loss, averaging 7.1%. Low levels of loss ranged from 1.8 - 2.8%, average levels of loss ranged 3.2 - 5.7% loss, and high levels of loss ranged 6.2 - 7.5% (Figure 5).

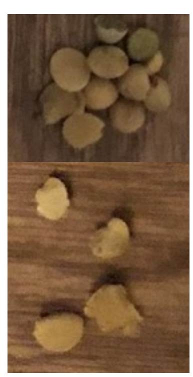
In terms of the amount of loss each category of efficiency represents, within the 27% of highest loss farms accounted for 44.4% of total losses, whereas within the 46% of average loss farms accounted for 43.3% of total losses, and within the 27% of the most efficient farms contributed 12.3% of overall losses.

The 1989 study also found an average of 1.4% of soybeans were split or cracked.[34] This study found less than 1% of split beans in fields, indicating improvements in combine settings- either by operators or through improved technology.

34 Ibid.

TABLE 12. TYPES OF SOYBEAN LOSS

TYPE OF LOSS	WHOLE BEANS	SPLIT BEANS	BEANS IN PODS	TOTAL BEANS
Average loss (beans/10 ft2)	9.4	0.9	6.7	16.2
% of loss	55.3%	5.3%	39.4%	100%
Causes	Dry/Low moisture content leads to preharvest bean drop (exacerbated by wind and wildlife) and increases likelihood of header shatter during harvest	Combine settings	Header reel height, equipment sophistication, combine settings	


Types of Soybean Losses

This study collected three types of soybean loss during field measurement. Whole bean losses are standalone intact beans, caused mostly by dry or low moisture content, which can either drop beans preharvest or increase header shatter losses during harvest. Split beans can be caused by dry conditions, but more often combine operation. Beans left in pods in the field can be caused by the header reel not being low enough to the ground (a combine operator choice based on levelness of field and sophistication of equipment), equipment sophistication (draper headers leave less soybeans in the field than auger-based headers; advanced headers can tilt to accommodate crops grown on a slope), and operator settings that allow collected pods to be ejected from the combine without being shelled.

Other Factors Impacting Soy Harvest Efficiency

Soy field data was cross-analyzed with farm-specific survey data to identify any trends that may indicate key factors influencing harvest-related losses.

Interestingly, soybeans planted at 15-inch row spacing saw half the percentage of harvest losses (2.81%) compared to fields planted at 30-inch spacing (5.75%). This could be explained, in part, by the fact that heavier combines experience less soybean loss from shatter and 15-inch row spacings can increase a combine's weight more quickly.

Farmers were asked qualitative factors impacting harvesting losses, including how many years of experience they have harvesting and the model of combine they use to harvest. Experience level was categorized as Typical (<30 years) or Expert (>30 years) and combine sophistication was classified as Midrange, meaning the equipment has comparatively more manual settings, or Flagship, which includes advanced technologies such as sensors that assist in minimizing header, threshing, and cleaning losses, and can automatically adjust settings based on field conditions. Flagship models present real time harvest information to combine operators on a digital screen so they can adjust accordingly.

TABLE 13: IMPACT OF ROW SPACING ON PERCENT OF SOYBEAN LOSS

	ROW SPACING IN INCHES (NUMBER OF FARMS USING THAT SPACING)		
	10 (1)	15 (7)	30 (6)
% of Soybean Loss	4.20%	2.81%	5.75%

TABLE 14: COMBINE SOPHISTICATION IMPACT ON SOY LOSSES

	OPERATOR EXPERIENCE LEVEL		
COMBINE SOPHISTICATION	TYPICAL	EXPERT	AVERAGE
	% of Soybean Loss		
Flagship	3.53%	2.98%	3.39%
Midrange	5.58%	4.42%	4.91%
Average	4.21%	3.94%	

Overall, combine sophistication has a greater impact on level of loss than operator experience, although both are influential. Worth noting, all large farms, those greater than 1,000 acres, had flagship combine models, which is common as larger farmers can afford the greater investment in technology and require relatively new equipment with low mileage to reduce mechanical issues and maintain an efficient pace of harvesting. Similarly, large farms also tend to have draper headers, which are known for being more efficient at harvesting.

Economic Loss

Surveyed farmers were asked their estimated harvest losses and 2020 yields to compare with field data. These losses were monetized and scaled to the national level for an estimate of total losses in the US.

Economic losses were calculated based on the levelized price of soy for October ($10 per bushel) multiplied by average loss for each farmer, ranging from $10.03 per acre to $52.06 per acre. The average economic loss across all 15 soy farms was calculated at $23.54 per acre. Total average economic losses were calculated based on the overage amount (1.%) and 2019 production figures (3.5 billion bushels) to reveal $530 million nationwide.

Farmers gave their harvest loss estimates in bushels/acre, although this came out to 3% of harvest, which is the industry goal for soybeans and indicates farmers familiarity and application of this information. While losses were greater than anticipated, it was not by a startling amount.

Transporting Grain from Field to Storage or Selling Immediately

Farmers similarly choose to store soy on-farm in grain bins or sell immediately if the price is high enough. Market options include grain elevators, cooperatives, seed suppliers (if they have a contract), or grain dealers who store farmers' harvest and sell at the best price they can find, charging a percent of the profits. 64% of farmers reported selling soy immediately after harvest rather than storing due to high market prices (see Table 15). For sales of the 2020 harvest, 71% of survey participants (10 respondents) reported selling soy to an elevator as their primary market, 21% sold their soy at a cooperative (3 respondents), and 7%, or 1 farmer, sold their soy to a grain dealer.

TABLE 15: SOY ECONOMIC LOSSES

FARM ID	GROWER ESTIMATED HARVEST LOSSES	2020 YIELD PER ACRE	TOTAL SOYBEAN LOSS	TOTAL ECONOMIC LOSS* ($)
		bushels per acre		
4	-	42	1.89	18.95
6	1	69	5.21	52.06
9	-	60	3.7	36.99
10	-	57	1.83	18.32
12	1	57	1	10.03
14	1	50	2.1	21.02
16	6	56	2.87	28.69
18	1	58	2.09	20.88
20	1.5	47	2.66	26.62
22	2	50	1.09	10.92
24	0.48	49	3.62	36.16
25	2	55	1.11	11.06
27	1	40	1.13	11.27
29	1	55	1.84	18.45
31	0.75	44	3.17	31.74
Average	1.56	52.6	2.35	$23.54
Loss as a % of Yield	3.00%		4.50%	

* Based on contemporary price average $10/bushel

TABLE 16: SOY FROM FIELD TO FIRST POINT OF STORAGE

	IMMEDIATELY AFTER HARVEST		ANY TIME AFTER HARVEST - WITHIN 12 MONTHS			
FARM ID	% STORED ON-FARM	% SOLD OFF FARM	END MARKET 1	% TOTAL YIELD	END MARKET 2	% TOTAL YIELD
F27	75	25	Elevator	100		
F14	70*	10	Elevator	10	Seed supplier	20
F29	15	85	Elevator	100		
F24	10	90	Elevator	100		
F22	7	93	Elevator	100		
F4	0	100	Dealer	100	Elevator	100
F6	0	100	Cooperative	100		
F9	0	100	Elevator	100		
F12	0	100	Cooperative	100		
F16	0	100	Elevator	100		
F18	0	100	Cooperative	100		
F20	0	100	Elevator	100		
F25	0	100	Elevator	80	Cooperative	20
F31	0	100	Elevator	100		

* Kept on farm for own cattle feed

IMAGE 5. SEMI TRUCK OF RECENTLY HARVESTED GRAIN DRIVING DOWN A RURAL MISSOURI HIGHWAY.

QUALITATIVE FINDINGS FOR CORN AND SOYBEANS

Moisture Content and Harvesting Speed

Farmers and extension specialists were asked to detail optimal levels of soybean moisture and the factors that weigh in on deciding what moisture level to harvest. The recommendation is to begin harvesting soy at 14-15% so that collection is complete before the field moisture content drops below 11%, which significantly increases shatter loss. Additionally, once grains are harvested they begin to dry, and the beans should ideally arrive at the elevator at 13% to avoid quality price docking. Farmers reported that they aim to start harvesting soy at 13% because they perceive higher moisture content as a risk for harvest losses. Actual average moisture measured was 10.8% for soy as measured by farmers.

Extension programming recommends harvesting at speeds 2.8-3.0 miles per hour to achieve best harvesting efficiency; however, due to the short period of time available for harvest farmers opt to drive faster, reporting ground speed of 4.2 mph on average.

In 1989, Ohio soybean farmers' combine speed ranged from 2 to 5.6 miles per hour, with an average of 3.2 MPH.[35] Today, soybean operators are driving faster, while maintaining similar levels of loss, which may be a function of advances in combine technology, as combine companies respond to farmers' demands of faster machines to cover more ground quickly, although this may require further exploration.

35 ibid

"I WAS AMAZED AT THE CORN LOSS NUMBER AT 8.8 BU/ACRE, WHEN FARMERS WERE EXPECTING 1.2 BU/ACRE. SOY WAS A LITTLE MORE IN LINE AT 2.18 BU/ACRE COMPARED TO 1.5 BU/ACRE. I'LL ATTRIBUTE MY SUCCESS TO SLOWER GROUND SPEED THIS YEAR. PREVIOUS YEARS I RAN AT 4.5 MPH, BUT HELD IT TO 3.7 TO 4 MPH THIS YEAR. I ALSO RAN THE REEL SPEED SLOWER AND HIGHER THIS YEAR. FUTURE PLANS MAY INCLUDE GETTING A DRAPER HEADER. IF WE GET TOO GOOD, THERE WON'T BE ANYTHING FOR WILDLIFE TO FEED ON!"

FARM 25

SECOND MOST EFFICIENT SOYBEAN HARVESTER

Combine Setting Selection

Farmers discussed their priorities when preparing combine settings, a process that requires weighing various factors that impact harvest efficiency such as product quality, quantity, labor costs, equipment sophistication, end market, storage, etc. Farmers most frequently reported prioritizing cleanliness of the product, a quality indicator, meaning that they set the threshing controls as tightly as possible in order to reduce the amount of debris that ends up in the truck. Grain quality standards[36] set by the USDA determine if farmers will be docked (receive a lower price per bushel) at the elevator. Docking rates are standard for all farmers but can vary between elevators.

36 Federal Grain Inspection Service. United States Standards for Soybeans, 2007, www.ams.usda.gov/sites/default/files/media/SoybeanStandards.pdf.

TABLE 17: FARMER PRIORITIES WHEN SELECTING COMBINE SETTINGS

	CORN		SOY	
TYPE OF INDICATOR	FACTOR	NUMBER OF RESPONDENTS	FACTOR	NUMBER OF RESPONDENTS
Quality indicators	Cleanliness	8	Cleanliness	6
	Maintain grain quality	2	Maintain grain quality	1
	Prevent damage	2	Prevent damage	4
Quantity indicators	Prevent loss	6	Prevent loss	5
	Prevent kernels left on cob	2		
Efficiency indicator	Optimal speed/ efficiency	2	Optimal speed/ efficiency	2

Preventing loss was also a high priority for both corn and soy harvesting, meaning that farmers are also highly aware of header loss, such as disc plate settings for corn and reel settings for soybeans, both of which can reject corn ears and soybean pods from entering the combine. As a rule of thumb, 75% of soybean harvest losses can be attributed to header losses, such as beans popping out of the pods upon contact with the reel before entering the combine.[37] Header losses can be caused by beans being too dry when harvested, improper reel settings or driving the combine too fast.

37 Dunphy, Jim, and E. O. Beasley. "Reduce Soybean Harvest Losses." NC State Extension Publications. November 22, 2017. Accessed December 08, 2020. https://content.ces.ncsu.edu/reduce-soybean-harvest-losses.

Spill Management

When asked about grain spills, farmers noted that not much is spilled in the harvesting process but is often caused by human error instead of equipment error when it does occur (i.e., forgetting to shut a grain cart door, auger placement when transferring grain, etc.). Depending on how much is lost, farmers will either shovel it back in or leave it for wildlife to eat. One farmer noted selling it to a local hog farmer who comes and collects leftover grain with a rake and shovel while another farmer feeds it to his cattle. One farmer noted he uses a tarp under the auger for easy cleanup. Three of the farmers in this study have concrete pits which have very low losses as grain can easily be swept into the pit.

Concrete pits are a key feature of grain elevators and ethanol plants, as well as very large farms. The three farms in this study with concrete pits planted more than 2,500 acres of corn and soybeans. Concrete pits have slats that allow grain to fall into an underground collection pit with an adjustable auger system that then transports grain into the appropriate bin (see Images 6 & 7). This contained system sees little to no loss as grain that overflows outside of the grate can easily be swept in.

Harvested grain is rarely if ever rejected. Modern storage practices and the non-perishable nature of grain means that even if grain does not meet elevator quality standards, it can be sold as livestock feed (see Image 8).

IMAGES 6 & 7. CONCRETE PIT

IMAGE 8. GRAIN PILE ON GROUND AND LOSS FROM TRANSFERRING GRAIN

IMAGE 9. VIEW OF CORN HARVEST FROM GRAIN WAGON

SPATIAL COMPARISON OF LOSS TO THE NORTHERN GREAT PLAINS

The following two figures show the potential spatial impact of food loss avoidance within the geographical boundary of the Northern Great Plains (NGP) region. Data on grassland conversion is from WWF's [2020 Plowprint report](). Overall, the amount of land associated with the loss rates found in this study translates to approximately 8 million acres[38] of conversion that could have been avoided in 2019, which is roughly 16 times the amount of conversion that occurs in the NGP every year.

38 Total national impact of corn and soy = 8,668,000 acres

Figure 5 shows the total cropland footprint in the NGP in 2019 (the "Plowprint," in dark gray), with the areas planted to corn and soy in 2019 shown, respectively, in yellow and green. Using the measured rates of corn and soy loss (4.7% and 4.5%) derived in this report as the upper rate and the industry estimate of loss (1%) as the lower rate, the polygons shaded in red represent the acreage of currently intact land that could be converted to cropland as a result of combined soy and corn losses in the NGP. Contrarily, if food loss were significantly reduced or eliminated, current production levels could be maintained without converting additional lands.

FIGURE 5. THE POTENTIAL IMPACT OF FOOD LOSS AVOIDANCE IN THE NGP BY FOOD LOSS PERCENT

Figure 6 again shows the total cropland footprint in the NGP in dark gray, with the orange dots illustrating the spatial impact of *national* soy and corn losses. Even at loss rates of 4.5% and 4.7%, national corn and soy losses are equivalent to an area nearly two times the size of the total 2019 NGP corn and soy acreage. In other words, by eliminating these loss rates nationally, the conversion of NGP land growing corn and soy today could have been avoided twice over.

FIGURE 6. THE POTENTIAL IMPACT OF FOOD LOSS AVOIDANCE IN THE NGP BY ACRES

LOOKING TO THE FUTURE

Tracking Postharvest Loss in Africa / Global Comparisons

The African Postharvest Losses Information System (APHLIS), funded by the European Commission and Bill and Melinda Gates Foundation, collects, analyzes, and disseminates postharvest loss data for cereal grains in sub-Saharan Africa. APHLIS+ will expand the crops covered and include economic and nutritional dimensions of postharvest losses.[39]

APHLIS+ provides data WWF can use to make global comparisons. APHLIS delineates harvest-related losses into eight stages: 1) harvesting/field drying, 2) further drying, 3) threshing and shelling, 4) winnowing, 5) transport from field, 6) household-level storage, 7) transport to market, and 8) market storage.

The combine was aptly named for combining the harvesting processes of gathering/reaping, threshing and sorting/winnowing.[40] Mechanization allows US farmers to seamlessly integrate three steps into one, reducing the stages from eight to five, with an additional sixth stage, drying, occurring as needed. This also reveals a difference in storage where US farms store seeds, farmers in Africa frequently store their grain on the ear. This requires more space, but can decentralize contamination, spoiling or other forms of grain quality damage.

Mechanization can greatly reduce harvest related losses but combines primarily see an increase in demand where there are large land holdings and/or manual harvesting labor is scarce. With much of Sub-Saharan African populations depending on agriculture for their livelihoods and limited alternative job opportunities, introduction of mechanization should be assessed for appropriate fit.

APHLIS estimates 2019 maize losses in Africa as totaling 15.8% of production and 5.7% in storage, broken down as: 6.4% during the harvesting/field drying stage, 4% during further drying, 1.3% while threshing and shelling, negligible losses during winnowing, 2.4% during transportation from field, 3% during household storage, 1.7% while transporting to market, and 2.7% in market storage.[41] This indicates an opportunity for mechanization to reduce losses. Granted, the viability of this option depends significantly on local context, especially the percent of population engaged in agriculture, land holding sizes, etc. APHLIS+ intends to improve the scope of crops included in their database, which currently does not include soybeans.

39 "APHLIS." APHLIS. Accessed December 08, 2020. https://www.aphlis.net/en/page/7/about-aphlis.
40 https://www.agriculture.com/machinery/harvesting/the-combine-king-of-the-harvest

41 "Value Chain: All countries - Maize – 2019." (2019). APHLIS. Accessed December 12, 2020. https://www.aphlis.net/en/page/20/data-tables#/datatables?year=20&tab=value_chain&metric=prc&crop=3

Global Comparisons

In 2019/2020, the US produced 31.06% of global corn production, followed by China (23.42%), Brazil (9.07%), and the European Union (5.99%), with remaining production (30.46%) spread across the globe.[42] In addition to being the largest producer of corn in terms of quantity, the US also leads the world in efficiency, in terms of bushels/acre produced. Nationwide, US corn yields average 181.8 bushels/acre in 2020.[43] Since 2016, China has seen corn yields averaging 95.6 bushels/acre.[44] Brazil achieves yields of 89.9 bushels/acre in 2020.[45] Overall, the European Union experiences average yields of 115 bushels/acre.

Yield varies greatly within each country, depending on quality of soil and other climate variables (annual and seasonal precipitation, temperature, wind speed, etc.). In the US, land being converted for corn production tends to be prairie, which has marginal yields per acre. Improved efficiencies worldwide can assist countries in meeting their domestic corn needs and reduce conversion of marginal lands globally.

BOX 1. POSTHARVEST LOSSES: COMPARING CAMEROON PALM OIL WITH US ROW CROPS

A 2020 postharvest loss assessment of palm oil in Cameroon commissioned by WWF Africa and conducted by ABA, clearly highlighted the issue of forest land being converted into palm plantations, with a clear link to high rates of losses at the farm level and inefficiencies during palm oil processing, equaling 10-16% of crude palm oil production*. In the United States, a well-developed grain sector and harvesting mechanization assists farmers in reducing harvest related losses, where harvest losses are 3.7% greater than what is feasibly achievable for corn, and 1.5% greater for soybeans.

"Postharvest Loss Initiative in Palm Oil for TRIDOM with Focus on Cameroon." (2020). Agribusiness Associates developed for World Wildlife Fund Africa.

42 Shabandeh, M. (2020). "Distribution of global corn production in 2019/2020, by country. www.statista.com/statistics/254294/distribution-of-global-corn-production-by-country-2012/ Published August 25, 2020. Accessed January 10, 2021.

43 https://release.nass.usda.gov/reports/crop0820.pdf

44 Zulauf, C. (2020). "China's Corn Sector". farmdoc daily. 910):197, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, November 15, 2020. http://farmdocdaily.illinois.edu/2020/11/chinas-corn-sector.html. Accessed January 10, 2021.

45 Alves, Bruna. (2020). "Corn Yield in Brazil 2020". Statista. Published July 7, 2020. Accessed January 10, 2021. www.statista.com/statistics/740444/corn-yield-brazil

Future Storage Research

The scope of this study did not include losses that occur during storage. Storage studies can take place for corn in 2021, while a soybean storage study may benefit from waiting until 2022 as most farmers in 2020 immediately sold their beans to secure high prices. A soy storage study in 2021 would need to explore why farmers chose to store on-farm instead of selling and adjust findings accordingly. That said, storage studies could easily focus on losses at grain elevators and cooperatives. These facilities could further implement the Food Loss and Waste (FLW) quantification methods of drawing on records and mass-balance approaches.[46]

Future survey tools can also include a section of questions that explore land conversion trends and motivations (i.e. when was the last time your farm increased in size, how was additional land acquired (rent, purchase); what was the land use before going into corn production? What motivated the farm to increase acreage planted in corn?).

Land Use Changes

Limiting land use changes from natural ecosystems to crop land, especially monocropping, is a key pillar of conservation. In many contexts, like Cameroonian palm oil (see Box 1), postharvest loss and waste has a direct impact on the ability to meet consumer demand. As noted, an array of global conditions caused a late price hike for soybeans. For corn, Derecho winds significantly impacted yields, which meant corn production, still higher than average for most parts of the country, was on par with demand instead of exceeding it. With harvest-related losses hovering around 4.7% for corn and 4.5% for soybeans, and the ideal target for corn being 1% and soybeans being 3%, this leaves a gap of 3.7% for corn and 1.5% for soybeans. Reducing these losses will mean more revenue for farmers.

A 2016 mail survey of farmers in the eastern Dakotas revealed 40% of respondents converted grassland into cropland from 2004 to 2014. Most land came from previous conservation reserve program (CRP) land (62.7%), while some was from native grasslands (19.6% of 5.1%), and tame grassland conversion (17.6%). The study found the following characteristics indicated an increased likelihood of converting land: larger farms, younger farm operators, higher proportions of rented croplands, marginal yields.[47]

This research found that larger farms tend to be more efficient at harvesting because they can afford more sophisticated equipment. While newly converted lands are potentially experiencing efficient harvesting, this is still occurring on marginal lands. US farmers are acutely aware of market prices, therefore improving yield efficiency in other countries may reduce the need for importing corn from the US. Consistently lower corn prices would signal to farmers a lack of demand and may slow or even reverse land conversion, especially those related to the conservation reserve program (CRP). This is a long-term strategy. A short to medium term strategy to

46 https://flwprotocol.org/wp-content/uploads/2016/05/FLW_Protocol_Guidance_on_FLW_Quantification_Methods.pdf

47 Wimberly, Michael C., … (2017). Cropland expansion. And grassland. Loss. in the. Eastern Dakotas: New insights from a farm-level survey". Land. Use Policy (63): 160-173. http://www.sciencedirect.com/science/article/pii/S0264837716310857

slowing the pace of land conversion may include influencing the US Farm Bill's conservation programs and further exploring ethanol plant placement, which have a more direct influence on land conversion in the US.

Conservation Programs

During the 1985 Farm Debt Crisis, crop supply outpaced demand, decreasing crop prices. As a response, farmers broke new cropland to compensate for low prices, while the federal government looked for policies that would allow them to stop hemorrhaging money paying out unprofitable farmers, stabilize crop prices, and improve conservation as a side benefit. The Maddigan Amendment significantly increased investments in the Conservation Reserve Program (CRP) to remove land from production quickly.[48] Decades of backlash to direct government subsidies for agriculture led to decreased direct payments to farmers, with the primary safety net for farmers being crop insurance. Farmers determine the level of yield assurance they are willing to pay for on their farm, although this only covers 38% of insurance costs, with the government paying the remaining 62%, as the crop insurance scheme is neither self-sufficient nor a private product .[49]

From 2014 to 2016, the federal government spent $12.7 billion annually - $7.5 billion on commodity floor prices, and $5.2 billion on federal crop insurance. Corn payments account for 46% of funds and soybeans 15% (wheat receives the second most amount of support at 16%). Granted, corn has the greatest planted acreage and value, meaning rice and peanuts receive the highest levels of support. Note, specialty crops and livestock, including fruits, vegetables, and tree nuts, receive little to no direct government support. In 2015, farms contributed $136.7 billion, or 1% of US GDP (govt spending is equivalent to 9.3% of farm contributions to US GDP in 2015).[50]

In 2020, the Derecho windstorm negatively impacted hundreds of thousands of acres of crop production throughout central Iowa. USDA projected Iowa would have average corn yields of 202 bushels/acre in August, which decreased to 191 in September and 186 in October, as harvest was underway. 8.4 million acres of corn were not harvested in 2020.[51]

Interestingly, soybean acres to be harvested remain the same and anticipated bushels/acre increased from 54 in September to 56 in October. The total USDA forecast for corn and soybeans dropped about 1%. The effects of the pandemic initially dropped prices for corn and soy, but globally, adverse weather and increasing demand raised prices during harvest, an unusual time in an unusual year.[52]

Main Street Data estimated that 185 million bushels of corn was lost in Iowa due to Derecho.[53] However, 2020 remains a record-breaking year for corn production in the US. Corn prices continued to rise from late 2020 into the beginning of 2021.[54]

Most landowners prefer to maximize the profit

48 Add reference to: Food. Security Act of 1985, Conference Report (Laurel. Read me the report)
49 Congressional Research Service. (2017). "Farm Safety-Net Payments. Under the 2014 Farm Bill: Comparison by Program Crop". http://fas.org/sgp/crs/misc/R44914.pdf

50 www.hortidaily.com/artcile/6033810/us-agriculture-contributed-992-billion-to-economy-in-2015/
51 https://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornac.php
52 Eller, Donnelle. (2020). Iowa's estimated Derecho crop losses increase by more than 50% in latest USDA report. Des. Moines Register. Accessed January 9, 2020.
53 http://mainstreetdata.co/2020/08/27/iowa-corn/
54 www.macrotrends.net/2532/corn-rpices-historical-chart-data

from their land as much as possible, which may incentivize conversion into cropland if sufficient federal support for maintaining natural resources is not in place. The US Farm Bill includes a range of conservation programs farmers, ranchers and landowners can participate in.[55] Worth noting, Section 404 of the Clean Water Act and the Food Security Act Swampbuster program stipulate that farmers cannot convert or drain wetlands for agricultural production and continue to receive federal funds, such as crop insurance.[56] While this protects wetlands, there are few comparable acts for the conversion of prairie lands, which represents a majority of land being converted into agricultural production, specifically corn production, today.[57] The Grassland Reserve Program (GRP), which preventatively paid farmers from converting grasslands into cropland or urban development, was repealed in the Agricultural Act of 2014.[58]

The 2020 US Farm Bill increased the eligible acres under conservation programs, but as funding was not increased, landowners received lower annual payments for participation.[59] This perpetuates the tough decisions landowners are faced to make each year in whether to enroll or re-enroll in conservation programs.[60]

Ethanol Production

In Iowa, 53% of corn produced is sold to ethanol plants,[61] of which there are 44 ethanol plants in the state.[62] Local ethanol plants incentivize corn production and expansion of acreage,[63] and this expansion outpaces agricultural and biofuel policies in the US.[64] In this study, farmers preferred taking corn to an ethanol plant compared to a grain elevator as ethanol plants do not begin docking farmers for a high grain moisture content until 17%, compared with 15.5% at a grain elevator. Ethanol plants do not necessarily pay more than a grain elevator, but the relative delay in enforcing a docking system establishes good will between ethanol facility and farmer, improving supplier loyalty. An ethanol plant needs to achieve a certain rate of production to be economically viable and profitable, which means a greater incentive to raise prices to alter farmer production and selling behaviors. Further exploration into where ethanol plants are established can provide insights into which environmentally sensitive lands may experience land use change pressure.

55 Conservation programs managed by USDA's Farm Service Agency (FSA) worth exploring include: the Conservation Reserve Program (CPR), which pays farmers an annual Rent to plant environmentally beneficial plant species on sensitive land; the Conservation Reserve Enhancement Program, which pays farmers to remove high-priority conservation land from agricultural production; the Emergency Conservation Program (ECP), which assists farmers to restore agricultural land after natural disasters or severe droughts; the Emergency Forest Restoration Program (EFRP), which is similar to the ECP but for privately Owned forests; and the Farmable Wetlands Program (FWP), which pays farmers and ranchers annually to restore wetlands. https://www.fsa.usda.gov/programs-and-services/conservation-programs/

56 https://www.epa.gov/cwa-404/cwa-section-404-and-swampbuster-wetlands-agricultural-lands

57 Rashford, Benjamin S., et al. "Economics of Grassland Conversion to Cropland in the Prairie Pothole Region." Conservation Biology, 2010, doi:10.1111/j.1523-1739.2010.01618.x.

58 https://www.fsa.usda.gov/programs-and-services/conservation-programs/grassland-reserve/index

59 Key Informant Interview: Kristy Breid, Monroe County USDA Office, Paris, Missouri

60 Shuck, Julia. (2009). "Should I Sign Up Again?" Farm Journal, reprinted in Dairy Herd: https://d28e2b5z7p5q0k.cloudfront.net/news/should-i-sign-again

61 Ethanol Production. Iowa Corn. Retrieved on December 7, 2020 from https://www.iowacorn.org/corn-uses/ethanol

62 Renewable Fuels Assn, 2020 https://ethanolrfa.org/biorefinery-locations/

63 VO, H.D. (2020). Sustainable agriculture & energy in the U.S.: A link between ethanol production and the acreage for corn. https://search.proquest.com/openview/c2c93f696ed3e2b2f90fe2437232935f/1?pq-origsite=gscholar&cbl=1416337

64 Lark, T.J., Salmon, J.M., Gibbs, H.K. (2015). Cropland expansion outpaces agricultural and biofuel policies in the United States. Environmental Research. (10) 4. https://iopscience.iop.org/article/10.1088/1748-9326/10/4/044003

IMAGE 10. CORN LEFT IN FIELD AFTER HARVEST

CONCLUSIONS

Overall, corn farmers lost 4.7% of their crop during harvest as compared to the industry goal of 1% and soy farmers lost 4.5% of their crop during harvest compared to the industry goal of 3%. Farmers with higher losses tend to have smaller pieces of land and have less sophisticated equipment.

An awareness campaign targeting farmers that meet the specific demographics can potentially reduce overall industry losses. Specific awareness campaign activities may include:

- Publishing articles of research findings in rural newspapers to create awareness, and emphasizing the need to check combine settings when moving between fields, the importance of operator experience, and factoring in the impact combine sophistication will have on harvest related losses,
- Partnering with local extension agents and Young Farmers and Leaders groups, facilitated by high school agricultural vocational educators,
- Producing and distributing materials, specifically visual reference guides of what different levels of harvest loss look like per square foot.

In terms of slowing down land change conversion, exploring the Renewable Fuel Standards policy and federal conservation programs may further indicate how to further engage in these key areas of influence.

The study also noted large farms typically have more sophisticated flagship combines and tend to have lower levels of losses. As the trend of farms being consolidated to give way to larger farms and the increasing corporatization of corn and soy farms continues, it is expected that harvest losses will decrease with the more sophisticated equipment.

"ANECDOTALLY, I FIND A FAIR PERCENTAGE OF COMBINE OPERATORS MAY BE MORE INTERESTED IN SPEED OF HARVEST THAN IN STOPPING THE COMBINE TO COUNT SOYBEANS, CORN KERNELS, OR WHOLE DROPPED COBS. AT FALL FIELD DAYS, I HAVE RANDOMLY SCATTERED THREE OR FOUR BUSHELS PER ACRE ON 10 SQ. FT. OF THE GROUND SURFACE AND ASKED FARMERS TO VISUALLY INSPECT THE AREA AND DETERMINE WHETHER THIS WAS ACCEPTABLE LOSS OR NOT. TOO OFTEN FARMERS ARE UNSURE IN THEIR JUDGMENT AND I GET "BLANK STARES" BACK WITH UNCERTAINTY WHETHER OR NOT THE LOSS IS ACCEPTABLE."

FORMER IOWA STATE EXTENSION AGENT,
HARVEST LOSS SPECIALIST

IMAGE 11. HARVESTED CORN FIELD AT SUNSET

ANNEX A. FIELD COLLECTION PROTOCOL

Corn and Soybean Harvest Efficiency Study

Field Collection Protocol

SUPPLIES

- Sealable sandwich bags
- Grocery bags
- Sticky notes
- Ink pen
- Relative Humidity Reader
- Cellphone (GPS coordinates)
- Digital kitchen scale
- 10 ft2 hoop or square (PVC pipe) Lightweight container (for holding seed while weighing)
- Handheld Grain Moisture Reader
- Optional: tight fitting garden gloves, headlamp for collecting at dusk

PREPARATION

- Write Farm # and Sample # on 3 sticky notes
- Put each sticky note in a plastic sandwich bag and put all three labeled sandwich bags in a grocery bag. Take extra grocery bags when collecting corn in case whole ears are found in multiple plots.

COLLECTING FIELD SAMPLES

Once at harvested field,

- Walk into the field, 300 feet away from the border, especially away from trees.

- Randomly throw out a 10 ft2 plot guide.
- Collect whole corn ears and put in a plot-specific grocery bag.
- Clear debris (corn stalks and husks, beanstalks and empty pods).
- Put collected seeds into a sandwich bag.
- Repeat until 3 repetitions have been collected.
- When collecting seeds from the second repetition, take measurements for relative humidity and ambient temperature.
- Record the GPS coordinates.

COUNTING FIELD SAMPLES - CORN

- Optional: Lay out a plastic sheet for easy clean up
- Dump collected seeds into a pile. Separate into:
  - » Whole seeds
  - » Split/Cracked/Damaged seeds
  - » Cob chunks
  - » Ears of corn
- Count seeds (tip: sort into piles of 10)
- On sticky note, record
  - » Number of whole seeds (W#)
  - » Number of split/cracked/damaged seeds (S#)
  - » Number of kernels per cob chunk (#C1, #C2, etc.)
  - » Weigh ear of corn (E#oz)
- Photograph seeds, cob chunks, ears and sticky notes with results for manual backup.

COUNTING FIELD SAMPLES - SOYBEANS

- Optional: Lay out a plastic sheet for easy clean up
- Dump collected seeds into a pile. Separate into:
  - » Whole seeds
  - » Split/Cracked/Damaged seeds
  - » Pods with beans (remove beans from pods)
- Count seeds (tip: sort into piles of 10)
- On sticky note, record
  - » Number of whole seeds (W#)
  - » Number of split/cracked/damaged seeds (S#)
  - » Number of pods and total number of beans in pods (#P# beans)
- Photograph seeds, cob chunks, ears and sticky notes with results for manual backup.

CALCULATIONS

- Average data points across the three (3) repetitions to provide an overall loss estimate for the field:
  - » (P1 + P2 + P3) 3
- Scale this out to loss per acre:
  - » average field loss/10 ft2 x 4,356 = seed loss/acre
- And convert into bushels loss per acre:
  - » Corn: seed loss/acre 90,000 seeds/bushel = loss in bushels/acre
  - » Soybeans: seed loss/acre 210,000 seeds/bushel = loss in bushels/acre
- Determine percent loss:
  - » loss in bushels/acre yield bushels/acre
- Average data across all farms for general estimates to scale results to the national level.

CROP LOSS CONVERSIONS

- 1 bushel of corn = 56 lbs = ~90,000 kernels
- 1 bushel of soybeans = 60 lbs = ~210,000 beans
- 1 acre = 43,560 ft2
- 1 oz = 100.5 kernels

ANNEX B. SOYBEAN SURVEY

SOYBEAN - Survey of Current Farm and Postharvest Practices

Code: Farm____ Name of Data Collector:

Farm Characteristics			
Date		Name	
Email		Phone Number	
Farm land being sampled is:	_____ *owned* _____ *rented*	Other crops or livestock?	____ yes _____ no
How many years of harvesting experience?			
2019 corn yield	bushels per acre		
Acres of soybeans planted		Population	Row Spacing (inches)
What are your estimate on-farm post-harvest losses?		What are the causes of loss?	
Adjusted planting practices this year?			
Has COVID-19 had any impact on planting or harvesting?			

Harvesting Practices		
Soy harvest 2020 date range		*Current 2020 yield:*
At what % moisture content do you harvest?		How do you test moisture content?
Adjusted any harvesting practices this year?		
What do you do with stubble?		

Combine and Settings		
Combine model and number		
Do you have a draper header?	_____ Yes ____ No	
Header model & number:		Header size:
What settings did you change?	Ground speed (mph):	Threshing speed range (RPM):
	Concave Clearance (mm):	Cleaning fan speed range (RPM):
	Chaffer/Upper Sieve Clearance (mm):	(Lower) Sieve clearance (mm):
Why choose these settings?		
Adjusted any combining practices this year?		

Transportation			
Describe how get grain from combine to first point of storage:			
Where does harvested corn go?	__________ % stored on-farm	__________ % sold immediately, specify:	__________ % off-farm, specify:
Where/Who sell corn to? (What percent goes to each market?)	A.	B.	C.
Distance ransport grain from field (miles)			
Travel time (minutes) from farm to market			
Estimated losses transporting to storage			
Adjusted any transportation practices this year?			

Storage		
Storage methods	__ Grain bin __ Flat Storage ___ Grain bags (12-15,000 bushel) ___ Managed piles __ Other, specify ______________	
On-farm unloading practice	____ auger unloads from truck/trailer to bin _____ concrete pit	Estimated losses:
What happens to spilled grain?		

How long typically store soybeans? (months)		
When sold all 2019 stored grain?		
How much lose in storage annually?		Causes of loss:
How much lose in storage this past year/2019?		Have you ever lost a bin of soybeans? (Y/N)
Adjusted storage practices this year?		

ANNEX C. CORN SURVEY

CORN - Survey of Current Farm and Postharvest Practices

Code: Farm____ Name of Data Collector:

Farm Characteristics			
Date		Name	
Email		Phone Number	
Farm land being sampled is:	_____ *own* _____ *rent*		
Other crops or livestock?	____ yes _____ no		
How many years of harvesting experience?			
2019 corn yield	bushels per acre		
Acres of corn planted		Population	Row Spacing (inches)
What do you estimate harvest losses to be?		What are the causes of loss?	
Any planting practices adjusted this year?			
Has COVID-19 had any impact on planting or harvesting?			
Harvesting Practices			
Corn harvest 2020 date range			
Yield per acre so far (2020)	bushels per acre		
At what % moisture content do you harvest?		How do you test moisture content?	
Adjusted any harvesting practices this year?			
What do you do with stubble?			
Combine and Settings			
Combine model and number			
Header model & number:		Header size:	
What settings did you change?	Ground speed (mph):	Threshing speed range (RPM):	
	Cleaning fan speed range (RPM):	Concave Clearance (mm):	
	Chaffer/Upper Sieve Clearance (mm):	(Lower) Sieve clearance (mm):	
Why choose these settings?			
Adjusted any combining practices this year?			
Transportation			
Describe how get grain from combine to first point of storage:			
Where does harvested corn go?	__________ % stored on-farm	__________ % sold immediately, specify:	__________ % off-farm, specify:
Where/Who sell corn to? (What percent goes to each market?)	A.	B.	C.
Distance ransport grain from field (miles)			
Travel time (minutes) from farm to market			
Estimated losses transporting to storage			
Adjusted any transportation practices this year?			
Location of storage	__________ % On-farm	__________ % Off-farm, specify:	
Storage methods	__ Grain bin __ Flat Storage ___ Grain bags (12-15,000 bushel) ___ Managed piles __ Other, specify _____________		

On-farm unloading practice	____ auger unloads from truck/trailer to bin _____ concrete pit _____ Other, specify:		
What happens to spilled grain?			
Is drying done on the farm?	___ Yes ______ No	*If yes, describe method used*	*Dry to what moisture content?*
How long typically store corn? (months)			
When sold all of 2019 stored grain?			
How much lose in storage each year?		Causes of loss:	
How much lose in storage this past year?		Have you ever lost a bin of corn?	
Adjusted any of your storage practices this year?			