No Grain Left Behind

PART VI Harvest Efficiency and Post-Harvest Loss

Agribusiness Associates Inc.

WWF

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EXECUTIVE SUMMARY

An estimated 2.5 billion tons of food goes uneaten around the world each year. New estimates indicate that of all the food grown, approximately 40% goes uneaten, an increase over the previously estimated 33%.[1] Research on quantifying post-harvest loss has been limited; however, new research out of WWF—UK[2] reveals that as much as 1.3 billion tons of food is lost on farms globally during and after harvest. This is the equivalent of 15% of all food produced globally. In a time where biodiversity and ecosystem vitality are declining at a rapid rate due to a changing climate and degradation of renewable natural resources, understanding how and where loss occurs in the food system is integral to mitigating the impact the food system has on our environment as well as anticipating when and where we will have food shortages. We no longer have time, or space, to not assess food loss and waste, much less accept these levels of loss and waste as a cost of doing business.

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 cropland.[3,4] Existing research focuses primarily on increasing yield, leaving a gap to understanding grain loss. While knowing the yield gap from potential yield estimates is

1 Da Gama, Lilly, Pete Pearson, Leigh Prezkop, Liam Walsh, and Callum Weir. "The Global Impact of Food Loss and Waste on Farms." *DRIVEN TO WASTE, 2021*. **https://wwfint.awsassets.panda.org/downloads/wwf_uk__driven_to_waste__the_global_impact_of_food_loss_and_waste_on_farms.pdf**.

2 Ibid.

3 Seth Meyer, and Joseph L. Parsons. "Acreage." *United States Department of Agriculture (USDA)*, National Agricultural Statistics Service (NASS), June 30, 2021. **https://www.nass.usda.gov/Publications/Todays_Reports/reports/acrg0621.pdf**.

4 McDaniel, Jody, and Bruce Boess. "Farms and Land in Farms Summary." *United States of Agriculture (USDA)*, National Agricultural Statistics Service, February 2020. **https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0220.pdf**.

important, it is not a reflection of losses in the field. Measuring and identifying loss drivers to improve the management and total yield presents an opportunity to capture food early in the value chain—with the potential to improve harvests, benefit producers, the land, and the resources used to produce the crop. This research does not include on-farm storage loss, an area that should be considered for future research.

This study collected baseline primary data from a sample of farms that revealed 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 there is potentially a loss of 507 million bushels of corn worth $2.1 billion, based on 2019 production figures and prices.[5] The range of loss from field samples was .5% to 18%. For soybeans, the study found the average loss was 4.5%, whereas 3% is the accepted industry loss. This means a loss overage of 1.5%, which when scaled to the national level equates to a potential loss of 53 million bushels of soy worth $0.53 billion. The range of loss samples was 1.8% to 7.4%. The ranges of loss from samples on both corn and soy farms highlight the fact that rate of loss can be highly variable. As a result, country-level estimates for loss made in this report are meant only to be illustrative of the potential for loss at scale.

This study illustrates the staggering amount of land that is most likely used to produce corn and

5 Censky, Stephen L., and Joseph L. Parsons. "Crop Production Summary." *United States Department of Agriculture (USDA),* National Agricultural Statistics Service, January 2020. **https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan20.pdf**.

soy that is left behind in-field or never sold. Although this sample is a snapshot for a small area of production, it can help us understand the breadth of the problem and the wide range of losses that are not being monitored and tracked. Applying this study's loss rates across the total corn and soy acreage in the US would amount to a projected area of land that is four times greater than what was converted to cropland in 2018 across the Great Plains.[6] The location of ethanol plants, an important factor for expansion of corn production as discussed later in this paper, 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, an issue of particular concern in North and South Dakota.

Type of equipment and level of combine operator experience were the most significant factors in determining the level of loss across farms. These findings can be applied in the US by greater training of combine operators, investment in better equipment, and establishment of equipment sharing schemes for farmers that may not be able to afford the cost of equipment or who have smaller farms. Traders and other companies buying significant amounts of commodities can help fill these gaps to reduce loss and work towards their Scope 3 goals.

6 World Wildlife Fund. "The Plowprint Report: 2018." (2018).

INTRODUCTION

As the world's largest producer for both corn and soybeans, producing 15.1 billion tons of corn and 4.4 billion tons of soy in 2021 alone, the US has an extremely efficient commodity crop production system.[7] Although agricultural land decreased from 63% of US land in 1949 to 45.5% in 2017, production continues to increase, shining a light on increasing productivity and agricultural intensification. With additional pressures on global agriculture from climate change, war, and population growth, this efficiency will continue to be vital. It was surprising, then, that in a first of its kind study by WWF, farm-level post-harvest food loss for corn and soy significantly surpassed previous estimates.

Any increase in loss for commodities grown at such a scale has a tremendous impact on both greenhouse gas (GHG) emissions released, as well as decreased food availability. Improving the overall efficiency of the global food system through reduced food loss can help address food insecurity by increasing overall food supply, reducing pressure on the environment by decreasing the amount of land needed to produce food for the world's population and reducing GHG emissions from reductions of inputs used to grow food, only to have it go to waste. Global comparative analysis on food loss across crops and geographies is needed. Only with more transparent and better data can we mitigate issues like loss and land conversion. This data can be aggregated and shared anonymously. If voluntary sharing efforts are not adopted in the near term, governments should take the lead to aggregate and anonymize reporting on food loss and waste. Additionally, with many companies making commitments to reducing GHG emissions in their supply chains, addressing farm-level post-harvest loss represents an opportunity to contribute to Scope 3 goals. Although achieving 0% post-harvest loss is impossible, greater efficiency can be achieved; this study seeks to find this area of diminishing returns on reducing loss.

7 Barrett, Jim. "Corn and Soybean Production up in 2021, USDA Reports Corn and Soybean Stocks up from Year Earlier, Winter Wheat Seedings up for 2022." *United States Department of Agriculture*, National Agricultural Statistics Service, January 12, 2022. **https://www.nass.usda.gov/Newsroom/2022/01-12-2022.php**.

While this study focused on the United States, if post-harvest crop loss was higher than estimated in the world's most efficient commodity production system, it seems likely that estimates in other parts of the world may also be underestimated.[8] In Brazil, for example, government estimates of soy losses are around 10-15%, although industry estimates are around 20%. The African Post-Harvest Loss Information System (APHLIS) 2019 estimates for Africa generally assume 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.[9] This totals to 11.7% in losses at the field level.[10] If those estimates are also low, there is a tremendous opportunity to reduce loss, which is particularly important both for climate change but also due to the economic pressure from rising food prices across the world.

The impact of the conflict in Ukraine is expected to continue to put upward pressure on food prices. In 2022 in the US, all food prices are predicted to increase between 8.5 and 9.5 percent, food-away-from-home prices are predicted to increase between 6.5 and 7.5 percent, and food-at-home prices are predicted to increase between 10.0 and 11.0 percent.[11] Globally, as major exports are stuck in fields and ports in Ukraine and Russia coupled with rising fertilizer and fuel prices, food prices as measured by the Food and Agriculture Organization's (FAO's) Food Prices Index are at their highest level since the series started in 1990, although the last five years show a particular spike aligned with increases in commodity prices (Figure 1).[12]

8 Gustavsson, Jenny, Christel Cederberg, Ulf Sonesson, Robert Van Otterdijk, and Alexandre Meybeck. "Global food losses and food waste." (2011).

9 APHLIS. "Post Harvest Losses in 2021:" APHLIS, (2022). **https://www.aphlis.net/en/data/tables/dry-weight-losses/XAF/all-crops/2021**

10 APHLIS does not collect data for soy.

11 MacLachlan, Matthew, and Megan Sweitzer. "USDA ERS - Summary Findings." Economic Research Service; U.S. Department of Agriculture (USDA), September 23, 2022. **https://www.ers.usda.gov/data-products/food-price-outlook/summary-findings/**.

12 Index, FAO Food Price. "World Food Situation." *FAO: Rome, Italy* (2021).

Figure 1: Commodity prices and index, 2017-2022.

SOURCES: THE CHICAGO COUNCIL ON GLOBAL AFFAIRS, *ADVANCING GLOBAL FOOD SECURITY IN THE FACE OF A CHANGING CLIMATE*, GERALD C. NELSON, MARCH 2014; FAO FOOD PRICE INDEX, 2017; BLOOMBERG FINANCE L.P. 2022

This study has proven, once again, the value of measurement. It was long assumed that commodity production in the US was so efficient that farm-level post-harvest loss was not meaningful. We now know that's simply not true, and what's more, that there are key steps that can be taken to reduce the loss. It's time for companies to take those steps to first measure and then reduce loss in their supply chains to increase food security, improve farmer incomes, and address Scope 3 emissions.

US CORN AND SOY PRODUCTION

Of the 896.6 million acres of total land in farms in the US,[13] 92 million acres was planted in corn and 83.8 million acres was planted in soy in 2020, representing nearly 20% of US farmland.[14] WWF's annual Plowprint report revealed that in 2020 an estimated 1.8 million acres of grassland were plowed up, primarily to make way for row crop agriculture. Within the Northern Great Plains (NGP), the Great Plains' most intact region, nearly 385,000 acres were plowed up for cropland during this same period. Although the total agricultural land in the US decreased by nearly 20% since 1949, commodity prices, environmental factors, government policies and programs, and population growth can affect land-use decisions and lead to this kind of plow up. Additionally, climate change is beginning to shift crop production to different regions as weather patterns change, which is likely also a factor.[15]

About a third of corn grown in the US 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 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.[16]

13 Nickerson, Cynthia, and Allison Borchers. "How is land in the United States used? A focus on agricultural land." Amber Waves. ERS Publications (2012).

14 Seth Meyer, and Joseph L. Parsons. "Acreage." *United States Department of Agriculture (USDA),* National Agricultural Statistics Service (NASS), June 30, 2021. **https://www.nass.usda.gov/Publications/Todays_Reports/reports/acrg0621.pdf**.

15 Wilson, Scott. "As It Enters a Third Year, California's Drought Is Strangling the Farming Industry." *Washington Post*, March 21, 2022. **https://www.washingtonpost.com/nation/2022/03/21/california-drought-vanishing-farms/**.

16 Capehart, Tom, and Susan Proper. "Corn is America's Largest Crop in 2019." *United States Department of Agriculture* (2019).

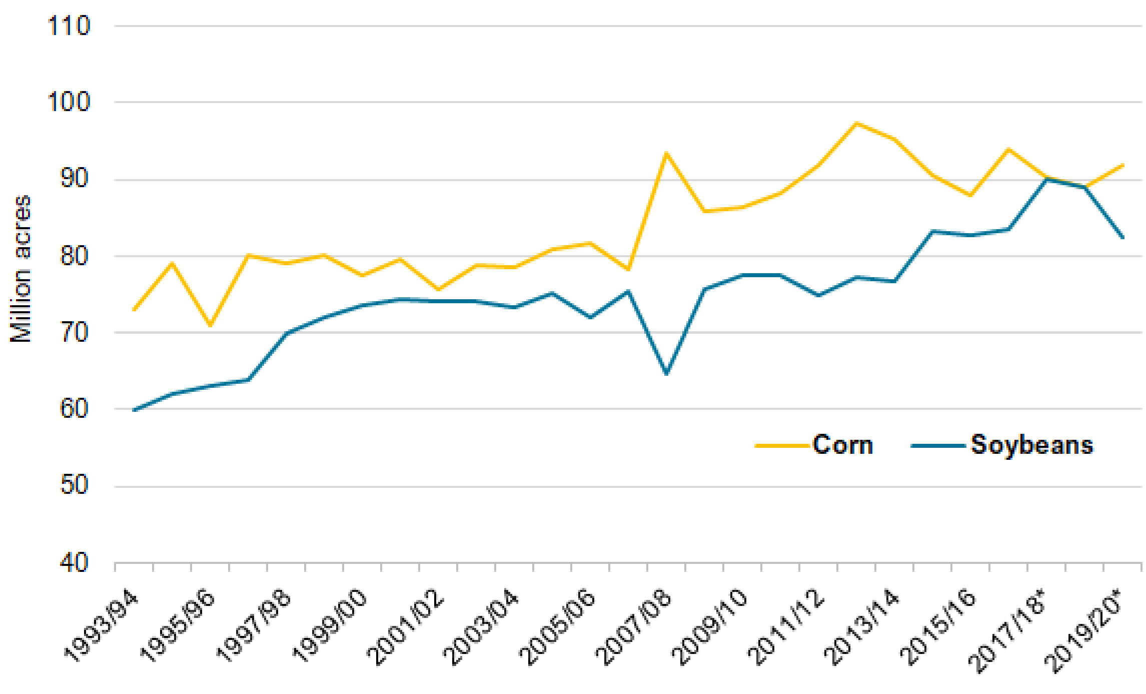


Figure 2: U.S. corn and soybean planted acreage history

SOURCE: USDA OCE

Approximately 85% of soybeans grown in the US are used for animal feed and soybean oil.[17] Soybean oil is split with around 68% of soybean oil used as food, 25% as biodiesel in the US, and 7% for creating industrial products like paints, plastics, cleaners, etc.[18]

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 dried distiller grains and solubles (DDGS).[19] On the other hand, soybean oil is separated from soybean meal that is fed to livestock, leaving a coproduct requiring an end market.[20] This allows soybeans to curtail the issue commonly faced by corn.

All of these contextual market issues have a role to play in how post-harvest loss for corn and soy is addressed. The various stakeholders involved in purchasing soy and corn, ranging from ethanol, consumer products, and animal protein producers are all responsible for addressing the loss, both for their Scope 3 GHG emissions, as well as for their bottom lines.

17 USDA (United States Department of Agriculture). "USDA Coexistence Fact Sheets: Soybeans." (2015).

18 Krull, Chris. "Uses for Soybeans." U.S. Soy, May 11, 2018.

https://ussoy.org/uses-for-soybeans/?persona=influential-buyers-feed-ingredients-animal-consumption&pillar=innovation-beyond-the-bushel.

19 https://www.agweb.com/Understanding-the-Relationship-Between-Ethanol-and-DDGS

20 Haines, Doug, and Jon Van Gerpen. "Biodiesel and the Food vs. Fuel Debate – Farm Energy," April 3, 2019. **https://farm-energy.extension.org/biodiesel-and-the-food-vs-fuel-debate/#Biodiesel_is_often_made_from_animal_feed_by-products**.

RESEARCH RESULTS

In the US, estimates indicate 16 percent of food waste occurs at the farm level as loss, which is about 19 million tons per year and includes all crop types. However, this number is based on limited field studies, which vary considerably with regional conditions.[21] WWF's prior research into specialty crop loss has also found considerable differences in loss depending on the crop.[22] A 1989 Ohio harvesting efficiency study, frequently referenced by extension agents today, found 1% losses in corn and 4% losses in soybeans.[23] This study (see Appendix 1 for methodology) sought to provide more up to date estimates on commodity crop post-harvest loss based on food loss measurement methods, rather than an analysis of efficiency.

21 Xue, Li, Gang Liu, Julian Parfitt, Xiaojie Liu, Erica Van Herpen, Åsa Stenmarck, Clementine O'Connor, Karin Östergren, and Shengkui Cheng. "Missing food, missing data? A critical review of global food losses and food waste data." *Environmental science & technology* 51, no. 12 (2017): 6618-6633

22 Pearson, Pete, Monica McBride, and Leigh Prezkop. "No Food Left Behind, Part 2: A Tale of Two Markets: A Model for Working Together to Fully Utilize the Surplus | Publications | WWF." World Wildlife Fund, July 9, 2019. **https://www.worldwildlife.org/publications/no-food-left-behind-part-2-a-tale-of-two-markets-a-model-for-working-together-to-fully-utilize-the-surplus**.

23 Gliem, J. A., R. G. Holmes, and R. K. Wood. "Corn and soybean harvesting losses." *Paper-American Society of Agricultural Engineers* 90-1563 (1990).

On Farm Measured Corn Losses

Across all 15 corn 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 noted that harvest loss of 1% is their general estimate for unavoidable loss, which is built into the cost of doing business.[24]

Based on the 16 in-field sample measurements on a total of >15,050 acres of corn plantings, the remaining seeds per acre 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 was 2.75%. Comparing the measured average harvest loss (4.7%) to commonly accepted industry goals of harvest loss (1%) there is a difference, or overage of 3.7%.

24 This is an estimate from extension agents not necessarily based on scientific evidence, but rather anecdotal field-based observations.

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 **technical report** for detailed results). Leading causes of kernel and cob damage include insect damage, wind, climate, moisture content, equipment settings, or improper threshing and combine operating.

On Farm Measured Soy Losses

For soy, a total of 14 farmers were interviewed with 15 farms on a total of >15,628 acres of soy plantings, which allowed for in-field measurements in three regions across Iowa and Missouri. Measurements were taken directly after the harvest, to observe harvesting techniques and nuances, and to also minimize the risk of inaccurate data collection. Market prices had significantly increased during 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, and strong Chinese demand[25] that greatly incentivized growers to sell their harvest immediately without storing.

Across all 15 farms assessed, growers estimated that 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

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

bushels per acre or 4.5% of harvested yield, 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.

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. Other reasons for loss include combine sophistication and operator experience. Flagship combines tend to exist on larger farms whereas smaller farms have less sophisticated combines.

Economic Loss

Economic losses were calculated based on the average price of corn for the month ($4.11 per bushel) multiplied by the 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 Technical Report). The average loss was 4.7%, whereas extension agents encourage less than 1% loss. This means a level of loss 3.7% higher than generally expected which when scaled to the national level, means a loss of 503 million bushels of corn worth $2.07 billion, based

Table 1: Economic losses of corn.

	Accepted Industry Loss (1% loss)	Corn Loss Based on Study Findings at National Level (4.7% loss)	Difference
Loss (bushels)	137M bushels	644M bushels	507M bushels
USD of loss	$563M	$2.7B	$2.1B
GHG footprint from on-field decomposition	472,000 tons CO_2e	2,220,000 tons CO_2e	1,750,000 tons CO_2e
Embedded emissions of wasted product	2,880,000 tons CO_2e	13,500,000 tons CO_2e	10,600,000 tons CO_2e

Table 2: Economic losses of soy.

	Accepted Industry Loss (3% loss)	Soy Loss Based on Study Findings at National Level (4.5% loss)	Difference
Loss (bushels)	107M bushels	160M bushels	53M bushels
USD of loss	$1.1B	$1.6B	$533M
GHG footprint from on-field decomposition	314,000 tons CO_2e	472,000 tons CO_2e	157,000 tons CO_2e
Embedded emissions of wasted product	3,200,000 tons CO_2e	4,800,000 tons CO_2e	1,600,000 tons CO_2e

on 2019 production figures.[26] The tables illustrate these figures in addition to GHG footprint from on-field decomposition when the crop is left behind, and the embedded emissions of that product being wasted. These numbers are based on the total amount of loss which includes the accepted industry standards of 1% for corn, and 3% for soy.

For soy, economic losses were calculated based on the average price 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.

Taken together, this amounts to $4.3 billion in losses, equivalent to 18,300,000 tons of GHG emissions. With the scale of US commodity production, the level of corn loss alone found in this study when scaled to national levels was nearly equivalent to the total 2021 corn exports to Mexico (16.84M metric tons), the second largest buyer of US corn for that year.[27] And though the samples were taken in Iowa and Missouri, production practices are similar in other states for the same commodities. It is worth noting, however, that national farm averages may vary from the farms sampled for this study.

26 Censky, Stephen L., and Joseph L. Parsons. "Crop Production Summary." *United States Department of Agriculture (USDA),* National Agricultural Statistics Service, January 2020. **https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan20.pdf**.

27 USDA. "U.S. Trade with Mexico in 2021." USDA Foreign Agricultural Service, 2022. **https://www.fas.usda.gov/regions/mexico**.

MITIGATING LOSS

This study showed that combine operators with more than 30 years of harvesting experience have less loss, as do farms using technologically sophisticated Flagship combine models.[28] The combine model has a more significant impact on reducing loss than 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. Larger farms (any farmer planting more than 1,000 acres) able to purchase more sophisticated combine models generally had less loss, about an average of 3.8% for corn and 3.9% for soy while smaller farms had higher levels of loss, about 6.8% for corn and 5.2% for soy. Larger farms will likely have more Flagship combines, the most efficient type of harvester.

This study's data gleaned from US-based commodity production poses an interesting question for other high-production countries on whether loss levels may be much greater than estimated due to equipment and operator experience. At the same time, emerging economies have a significant amount of subsistence and small holder farmers who harvest their crop by hand, which is typically efficient at reducing loss at the harvest stage, although the systems further up the supply chain in terms of transport, lack of infrastructure, and government corruption, can often further increase losses. Given differences in production systems, economics, and more, the same mitigation solutions that may work for the US based on this study, namely equipment (whether purchased or leveraging sharing agreements) and training/greater experience, may not be applicable in other contexts and represent an area requiring further investigation. This study illustrates the imperative need for global reporting on farm loss and comparative analysis across countries.

While this study focused on field level post-harvest loss, US-based loss at the storage level could be another area where loss is underestimated. WWF staff have anecdotally observed grain left in grain bags and on tarped piles on the road, storage methods that typically lead to higher levels of loss, but which have not been studied in depth. Growers often store grain for longer periods of time due to market fluctuations but this may lead to higher levels of loss. Exploring storage-based loss measurement and markets-based storage alternatives could be future opportunities to reduce loss.

Finally, government policy and subsidies have a large role to play in reducing loss and decreasing pressure on our natural resources. Subsidies may cause overproduction, which draws lower-quality farmlands into active production. Areas that might have been used for parks, forests, grasslands, and wetlands get locked into agricultural use, and lands that would have been used for pasture or grazing

28 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.

have been shifted into crop production. An example of this is with ethanol production. Local ethanol plants incentivize corn production and expansion of acreage which outpaces agricultural and biofuel policies in the US.[29] 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 facilities and farmers, 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.

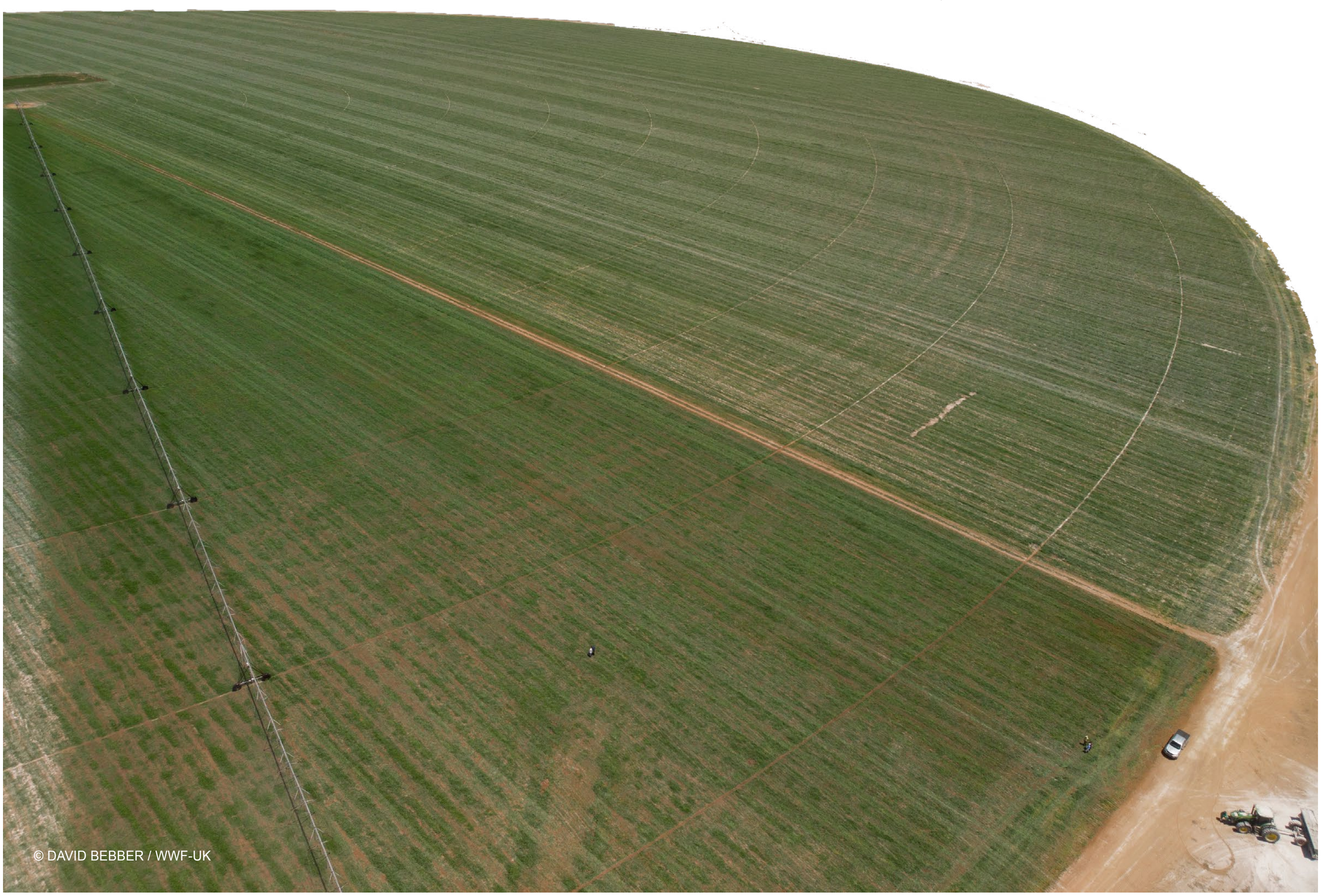
The location of ethanol plants and availability of government conservation programs seem to have the greatest influence on US farmer and landowner behavior to convert natural prairie, which is currently the most susceptible to land use change. At times, subsidies and other policies may discourage farmers from innovating, cutting costs, diversifying their land use, and taking other actions that could reduce loss and lead to greater product utilization.

29 Lark, Tyler J., J. Meghan Salmon, and Holly K. Gibbs. "Cropland expansion outpaces agricultural and biofuel policies in the United States." *Environmental Research Letters* 10, no. 4 (2015): 044003.

CONCLUSION

Food is being left behind in fields as prices continue to increase to all-time highs, and biodiversity loss and resource stress are happening at alarming rates. In the US, our advanced and mechanized systems for producing, harvesting, and storing grain crops are not 100% fool-proof. If this is the case in the US, we can suspect that production systems, storage, and lack of infrastructure in other parts of the world are leading to greater levels of loss. But with greater measurement, transparency and comparative analyses, knowing that levels of post-harvest commodity loss were higher than anticipated presents an addressable problem. In the US, we can focus on better training of farm operators and investing in more sophisticated equipment. For farmers that cannot afford equipment on their own, renting or equipment sharing programs could be established or expanded upon. Companies buying large quantities of commodity crops can work with their suppliers to help implement these changes.

A significant portion of deforestation and conversion is driven by soy production, either directly, or indirectly through land clearing for pasture that is then converted to soy production. This harmful land use change leads to biodiversity loss and greenhouse gas emissions due to released carbon, among other detrimental environmental impacts. If commodity crop post-harvest losses



were reduced, some of the pressure to convert habitat for production could be alleviated, making better use of land that's already in agricultural production, but only if there is a push to limit land use change by governments and focus on loss and waste reduction as a primary strategy for increasing yields and profits. Annual comparative analysis globally on food loss across all crops and geographies is imperative, with more transparent and better data flows, so that we can begin to mitigate issues like loss and land conversion. This data can be aggregated and shared anonymously. If voluntary sharing efforts are not adopted in the near term, governments should look to require aggregate and anonymized reporting on food loss and land conversion from traders so that brands, retailers, and consumers can begin to make the necessary changes to reduce loss and embedded Scope 3 emissions.

Now more than ever there are tremendous challenges facing global agriculture. Given rising food prices, global conflict, and increasingly dire effects of climate change, addressing post-harvest commodity crop loss is imperative. We can no longer operate under the assumption that we are at peak efficiency. It is imperative for growers to measure and validate their post-harvest loss estimates to identify and mitigate specific causes. More importantly, traders and producers must globally share loss data across their supply chains. This is a problem for which the US can lead the way in measurement and transparency.

APPENDIX 1: METHODOLOGY

This study focuses on losses that occur during harvest to the first point of storage, including seed transfer and transportation, drawing on the Food Loss and Waste Quantification Methods of direct weighing, counting, and surveys.[30] Direct weighing was taken in ounces for ease of conversion into bushels lost 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. 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.

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.[31] 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 from the Midwest in Iowa and Missouri. Field samples may be considered representative of what is seen farm-to-farm in the US, although the results outlined here may be below average due to potential volunteer bias, i.e. growers who know they have little loss volunteering in the study versus larger growers who may have significant levels of loss. Further study on post-harvest loss for commodity crops is recommended to better understand its impact and mitigation potential.

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

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