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RESEARCH ARTICLE

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Cost of agricultural injuries in the United States: Estimates based on surveillance, insurance, and government statistics

Suraj Adhikari MS[1] | Fernando Wilson PhD[2] | Risto Rautiainen PhD[1]

[1]Department of Environmental, Agricultural and Occupational Health, University of Nebraska Medical Center, Omaha, Nebraska, USA

[2]Matheson Center for Health Care Studies, University of Utah, Salt Lake City, Utah, USA

Correspondence
Risto Rautiainen, PhD, 984395 Nebraska Medical Center, Omaha, NE 68198-4388, USA.
Email: rrautiainen@unmc.edu

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Abstract

Background: Agriculture is a hazardous industry but the frequency and severity of agricultural injuries are not well documented as nonfatal injuries to self-employed farmers are excluded from national surveillance. The aim of this study was to provide new injury rate and cost estimates in US agriculture.

Methods: Injury data were obtained from 2018 to 2020 Farm and Ranch Health and Safety Surveys. Responses from 7,195 farm/ranch operators included injury frequency, medical expense, and lost work time data. These injury rate and cost data were used to estimate national injury costs for self-employed farmers using Census of Agriculture operator count, injury costs for hired agricultural workers using Bureau of Labor Statistics (BLS) nonfatal injury count, and fatal injury costs using BLS count of fatal injuries.

Results: The injury rate for self-employed farmers and ranchers was 15.25 injuries per 100 operators or 11.9 "recordable" injuries per 100 full time equivalent operators (FTE). Average costs for nonfatal injuries were: $10,878 for medical care, $4735 for lost work time, and $15,613 in total per injury case. The total national agricultural injury cost estimate was $11.31 billion per year; 11.3% higher than the earlier benchmark using 1992 data; both in March 2024 dollars. The cost burden was 2.1% of the US national gross farm income and 13.4% of the net farm income in 2019.

Conclusions: Injuries result in significant economic losses to farm and ranch operators, their family members, workers, and society. Preventive efforts should be scaled up to reduce the frequency and costs of agricultural injuries.

KEYWORDS
agriculture, cost, farm, injury, operator, ranch

1 | INTRODUCTION

According to the US Bureau of Labor Statistics (BLS), the agriculture, forestry, fishing, and hunting sector had the fourth highest fatality count (417) and the highest fatality rate (18.6 per 100,000 full-time equivalent workers [FTE]) among major industry sectors in the United States in 2022. This rate was about five times higher than the rate (3.7 per 100,000 FTE) for all industries combined.[1] The number of recordable nonfatal injury cases in the agriculture sector was 39,500 while 15,200 involved days away from work (DAFW).[2] The agriculture sector had the fourth highest nonfatal injury rate (4.1 injuries/100 FTE) of major industry sectors in 2022.[3] These nonfatal injury statistics for agriculture

are based on the BLS Survey of Occupational Injury and Illness (SOII), which includes hired workers in agriculture, generally on farms with more than 10 employees. However, a major part of the agricultural workforce; self-employed farmers, ranchers, and their family members are excluded from SOII surveillance, and their nonfatal injuries are not represented in BLS statistics, nor in other national statistics.[4]

The number of agricultural workers (FTE) used in BLS statistics was 2.2 million, and about one-third of them (0.8 million) were self-employed or unpaid family workers in 2022.[5] The 2017 Census of Agriculture reported 2,042,220 farms, 3,399,834 producers (operators), and 6,577,050 persons living in the producers' households. About 1.4 million producers had farming as their primary occupation.[6] A total of 513,137 farms reported expenses for hired employees in the amount of $31.6 Billion, which at an average salary of $14 per hour converts to 1.1 million FTE hired workers.[7] Given the available information it is difficult to construct estimates of the numbers of workers and working hours in agriculture as both self-employed farmers and hired workers may work in agriculture part time, or seasonally. Even with the uncertainties in employment estimates, it is clear the exclusion of self-employed farmers from national injury surveillance leaves a major gap in understanding the full burden of the agricultural injuries and related costs in the United States.

While there are challenges in quantifying the numbers of workers and occupational injuries in agriculture, it is even more challenging to estimate the costs of these injuries with available information. The National Safety Council's (NSC) estimates for all 2022 work injury costs across occupations in the United States were $167 billion in total, $1040 per worker, $40,000 per medically consulted injury and $1,390,000 per work-related death.[8] Few studies have estimated agricultural injury costs comprehensively at a national level. Leigh et al.[9] estimated the cost of job-related agricultural injuries as $4.57 billion in the United States in 1992, which is about $10.16 billion in 2024 when adjusted for inflation. This estimate was equal to 2.8% of the value of agricultural products sold on farms in 1992.[10] After three decades, this study is still used as the benchmark of injury costs in US agriculture. Similarly, few recent studies are available elsewhere. One study in Finland used national data for 1982–1999 from a workers' compensation system that is mandatory for all farmers.[11] The costs equaled 0.7% of national gross farm income (GFI) and 2.2% of net farm income annually.[12] Other studies have addressed agricultural injury cost in specific study populations,[13] types of incidents[14] or insurance systems.[15,16]

Given the limited data on agricultural injury costs, persistently high injury and fatality rates in agriculture, changes in the agricultural workforce, changing working conditions and hazards, and increasing labor and medical care costs, it is important to generate updated information on the frequency, severity, and economic burden from agricultural injuries to guide preventive investments and efforts. Recent agricultural injury surveillance efforts provide an opportunity to re-evaluate national agricultural injury cost estimates with new data on injuries and related costs particularly to self-employed farmers and ranchers.[17,18] The aim of the current study was to estimate the frequency and cost of agricultural injuries and fatalities in the United States using surveillance data for self-employed farmers and ranchers and insurance and government data for hired agricultural workers.

2 | METHODS

Information on agricultural injuries was obtained from the 2018 and 2020 Farm and Ranch Health and Safety Surveys (FRHSS)[17,18] that are part of the Central States Center for Agricultural Safety and Health (CS-CASH) surveillance program. This surveillance covers self-employed farm and ranch operators in seven states in the central US, namely Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. United States Department of Agriculture (USDA) defines agricultural operations (farms and ranches) as "any place from which $1000 or more of agricultural products were produced or sold, or normally would have been sold, during the year." A farm operator is defined as "a person who runs the farm, making day-to-day management decisions."[6] An official USDA definition for a ranch is not available, but ranches are commonly known as operations that raise grazing livestock on large areas of land. We asked respondents to self-identify their operation as a farm or a ranch. The 2017 Census of Agriculture data were used to quantify the number of agricultural producers at the national level.[6] The BLS Census of Fatal Occupational Injuries (CFOI) was used to quantify occupational fatalities in agriculture (self-employed and hired workers),[1] and the BLS Survey of Occupational Injuries and Illnesses (SOII) was used to quantify the number of hired workers and nonfatal injuries to hired workers in agriculture.[3]

2.1 | Data collection, farm and ranch operators

CS-CASH, based at the University of Nebraska Meeical Center, administered two similar surveys; first in 2018 by email and mail, and second in 2020 by mail only; both to farms and ranches selected from the Farm Market iD (FMiD) databases.[17,18] FMiD became part of Data Transmission Network (DTN) in February 2021. DTN is a subscription-based service for the analysis and delivery of real-time weather, agricultural, energy, and commodity market information. It has profiles and datapoints for more than 95% of US producers.[19]

Mail surveys were sent out to 16,826 farm/ranch operations in 2018 and 17,328 operations in 2020. These study samples were drawn randomly, stratified by state (~2500 operations per state). Operations included in the 2018 sample were eliminated from the drawing of the 2020 sample to obtain unique farm/ranch operations each year. The selection criteria included having an email address (in the 2018 sample only) and a minimum of $5000 in annual GFI to focus on active farm operations. The survey questions included information on agricultural injuries, illnesses, exposures, and preventive practices for up to three operators (principal, second, and third) during the previous 12 months. The survey form is available in Supporting Information Materials.

The survey included questions about operator demographics, work time on the farm/ranch, injury incidents and their characteristics, work-related chronic health conditions and associated exposures, use of

personal protective equipment, and preventive safety practices. The questions about injuries addressed body part injured (eye/head/neck, chest/trunk, back, arm/shoulder, finger, hand/wrist, leg/knee/hip, ankle/foot/toe, and other), types of professional medical care received (none, doctor/clinic visit, and hospitalization), lost farm/ranch worktime (no lost time, <1/2 day, ½–1 day, 2–6 days, 7–29 days, and ≥30 days), medical out of pocket costs, and cost paid by insurance (in $ amounts). These injury characteristics questions were asked only about the most serious injury to keep the survey form concise. The 2018 data were entered into the University of Nebraska Medical Center REDCap system, while the 2020 data entry was partially automated by scanning the returned forms into TeleForm software. Data were quality checked manually, and then exported into SAS-formatted research datasets. The survey data were merged with 38 farm production variables from FMiD data at the operation level. Farm variables included county, state, acres of corn, soybeans, wheat, hay and so forth, heads of livestock including dairy and beef cattle, and estimated GFI. Analyses were conducted from an operator-level data set.

The CS-CASH surveillance program was reviewed by the University of Nebraska Medical Center's biomedical institution review board (IRB # 0071-23-EX). This project was determined to be exempt under 45 CFR 46:104(d), Category 2, research that only includes survey procedures.

2.2 | Injury costs, all agricultural workers

The national agricultural injury cost analysis consisted of combining regional injury rate and cost data for self-employed farmers and ranchers, national farm operator count from the Census of Agriculture, nonfatal injury and population counts from BLS SOII, and fatality count from BLS CFOI in a sequence described in Figure 1 and Steps 1–6 under 2.3 Data Analysis.

In the primary FRHSS data analysis, the self-reported costs for the most serious injuries to farmers and ranchers were calculated, along with injury rates using relevant denominators. In secondary analyses, the estimated costs from reported additional (second and third) injuries to each operator, future costs from long-term disabilities (LTD) lasting more than 30 days, and fatal injury costs were added using available information from governmental and insurance sources.[12,20,21] Estimates from the survey data were then scaled up to the national level using 2017 Census of Agriculture information on the numbers of producers.[6] National fatal injury costs were estimated separately by multiplying the 2019 BLS CFOI count of fatalities in crop and animal production by the estimated average fatality case cost from our survey.[1] Finally, BLS SOII count on injuries to hired employees, multiplied by average nonfatal injury cost from our survey was added to national estimates that included both self-employed and hired agricultural workers.[2]

Injury-related costs were divided into direct and indirect costs. Direct costs consisted of self-reported out-of-pocket, and insurance covered medical expenses. Indirect costs consisted of the estimated monetary value of reported lost workdays due to injury, initially truncated at 30 days. A workday was valued at $200.80, based on 8-h days and mean hourly wages for farmers and farm and ranch managers ($25.10).[20] Other costs were ignored, such as future medical expenses, rehabilitation, productivity losses, reduced yields due to delayed work, sick days from off-farm employment, damage to equipment in injury incidents, reduced quality of life, pain and suffering, reduced contributions to household and society, reduced opportunity costs, administrative and legal costs, as well as other costs that have been discussed in the literature.[9,12]

2.3 | Data analysis

2.3.1 | Step 1: Farm and ranch operations, operators, and work time

The FRHSS survey data were entered at the operation level with one response per operation. Operation level data were converted to operator level, and analyses were conducted using an individual operator as the unit of analysis.

Two workforce size indicators were used as denominators: the number of individual operators and the estimated number of FTE

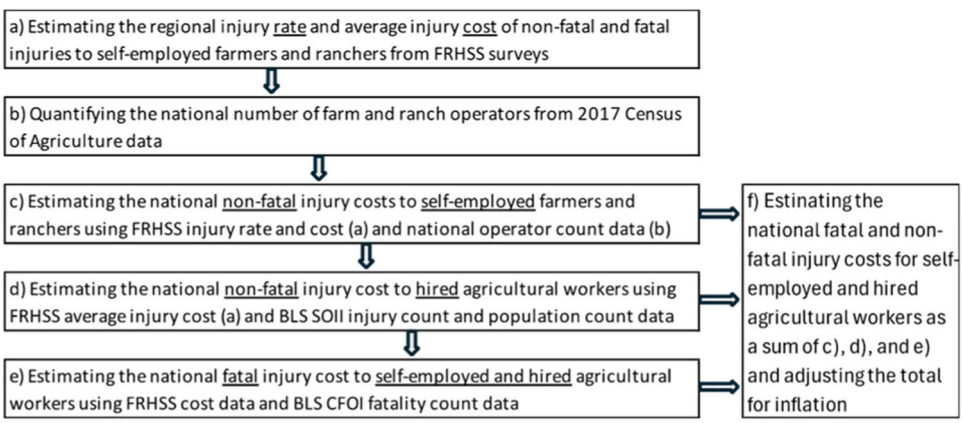

FIGURE 1 Process description for analyses of national agricultural injury and fatality costs for self-employed and hired workers.

operators (workers). BLS defines full-time workers in injury statistics as those working 40 h per week and 50 weeks per year (total 2000 h/year).[21] Each responding operator was assumed to work full time, sharing their FTE work time between farm/ranch work and working in another off-farm occupation. The estimated FTE work effort in farm/ranch work was assigned for each operator as the midpoint of the response category they selected out of five options: 100%, 75-99%, 50–74%, 25–49%, or 0–24%. The corresponding assigned farm/ranch work FTE effort factors were: 1.000, 0.875, 0.625, 0.375, and 0.125 FTE.

2.3.2 | Step 2: Injuries and injury rates to farm and ranch operators

Injury counts and rates were calculated from responses to the injury and work effort questions. The overall injury count was obtained from the survey question: "How many farm-related injuries occurred to each operator during the past 12 months?" with response options: None, 1, 2, and 3 or more injuries where 3 or more was coded as 3. Possible subsequent injuries beyond 3 in 12 months were ignored as they have been rare in other studies.[22] Medical care and lost workday variables were used to define injury cases at different severity levels similar to those used in national BLS statistics: "Recordable injuries" and "Days away from work (DAFW) injuries."[3] Injury rates were then calculated using two denominators: number of operators and number of FTE operators.

2.3.3 | Step 3. Primary analysis of reported injury costs, farm and ranch operators

Direct costs—medical care

Medical costs (out-of-pocket and paid by insurance) were requested from each operator for their most serious injury case during the past 12 months. The total and mean costs were calculated for out-of-pocket, insurance covered, and combined costs as reported. Average costs were calculated for several severity categories of injuries. The average cost burden was calculated per operator and FTE operator.

Indirect costs—lost work time

Lost work time costs were estimated from the question about the most serious injury: "How much lost farm/ranch work time resulted from this injury?" The six response options were: no lost time, less than ½, ½–1, 2–6, 7–29, and 30 days or more. The midpoint of each category was assigned as the estimated lost time for each injury case. For the category 30 days or more there is no midpoint, and a conservative estimate of 30 days was used in the primary analysis.

The monetary value of a lost workday was estimated using USDA information for average hourly wages and 8-h workday; 8 h/day * $25.10/h = $200.80/day.[20] The question was limited to lost farm/ranch work time, excluding possible lost wages from off-farm employment.

Fatal injury cases

Information on fatal injuries was not collected directly, but respondents could describe fatal injury cases in the open-ended questions. The value of lost work time was used as the basis of estimating the monetary loss from fatality cases. The lost time for fatal injuries was estimated as: lost years (expected retirement age 70 years—age at fatal injury) *2000 h/year *$25.10/h.[20] A range of salaries have been reported for agricultural workers including $41/h for farmers and managers, and $14/h for agricultural workers.[21] The USDA estimate was considered most appropriate for farmers and family members that could work in different roles during their lifetime, ranging from youth to elderly farmers on the operation.[23]

2.3.4 | Step 4. Secondary analysis of estimated injury costs, farm and ranch operators

LTD cases

Future lost time costs were estimated for cases with 30 or more days of lost time due to injury. The number of days lost in these LTD cases was assigned as 160 days based on reanalysis of 90,016 Finnish farmers workers' compensation insurance claims during a 15-year period, 2004–2018.[24] A total of 19,913 (22.1%) out of 90,016 claims were LTD cases with 30 or more days of lost time, determined by medical evaluation (mean 160 days, range 30–5993 days). This average (160 days) included closed and open claims with compensated days in the past and actuarial assessment of future lost days based on injury severity in open cases, truncated at retirement age 65, when disability compensation would convert to farmers old age pension.

Second/third injury cases

Analyses of insurance data have shown that about one out of ten injured farmers have more than one injury within 1 year.[22] Further, when comparing the costs of subsequent injuries within 1 year, the second most costly injury was 0.47 times as costly, and the third most costly injury was 0.40 times as costly as the costliest injury on average (reanalysis of claims data).[12] We applied and rounded these ratios so that the second injury costs were estimated to be ½ of the first/most serious injury, and third injury cases were estimated as ¼ of the first/most serious injury. The third injury cost ratio was lowered considering the uncertainties in recall of multiple injuries in 1 year.

2.3.5 | Step 5. Total injury costs to operators, regional survey data

The primary analysis of injury costs was calculated as a sum of direct and indirect costs for nonfatal injuries and the costs of fatal injury cases. The total injury costs were then calculated as an average per injury case and as an average cost burden per operator (incl. injured and not injured operators). Secondary analyses were performed,

adding the estimated value of lost time beyond 30 days after injury and the cost of second and third injury cases. Similarly, the total reported and estimated injury costs were calculated as an average per injury case and per operator. The primary and secondary analyses formed the basis of calculating the range for national cost estimates.

2.3.6 | Step 6. Total injury costs to all agricultural workers, national estimates

The cost estimates from the regional survey sample were transposed to the national level by multiplying the average injury cost per operator by the number of operators (producers) in the United States using the 2017 Census of Agriculture number of producers.[6] Two estimates were calculated, the primary estimate without LTD based on 1st injury costs alone (conservative estimate) and the secondary estimate including 1st, 2nd and 3rd injuries and their LTD costs (robust estimate). The cost of injuries to hired agricultural workers was estimated at the national level by multiplying the average cost of injuries in our study sample by the number of injuries reported by BLS for agricultural workers in 2019: 50,900 recordable injuries. We used our new cost estimate in the absence of established cost estimates for injuries to hired agricultural workers.[25] The cost of injuries to hired workers was added to both the primary estimate without LTD and the secondary estimate with LTD to provide a range for the national costs. The cost of fatalities was estimated by multiplying the BLS number of fatalities in crop and animal production ($n = 410$) by the average cost of fatality cases in our survey. The cost of fatal injuries was included in both national estimates.

SAS Studio (v3.8 basic edition) and Microsoft Excel (Version 16.54) were used for analyses that included descriptive statistics and cross tabulations. All calculations were performed independently by two authors (S. A. and R. R.) to find and reconcile any errors and differences in interpretations.

3 | RESULTS

3.1 | Farm and ranch operations, operators, and work time

The mail surveys were sent to 16,822 farm/ranch operations in 2018 and 17,328 operations in 2020 (total $n = 34,150$ operations). The number of usable responses was 3034 in 2018 and 2442 in 2020 (total $n = 5476$ operations). The response rates were 18.0% in 2018 and 14.1% in 2020 (16.0% for both years combined). Most operations identified themselves as a farm (77.4%), the rest identifying as ranches (11.8%) or both (10.8%). Nebraska had the highest response rate (22.4%) while Missouri had the lowest rate (9.6%).

In the combined operator-level data set for 2018 and 2020, there were 7915 operators: 5476 (69.2%) of them principal operators, 1901 (24%) second operators, and 538 (6.8%) third operators. The average age of all operators was 58, ranging from 18 to 99 years of age. The average ages were 62 for principal operators, 52 for second operators, and 39 for third operators. The percentage of male operators was 85% overall, 97% among principal operators, 49% among second operators, and 82% among third operators. The estimated working-hour-based number of full time equivalent (FTE) operators was 5975 FTE, which was 77% of the actual number of individual operators (7915 operators).

A comparison of principal operator and farm production characteristics between nonresponding versus responding farms included: average age of principal operator 60 versus 61 years; growing corn 79 v. 84%; growing hay 65 v. 66%; raising beef cattle 42 v. 44%; and average GFI $377,083 v. $389,627, respectively. Further analysis of survey respondents and nonrespondents showed minimal evidence of nonresponse bias.[17]

3.2 | Injuries and injury rates, farm, and ranch operators

Out of 7915 operators, 973 reported one or more injuries (injury proportion 0.1229) in the previous 12-month periods of the 2018 and 2020 surveys. When including all reported injuries, the total number of injuries was 1207 where 179 operators had also a second injury, and 55 operators had a third injury for a total of 234 additional injuries (19.4% of all injuries were second or third injuries). The injury rate was 15.25 injuries/100 operators or 20.20 injuries/100 FTE operators.

Of the most serious injuries ($n = 973$), 688 required medical care and 660 resulted in lost work time. By definition, the number of injuries requiring medical care or lost time (or both), comparable to the BLS *Recordable Injuries*, was 710, and the number of injuries with more than 1 day of lost time, comparable to BLS *DAFW*, was 403.[2] Further counts and rates of injuries are provided in Table 1.

3.3 | Primary analysis of reported injury costs, farm and ranch operators

3.3.1 | Direct costs—medical care

Respondents who reported one or more injuries during the past 12 months were asked about the medical costs for their most serious injury. Out of 973 first/most serious injury cases, 688 required medical care. The reported total costs for medical care consisted of $2,906,927 paid out-of-pocket and $7,677,464 paid by insurance; $10,584,391 in total. The average total medical cost for the "first/most serious injuries" was $10,878 while the median cost was $1300, maximum out of pocket $400,000, maximum paid by insurance $500,000 and maximum combined total cost $605,000 for one injury case.

3.3.2 | Indirect costs—lost work time

There were 660 injury cases with lost work time, with a total of 6305 lost days due to disability from injury. The total monetary value of the

reported lost time from the first/most serious injury was $1,265,893 where a lost workday was valued at $200.80 using an 8-h workday and the USDA average hourly wages for farmers/farm managers, $25.1/h.[20] The average value of lost time was $1848 for (any) lost time injury cases and $2978 for lost time cases with more than 1 day of disability. Further cost indicators using this method are presented in Table 2.

TABLE 1 Number of injuries and rate per capita by type of injury.

	N	Injury rates per 100 operators	
		Operators (N = 7,915)	FTE Operators[a] (N = 5975)
Total injured operators (Injury proportions (%)[b])	973	12.29	16.28
Injuries, including 1st, 2nd and 3rd injuries	1207	15.25	20.20
Injuries, medical care or lost time ("Recordable injuries"[c])	710	8.97	11.88
Injuries, professional medical care	688	8.69	11.51
Injuries, any lost time	660	8.34	11.05
Injuries, >1 day lost time ("Days Away From Work injuries"[c])	403	5.09	6.74
Serious injuries, medical care and >1 day of lost time	381	4.81	6.38
Long-term disability (LTD) ≥ 30 days of lost time	128	1.62	2.14
Fatalities[d]	3	37.90	50.21

[a]FTE = full time equivalent worker, working 2000 h/year;
[b]Injury proportion = injured operators/all operators;
[c]Recordable and days away from work injuries were approximated from survey data, as in OSHA;
[d]Rate = Fatalities/100,000 workers.

3.4 | Secondary analysis of estimated injury costs, farm and ranch operators

3.4.1 | Long term disability (LTD) cases

Lost time injury cases were then analyzed with a method that considered the future cost of lost time in LTD cases. Cases with 30 days or more of lost time were calculated as 160 days times the daily salary ($200.80) = $32,128 per case. When cases with LTD (160 days) was considered, the estimated total lost time costs increased to $4,489,085 from $1,199,981 which is significantly higher than the primary analysis where a conservative estimate of 30 days was used for lost time cost. The cost indicators using this method are presented in Table 3.

3.4.2 | Additional 2nd and 3rd injury costs

A total of 179 out of 973 injured operators had a second injury, and 55 had a third injury for a total of 234 additional injuries, which was nearly one-fifth (19.4%) of all reported injuries. The cost of second injuries was assumed to be 50% of the cost of the first/most serious injury for each injured operator; for third injuries, the cost was assumed to be 25% of the cost of the first injury. Thus, the total costs were $1,397,377 for the second, and $214,681 for the third injuries, or $1,612,058 in total for all additional injuries.

3.4.3 | Fatal injury costs

Six fatality cases were self-reported and described in the surveys. Cases where an agriculture-related event or exposure was described were counted as occupational agricultural fatal injury cases, regardless of age.

TABLE 2 Nonfatal injury costs; medical care and value of lost time.

	N	Average medical cost ($)	Average lost time cost ($)[a]	Average total cost ($)
Operators	7915	1337	160	1497
FTE operators[b]	5975	1771	212	1983
Operators injured/1st injuries	973	10,878	1301	12,179
Injuries, medical care or lost time[c]	710	14,779	1783	16,562
Injuries, medical care	688	15,027	1772	16,799
Injuries, any lost time	660	15,685	1848	17,532
Injuries, >1 day of lost time[d]	403	23,858	2978	26,835

[a]Value of lost day calculated as 8 h × $25.1/h = $200.80; Lost days calculated as 30 in "30 days or more" cases;
[b]FTE = full time equivalent worker, working 2000 h/year;
[c]Comparable to OSHA recordable injury;
[d]Comparable to OSHA days away from work injury (DAFW).

Three of the six cases were determined to be agricultural injuries; an 11-year-old male died in a farm accident, a 16-year-old male died in a baler accident, and a 52-year-old male died of a heart attack while working on the farm picking up rocks. Three of the six fatalities were determined to be chronic conditions with no clear indication of occupational injury. Using the expected retirement age (70 years), annual working hours (2000 h), and the USDA salary estimate for farmers ($25.10/h)[20]; and the ages of the three victims; the estimated lost work time values in these cases were $2,961,800, $2,710,800, and $903,600 for a total of $6,576,200.

TABLE 3 Nonfatal injury costs; medical care and value of lost time including long term disability cases.

	N	Average medical cost ($)	Average lost time cost ($)[a]	Average total cost ($)
Operators	7915	1337	582	1919
FTE operators[b]	5975	1771	771	2543
Operators injured/1'st injuries	973	10,878	4735	15,613
Injuries, medical care or lost time[c]	710	14,779	6489	21,268
Injuries, medical care	688	15,027	6553	21,580
Injuries, any lost time	660	15,685	6831	22,516
Injuries, >1 day of lost time[d]	403	23,858	11,139	34,997

[a]Value of lost day calculated as 8 h × $25.1/h = $200.80; Lost days calculated as 160 in "30 days of more" cases;

[b]FTE = full time equivalent worker, working 2000 h/year;

[c]Comparable to OSHA recordable injury;

[d]Comparable to OSHA days away from work injury (DAFW).

3.5 | Total injury costs, farm, and ranch operators

The total injury costs were estimated in steps, first by calculating the reported direct medical costs and indirect lost time costs, then adding the estimated cost from LTD cases, followed by adding the estimated cost for additional (second and third) injury cases. Finally, we added the estimated cost of fatality cases. Two total and average cost estimates were constructed: first (conservative) without and second (robust) with LTD cases and second and third injury cases. The results are presented in Table 4.

3.6 | Total injury costs, national estimates

National injury cost estimates were calculated using separate methods for nonfatal and fatal injuries and self-employed operators and hired agricultural workers. The nonfatal injury cost estimates for farmers and ranchers were done in two phases:

1. Expected national injury counts were estimated using injury rates from our survey (12.29/100 for 1st injuries and 15.25/100 for all injuries) multiplied by the producer count from the 2017 Census of Agriculture.
2. Estimated injury costs were calculated by multiplying the expected national injury counts by average injury costs found in our survey ($12,179 for 1st injuries only and $14,561 for 1st, 2nd and 3rd injuries including LTD costs).

The costs of nonfatal injuries to hired employees were calculated by multiplying the number of nonfatal injuries reported by BLS SOII (50,900) in 2019 by the average cost of 1st injuries with LTD costs in our survey ($15,613). Fatal injury costs were estimated by multiplying the BLS CFOI 2019 count of fatalities in crop and animal production (410) by the average cost of fatalities in our survey ($2,192,067).

TABLE 4 Total injury costs incurred by survey respondents (*N* = 7915).

	Injuries *N*	Average cost Per injury	Total cost By category	Cumulative cost Total	Cumulative cost Per operator
1st injuries	973	12,179	11,850,284	11,850,284	1497
1st injuries, long term disability	128	32,128	4,112,384	15,962,668	2017
2nd and 3rd injuries	234	6889	1,612,058	17,574,726	2220
Total 1st, 2nd, 3rd injury categories	1207	14,561	17,574,726		
Fatalities	3	2,192,067	6,576,200	23,379,854	2954
Total, 1st injuries and fatalities	976	18,880	18,426,484		2328
Total including all categories	1210	19,322		23,379,854	2954

Finally, two estimates were produced from the nonfatal and fatal cost estimates for all agricultural workers: a conservative estimate that included only the 1st injury costs to operators, hired employee injury costs, and fatal injury costs to all workers. The robust estimate included 2nd and 3rd injury cases and the value of lost time from LTD cases. The estimates are provided in Table 5.

Finally, the total injury cost estimates were adjusted for inflation, using the Bureau of Labor Statistics inflation calculator. The cost estimates were considered to be in July 1, 2019 dollars. The adjusted estimate without LTD was $8.30 billion and the total estimate with LTD was $11.31 billion in March 1, 2024 dollars.

4 | DISCUSSIONS

This study used regional agricultural injury surveillance information with insurance and government statistics to estimate national agricultural injury costs in the United States. Our key findings were:

1. The regional FRHSS survey injury rate for self-employed farmers and ranchers was 15.25 injuries per 100 operators. When using a sub-section of injuries and denominator population that are comparable the BLS SOII definitions, the injury rate was 11.9 "recordable" injuries per 100 FTE operators, which is 2.3 times higher than the rate (5.2 recordable injuries/100 FTE workers) in BLS SOII statistics for agriculture.[3]
2. The national agricultural injury cost estimate was $11.31 billion per year; 11.3% higher than the earlier benchmark estimates $10.16 billion[9]; both adjusted for inflation, in March 2024 dollars. The cost burden was 2.1% of the US national GFI and 13.4% of the net farm income in 2019.

Injury is a major concern in agriculture globally. In the United States, agriculture had the highest reported fatal injury rate (18.6/100,000 FTE)[1] and one of the highest nonfatal (4.1/100 FTE)[3] injury rate compared to other major industries in 2022. The US also has a higher agricultural fatality rate compared to regions with similar agriculture including Canada (11.5 fatalities/100,000)[26] and Europe (EU-28 4.2 fatalities/100,000).[27] It should be noted that obtaining accurate agricultural injury data is challenging in every country as evidence in a study that found great differences in Eurostat injury and fatality counts and rates between countries.[27]

The current study provided new nonfatal injury rate estimates for self-employed farmers and ranchers who are excluded from national nonfatal injury statistics. Our overall injury rates (15.25/100 operators, 20.20/100 FTE) were high but within the wide range (0.9–42/100 person-years) reported for farmers in earlier studies.[28,29] Minor injuries not requiring medical care or lost time were included in these rates. As a unique feature, our surveillance data enabled calculation of injury rates in a way that is comparable to BLS SOII statistics based on Occupational Safety and Health Administration (OSHA) record keeping for hired agricultural workers in companies with 11 or more employees.[30] Our BLS equivalent rates

TABLE 5 Injury costs in agriculture, national estimates.

	FRHSS survey[a] Injuries *N*	National estimates Cost per injury	Workers *N*	Injuries *N*	Total injury cost
Nonfatal injuries					
Self-employed farmers and ranchers[b]					
1st injuries	973	12,179	3,419,714	420,389	5,119,972,677
1st, 2nd, and 3rd injuries with long term disability	1207	14,561	3,419,714	521,490	7,593,245,464
Hired agricultural workers[c]					
BLS SOII, crops and animals, 2019[d]		15,613	608,322	50,900	800,292,470
Fatal injuries					
Self-employed and hired agricultural workers					
BLS CFOI crops and animals, 2019[d]			1,757,300	410	898,747,333
National injury cost estimates					
Total, conservative estimate					6,819,012,481
Total, robust estimate					9,292,285,268

Abbreviation: BLS, Bureau of Labor Statistics; CFOI, Census of Fatal Occupational Injuries; FRHSS, Farm and Ranch Health and Safety Surveys; SOII, Survey of Occupational Injuries and Illnesses.

[a]FRHSS, *n* = 7915 operators;

[b]Worker number is the number of producers in the 2017 Census of Agriculture;

[c]Injury cost total calculated as FRHHS cost per injury *BLS SOII count of injuries;

[d]BLS SOII and CFOI worker numbers calculated from the published injury counts and rates.

for farmers and ranchers were 11.9 "recordable" injuries/100 FTE operators, and 6.7 "days away from work (DAFW)" injuries/100 FTE operators. The corresponding BLS rates for agriculture were 5.2 recordable injuries/100 FTE and 1.7 DAFW injuries per 100 FTE.[3] Our rate for recordable injuries is 2.3 times higher and DAFW injuries 3.9 times higher than the BLS rate. The large difference may be partially explained by under-reporting as Leigh et al. argued that BLS statistics may miss as many as 77.6% of the Nonfatal injuries to agricultural workers.[31]

The economic burden of injuries to farmers, family members, workers, and the society is a concern as well. Due to lack of workers' compensation insurance and surveillance data for farmers, it has been difficult to estimate the frequency and cost of agricultural injuries in the United States. BLS injury and fatality data have not addressed costs of injury. NIOSH has discontinued their national agricultural injury surveillance efforts. To date, we have relied on a study by Leigh et al. which estimated the national agricultural injury costs at $4.6 billion (range $3.14 billion to $13.99 billion) in 1992.[9] Leigh's study used existing national survey data sources, made adjustments due to their weaknesses, and then used the human capital method, allocating costs to direct and indirect expenses. More recently, the Agricultural Safety & Health Council of America (ASHCA) estimated the annual cost at $8.3 billion in 2015 and the cost of a tractor overturn fatality at $1 million on average.[32] The current study was designed to provide new injury cost estimates based on farmers' actual self-reported injury costs (out-of-pocket and paid by insurance). Injury rate and cost data from surveys of farmers and ranchers were combined with USDA Census of Agriculture data on operators, BLS CFOI and SOII injury data, and workers' compensation insurance claims data. Our agricultural injury cost estimates range from $6.82 billion (conservative) to $9.30 billion (robust) using data collected in 2018 and 2020. With inflation adjustment, these estimates equal $8.30 billion and $11.31 billion in March 2024 dollars. Our robust estimate is slightly higher than the Leigh et al. 1992 estimate[9] after adjustment for inflation: $10.16 billion.[33]

Our cost estimates included cost of medical care as reported, and the value of lost time in DAFW and fatality cases. For fatalities, we based our estimate (average $2,192,067 per case) on three cases: two of them young individuals with a great number of potential work years lost. The youngest victim could not have been employed legally outside of his home farm and would not have been included in CFOI data. However, we included this case as it is well known that children and youth start working on their home farm at a very young age, and they are at risk of being injured or killed while doing agricultural work. Agricultural injury situations that are not included in BLS statistics are described in a recent publication titled "What about the rest of them?."[22] Other recent estimates of fatality costs per case have ranged from $1.2 to $1.5 million in 2021 dollars.[8,34] Our estimate is higher, but it may reflect the special circumstances in agriculture, including children's participation, and the long-ranging effects of a death to the farm business and household income. However, using an estimate of $1.5 million for fatality costs would decrease our robust estimate by only $284 million.

The average length of lost work time in LTD cases (160 days) was based on analysis of nearly 20,000 Finnish farmers' insurance cases that required 30 or more compensated DAFW. Similar data would be difficult to obtained in the United States as farmers are rarely covered by workers compensation. However, it is likely that agricultural injuries in the United States follow a similar "Heinrich's pyramid" severity distribution structure, which has been widely tested and discussed in the literature.[22,35] Earlier analyses of data from the same insurance system showed that lost time compensation was the largest cost component, and that a small number of serious claims (0.5% of claims) represented nearly one-third of the total insurance costs, and 20% of the most serious claims represented 79.5% of the total costs.[12] These findings emphasize the high cost of lost time in LTD cases, which we excluded from our conservative estimate but included in the robust estimate.

Hourly salary had a critical role in estimating the value of lost work time. In practice, there is no hourly salary for self-employed farmers and ranchers, and work/labor is only one contributor to the annual gross and net income of a farm, along with enterprise assets and natural resources. We used a USDA salary estimate for farmers, ranchers, and agricultural managers in 2019, $25.1/h,[20] which is within the wide range of BLS salary estimates for agricultural workers ($14/h) and farmers and managers ($41/h).[21] Other income/salary estimates were also considered. The median and mean wages for all occupations in 2019 were $19.14/h and $25.72, respectively.[36] Average annual compensation in the United States was $51,916 in 2019,[37] and the median household income was $68,703.[38] The median farm household income of $83,111 was about 20% higher than the median for all households combined.[39]

Due to data limitations, we were unable to examine other costs such as future medical expenses, rehabilitation, reduced yields due to delayed work, sick days from off-farm employment, damage to equipment in injury incidents, reduced quality of life, reduced contributions to household and society, reduced opportunity costs, administrative and legal cost, as well as other costs that have been discussed in the literature.[9,12,16,40] Thus, our estimates could be considered conservative. The ratio of direct (medical) to indirect (lost productivity) costs was approximately 8:1 in the conservative method and 2:1 in the robust method. Our methods are likely undercounting indirect (and intangible) costs, as others have found the direct to indirect cost ratio to be about 1:2[41] or more recently 0.8:1[42] reflecting the higher pace of increase in direct medical costs over indirect costs. In the Finnish farmers' workers compensation system, medical and rehabilitation costs were only 22% while lost time compensation was 60% of the total insurance costs.[12] Cost sharing with the national health insurance contributes to low medical costs in this workers' compensation system.

The injury cost burden can be measured as a proportion of agricultural income. Our estimated cost of injuries ($9.3 billion) was 2.1% of the US national GFI ($437.8 billion)[43] and 13.4% of the net farm income ($69.4 billion).[44] In comparison, the annual cost of injuries equaled 0.7% of the national GFI and 2.2% of the net farm income in Finland.[12] The large difference could be partially explained

by a lower injury rate (7.4/100) and the universal national health insurance and health care systems covering part of the workers' compensation costs in Finland. The overall health care expenditures also differ: 9.04% of the GDP in Finland, and 16.89% in the United States in 2018.[45] Workers' compensation premium rates provide another indication of the cost burden of occupational injury. The US national average for workers' compensation premiums was $1.85 per $100 of payroll or $0.48 per hour worked; equal to $960 in 2018. For agricultural workers in Washington state, the annual premium was $1858; similar to the injury cost burden per operator in our study ($2220, excluding fatality costs).[46]

Many assumptions were made in constructing the national injury cost estimate, given the limitations with the available data sources. Following are potential sources of error that could result in over-estimation of our injury cost estimate: (1) the survey region having more full-time operators compared to other regions[6]; (2) estimating fatality costs based on younger workers compared to BLS CFOI fatality cases[1,2]; (3) our hourly salary estimate ($25.1) could be considered high as labor is only one part of farm productivity along with natural resources and other assets, (4) potential response bias where those injured recently may respond to injury surveys more readily. On the other hand, the following sources could result in under-estimation of our injury cost estimate: (1) the Ag Census number of persons living in operator's household is twice as high as the number that operators provided for our estimate[6]; (2) The number of hired workers is higher in Ag Census compared to BLS CFOI and SOII population we used[1,2,6]; (3) We used CFOI fatality count, which excludes many worker categories exposed to farm hazards.[23] (4) We based indirect costs only on lost time while many other indirect costs have been described in the literature.[9,12]

5 | LIMITATIONS

This study was largely based on regional survey data. The climate, growing conditions and agricultural work practices differ considerably between states and regions, and it is important to understand how the seven-state region in north-central US differns from the nation, overall. According to the 2017 Census of Agriculture, this region represents 20.1% of the operations and 20.0% of the operators (producers).[6] Regional versus national differences included: primary occupation farming 45% versus 41%, female producers 34% versus 36%, average age 57 versus 58 years, respectively. Similarly, the difference in 2022 BLS CFOI fatality rates was 27.4/100,000 FTE versus 23.9/100,000 FTE.[47] Nonfatal injury data could not be compared as SOII data are not available for North Dakota and South Dakota. While the age and gender differences are minimal, a higher proportion of operators had agriculture as their primary occupation, and the fatality rate was higher in this region. Higher agricultural work exposure time (more full time agriculture workers) in the region could result in overestimation of the national costs, but we could not quantify it with limited data on nonfatal injuries.

The low (16%) FRHSS survey response rate was a limitation, however an earlier study found little evidence of nonresponse bias.[17] The farm production characteristics of the responding versus nonresponding operations were nearly identical in 2018: any livestock 46/46%; cow calf 16/16%; dairy 5/5%; wheat 40/47%; corn 90/89%; soybeans 86/84%, and hay production 67/69%, respectively.[48] However, we could not verify or rule out a potential self-selection bias where those with injuries could have a greater interest in responding to surveys that deal with injuries and safety. Most of the data were self-reported. It is likely that only one respondent on each operation reported for all (up to 3) operators, and their ability to know and recall injuries and costs for others could be limited. Knowing and recalling injury costs, particularly those that were covered by insurance could be challenging. Particularly the costs paid by insurance may receive little attention even if insurers send statements of their reimbursements to providers and to the patients/policy holders. Analyses of actual payments would improve the accuracy of the data, compared to self-reported costs. Further, our methodology of estimating the productivity loss from fatal injuries based on foregone hours of work and average wages may understate the economic value of life lost due to these injuries.

6 | CONCLUSION

This study quantified the frequency and cost of occupational injuries in agriculture. The injury rate (11.9 "recordable" injuries/100 FTE workers) for farmers and ranchers was 2.3 times higher than the official rate for agricultural workers in BLS statistics. Average costs for nonfatal injuries were: $10,878 for medical care, $4735 for lost work time, and $15,613 in total per injury case. The inflation-adjusted national agricultural injury cost estimate ($11.31 billion in March 2024) was 11.3% higher than the previous benchmark estimate. The injury cost burden was 2.1% of the US national GFI and 13.4% of the net farm income in 2019. Injuries result in significant economic losses to farm and ranch operators, their family members, operations, and society. Preventive efforts should be scaled up to reduce the frequency and costs of injuries in agriculture.

AUTHOR CONTRIBUTIONS

Conceptualization and study design was by Suraj Adhikari, intellectually supported by Risto Rautiainen. Suraj Adhikari and Risto Rautiainen equally contributed to formal analysis and interpretation of the data. Methodology for the manuscript was developed by Suraj Adhikari and Risto Rautiainen, and reviewed and approved by Fernando Wilson. The initial draft was prepared by Suraj Adhikari which was critically reviewed and revised by Risto Rautiainen and Fernando Wilson. Suraj Adhikari did the data curation, and calculations were performed independently by Suraj Adhikari and Risto Rautiainen, who reconciled any errors or differences in interpretations. Risto Rautiainen as Principal Investigator managed the administration and obtained funding for the study.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS APPROVAL AND INFORMED CONSENT

This surveillance was determined to be exempt (not human subjects research) by University of Nebraska Medical Center's biomedical institution review board (IRB # 452-11).

ORCID

Risto Rautiainen http://orcid.org/0000-0001-7295-5277

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