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Tracking the prevalence of rollover protective structures on U.S. farm tractors: 1993, 2001, and 2004☆

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Abstract

Problem: Between 1992 and 2005, 1412 workers on farms died from tractor overturns. A Rollover Protective Structure (ROPS) is a proven intervention to reduce overturn deaths. However, farm characteristics that are associated with the adoption of ROPS are not well understood. *Methods:* ROPS prevalence statistics were derived from National Institute for Occupational Safety and Health (NIOSH) surveys that tracked ROPS use on farms. Data were from the years 1993, 2001, and 2004. *Results:* In 1993, 38% of tractors were equipped with ROPS. This increased to 51% by 2004. ROPS prevalence rates were higher on farms in the Southern region of the United States, on farms where the operator was 25-34 years old, and on farms with $100,000 or more of farm sales. Low ROPS prevalence rates were associated with farm operators 65 years old or older and with farms with less than $10,000 of farm product sales. *Summary:* The increase in ROPS prevalence between 1993 and 2004 has not been sufficient to decrease the rate of tractor overturn deaths on farms. Incentive programs targeting older farm operators and low-income farm operations are suggested to increase ROPS use on tractors. *Impact on Industry:* The study provides farm characteristics associated with low ROPS prevalence rates. The results can be used to target farms for future ROPS promotion activities.

Keywords: Agriculture; Tractor overturn fatalities; ROPS prevalence; Trends; Risk factors

1. Problem

Agricultural tractor overturn deaths have been an identified problem since the 1920s, and today they continue to be the leading cause of agricultural occupational deaths in the United States. There was an average of 200 tractor-related fatalities annually between 1992 and 2005 in the United States, with tractor overturns accounting for 1412 of these deaths (National Institute for Occupational Safety and Health [NIOSH], 2006). The roll-over protective structure (ROPS) was developed to protect tractor operators from death and disability due to tractor overturns by providing a protective zone for the tractor operator in the event of a tractor overturn. ROPS are most effective when used in conjunction with a seatbelt, which keeps the tractor operator inside the protective zone during an overturn.

The effectiveness of ROPS has been well documented (Lehtola, Marley, & Melvin, 1994; Springfeldt, Thorson, & Lee, 1998; Thelin, 1998; Reynolds & Groves, 2000; Myers, Cole, & Westneat, 2008). The National Institute for Occupational Safety and Health (NIOSH) has estimated that fatality rates due to tractor overturns could be reduced by a minimum of 71% (NIOSH, 1993) if all tractors were equipped with ROPS in the United States. Increasing the use of ROPS on tractors has long been a recognized public health need (National Coalition for Agricultural Safety and Health [NCASH], 1989; NIOSH, 1992) and has been shown to be a cost effective means of reducing fatalities from tractor overturns (Kelsey & Jenkins, 1991; Myers & Snyder, 1995; Pana-Cryan & Myers, 2000; Owusu-Edusei & Biddle, 2007).

The first major attempt to increase the use of ROPS on farm tractors in the United States was made by the Occupational Safety and Health Administration (OSHA). In 1976, OSHA required all agricultural employers to equip all employee-operated tractors

☆ The findings and conclusions in this report are those of the authors and do not necessarily represent the views of CDC, NIOSH.

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manufactured after October 25, 1976, with ROPS and safety belts (OSHA, 2005). This standard, which is still in effect today, does not apply to family members (family-only farms) and, since its inception, has not been enforced on farms with less than 11 full-time employees. These restrictions mean that only about 8% of all farms in the United States are covered by this standard (Wilkins, Engelhardt, Bean, Byers, & Crawford, 2003).

Another major effort to increase the use of ROPS was taken by the American Society of Agricultural Engineers (ASAE—now the American Society of Agricultural and Biological Engineers, or ASABE). In 1985, ASAE adopted a voluntary standard, S318.10, which encouraged tractor manufacturers to install ROPS and seatbelts on all new tractors for use in the U.S. market (ASAE Standards, 1985). All major tractor manufacturers agreed to adopt this standard, and since 1986, nearly all new agricultural tractors sold in the United States have been equipped with ROPS and seatbelts as standard equipment. The adoption of this ASAE standard also contributed to additional efforts by tractor manufacturers to promote ROPS to farmers. In 1993, the five leading tractor manufacturers started a ROPS incentive program that offered ROPS retrofit kits to local dealers for older tractor models that had a manufacturer-approved ROPS. Dealers were encouraged to sell these kits to farmers at cost (Freeman, 1999).

It was anticipated that the voluntary ROPS standard would lead to a decrease in the number and rate of tractor overturn deaths on U.S. farms. Yet by the late 1990s, tractor overturn fatality rates had not decreased dramatically because of the large number of tractors in use on U.S. farms that were not equipped with ROPS (Myers, 2003). Common reasons farm operators have given for not using ROPS include: the ROPS are too tall to allow tractors to enter farm buildings or interfere with farm operations where low clearances are an issue (e.g., tractors used in orchards); the farmer's belief, particularly among older farmers, that they know how to control a tractor, making ROPS unnecessary; and it is too costly to retrofit older tractors with ROPS, even if it will continue to be used for decades (Struttmann, Brandt, Morgan, Piercy, & Cole, 2001; Hallman, 2005).

In 1995, Myers and Snyder published detailed findings based on a 1993 NIOSH survey that looked at the prevalence of ROPS-equipped tractors on farms in the United States, the makes and models of farm tractors in common use that did not have ROPS, and an economic analysis of the cost of retrofitting most of these tractors with ROPS. Though additional studies have been conducted on the use of ROPS on farms in individual states, no national data on ROPS prevalence has been reported since 1993. The primary purpose of this study was to assess the prevalence of ROPS-equipped tractors on U.S. farms for the years 2001 and 2004 and to see how the prevalence of ROPS changed since the 1993 NIOSH study. In addition, farm and farm operator demographic characteristics associated with low ROPS prevalence on farms were identified.

2. Methods

Estimates of all tractors and ROPS-equipped tractors in use on U.S. farms for the calendar years 2001 and 2004 were derived from the NIOSH Occupational Injury Surveillance of Production Agriculture (OISPA) surveys. The OISPA is a computer-assisted telephone interview (CATI) survey of a stratified random sample of 25,000 farming operations across the United States. The strata for the sample were the nine geographical regions that were defined by the U.S. Bureau of the Census (BOC, 1975), with an equal allocation of samples per region. These OISPA surveys were conducted for NIOSH by the U.S. Department of Agriculture, National Agricultural Statistics Services (NASS). The 2001 data were collected during February 2002 through April 2002; the 2004 data were collected between February 2005 and April 2005. Participation in OISPA surveys was voluntary.

For these surveys, a farm is defined as any operation with $1,000 or more of gross agricultural production within a calendar year. The type of farming operation was classified using an existing NASS coding system based on the North American Industrial Classification System (NAICS). The type of farm information for the 2001 and 2004 surveys were then regrouped to match the type of farming operation information collected in the 1993 survey. This required reducing the codes from a set of 15 farm types to a set of 7 farm types. The only farms excluded from the 2001 and 2004 OISPA surveys were very large swine confinement operations. The tractor portion of the survey requested the respondent provide information on the number of tractors on the farm and how many tractors were equipped with ROPS.

Sampling weights were post-stratified based on the number of farms responding within three broad "value of sales" categories (<$10,000; $10,000-$99,999; >$99,999) within the nine geographical regions stated previously. Value of sales was selected for the post-stratification process because it had been found in previous data to be strongly associated with a number of farm demographic variables, which reduces the impact of non-response for the survey. Farm counts within the 27 strata were obtained from farm numbers published by the NASS (2002, 2005). Results were then combined into four major U.S. regions for statistical comparisons.

Estimates of ROPS prevalence for both years were compared to ROPS prevalence estimates published by Myers and Snyder (1995) to assess changes over time. In addition, ROPS prevalence was derived for a number of demographic characteristics. These included value of sales, age of the farm operator, acreage, whether the farm was a full- or part-time operation, and type of farming operation. Confidence intervals for estimates and percentages were derived using standard equations for a stratified simple random sample (Cochran, 1977) with programs developed using SAS. Tests of significance for totals and percentages were based on whether the 95% confidence intervals for estimates overlapped.

3. Results

3.1. Survey Response and Tractor Estimates

In the 2001 survey, 15,259 farm operators responded to the survey for a crude response rate of 61%. Of the 9,741 non-

respondents, 8,544 were due to a failure to reach the farm operator by telephone during the survey period. A total of 1,197 operators refused to participate in the survey once contacted. Excluding non-contacts, the adjusted response rate for contacted operators was 92.7%. The unadjusted response rates by value of sales categories were similar, ranging from a low of 59.2% for farms with less than $10,000 of sales to a high of 62.2% for farms with sales over $99,999.

In the 2004 survey, 16,239 farm operators responded to the survey for a crude response rate of 65%. Of the 8,761 non-respondents, 4,650 were due to a failure to reach the farm operator by telephone during the survey period. A total of 3,643 operators refused to participate in the survey once contacted. Excluding non-contacts, the adjusted response rate for contacted operators was 82.1%. The unadjusted response rates by value of sales categories were similar, ranging from a low of 62.1% for farms with less than $10,000 of sales to a high of 66.9% for farms with sales between $10,000 and $99,999.

There were an estimated 4,176,000 (95% CI±69,000) tractors in use on farms in 2001, for an average of 1.94 tractors per farm. ROPS were estimated to be present on 1,933,000 (95% CI±51,000) of these tractors (46%: 95% CI±0.9%). For 2004, there were an estimated 3,961,000 (95% CI±64,000) tractors in use on farms, for an average of 1.87 tractors per farm. ROPS were estimated to be present on 2,020,000 (95% CI± 49,000) of these tractors (51%: 95% CI±0.8%). From 2001 to 2004, there was a 2% decrease in the number of farms, a 5% decrease in the number of tractors on farms, a 5% increase in the number of tractors outfitted with ROPS, and a 13% decrease in the number of tractors without ROPS.

3.2. ROPS Prevalence Rate Change with Time

Table 1 presents the distribution of ROPS-equipped tractors for the broad categories of crop and livestock operations for the years 1993, 2001, and 2004. The overall prevalence of ROPS increased significantly from 1993 to 2004, from 38% to 51% respectively. For all three years examined, crop operations had a higher overall prevalence of ROPS-equipped tractors than livestock operations.

Table 1
Estimated number of tractors and the percentage with ROPS by farm group – 1993, 2001, and 2004

	1993[1]		2001		2004	
Farm Group	Tractor Estimate	% Tractors with ROPS (95% CI)	Tractor Estimate	% Tractors with ROPS (95% CI)	Tractor Estimate	% Tractors with ROPS (95% CI)
Crop	2,380,000	41% (±1.2)	1,998,000	48% (±1.3)	1,827,000	53% (±1.2)
Livestock	2,330,000	34% (±1.2)	2,131,000	45% (±1.2)	2,094,000	49% (±1.1)
Unknown	—	—	46,000	33%	39,000	35%
Total[2]	4,710,000	38% (±0.9)	4,176,000	46% (±0.9)	3,961,000	51% (±0.8)

[1]from Myers and Snyder, 1995.
[2]columns may not sum to the total due to rounding.

Table 2
Estimated number of tractors and the percentage with ROPS by farm type – 1993 and the average of 2001 and 2004

	1993[1]		2001 and 2004 Averages	
Type of Farm	Tractor Estimate	% Tractors with ROPS (95% CI)	Tractor Estimate	% Tractors with ROPS (95% CI)
Cash grain	1,112,000	48% (±1.9)	1,012,000	56% (±2.0)
Vegetable, fruit, nut	448,000	32% (±2.4)	223,000	46% (±2.9)
Nursery	77,000	37% (±3.7)	64,000	52% (±4.5)
Livestock	1,744,000	33% (±1.4)	1,546,000[3]	47% (±1.4)
Poultry	62,000	34% (±7.8)	54,000	57% (±6.5)
Dairy	524,000	37% (±2.8)	278,000	51% (±3.0)
All other farms	744,000[2]	38% (±1.8)	849,000[4]	43% (±1.7)
Unknown	—	—	43,000	34%

[1]from Myers and Snyder, 1995.
[2]includes field crops and unclassified crop and animal farms.
[3]includes beef cattle, hogs, sheep, goats, wool and mohair.
[4]includes field crops, aquaculture, equine, and unclassified crop and animal operations.

The largest increase in ROPS prevalence during this time period was seen for livestock operations (up 15%). The rate of change was fairly consistent for livestock operations, averaging an increase of 1.36% per year between 1993 and 2004. This rate of change was slightly higher between 1993 and 2001 (+1.38% per year) than for the three-year period 2001 to 2004 (+1.33% per year). Crop operations also had a significant increase in the proportion of ROPS-equipped tractors (up 12%). The rate of change for crop operations was lower than that seen for livestock operations (+1.09% per year between 1993 and 2004), and was more pronounced for the three-year period 2001 to 2004 (+1.67% per year) than from 1993 to 2001 (+0.88% per year).

Table 2 presents the distribution of ROPS-equipped tractors for the year 1993 compared to the average ROPS prevalence for the two calendar years 2001 and 2004 by the type of farm at a more detailed level. These categories were selected to match the farm categories reported by Myers and Snyder in 1995. All farm types had significant increases in the prevalence of ROPS-equipped tractors. The largest increase was seen for poultry operations, with an increase of 23%. This increase moved poultry farms from one of the lowest farm types in 1993 with regards to ROPS prevalence to the highest average prevalence using the 2001 and 2004 average. A similar change was seen for nursery operations, which had a 15% increase in ROPS prevalence over this time period. Nursery operations went from having a significantly lower ROPS prevalence than grain farms in 1993 to a ROPS prevalence not statistically different from grain farms for the 2001 and 2004 average. Dairy, livestock, and "vegetable, fruit, and nut" operations all had ROPS prevalence increases of 14%. Only grain operations and "all other farms" had increases less than 10%.

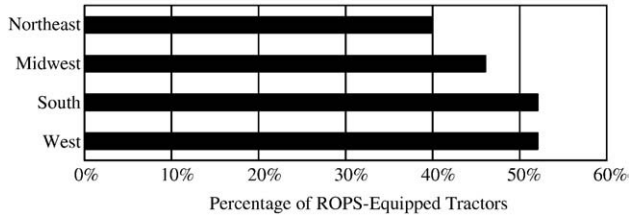

Fig. 1. Percentage of ROPS-Equipped Tractors by Region: 2001 and 2004 Averages.

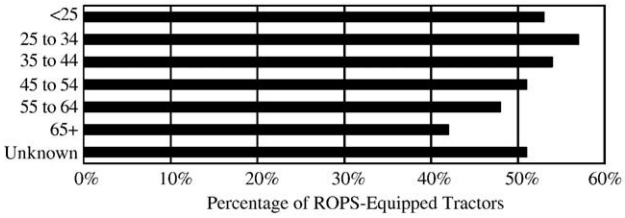

Fig. 2. Percentage of ROPS-Equipped Tractors by Age of the Farm Operator: 2001 and 2004 Averages.

3.3. ROPS Prevalence Rates by Farm Demographic Characteristics

The percentage distribution of ROPS use by region is presented in Fig. 1. The South and West had the same prevalence of ROPS use (South = 52%; 95% CI ± 1.7; West = 52%; 95% CI ± 1.6), followed by the Midwest region (46%; 95% CI ± 1.6), and the Northeast (40%; 95% CI ± 1.7).

The percentage distribution of the prevalence of ROPS-equipped tractors by value of sales is presented in Table 3 for the years 2001 and 2004. In both years, the total number of tractors in use was similar for each of the three value of sales categories. The highest percentage of farms with ROPS-equipped tractors in both 2001 and 2004 were farms with value of sales over $99,999, (64% and 67%, respectively); the lowest percentage of ROPS-equipped tractors for both years was on farms with value of sales less than $10,000 (33% in 2001 and 40% in 2004). On farms with a value of sales between $10,000 and $99,999, ROPS use, while statistically higher than farms with <$10,000 in sales, was less than 50% for both years.

When averaging the results of the 2001 and 2004 surveys, farms with primary operators over the age of 44 years reported 3,156,000 of the 4,069,000 estimated farm tractors (78%): farms with operators 45-54 years of age reported an average of 1,110,000 tractors; farms with operators 55-64 years of age reported an average of 1,043,000 tractors; and farms with operators 65 years old and older reported an average of 1,003,000 tractors.

The distribution of the average ROPS prevalence for these two years of data by age of the farm operator is presented in Fig. 2. These data show that the older the age of the primary farm operator, the less likely tractors on the farm were equipped with ROPS. On farms with operators younger than 55 years, over 50% of tractors were equipped with ROPS. The highest prevalence estimate was 57% on farms where the operator was 25- to 34-years old, followed by 54% on farms where the operator was 35- to 44-years old. Farms where the primary operator was over the age of 54-years had a ROPS prevalence estimate less than 50%; farms operated by 55- to 64-year-olds had 48% of their tractors equipped with ROPS; farms operated by farmers over 65-years of age had 42% of the tractors equipped with ROPS.

The distribution of the average ROPS use for the two years of data by value of sales and age of the farm operator is presented in Table 4. These data show an interaction in the prevalence of ROPS on farms between the value of sales for the farm and age of the primary operator when the farm value of sales was under $100,000. With the exception for farm operators less than 25 years of age on farms with a value of sales of $10,000 to $99,999, ROPS prevalence rates show a steady decrease with increasing operator age in both sales categories. Such a linear trend for ROPS prevalence on farms with value of sales over $99,999 was not as apparent.

For farms with a value of sales under $10,000 and primary operators over 35 years of age, the ROPS prevalence rate was reported to be at or less than 40%; farms that had operators 65 years of age and older had the lowest ROPS prevalence at 32%. Farms reporting a value of sales between $10,000 and $99,999 had ROPS prevalence estimates less than 50% for farms with operators over 35 years of age; farms with primary operators over the age of 65 years again had the lowest prevalence of ROPS-equipped tractors. For farms in the

Table 3
Estimated number of tractors and the percentage with ROPS by farm value of sales, 2001 and 2004

Value of Sales	Tractor Estimate (95% CI)	% Tractors with ROPS (95% CI)
2001		
<$10,000	1,452,000 (±44,000)	33% (±1.5)
$10,000-$99,999	1,404,000 (±32,000)	44% (±1.3)
>$99,999	1,320,000 (±34,000)	64% (±1.6)
2004		
<$10,000	1,405,000 (±46,000)	40% (±1.8)
$10,000-$99,999	1,316,000 (±30,000)	47% (±1.4)
>$99,999	1,240,000 (±32,000)	67% (±1.6)

Table 4
Estimated percentage of tractors with ROPS by value of sales and age group of the operator: 2001 and 2004 averages

Age Group (years)	<$10,000	$10,000 to $99,999	>$99,999	Total
	% ROPS (95% CI) (95% CI)	% ROPS (95% CI)	% ROPS (95% CI)	% ROPS (95% CI)
<25	51% (±8.9)	49% (±15.8)	61% (±18.7)	53% (±10.2)
25-34	43% (±8.9)	61% (±7.2)	67% (±7.2)	57% (±4.5)
35-44	40% (±4.1)	49% (±3.7)	68% (±3.4)	54% (±2.2)
45-54	38% (±2.8)	47% (±2.6)	65% (±2.7)	51% (±1.6)
55-64	37% (±2.9)	46% (±3.2)	66% (±3.1)	48% (±1.7)
65+	32% (±2.8)	41% (±2.3)	62% (±3.7)	42% (±1.6)
Unknown	30%	53%	65%	51%

Table 5
Estimated number of tractors and the percentage with ROPS by farm value of sales and full- or part-time operation: 2001 and 2004 averages

Value of Sales	Tractor Estimate (95% CI)	% Tractors with ROPS (95% CI)
Full-Time		
<$10,000	219,000 (±14,000)	47% (±4.2)
$10,000-$99,999	532,000 (±18,000)	49% (±2.2)
>$99,999	1,131,000 (±29,000)	66% (±1.6)
Total	1,883,000 (±51,000)	59% (±1.3)
Part-time		
<$10,000	1,204,000 (±39,000)	34% (±1.6)
$10,000-$99,999	825,000 (±24,000)	43% (±1.6)
>$99,999	147,000 (±10,000)	58% (±3.7)
Total	2,176,000 (±54,000)	39% (±1.1)
Unknown		
<$10,000	5,000	9%
$10,000-$99,999	3,000	50%
>$99,999	2,000	56%
Total	10,000	29%

$100,000 or more value of sales category, each farm operator age group had a prevalence estimate above 60% with no statistically significant differences.

The average number of tractors and the percentage with ROPS for the two years of data are presented in Table 5 for both full- and part-time farming operations and value of sales. Part-time farms reported slightly more tractors than full-time farms; however, full-time farm operations reported the highest number of tractors equipped with ROPS (1,111,000 ROPS-equipped tractors on full-time operations; 849,000 ROPS-equipped tractors on part-time operations). The distribution of tractors by value of sales categories differed significantly between full- and part-time operations with full-time farms showing a positive linear relationship in tractor numbers by increasing value of sales and part-time farms showing a negative linear relationship. For both full- and part-time farms, the ROPS prevalence rate was seen to increase with increasing value of sales. Full-time farms had the highest ROPS prevalence for all three sales categories, with the largest difference (13%) for farms with sales less than $10,000.

Table 6 provides the breakdown of the average percentage of ROPS on farms by the number of acres on the farm for the two years of data. Farms less than 301 acres in size accounted for over half of all tractors reported on farms (57%) but were found to have the lowest prevalence of ROPS-equipped tractors (39%). ROPS prevalence increased significantly for farms having more than 300-acres, with farms greater than 700 acres having the highest ROPS prevalence rate (73%).

Table 6
Estimated number of tractors and the percentage with ROPS by acreage: 2001 and 2004 averages

Acreage	Tractor Estimate (95% CI)	% Tractors with ROPS (95% CI)
1-300	2,329,000 (±52,000)	39% (±1.0)
301-700	998,000 (±44,0000)	54% (±1.9)
>701	694,000 (±41,000)	73% (±2.2)
Unknown	47,000	61%

Table 7
Number of non-ROPS-equipped tractors by farm characteristics with low ROPS prevalence rates: 2001 and 2004 averages

Farm Characteristic	% Tractors with ROPS	Total Tractors	Non-ROPS Tractors	% Non-ROPS Tractors On All US Farms
Sales <$10K	36%	1,429,000	908,000	43%
Livestock farms (all)	49%	2,113,000	1,120,000	54%
Farmer >54 years	45%	2,046,000	1,124,000	54%
Part-time	39%	2,176,000	1,327,000	63%
1-300 acres	39%	2,329,000	1,420,000	68%
All Farms	49%	4,068,000	2,092,000	100%

Table 7 provides a summary of demographic categories with low ROPS prevalence rates, the average number of tractors without ROPS estimated to be on farms with each demographic characteristic, and the proportion of all tractors without ROPS accounted for by each demographic characteristic. The average number of tractors without ROPS from the 2001 and 2004 surveys was 2,092,000 tractors. Forty-three percent of these tractors were reported on farms with an annual value of sales less than $10,000; 54% were on livestock operations; 54% were located on farms operated by individuals 55 years of age or older; 63% were located on part-time farming operations; and 68% were on farms between 1 to 300 acres in size.

4. Discussion

4.1. Changes in the Prevalence of ROPS-Equipped Tractors

From a public health standpoint, the results of this study found a mixture of positive and troubling indicators based on the changes in the prevalence of ROPS-equipped tractors on U.S. farms since 1993. On the positive side, the percentage of ROPS-equipped tractors was found to have increased significantly between 1993 and 2004 at an average of 1.2% per year in ROPS prevalence (Table 1). Even more encouraging is the increase in the ROPS adoption rate between 2001 and 2004, which occurred mainly on crop operations. The overall rate of increase from 1993 to 2001 is similar to that predicted by Myers and Snyder (1995) of a 1.1% increase in ROPS prevalence per year, based solely on the impact of the 1985 ASAE S318.10 voluntary ROPS standard, (ASAE Standards, 1985).

A second positive finding is the large increases in ROPS prevalence for specific types of farming operations that had low proportions of ROPS-equipped tractors in 1993, such as poultry, nursery, dairy, livestock, and “vegetable, fruit, and nut” operations. These operations exhibited ROPS prevalence increases in the order of 1.4% to 2.7% per year (Table 2). It is important to note that these are farming operations that use a large number of tractors under 90 horsepower that are typically equipped with a two-post ROPS (NASS, 2004). These tractors were most impacted by ASAE S318.10.

In a preliminary analysis of more detailed NIOSH tractor data, Myers (2003) reported that between 1993 and 2001, the largest increase in ROPS-equipped tractors was seen for those with two-post ROPS. In addition, this earlier analysis found that between 1993 and 2001, there was no apparent increase in ROPS prevalence for tractors manufactured prior to 1985, while the ROPS prevalence was consistently over 92% for tractors manufactured between 1993 and 2001. These earlier findings, coupled with results presented in this study, strongly support the position that the majority of the increases in the prevalence of ROPS-equipped tractors on U.S. farms were directly attributable to manufacturers making ROPS and seatbelts standard equipment on new tractors as specified by the 1985 ASAE ROPS standard.

On the troubling side, while progress is being made in increasing the proportion of farm tractors equipped with ROPS on U.S. farms, these increases are occurring at a slow pace. Studies from Europe suggest that a ROPS prevalence rate between 75% and 80% is required before decreases in tractor overturn fatality rates begin to fall near zero (Springfeldt 1996; Springfeldt et al., 1998; Thelin, 1998). Data from Sweden further suggest that the decreases in fatalities are not linear with respect to increasing ROPS prevalence (Springfeldt et al., 1998; Thelin, 1998). The Swedish data found that fatality rates remained stable for ROPS prevalence rates between 40% and 75%.

This same pattern appears to be occurring in the United States. Between 1992 and 2004, the occupational fatality rate for tractor overturns in the U.S. agricultural production industry remained fairly stable at about 5 deaths per 100,000 workers annually (NIOSH, 2006), even while the percentage of ROPS-equipped tractors increased from 38% to 51% over a similar time period (1993 to 2004). Using the Swedish experience as a guide, at the current ROPS adoption rate of 1.18% per year, a 75% ROPS prevalence rate will not be obtained in the United States until the year 2024. The overturn fatality rate would then be expected to decline steadily, reaching a fatality rate at or near zero by 2028.

4.2. Factors Related to the Prevalence of ROPS-equipped Tractors

The findings from this study show that factors such as the physical size of the farm, whether the farm is operated as a full- or part-time enterprise, the age of the operator, and the annual income of the farm are all associated with the prevalence of ROPS-equipped tractors on U.S. farms. The data also suggest a strong regional influence on the prevalence of ROPS. For value of sales, studies from Iowa and Ohio reported similar findings to those presented in Table 3 with respect to the trend of increasing ROPS prevalence rates with farm sales (Sanderson et al., 2006; Wilkins et al., 2003). Similarly, several state studies have reported increasing ROPS prevalence rates with increasing acres farmed (Browning, Westneat, Truszczynska, Reed, & McKnight, 1999; May, Sorensen, Burdick, Earle-Richardson, & Jenkins, 2006; Sanderson et al., 2006; Wilkins et al., 2003). Wilkins et al. (2003), the only study found that looked at ROPS prevalence rates for full- and part-time farms, reported the same general pattern of a higher ROPS prevalence rate for full-time operations, although the difference was less than identified here (Table 5).

Value of sales, farm acreage, and full- or part-time status are three variables that can each be viewed as a measure of the economic status of the farming operation, and as such, either direct or indirect measures of the resources the farm operator may have at his or her disposal to purchase a new tractor or retrofit older tractors with ROPS. While not surprising, these three indicators all imply that the more economically profitable the farming operation (i.e., high sales, large acreage, and full-time operation), the higher the percentage of ROPS-equipped tractors on that operation is likely to be. Farmers with limited resources have been shown to not have the capital to buy new tractors or retrofit their existing tractors, placing them at a disproportionately higher risk for a tractor overturn fatality (Richardson, Loomis, Wolf, & Gregory, 1997). Sanderson et al. (2006) drew this same conclusion suggesting that the reason a farmer does not use ROPS may have more to do with economics and the size of the farming operation than information received in safety and health training encouraging the use of ROPS.

Still, economics does not seem to be the only factor influencing the decision to adopt ROPS; studies have shown that even with an economic incentive, ROPS acceptance by the farm operator was not 100%. Kelsey, May, and Jenkins (1996) found that in New York State, only 12% of farm operators interviewed were willing to pay the $400 for a ROPS retrofit, while 40% said they would never accept a retrofit even if it were free. In a study in Keokuk County, Iowa, Sanderson et al. (2006) reported that less than 20% of farmers would install ROPS through a subsidy program of 25%, while 89% said they would be willing to install ROPS only if the dealer covered 100% of the cost, including the pickup and return of the tractor to do the installation. Hallman (2005) found that farm operators in New York State were more willing to retrofit as the subsidy amount increased, with an incentive of 75% to 90% encouraging the greatest number of farm operators to retrofit. However, even with a 100% subsidy, 20% of the interviewed farmers stated they would not retrofit an older tractor with a ROPS.

The age of the farm operator also appears to be a strong indicator of the percentage of ROPS-equipped tractors on farms. Table 4 shows that, excluding farm operators less than 25 years of age on farms with over $10,000 of sales, as the age of the farm operator increases, the percentage of ROPS-equipped tractors decreases. This finding has been reported in several studies (May et al., 2006; Sanderson et al., 2006; Whitman & Field, 1995; Wilkins et al., 2003).

A study of senior farmers over the age of 60 years determined that many older farmers do not see the necessity or cost benefit to outfitting their tractors with ROPS (Whitman & Field, 1995), even though several studies have shown them to be the farmers at highest risk for a tractor overturn fatality (Fiedler et al., 1998; Gelberg, Struttmann, & London, 1999; Hard, Myers, & Gerberich, 2002; Hayden, Gerberich, & Maldonado, 1995; Meyer, 2005; Mitchell, 1988; Myers & Hard, 1995; Myers et al., 1998). Whitman and Field (1995)

concluded that senior farmers perceived operating tractors without ROPS as a moderate risk because their experience as a tractor operator could prevent a serious tractor-related injury. In addition, while 88% of senior farmers stated they considered ROPS to be effective in preventing injuries, only 26% believed the safety benefits of ROPS outweighed the installation costs. The influence age has on the prevalence of ROPS-equipped tractors can be clearly seen in Table 7 where older farm operators account for 54% of the non-ROPS tractors identified in this study.

The actual type of farming operation appears to play a less prominent role in the 2001 and 2004 survey results than reported for ROPS prevalence rates in 1993 by Myers and Snyder (1995). Still, the livestock, "vegetable, fruit, and nut," and "all other farms" categories had ROPS prevalence rates less than 50%. Little additional information is available in the literature on the prevalence of ROPS-equipped tractors by type of farming operation. In two studies from the state of New York conducted in or around 2004, livestock operations were found to have ROPS prevalence rates ranging from 29% to 38%, vegetable and fruit operations from 48% to 56%, and dairies from 57% to 67% (May et al., 2006; Sorensen, May, Jenkins, Jones, & Earle-Richardson, 2006). Cash crop farms in New York were identified as having the lower ROPS prevalence rates, ranging from 29% to 34%. Spielholz, Sjostrom, Clark, and Adams (2006), in a study of farming operations in the state of Washington, did not specifically provide ROPS prevalence rates by type of farm but did identify tractors used for "utility," "inside/stationary," and "tree/vine/hops" work as having ROPS prevalence rates less than 50%.

4.3. Actions to Increase the Prevalence of ROPS-Equipped Tractors

Currently, there is no nationally organized program in place to increase the number of ROPS-equipped tractors on U.S. farms. Proposals have been presented to solve the ROPS issue through the use of a mixture of approaches (Donham, Osterburg, Myers, & Lehtola, 1998; Karlson & Noren, 1979; Kelsey & Jenkins, 1991; NCASH, 1989; Swenson, 2004). These include using education programs to inform farm operators of the value of ROPS, providing farm operators with an incentive to place ROPS on older farm tractors used on their farms (Donham et al., 1998; NCASH, 1989; Reynolds & Groves, 2000), providing voluntary standards or other programs to encourage farm equipment dealers to retrofit tractors with ROPS before resale to farm operators (Freeman, 1999), purchasing and scrapping older farm tractors without ROPS from farm operators (Myers & Snyder, 1995; Swenson, 2004), reducing the cost of ROPS retrofit kits (Harris, McKenzie, Etherton, & Cantis, 2002; Harris, Cantis, McKenzie, Etherton, & Ronaghi, 2005; Owusu-Edusei & Biddle, 2007), and enacting some form of state or national regulation to require tractors used on farms to be equipped with ROPS after some designated time period (Donham et al., 1998; Karlson & Noren, 1979; Kelsey & Jenkins, 1991; NCASH, 1989; Swenson, 2004). Programs requiring the use of ROPS have been shown to be effective in reducing overturn fatalities in Europe (Springfeldt, 1996; Springfeldt et al., 1998; Thelin, 1998).

To date, these proposals have failed to garner much long lasting support from the agricultural community due largely to an aversion among farmers to accept any new form of regulation and the small farmer's internal assessment that not having a ROPS on a tractor is cost effective given their time and monetary constraints (Sorensen, May, Paap, Purschwitz, & Emmelin, 2008).

To overcome these barriers, the most promising approach appears to be through the use of some form of economic incentive program. Limited incentive programs are currently being conducted in the states of New York and Virginia (Sorensen, 2006; Virginia Farm Bureau, 2008), and are showing promise in encouraging farm operators to retrofit older farm tractors. The one major hurdle to expanding incentive programs on a large scale is the cost. Assuming an incentive of $600 per retrofitted tractor, as in New York, a national program would require $1,200,000,000 to retrofit the approximately 2,000,000 tractors without a ROPS.

4.4. Limitations

Some of the limitations of this study include the inability to assess the overall impact of the non-respondents to the OISPA surveys. Farm demographic estimates derived from this study agree well with farm data published by NASS, suggesting that the post-stratification of the survey weights by the value of sales for the farm successfully reduced the impact of non-response. In addition, the results obtained in this study on the number of farm tractors per farm, the number of tractors with ROPS, and the key farm demographic factors associated with a low prevalence of ROPS on farms, agree well with the past literature. A second limitation is with the regional comparisons provided in this work. The regions encompass several states, and the overall regional rate may mask large differences in ROPS prevalence rates between states within each region. Finally, all the data on farm tractors were self-reported by the farm operator. It was not possible to verify the accuracy of the information being provided by the farm operator.

5. Summary

The prevalence of ROPS-equipped tractors increased significantly between 1993 and 2004 with major improvements seen on livestock operations, nursery operations, and "vegetable, fruit, and nut" operations. Much of these gains can be attributed to the major manufacturers selling tractors in the U.S. adopting the 1985 ASAE S318.10 voluntary ROPS standard. Still, ROPS prevalence rates remain low on farms with value of sales less than $10,000, farms operated by farmers over the age of 54 years, farms that are operated on a part-time basis, and farms under 300 acres in size. Given the ROPS adoption rates found by this study, the U.S. agriculture industry is still one to two decades away from having a ROPS prevalence rate sufficient to decrease tractor overturn fatality rates comparable to the level seen in Europe.

Currently, there is no consistent national program to retrofit tractors with ROPS in the United States. In the end, the solution to increasing the number of ROPS-equipped tractors in the U.S. will involve developing such a program using a mixture of approaches, including economic incentives and marketing, that take into account those critical subpopulations of the U.S. agriculture industry that currently lack the resources, or lack the desire, to retrofit tractors with ROPS.

6. Impact on Industry

These results indicate that there is set of demographic characteristics that should be effective in targeting areas of the U.S. with low ROPS prevalence rates. All of the identified demographic factors in this study are readily available from the 2002 Census of Agriculture, and will soon be available from the 2007 Census of Agriculture. These census data could be used to screen areas of the U.S., down to the county level, where there is a high probability of a low prevalence of ROPS-equipped tractors. This might be the most effective approach for initiating any large scale ROPS promotion campaign.

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