Accident Analysis and Prevention 70 (2014) 8–13

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Not just a rural occurrence: Differences in agricultural equipment crash characteristics by rural–urban crash site and proximity to town

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ARTICLE INFO

Article history:
Received 13 December 2013
Received in revised form 18 February 2014
Accepted 19 February 2014
Available online 28 March 2014

Keywords:
Traffic accident
Agricultural equipment
Epidemiology
Occupational accidents/injuries

ABSTRACT

Purpose: Although approximately one-third of agricultural equipment-related crashes occur near town, these crashes are thought to be a rural problem. This analysis examines differences between agricultural equipment-related crashes by their urban–rural distribution and distance from a town.
Methods: Agricultural equipment crashes were collected from nine Midwest Departments of Transportation (2005–2008). Crash zip code was assigned as urban or rural (large, small and isolated) using Rural–Urban Commuting Areas. Crash proximity to a town was estimated with ArcGIS. Multivariable logistic regression was used to estimate the odds of crashing in an urban versus rural zip codes and across rural gradients. ANOVA analysis estimated mean distance (miles) from a crash site to a town.
Findings: Over four years, 4444 crashes involved agricultural equipment. About 30% of crashes occurred in urban zip codes. Urban crashes were more likely to be non-collisions (aOR = 1.69[1.24–2.30]), involve ≥2 vehicles (2 vehicles: aOR = 1.58[1.14–2.20], 3+ vehicles: aOR = 1.68[0.98–2.88]), occur in a town (aOR = 2.06[1.73–2.45]) and within one mile of a town (aOR = 1.65[1.40–1.95]) than rural crashes. The proportion of crashes within a town differed significantly across rural gradients ($P < 0.0001$). Small rural crashes, compared to isolated rural crashes, were 1.98 (95%CI[1.28–3.06]) times more likely to be non-collisions. The distance from the crash to town differed significantly by the urban-rural distribution ($P < 0.0001$).
Conclusions: Crashes with agricultural equipment are unexpectedly common in urban areas and near towns and cities. Education among all roadway users, increased visibility of agricultural equipment and the development of complete rural roads are needed to increase road safety and prevent agricultural equipment-related crashes.

1. Introduction

Crashes involving agricultural (Ag) equipment on public roads are rare occurrences, but the effects can be devastating for the Ag equipment operator as well as occupants of other vehicles involved. Two percent of crashes with Ag equipment result in a fatality while less than one percent of all other motor vehicle crashes result in fatalities (Costello et al., 2009; Traffic safety facts, 2008). Almost two-thirds (65%) of Ag equipment-related crashes involve collisions with non-Ag vehicles, and one in three crash fatalities are to occupants of the non-Ag vehicle (Gerberich et al., 1996). Although deaths are infrequent in Ag equipment-related crashes, three out of four non-fatal crashes with Ag equipment result in an injury, with the non-Ag vehicle operator being more likely to be injured (Peek-Asa et al., 2007).

Agricultural equipment, designed primarily to be operated in the field with minimal road transportation, has characteristics that make its use on the road unique and challenging. First, Ag equipment are slow moving vehicles built to endure heavy workloads and not for high speed transportation (Committee on Agricultural Safety and Health Research and Extension, 2009). Second, Ag vehicle traffic on roadways aligns with timing of agricultural tasks and varies by time of day and seasons of the year. These factors have implications for when and how crashes occur. Prior research, although sparse, has shown the most frequent manner of collision with agricultural equipment involves the equipment being struck in the rear by the non-Ag vehicle on two lane roads with speed limits of 55 miles per hour (Gerberich et al., 1996; Pinzke and Lundqvist, 2004; Gkritza et al., 2010). The incidence of Ag

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http://dx.doi.org/10.1016/j.aap.2014.02.013

crashes follows a trend consistent with exposure due to seasonal agricultural tasks, with more crashes in the crop harvesting months (Pinzke and Lundqvist, 2004; Gkritza et al., 2010). The majority of crashes with Ag equipment occur during daylight; nevertheless, those occurring at dawn/dusk or night are more likely to result in an injury than those during the day (Gerberich et al., 1996; Gkritza et al., 2010).

Agricultural equipment-related crashes occur more frequently in rural areas because Ag equipment spend more time on rural rather than urban roads (Costello et al., 2009; National Highway Transportation and Safety Association's National Center for Statistics and Analysis, 2013; Gerberich et al., 1996; Peek-Asa et al., 2007; Committee on Agricultural Safety and Health Research and Extension, 2009; Pinzke and Lundqvist, 2004; Gkritza et al., 2010). However, prior studies have not untangled some of the unique differences found within rural areas, which may differentially influence crash patterns. For example, in isolated rural communities, rural roads are more likely to have dirt and gravel surfaces with no or few traffic controls. In contrast, larger rural communities often have increased traffic density and comparatively, more paved roads and traffic controls (Ramirez et al., 2013). To our knowledge there have not been any previous studies on patterns of Ag equipment crashes in various rural environments.

Interestingly, while Ag equipment-related crashes are generally thought to be a rural problem; two studies reported that over one in three Ag equipment crashes occurred within one mile of or in a town or city (Pinzke and Lundqvist, 2004; Gkritza et al., 2010). This suggests that Ag equipment crashes also occur in urbanized areas with greater traffic density and more exposure to passenger vehicles. With increasing urbanization, today's farmers must navigate roadways with more drivers unaccustomed to the presence of large Ag equipment on roadways. Farmers in one rural state have expressed concern over the increased traffic on rural roads and fear that drivers of passenger vehicles have not been adequately educated on the lighting and marking of Ag equipment and on how to interact with this equipment on the roadway (Luginbuhl et al., 2003). Evaluation of crashes involving Ag equipment in urban locations has not been previously conducted.

Prior research on roadway crashes involving Ag equipment has not assessed differences between urban and rural crashes, nor has research evaluated how crash patterns differ across gradients of rurality. Therefore, the objectives of this study were to: (1) determine how characteristics of Ag vehicle crashes, such as crash configuration, differ between urban versus rural zip codes and (2) among rural areas, determine how crash characteristics differ across gradients of rurality (i.e., large rural, small rural and isolated rural areas). To further understand crash proximity to towns and cities, an additional objective was to measure the average distance Ag equipment crashes occurred from town or city limits and compare the proportions of crashes across rural and urban zip codes. We hypothesize that (1) urban crashes will involve more vehicles, be more likely to occur within a town/city and will have different crash mechanisms than rural crashes, and (2) compared to isolated rural crashes, large and small rural Ag equipment crashes will also involve more vehicles and occur closer to a town or city.

2. Methods

Agricultural equipment crashes were identified from Department of Transportation (DOT) data from the nine states making up the Great Plains region (Iowa, Illinois, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin) for years 2005 through 2008. Ag equipment, for this analysis, was defined as tractors or any other self-propelled implement of husbandry (e.g. combine harvester). Within the DOT data, each state has a separate vehicle classification category for Ag equipment. This classification was used to select all crashes with Ag equipment. Crash level data extracted included manner of collision, season (month) and time when the crash occurred, crash location, and the number of vehicles (including Ag and non-Ag) involved in the crash. Because manner of collision categories differed by state, for uniform coding, we combined collision categories based on the Model Minimum Uniform Crash Criteria, (MMUCC), 4th edition (2012) to create seven categories: non-collision, head-on (front to front), rear-end (front to rear), angle, sideswipe-same direction, sideswipe-opposite direction, and other. Non-collisions include crashes with stationary objects (e.g., parked motor vehicle, trees, etc.), rollovers, ran-off road and collisions with non-motorists (e.g., pedestrian, bicyclist, animal, etc.).

To determine if the crash took place in a rural or urban zip code, ArcGIS 10.1 (ESRI 2012) was utilized to determine the location of the crash and the zip code in which the crash occurred. Two methods were used to determine where the crashes occurred. For the first method, law enforcement officers from Iowa, Illinois, Minnesota, North Dakota, South Dakota and Nebraska completing the crash report documented the *X*–*Y* coordinates of the crash. In Iowa, for example, officers have a handheld GPS device that automatically designates the coordinates of the crash location. These *X*–*Y* coordinates were then imported and projected to a UTM 15 coordinate data frame so that the crashes could be spatially located. For the second method, Wisconsin, Kansas and Missouri did not provide coordinates but instead provided the street the crash occurred on as well as the direction and distance from an intersection to the crash. Manual and automated geocoding was conducted to project where these crashes occurred. An accuracy check was then completed: all *X*–*Y* coordinates greater than one mile from an intersection, within 0.5 miles of a zip code boundary, or greater than 500 feet from a road (e.g. crash appeared to occur off-road) were manually reviewed and placed on the road segment given by the DOT location.

Zip codes were identified for each crash location after the geocoding process. Using Rural–Urban Commuting Area Codes (RUCA) 2.0 from the University of Washington (http://depts.washington.edu/uwruca/ruca-approx.php), the rurality of a zip code was approximated based on 2004 zip code boundaries. RUCA considers work commuting data from the 2000 census, proximity to an urbanized area (50,000+ population) or an urban cluster (10,000–49,999 population), and population density in its approximation of rurality. Ten RUCA codes are given to approximate rurality, for this analysis these codes were combined into four categories as recommended by the University of Washington (http://depts.washington.edu/uwruca/ruca-approx.php): urban, large rural, small rural, and isolated rural (Table 1). In addition, all rural codes (large, small and isolated) were combined to dichotomize urban versus rural zip codes.

3. Analysis

To illustrate how crashes are spatially related by rurality, a map of the nine states was created with each point representing the location of an Ag equipment-related crash. Zip codes were shaded to represent urban versus rural areas with urban being light gray and rural zip codes shaded darker gray. A portion of the map is enlarged, to display how the crash locations may differ across gradients of the rural zip codes (isolated, small, and large).

Frequencies and proportions of crashes by manner of collision, time of day, number of vehicles involved, and distance from a town were compared between urban and rural zip codes. Distance (miles) from the crash site to the boundary of the nearest incorporated place was calculated using ArcGIS. An incorporated place, using the United States Census Bureau definition, is a governmental

Table 1
Definition of urban–rural categorization using rural–urban commuting area (RUCA)[a] codes.

Urban-rural categorization of zip code		Size of largest town/city in zip code	OR/AND	% Of zip code commuting for work	RUCA codes
Urban		50,000+	OR	30–49% Commute to 50,000+ for work	1.0, 1.1, 2.0, 2.1, 3.0, 4.1, 5.1, 7.1, 8.1, 10.1
Rural	Large	10,000–49,999	OR	<30% Commute to 50,000+ for work	4.0, 4.2, 5.0, 5.2, 6.0, 6.1
	Small	2500–9999	OR	<30% Commute to 10,000+ for work	7.0, 7.2, 7.3, 7.4, 8.0, 8.2, 8.3, 8.4, 9.0, 9.1, 9.2
	Isolated	<2500	AND	<30% Commute to 10,000+ for work	10.0, 10.2, 10.3, 10.4, 10.5, 10.6

[a] University of Washington (http://depts.washington.edu/uwruca/ruca-approx.php).

unit incorporated under state law as a city or town and will hereafter be referred to as a town. Time of the crash was categorized based on 4–6 h increments (midnight–5:59am, 6:00am–11:59am, 12:00pm–5:59pm, and 6:00pm–11:59pm). The season in which the crash occurred was grouped by agricultural season based on the date of the crash. Distance from a crash to a town or city was categorized as less than one mile or greater than one mile—a grouping scheme based on previous research suggesting that one-third of crashes occur within one mile of a town/city (Pinzke and Lundqvist, 2004; Gkritza et al., 2010).

Multivariable logistic regression was used to estimate the odds of a crash characteristic in an urban zip code compared to rural zip codes. The dependent variable in the model was dichotomous (urban/rural) with rural serving as the referent group. Adjusted odds ratios and 95% confidence intervals (aOR[95% CI]) are presented. Crashes that occurred within the same state were found to be uncorrelated based on the hierarchical logistic regression correlation matrix; therefore the results were not clustered on state. A variable was considered for inclusion in the final multivariable model if it demonstrated a relationship in the bivariate analysis ($P < 0.20$) or if previous literature has shown an association. Covariates included in the final multivariable model were year of crash, manner of collision, time of day the crash occurred, season of the crash, number of vehicles involved and distance to a town or city.

To examine how Ag equipment-related crash characteristics differ within rural zip code gradients, frequencies and proportions were also reported by rurality (large, small or isolated rural). Multinomial logistic regression was employed with rurality as the dependent variable (large, small, and isolated rural [referent]) with year of crash, manner of collision, time of day the crash occurred, season of the crash, number of vehicles involved and distance to a town or city as independent variables. Adjusted odds ratios and 95% confidence intervals are given.

Additionally, a sub-group examination of crashes occurring outside a town was completed. Among these, the difference in mean distances to a town by the urban–rural distribution of the crash zip code was estimated via analysis of variance (ANOVA).

4. Results

From 2005 through 2008, there were 4444 DOT reported crashes involving Ag equipment across nine Midwest states. These crashes were found across all nine states, with many more crashes occurring in Illinois ($n = 774$), Iowa ($n = 762$), Wisconsin ($n = 681$), Missouri ($n = 662$), and Minnesota ($n = 550$) than Kansas ($n = 411$), Nebraska ($n = 318$), North ($n = 149$) and South ($n = 137$) Dakota. Crashes were found in both urban and rural zip codes in all the nine states (Fig. 1).

Almost one in three (30.2%) crashes occurred in urban zip codes. Isolated rural zip codes had the highest proportion of crashes (31.6%) followed by urban (30.2%), small rural (19.6%) and large rural (18.7%) zip codes.

Agricultural equipment crashes involving multiple vehicles (89.3% urban, 86.5% rural) or within a town occurred more often in urban than rural zip codes (25.1% urban, 16.0% rural, $P < 0.01$) (Table 2). A number of factors were found to be associated with an increased odds of crashing in an urban versus rural zip code: non-collisions versus rear-end collisions (aOR = 1.69[1.24–2.30]), crashes involving two or more vehicles versus a single vehicle (2 vehicles: aOR = 1.58[1.14–2.20], 3+ vehicles: aOR = 1.68[0.98–2.88]), and crashes that occurred in a town (aOR = 2.06[1.73–2.45]) and within one mile of a town (aOR = 1.65[1.40–1.95]). Although not statistically significant, small suggestive increased odds of occurring in an urban versus rural zip code were found among sideswipe collisions involving vehicles going in the opposite direction (aOR = 1.18[0.92–1.51]) versus rear-ends, and crashes in the evening between 6 pm and midnight (aOR = 1.14[0.94–1.40]) versus the morning hours.

Characteristics of Ag equipment crashes also differed by degree of rurality (Table 3). Crashes were more likely to occur in large rural (22.7%) than small (17.1%) and isolated (11.5%) rural zip codes ($P < 0.0001$). After controlling for covariates, non-collisions (e.g. ran off road, etc.) had double the odds of occurring in small as compared to isolated rural zip codes (aOR = 2.03[1.32–3.14]) compared to rear-end crashes but no differences in manner of collision between large and isolated rural zip codes were found. Crashes involving increasing numbers of vehicles were more likely to occur in small and large rural zip codes than isolated zip codes. Compared to single vehicle crashes, crashes with two vehicles (large rural, aOR = 1.59[0.99–3.03], small rural, aOR = 1.95[1.25–3.03]) and crashes with three or more vehicles had increased odds (large rural, aOR = 2.30[1.04–5.11], small rural, aOR = 3.16[1.49–6.69]) of occurring in large and small rural settings than in isolated rural areas. Crashes occurring within a town had 2.4 (95% CI: 1.85–3.11) times the odds of occurring in large rural zip codes than an isolated rural zip code. Time of day and season of the crash did not differ significantly across rural zip codes. Among Ag equipment crashes occurring outside a town ($n = 3610$), the majority occurred less than three miles from a town across all urban and rural zip codes (Table 4). As shown in Table, on average, crashes in urban zip codes were 2.0 miles from a town while large, small, and isolated rural were slightly but still significantly farther, from a town (2.4, 2.6, and 2.9 miles respectively, $P < 0.0001$). After adjusting for time of day, the mean distances did not change significantly.

5. Discussion

This is the first analysis to examine Ag equipment-related crash characteristics by rurality of crash zip code and approximate the distance from a crash location to a town. About a third of crashes involving Ag equipment occurred in urban areas. Across both rural and urban settings, crashes occurred, on average, approximately two miles from a town. These findings support the notion that agricultural operators are exposed to hazards in both rural and urban locations, as they traverse both rural and urban roadways delivering commodities to markets primarily located near population centers. Hazards on rural roads include limited sight distance and obscured vision, growth of non-farming populations in farming communities with reduced understanding of equipment hazards, and narrow shoulders (Luginbuhl et al., 2003). In urban locations,

Table 2
Frequency and adjusted odds of a farm equipment-related crash in urban versus rural zip codes, 9 Midwestern states, 2005–2008, ($n = 4444$).

	Rural ($n = 3104$) n (%)	Urban ($n = 1340$) n (%)	Urban vs. rural aOR (95% CI)[a]
Year			
2005	759 (24.5)	332 (24.8)	1.0 (Ref)
2006	741 (23.9)	321 (24.0)	1.03 (0.85–1.25)
2007	793 (25.6)	372 (27.8)	1.11 (0.92–1.34)
2008	811 (26.1)	315 (23.5)	0.89 (0.74–1.09)
Manner of collision[+]			
Non-collision	341 (11.7)	192 (14.7)	1.69 (1.24–2.30)
Head-on	86 (2.9)	30 (2.3)	0.87 (0.56–1.36)
Rear-end	704 (24.1)	310 (23.7)	1.0 (Ref)
Angle	544 (18.6)	217 (16.6)	0.96 (0.78–1.20)
Sideswipe, same	574 (19.6)	236 (18.1)	1.00 (0.81–1.51)
Sideswipe, opposite	284 (9.7)	146 (11.2)	1.18 (0.92–1.51)
Other	393 (13.4)	175 (13.4)	1.06 (0.84–1.33)
Time of day			
Midnight–5:59 am	58 (1.9)	27 (2.0)	0.77 (0.46–1.29)
6:00–11:59 am	888 (28.7)	409 (30.6)	1.0 (Ref)
Noon–5:59 pm	1566 (50.6)	623 (46.6)	0.86 (0.74–1.01)
6:00 pm–11:59 pm	584 (18.9)	277 (20.7)	1.14 (0.94–1.40)
Season			
Winter (Jan–Mar)	353 (11.2)	155 (11.5)	1.05 (0.84–1.32)
Planting (Apr–May)	544 (17.5)	257 (19.2)	1.07 (0.89–1.29)
Growing (Jun–Aug)	886 (28.5)	371 (27.9)	1.01 (0.86–1.19)
Harvest (Sept–Dec)	1321 (42.6)	557 (41.5)	1.0 (Ref)
Number of vehicles involved[+]			
1	410 (13.5)	142 (10.8)	1.0 (Ref)
2	2569 (84.5)	1145 (86.7)	1.58 (1.14–2.20)
3[+]	61 (2.0)	34 (2.6)	1.68 (0.98–2.88)
Distance to city or town[*]			
Within city/town	498 (16.0)	336 (25.1)	2.06 (1.73–2.45)
Within 1 mile of limits	593 (19.1)	331 (24.7)	1.65 (1.40–1.95)
>1 mile from limits	2013 (64.9)	673 (50.2)	1.0 (Ref)

[+] $P < 0.05$.

[*] $P < 0.01$.

[a] Model controls for all variables within the table.

Table 3
Frequency and adjusted odds of a crash by rurality of crash zip code, nine Midwestern states, 2005–2008, $n = 310$.

	Isolated rural ($n = 1405$)	Small rural ($n = 870$)	Large rural ($n = 829$)	aOR (95% CI)[a]	
	n (%)	n (%)	n (%)	Small vs. isolated rural	Large vs. isolated rural
Year					
2005	354 (25.2)	202 (22.9)	203 (24.5)	1.0 (Ref)	1.0 (Ref)
2006	342 (24.3)	203 (23.3)	196 (23.6)	1.05 (0.82–1.36)	0.99 (0.76–1.29)
2007	359 (25.6)	232 (26.7)	202 (24.4)	1.13 (0.88–1.45)	1.02 (0.79–1.33)
2008	350 (24.9)	233 (26.8)	228 (27.5)	1.21 (0.94–1.56)	1.19 (0.92–1.54)
Manner of collision					
Non-collision	149 (11.3)	111 (13.3)	81 (10.5)	2.03 (1.32–3.14)	1.30 (0.81–2.08)
Head-on	39 (3.0)	30 (3.6)	17 (2.2)	1.38 (0.82–2.31)	0.85 (0.46–1.59)
Rear-end	331 (25.0)	188 (22.5)	185 (24.0)	1.0 (Ref)	1.0 (Ref)
Angle	249 (18.8)	142 (17.0)	153 (19.9)	1.08 (0.81–1.43)	1.13 (0.84–1.50)
Sideswipe, same	283 (21.4)	146 (17.5)	145 (18.8)	0.90 (0.68–1.18)	0.99 (0.75–1.32)
Sideswipe, opposite	115 (8.7)	90 (10.8)	79 (10.3)	1.38 (0.99–1.92)	1.31 (0.93–1.86)
Other	156 (11.8)	127 (15.2)	110 (14.3)	1.46 (1.08–1.98)	1.34 (0.98–1.84)
Time of day					
Midnight–5:59am	28 (2.0)	15 (1.7)	15 (1.8)	0.80 (0.40–1.60)	0.86 (0.43–1.73)
6:00–11:59 am	401 (28.6)	243 (28.0)	244 (29.5)	1.0 (Ref)	1.0 (Ref)
Noon–5:59 p.m.	708 (50.5)	448 (51.6)	410 (49.6)	1.07 (0.87–1.31)	1.00 (0.81–1.25)
6:00 pm–11:59 pm	264 (18.8)	162 (18.7)	158 (19.1)	1.05 (0.80–1.38)	1.10 (0.83–1.46)
Season					
Winter (Jan–Mar)	147 (10.5)	90 (10.3)	116 (14.0)	1.03 (0.76–1.41)	1.30 (0.96–1.77)
Planting (Apr–May)	255 (18.2)	159 (18.3)	130 (15.7)	1.00 (0.78–1.29)	0.89 (0.68–1.16)
Growing (Jun–Aug)	390 (27.8)	256 (29.4)	240 (29.0)	1.21 (0.90–1.39)	1.08 (0.87–1.36)
Harvest (Sept–Dec)	613 (43.6)	365 (42.0)	343 (41.4)	1.0 (Ref)	1.0 (Ref)
Number of vehicles					
1	181 (13.5)	102 (11.8)	108 (13.7)	1.0 (Ref)	1.0 (Ref)
2	1137 (85.0)	740 (85.7)	665 (84.1)	1.95 (1.25–3.03)	1.59 (0.99–3.03)
3+	19 (1.4)	22 (2.6)	18 (2.3)	3.16 (1.49–6.69)	2.30 (1.04-5.11)
Distance to city or town					
Within city/town	161 (11.5)	149 (17.1)	188 (22.7)	1.49 (1.15–1.94)	2.40 (1.85–3.11)
Within 1 mile of limits	264 (18.8)	150 (17.2)	179 (21.6)	0.95 (0.75–1.20)	1.44 (1.15–1.82)
>1 mile from limits	980 (69.8)	571 (65.6)	462 (55.7)	1.0 (Ref)	1.0 (Ref)

[a] Referent is crash in an isolated rural zip code, model controls for all variables in the table.

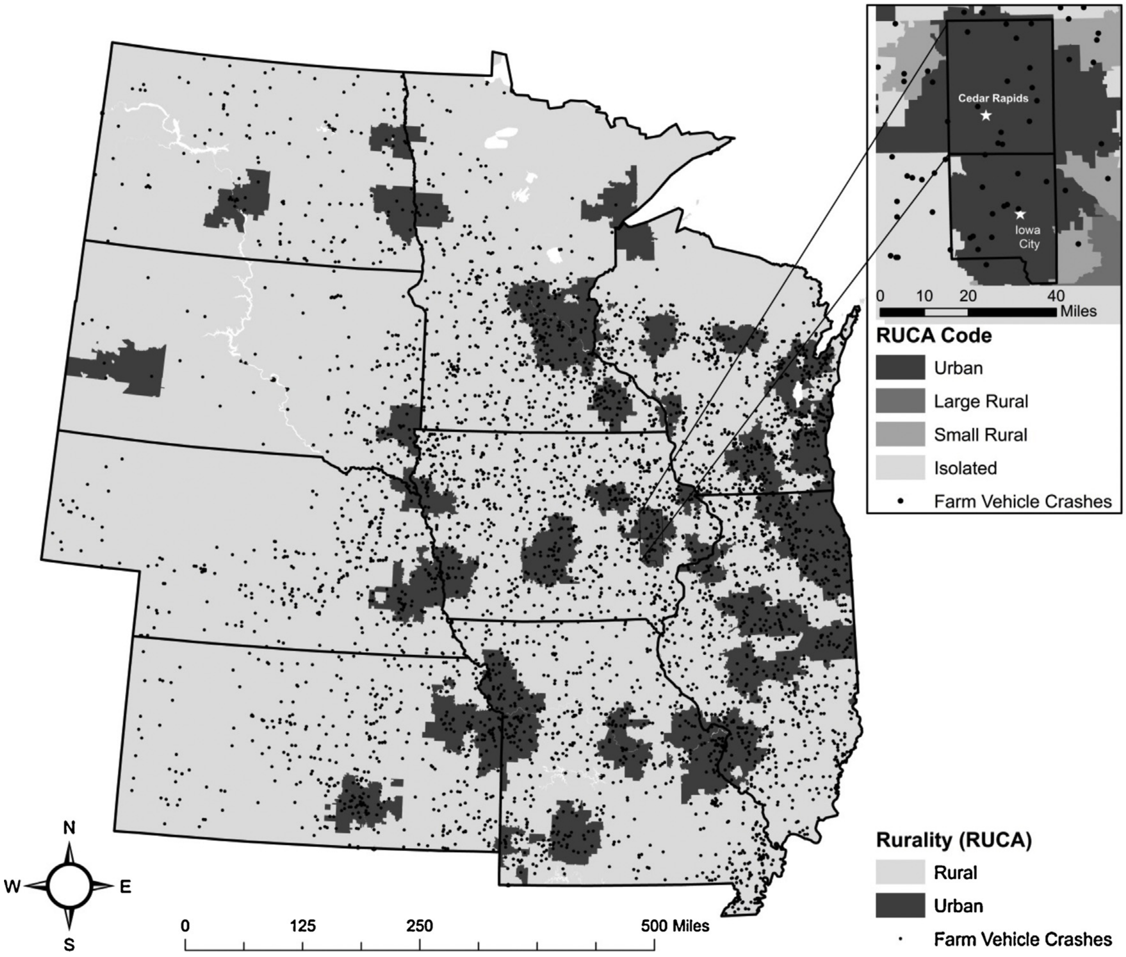

Fig. 1. Geospatial distribution of agricultural equipment-related crashes across nine Midwestern States, by urban–rural distribution, 2005–2008.

roadways may differ from rural roadways; in particular, traffic density is likely a strong contributing factor to crashes, as crashes in urban zip codes involved more vehicles than those in rural zip codes.

Of interest are the differences found within gradients of rurality, in which large rural zip codes had different types of crash configurations than small and isolated rural zip codes. A 1.5 to 3 fold increased odds of a crash in a small or large rural zip code involving two or more vehicles was found compared to an isolated rural zip code. In addition, a significant increased odds of a crash in large rural zip codes occurring within one mile of a town was found compared to isolated zip codes. These differences may again be attributed to traffic density and differences in roadway characteristics found even in various rural communities. Large rural communities may mirror urban settings with increased populations and high traffic density (Frumkin, 2002). The "urban sprawl" often seen in large rural communities is associated with heavy dependence on automobiles which has been associated with greater traffic density and increased traffic fatalities (Frumkin, 2002). Furthermore, roadways in large rural communities are paved and have more traffic controls, while small and isolated rural areas tend to have narrow dirt roads without shoulders. These rural roadway configurations have important implications for crashing.

Agricultural equipment-related crashes occurred in all areas of these nine Midwestern states. Approximately two in five crashes occurred within a mile of a town, which is a proportion similar to those found by researchers in Iowa and Sweden (Pinzke and Lundqvist, 2004; Gkritza et al., 2010). One might hypothesize that these crashes in close approximation to a town happened in small towns in very rural areas where farming is taking place, but our

Table 4
Among farm equipment-related crashes occurring outside a town or city, the mean distance, in miles, from crash site to a city/town, nine Midwestern States, 2005–2008, *n* = 3610.

	Miles to a city or town[a]					
	n (% of total)		Mean (Std dev)	*P-value*	Adj Mean (Std dev)[b]	*P-value*
Rurality						
Urban	1004	(27.8)	1.95 (1.56)	Ref	1.89 (2.79)	Ref
Large rural	641	(17.7)	2.37 (1.92)	<.0001	2.30 (2.54)	<.0001
Small rural	721	(20.0)	2.57 (1.89)	<.0001	2.50 (2.60)	<.0001
Isolated rural	1244	(34.5)	2.85 (2.34)	<.0001	2.77 (2.96)	<.0001

[a] Excludes those happening within a city or town.
[b] Adjusted for time of day.

results suggest otherwise. Almost half (49.8%) of all crashes occurring in urban zip codes occurred within one mile of or in a town while only 34% of rural crashes occurred within this same boundary. We hypothesize that the large proportion of crashes occurring so close to or with a town may occur during the transport of grain to market from a more remote farm location. Further research is needed to identify these farm-to-market transportation patterns, and how they are ultimately related to increased risk of crashing.

Crash configurations also differ in rural versus urban settings. In urban zip codes, greater odds of a non-collision crash were found versus rural zip codes, and compared with rural settings, crashes in urban settings were more likely to involve more than one vehicle. Urban settings provide other unique hazards, that may be challenging for large-sized Ag equipment and lead to a higher risk of non-collisions. For example, vehicles, regardless of size, must stay within their lanes in order to accommodate increased traffic density. In addition, Ag equipment operators must maneuver roads that have many more stationary vehicles (e.g. parked cars), and objects (e.g. street signs) than on rural roads. Also, due to the large size of Ag equipment, interactions with other moving motor vehicles can be difficult, and it has been suggested that "urban dwelling" citizens may not understand how to interact on the roadway with large Ag equipment (Luginbuhl et al., 2003).

Current transportation planning focuses on retrofitting current roads or developing new roadways as "complete streets". Developed for increased accessibility but not to maximize speed, complete streets are "roads designed to accommodate diverse modes, users and activities including walking, cycling, public transit, automobile, nearby businesses and residents" (Litman, 2013). This type of street design results in safer streets with reduced speeds and increased site distance for motorists (Litman, 2013). Applying the complete streets concept in rural areas is likely different than in urban areas. Unfortunately, to date, attention has only focused on complete streets within towns to fit the urban model, neglecting Ag equipment as a mode of transportation. In some instances, a rural complete street may just involve a wider shoulder to accommodate Ag equipment. Increasing shoulder width, particularly along two lane rural roads, has been shown to reduce the frequency and severity of all motor vehicle crashes, therefore adding additional shoulder width would be beneficial to all roadway users (Gross and Jovanis, 2007; Labi, 2011).

Further education on Ag equipment road use is needed for all drivers, in rural and urban settings. Our results suggest that differences in manner of collision, and proximity to town should be used to inform drivers of the risk of crashes with equipment. As found by Luginbuhl et al. (2003), farmers believe that few non-farming residents comprehend the speed differential between equipment and traditional motor vehicles. In addition, non-farmers may not understand the laws governing Ag equipment on roadways or how to interact with them. At the same time, educating Ag operators about increasing the visibility of their equipment through slow moving vehicle emblems, proper vehicle lighting and marking, removing dirt and dust from lighting/marking and the potential risks of operating their vehicles in towns, and risks of collisions with stationary objects is vital to reducing Ag equipment-related crashes.

This study has limitations. As a secondary analysis of data, the accuracy of the data is unknown and many variables important to this analysis contain missing data. In addition, the Ag equipment-related crashes recorded by DOT are potentially the most severe crashes and may not be representative of all agricultural equipment-related crashes. In a survey of North Carolina farmers, 5.3% said they had been in an unreported agricultural equipment crash (Luginbuhl et al., 2003). Differences in the definition and coding of farm equipment across the nine DOT departments may have resulted in a misclassification bias. To reduce this bias, the make and model of the equipment involved in each crash were manually reviewed by an investigator (MG) and removed if appropriate. In addition, items such as pickup trucks towing farm implements (e.g., wagons) were not included in this analysis. Unfortunately, this exclusion is likely to result in underreporting of Ag related crashes. Using our definition of rural/urban, we were unable to account for heterogeneity that may exist within our categories such as the quality and type of road networks and the culture of safety. Also, this is a case only analysis, and we do not have data on miles of roadway exposure experienced by Ag equipment and thus cannot measure risk of crashing. However, our study does elucidate difference in crash patterns on where crashes occur, and suggests areas for future research and intervention.

6. Conclusion

Agricultural equipment-related crashes are not just a rural problem; they occur within close proximity of a town and within urban zip codes. Education among Ag equipment and other motor vehicle users as well as increased conspicuity of Ag equipment and consideration of the complete street concept to fit rural roadways are needed to reduce the incidence of these crashes.

Funding

Funding for this research was provided by the National Institute for Occupational Safety and Health to the University of Iowa Great Plains Center for Agricultural Health (U50 OH007548-11).

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