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Exploratory Analysis of Farm Vehicle and Farm Labor Transportation-Related Crashes

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ABSTRACT

Objective: The purpose of this study was to investigate characteristics associated with farm vehicle and farm labor transportation-related roadway crashes in the state of Florida. Agricultural roadway crashes related to these vehicles have not been explored in Florida.
Methods: The data for this study comes from the Florida Department of Highway Safety and Motor Vehicles (FLHSMV) for the years 2013–2021. The data is recorded by the Florida Highway Patrol when a vehicular crash has occurred. The data is then coded to allow the selection of farm and agricultural-related vehicles. Specifically, this study focuses on farm labor transport vehicles and farm vehicles (e.g. farm tractors).
Results: There were 744 farm vehicle- and 209 farm labor transportation-related crashes during the 9-year study period. The farm labor transport vehicle crashes involved a total of 420 vehicles and 1,329 individuals, and the farm vehicle crashes involved 1,458 vehicles and 1,652 individuals. Injury risk for non-farm labor transportation vehicle occupants was significantly higher than injury risk for farm labor transportation vehicle occupants.
Conclusions: The average fatality rate for farm vehicle-involved (2.1 fatalities per 100 crashes) and farm labor transportation vehicle-involved crashes (2.9 fatalities per 100 crashes) were much higher than the overall FL roadway crash fatality rate (0.45 fatalities per 100 crashes).

KEYWORDS
Crash; farm vehicle; farm labor transportation; roadway

Introduction

Agricultural vehicles on public roadways can pose safety hazards in addition to those already present. The Bureau of Labor Statistics' (BLS) Census of Fatal Occupational Injuries (CFOI) data show that occupational fatalities resulting from roadway incidents involving motorized land vehicles in agriculture increased from 16% (70 of 431) in 2011 to 25% (90 of 354) in 2021.[1,2] The Agriculture, Forestry, and Fishing industry was reported to have the third highest rate of work-related roadway fatalities in the US.[3] Roadways are used by farm vehicle operators to transport agricultural vehicles from one field to another. Additionally, agricultural employers usually provide transportation for migrant and seasonal farm workers for employment-related activities.

Farm vehicles are dangerous on roadways because these vehicles move slowly, and drivers of the other vehicles usually approach these vehicles at a higher rate of speed.[4] Additionally, these vehicles are large and can obstruct the vision of the drivers of the other vehicles. These vehicles often move between farms on rural two-lane roadways. Rural roadways may have narrow shoulders and poor conditions that do not support large agricultural equipment.

Farm vehicles have a legal right to share the road with general motorists. According to the Florida Statutes (322.04), operators of farm vehicles that operate these vehicles temporarily on roadways are not required to have a license.[5] Farm vehicles must display slow-moving vehicle (SMV) emblems at the back of the vehicle indicating these vehicles travel at speeds less than 25 miles per hour (mph) when traveling on public roadways.[6] FVs should be "equipped with vehicular hazard warning lights visible from a distance of not less than 1,000 feet to the front and rear in normal sunlight, which shall be displayed whenever any vehicle is operated upon a highway".[6]

Farm labor transportation vehicles (FLTV) are used for the transportation of farm workers. FLTVs are defined as any vehicle equipped and

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used for the transportation of nine or more migrant or seasonal workers.[7] These vehicles often include retired school buses and passenger vans.[8] Because of the age of these vehicles, they can be unsafe and not well maintained. FLTVs are often used for transportation of migrant and seasonal workers to and from the work site. The H-2A temporary agricultural program permits farm employers to bring in foreign workers to perform harvest and other farm activities.[9] These workers are temporary and foreign, therefore must rely on transportation via the farm labor transport vehicle. Even though providing transportation to the workers is not mandatory, many agricultural employers and farm labor contractors choose to provide transportation.[8] Florida is the leading state in the number of H-2A certifications.[10]

FLTVs that transport migrant or seasonal farm workers are required to clearly display a sticker issued by the department, which states that the vehicle is authorized to transport farm workers. The sticker contains an expiration date in which the FLTV must be re-inspected.[11] If the sticker displayed is valid, this indicates that the vehicle has been inspected and passes the safety standards prescribed by the Secretary of Labor under s. 401 (b) of the Migrant and Seasonal Agricultural Worker Protection Act. FLTVs require all passengers to be restrained by a safety belt when the vehicle is in motion. However, it does not constitute negligence of the farm labor contractor if the migrant or seasonal worker does not employ the safety belt.[12] Drivers of FLTVs are required to be at least 21 years of age and have at least one year of driving experience. The drivers must have a Commercial Driver's License or Class E Driver's License. If the vehicle holds more than 15 passengers, then the driver must have a Class C license.[13]

A review of the literature revealed many studies of farm vehicles/farm equipment crashes on roadways.[4,14–20] A case study by Cordner,[21] *Traffic Injuries in Farm-Labor Vehicles in California*, was found that investigated FLTV crash events before and after a major incident in California in 1999. There have been no studies published that investigate farm vehicle or farm labor transportation vehicle crashes in Florida.

The objective of this study was to investigate the prevalence of FV and FLTV crashes during the study years (2013–2021). This study created a spatial map to visualize the observed crash count by county to understand the distribution of crashes in Florida. Additional analyses were conducted to test any association between the covariates and the incidence of injury and the possibility of a nonlinear association among temporal covariates.

Methods

Data

Data for the FV and FLTV-involved crashes were obtained from the Florida Highway and Safety Motor Vehicles (FLHSMV) for study years from 2013–2021.[22] The FLHSMV crash database includes separate hierarchically linked data tables that describe the event (crash), vehicles, drivers, passengers, roadway, and violation characteristics of each incident (see APPENDIX for a full list of variables). Crash incidents for this study were selected by determining the cases in which the crash involved at least one FV or FLTV. For each study year the crash, vehicle, and person-level data tables were merged into a single data table containing all variables of interest. The data filtering for the FV and FLTV was conducted separately. The tables were matched by a crash-specific report number after the FV or FLTV were determined. The specific codes that were used in this process can be seen in Figure 1. All data processing and statistical analysis were performed with the R statistical computing environment.[23]

Analysis

For the initial exploratory analysis the number of crashes, vehicles, people, and injuries were quantified. To visualize the distribution of crash count by county, spatial maps were created in R statistical computing environment using the *plot_usmap* function in the *usmap* package. Additionally, crash-, vehicle-, and person-level variables were studied individually to further understand the characteristics of these crashes.

To accurately calculate year-to-year costs of vehicle and property damages, yearly estimated property damage and estimated vehicle damage were adjusted to 2023 dollars using the inflation

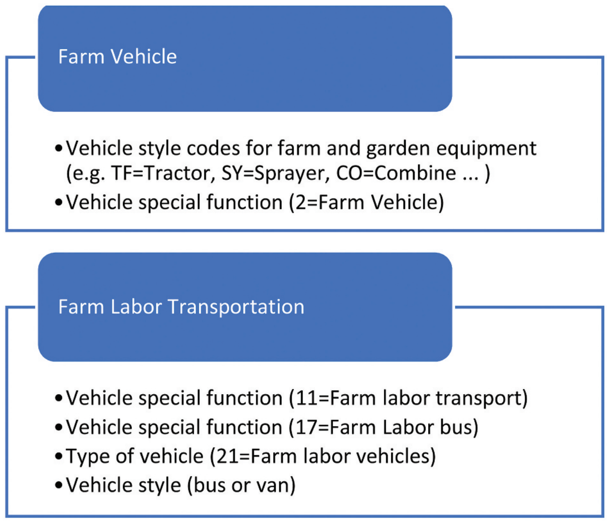

Figure 1. Vehicle-level data filtering criteria.

calculator provided by the U.S. Bureau of Labor Statistics.[24] These values were recorded by the investigating police officer. Estimated property damage is defined as the monetary value of damaged property and estimated vehicle damage is defined as the amount of estimated damage recorded in the crash report.

Person level statistical analyses were conducted only for the crashes involving people. The cases in which the injury severity variable was missing or there were zero people involved in the crash were excluded from this part of the study. A chi-squared test was used to determine if there were statistically significant differences between the proportion of those injured in the FV/FLTV or the occupants of the other vehicle. The FLHSMV injury severity variable was recoded to fit within the format for the analysis. The outcome variable of injury is coded as "0" for no injury and "1" for injury if any injury occurs from the individuals involved in the crash. If an individual was marked with their injury severity as being possible, non-incapacitating, incapacitating, or fatal, the individual was marked for having an injury.

The final goal of the study was to determine which crash characteristics were related to the outcome of injury. The statistically significant covariates would reveal the crash characteristics that increased or decreased the odds of injury. Logistic regression was used to discover which event-level covariates increase the odds of injury due to the crash. The logistic regression was chosen to estimate the probability of an event occurring, based on characteristics of the crash.

FV- and FLTV-involved crash data were merged to conduct two separate logistic regression models to understand the effects of the covariates. Combining FV and FLTVs for the logistic regression provided a sufficiently large dataset ($n = 932$) to conduct the logistic regression for the number of predictors. The larger the dataset for the number of predictors provides more accurate estimates resulting from our model. The model was split to include covariates that had similar characteristics and to maintain sufficient model fit. The first model included the covariates which are temporally varying variables that were weather-related and those that quantified people and vehicles involved. These specific covariates are:

- total number of persons (occupants),
- total number of vehicles,
- environmental variables (light and weather conditions): The lighting condition had six possible values (daylight, dusk, dawn, dark-lighted, dark-not-lighted, and dark-unknown lighting). For the analysis, lighting conditions were aggregated into daylight, dusk/dawn, and dark.

The second logistic regression included the covariates that were related to the crash location and surroundings. The specific covariates are:

- the type of location (rural or urban),
- road system identifier,
- type of shoulder,
- type of intersection,
- type of impact,
- road surface condition,
- first harmful event,
- harmful event location.

The outcome variable for both models was the indicator (binary) if any injuries resulted from the crash. The covariates reflected the aspects of the specific crash that the individual was involved in. The covariates in our model will be considered significant based on their p-value output from the model α = .05.[25]

Additionally, a Generalized Additive Model (GAM) was used to cast the variables of the month of the year and hour of the day as smooth functions, to identify any potential nonlinear and/or nonmonotonic relationships (i.e., those that are either non-increasing or non-decreasing) between these predictors and the log-odds of injury. A non-monotonic relationship is a relationship among variables in which an increase or decrease of the independent variable is not clearly associated with an increase/decrease of the dependent variable. If these relationships are found to be significant, then the plot that results from this model will show if any time of day or month of the year influences injuries resulting from the crash.

Results

The data summaries revealed 953 crashes involving FVs and FLTVs during the 9-year study period (2013–2021). Of these crashes 209 involved FLTVs and 744 involved FVs. The spatial map showed that Miami-Dade ($n = 150$, 15.7%), Palm Beach ($n = 105$, 11.0%), and Polk ($n = 63$, 6.6%) counties had the highest counts of crashes (Figure 2).

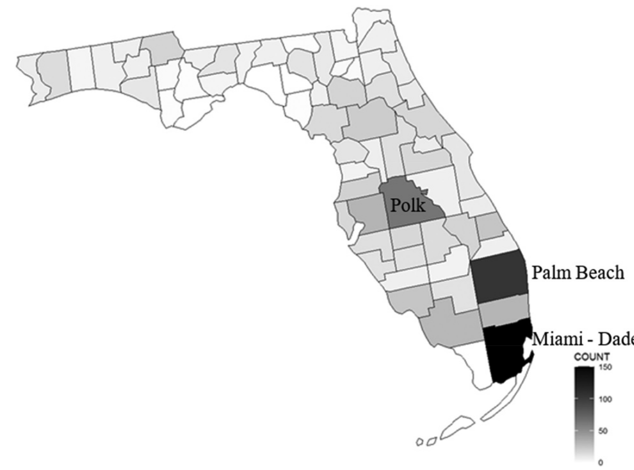

Figure 2. Distribution of FV and FLTV crashes.

Most of these crashes involved two vehicles (Table 1) and a minimum of zero to a maximum of 64 people. In 13 crashes (12 FVs and one FLTV), there were no individuals reported. These crashes were related to hit-and-run, collisions with fixed objects (mailboxes, fences, posts, etc.), and collisions with parked motor vehicles that occurred off-roadways, on shoulders, in parking lanes, or on roadsides.

There was no clear divide between the number of crashes occurring in rural versus urban areas for the FLTV crashes. However, FV-related crashes occurred in rural areas more often than FLTV crashes (66.5% vs. 48.8%). The most common first harmful event, which is the first injury or damage-producing event, was a collision with another motor vehicle in transit in 71.9% ($n = 535$) of the FV crashes and 82.3% ($n = 172$) of FLTV crashes. The other category under first harmful event includes the remaining data that has low values or was classified as other (e.g., other non-collision, other collision with non-fixed object, other collision with fixed object) by the FLHSMV.

The most common type of impact for FV crashes involving other vehicles in transit were front to rear ($n = 197$, 37%), angle ($n = 133$, 25%), and sideswipe ($n = 122$, 23%). For the FLTV-involved crashes involving other motor vehicles in transit, the most common type of action was front to rear ($n = 69$, 40%), angle ($n = 42$, 25%), and sideswipe ($n = 32$, 18%).

Regarding vehicle level variables, FV crashes involved a total of 749 FVs and 709 were the other vehicles. Other vehicles involved in the FV crashes were mostly passenger cars ($n = 319$), pickup trucks ($n = 142$), and sport utility vehicles ($n = 103$) (Table 1). FLTV crashes involved a total of 420 vehicles. The types of farm labor transportation vehicles were buses

Table 1. Summary statistics for crash- and vehicle-level variables.

Crash specific variables	FV ($n = 744$)	FLTV (n = 209)
Number of vehicles involved		
Single vehicle	78 (10.5%)	17 (8.1%)
Two vehicles	631 (84.8%)	174 (83.3%)
Three and more vehicles	35 (4.7%)	18 (8.6%)
Number of persons involved		
One person	136 (18.6%)	23 (11.1%)
Two people	456 (62.3%)	86 (41.3%)
Three and more people	140 (19.1%)	99 (47.6%)
Rural/Urban		
Rural	495 (66.5%)	102 (48.8%)
Urban	249 (33.5%)	107 (51.2%)
First harmful event		
Collision with motor vehicle in transport	535 (71.9%)	172 (82.3%)
Collision with parked motor vehicle	59 (7.9%)	18 (8.6%)
Collision with work zone/maintenance equipment	23 (3.1%)	-
Overturn/Rollover	14 (1.9%)	2 (1.0%)
Collision with fence	2 (0.3%)	2 (1.0%)
Collision with non-fixed object	20 (2.7%)	1 (0.5%)
Collision with utility pole/light support	17 (2.3%)	2 (1.0%)
Collision with pedestrian	6 (0.8%)	2 (1.0%)
Ran into water	6 (0.8%)	-
Collison with pedal cycle	7 (0.9%)	-
Others	75 (10.1%)	10 (4.8%)
Vehicle specific variables	**FV (*n* = 1,450)**	**FLTV (*n* = 420)**
Type of vehicle		
FLTV	-	211 (50.2%)
FV	749 (51.6%)	-
Passenger cars	319 (22%)	100 (23.8%)
Pickup trucks	142 (9.8%)	38 (9%)
Sport utility vehicle	103 (7.1%)	29 (6.9%)
Medium/Heavy trucks	69 (4.8%)	14 (3.3%)
Other light trucks	7 (0.5%)	10 (2.4%)
Other vehicles	61 (4.2%)	18 (4.3%)
Disabling functional damage*		
Disabling	449 (33.5%)	94 (24.2%)
Functional	363 (27.1%)	138 (35.5%)
Minor	324 (24.2%)	122 (31.4%)
None	204 (15.2%)	35 (9.0%)
Most harmful event*		
Collision with motor vehicle in transport	1101 (75.9%)	345 (84.6%)
Collision with parked motor vehicle	109 (7.5%)	36 (8.8%)
Overturn/Rollover	20 (1.4%)	3 (0.7%)
Collision with fence	2 (0.1%)	1 (0.2%)
Thrown or falling object	7 (0.5%)	-
Collision with workzone/maintenance equipment	33 (2.3%)	-
Struck by falling object, shifting cargo	7 (0.5%)	2 (0.5%)
Collision with utility pole/light support	26 (1.8%)	2 (0.5%)
Others	145 (10.0%)	19 (4.5%)

*Unknown or missing variables not included in the percentages.
Abbreviations: FV, Farm vehicles; FLTV, Farm Labor Transportation Vehicles.

(n = 127) and vans ($n = 84$). The remaining 209 were the other vehicles involved in the FLTV crashes (Table 1). The vehicle level most harmful event that produced the most severe injury or greatest property damage for this vehicle was a collision with another motor vehicle for both FV and FLTV-involved crashes.

FV and FLTV crashes resulted in both vehicle-related and property-related damage. Disabling damage to the vehicle requires that the vehicle be carried or towed from the crash scene and this occurred 449 (33.5%) and 94 (24.2%) times, respectively. Functional damage, which affects the operation of a motor vehicle or its parts, was the most common type of damage among the FLTV crashes (35.5%). By using the Bureau of Labor Statistics (BLS) Inflation Calculator,[24] the cost of vehicle damage for FV and FLTV-involved crashes over the nine-year study period were estimated at US$ 6,508,699 and US$ 1,358,209, respectively (in

June 2023 US dollars). The inflation-adjusted estimated property damage was lower than the vehicle damage. Property damages were calculated as US$ 355,989 for FV- and US$ 41,150 for FLTV-involved crashes over the study period.

Regarding travel speed, we identified that 53% of the FV-involved crashes occurred on roads where the posted speed limits were more than 56 km/h (35 mph). The estimated speed of farm vehicles at the time of the crash was either at or under 40 km/h (25 mph) 91% of the time and only 2% of the FVs' estimated speed was 16 km/h (10 mph) or more than the posted speed limit. Eleven percent ($n = 71$) of the other vehicles involved in these crashes were exceeding the speeding limit (16 km/h – 10 mph or more than the posted speed limit) at the time of the crash. Speed differences between non-FVs and FVs (closure speed) were calculated and in 443 cases, non-FVs were traveling on average 47 ± 25 km/h (30 ± 16 mph) faster than FVs (data not shown).

FV and FLTV crashes involved 1,652 and 1,329 individuals, respectively (Tables 2, 3). The mean age of a FV driver was 47 years (±16.7 years; youngest 15, oldest 99 years old) while the mean age of a FLTV driver was 49 years (±14.6 years; youngest 19, oldest 97 years old). The mean age of the FV driver in our study is similar to the mean/median ages of 44,[4] 41.1,[19] and 40.4[26] found in previous farm vehicle crash studies.

There were up to four contributing driver action values recorded by the investigating officers. The most common contributing driver actions by FV, FLTV, non-FV, and non-FLTV drivers were listed in Tables 2 and 3. Operating a motor vehicle carelessly was the most observed driver-contributing action reported by all vehicle types involved in these crashes. However, a higher

Table 2. Person-level variables for FV-involved crashes.

Variables	FV		Non-FV	
	Driver ($n = 673$)	Passenger ($n = 69$)	Driver ($n = 630$)	Passenger ($n = 280$)
Age*				
Under 18	10 (1.5%)	36 (52.2%)	8 (1.2%)	138 (49.3%)
18–24	53 (7.9%)	3 (4.3%)	69 (11.0%)	29 (10.4%)
25–34	90 (13.4%)	15 (21.7%)	98 (15.6%)	11 (3.9%)
35–44	84 (12.5%)	5 (7.2%)	83 (13.2%)	18 (6.4%)
45–54	102 (15.2%)	1 (1.4%)	94 (14.9%)	6 (2.1%)
55–64	113 (16.8%)	5 (7.2%)	91 (14.4%)	15 (5.4%)
65 and older	78 (11.6%)	3 (4.3%)	90 (14.3%)	20 (7.1%)
Injury severity*				
None	549 (81.6%)	45 (65.2%)	470 (74.6%)	226 (80.7%)
Possible	33 (4.9%)	3 (4.3%)	59 (9.4%)	21 (7.5%)
Non-Incapacitating	33 (4.9%)	14 (20.3%)	56 (8.9%)	20 (7.1%)
Incapacitating	25 (3.7%)	6 (8.7%)	26 (4.1%)	4 (1.4%)
Fatal	7 (1.0%)	1 (1.4%)	6 (1.0%)	2 (0.7%)
Seat Belt Use*				
Not applicable	254 (37.7%)	58 (84.1%)	44 (6.9%)	63 (22.5%)
None used	54 (8/0%)	7 (10.1%)	18 (2.9%)	32 (11.4%)
Shoulder and lap belt used	169 (25.1%)	3 (4.3%)	522 (82.9%)	142 (50.7%)
Shoulder belt only used	10 (1.5%)	-	5 (0.79%)	-
Lap belt only used	77 (11.4%)	-	13 (2.1%)	1 (0.36%)
Driver Actions**				
No contributing action	336 (49.9%)		351 (55.7%)	
Motor vehicles operated carelessly	79 (11.7%)		145 (23.0%)	
Improper backing	36 (5.3%)		10 (1.6%)	
Followed too closely	13 (1.9%)		13 (2.1%)	
Failed to yield right-of-way	61 (9.1%)		31 (4.9%)	
Improper turn	18 (2.7%)		2 (0.3%)	
Ran red light	2 (0.3%)		1 (0.2%)	
Drove too fast for the conditions	1 (0.1%)		3 (0.4%)	
Improper passing	2 (0.3%)		41 (6.5%)	
Failed to keep in proper lane	17 (2.5%)		8 (1.3%)	
Other	124 18.4%)		66 10.5%)	

*Unknown or missing variables not included in the percentages.
**Multiple driver actions were merged, so the sum of percentages is higher than 100%.
Abbreviations: FV, Farm vehicles; FLTV, Farm Labor Transportation Vehicles.

Table 3. Person-level variables for FLTV-involved crashes.

Variables	FLTV Driver (*n* = 203)	FLTV Passenger (*n* = 870)	Non-FLTV Driver (*n* = 194)	Non-FLTV Passenger (*n* = 62)
Age*				
Under 18	-	2 (0.3%)	3 (2.3%)	16 (34.8%)
18–24	6 (3.5%)	148 (21.6%)	9 (7%)	4 (8.7%)
25–34	31 (17.9%)	240 (35%)	25 (19.5%)	6 (13%)
35–44	24 (13.9%)	147 (21.5%)	22 (17.2%)	7 (15.2%)
45–54	53 (30.6%)	86 (12.6%)	21 (16.4%)	5 (10.9%)
55–64	40 (23.1%)	44 (6.4%)	28 (21.9%)	4 (8.7%)
65 and older	19 (11%)	18 (2.6%)	20 (15.6%)	4 (8.7%)
Injury severity*				
None	177 (92.7%)	720 (87.2%)	150 (82.9%)	44 (75.9%)
Possible	9 (4.7%)	46 (5.6%)	14 (7.7%)	10 (17.2%)
Non-Incapacitating	3 (1.6%)	26 (3.1%)	11 (6.1%)	4 (6.9%)
Incapacitating	2 (1.0%)	30 (3.6%)	4 (2.2%)	-
Fatal	-	4 (0.5%)	2 (1.1%)	-
Seat Belt Use				
Not applicable	5 (2.5%)	347 (39.9%)	6 (3.1%)	7 (11.3%)
None used	5 (2.5%)	355 (40.8%)	4 (2.1%)	4 (6.5%)
Shoulder and lap belt used	172 (84.7%)	82 (9.4%)	171 (88.1%)	40 (64.5%)
Shoulder belt only used	5 (2.5%)	-	1 (0.5%)	-
Lap belt only used	7 (3.4%)	38 (4.4%)	2 (1.0%)	1 (1.6%)
Driver Actions**				
No contributing action	108 (53.2%)		116 (60.0%)	
Motor vehicles operated carelessly	26 (12.9%)		35 (18.0%)	
Improper backing	15 (7.5%)		8 (4.1%)	
Followed too closely	14 (6.9%)		13 (6.7%)	
Failed to yield right-of-way	9 (4.4%)		14 (7.2%)	
Improper turn	8 (3.9%)		2 (1.0%)	
Ran red light	3 (1.5%)		-	
Drove too fast for the conditions	2 (1.0%)		2 (1.0%)	
Other	42 (20.7%)		27 (13.9%)	

*Unknown or missing variables not included in the percentages.
**Multiple driver actions were merged, so the sum of percentages is higher than 100%.
Abbreviations: FV, Farm vehicles; FLTV, Farm Labor Transportation Vehicles.

proportion of non-FV and non-FLTV drivers operated their vehicles carelessly compared to the FV and FLTV drivers (23.0% and 18.0% of non-FV and non-FLTV drivers vs. 11.7% and 12.9% of FV and FLTV drivers). Other most common driver-contribution actions were failing to yield right-of-way, following too closely, and improper backing. Only a small proportion of the drivers were reported driving too fast for the conditions (1.0% or less for all drivers). The other category is a sum of the values such as ran off roadway, disregarded traffic sign or other road markings, overcorrecting/oversteering, etc.

Farm and agricultural-related Florida Statutes were violated in 27 FVs. Twenty FVs violated statute 316.2295 - Lamps, reflectors and emblems on farm tractors, farm equipment and implements of husbandry and additional three FVs violated 316.221-Taillamps. There were two violations for 316.2225 - Additional equipment required on certain vehicles and two violations for 316.515-maximum width, height, and length requirements.

The results of this study show that approximately 11% of the drivers of FLTVs involved in crashes do not have the proper class of driver's license ($n = 14$) or do not have a driver's license ($n = 9$). The drivers that did not have the proper licensing, do not have the proper training to operate the farm labor transport vehicles. There were 870 passengers on the FLTV and 355 (40.8%) were shown to not be wearing a seatbelt at the time of the crash.

The FV crashes resulted in a total of 316 injuries (19.1% of 1,652 people involved); 122 of these injuries were occupants of the FV and 194 were non-FV occupants (Table 2). There were 16 fatalities. The chi-square test revealed no significant differences in injury risk between the FV occupants and non-FV occupants (17.0% vs 21.8%) ($\chi^2 = 5.7$, df = 1, $P = .02$).

A total of 1,329 people were involved in FLTV-related crashes and 65% ($n = 870$) of the individuals were the passengers of FLTVs. The FLTV crashes resulted in 165 total injuries (12.4% of 1,329 people involved) with 120 of these injuries being occupants of the FLTV and the remaining 45 were non-FLTV occupants (Table 3). These crashes resulted in six fatalities. The chi-square test showed that occupants of the non-FLTV vehicles had a significantly higher risk of being injured when compared to the occupants of the FLTV (17.6% vs 11.2%, $\chi^2 = 7.8$, df = 1, $P < .001$).

FV- and FLTV-involved crash data were merged to conduct logistic regression models. Table 4 lists the injury and no-injury outcomes reported for each factor level. The total number of persons and vehicles involved showed a significantly increased risk of injury. The results show that lighting conditions are highly significant relative to injuries as indicated by odds ratios. The incidents occurring during the dark resulted in an increased risk of injury by a factor of 2.56 compared to the crashes occurring during daylight.

The second logistic regression model included the spatial variables (Table 4). A state highway and

Table 4. Crash characteristics and odds ratios.

Factor level	Injury	No injury	OR*	95% CI	*P*-value
Logistic Regression Model 1					
Total number of persons	257	675	1.04	1.02–1.07	.002
Total number of vehicles	257	675	1.52	1.05–2.21	.027
Light condition					
Daylight	182	560	1.00	Ref	-
Dark	59	75	2.56	1.74–3.77	.000
Dusk/Dawn	16	35	1.23	0.62–2.33	.531
Weather condition					
Clear	203	536	1.00	Ref	
Cloudy/Rain	53	126	1.11	0.76–1.60	0.579
Logistic Regression Model 2					
Rural/Urban					
Rural	190	394	1.00	Ref	-
Urban	67	281	0.63	0.07–0.76	.018
Road system identifier					
County road	72	173	1.00	Ref	-
Local highway	67	213	1.06	0.69–1.64	.781
Parking lot	5	63	0.78	0.19–2.58	.702
State highway	64	100	1.74	1.10–2.75	.017
US highway	36	36	1.60	0.93–2.74	.089
Type of shoulder					
Paved	85	233	1.00	Ref	-
Unpaved	143	323	1.20	0.84–1.72	.321
Curb	29	119	0.72	0.42–1.19	.207
Type of intersection					
Four-way intersection	24	70	1.00	Ref	-
T-intersection	27	71	1.05	0.54–2.07	.888
Type of impact					
Front to rear	132	175	1.00	Ref	-
Front to front	9	16	0.49	0.34–2.13	.772
Angle	52	154	0.88	0.32–0.74	.001
Sideswipe	26	166	0.25	0.14–0.40	.000
Road surface condition					
Dry	232	585	1.00	Ref	-
Wet/Ice/Frost	21	59	0.89	0.50–1.55	.697
First harmful event					
Collision with parked motor vehicle	5	66	1.00	Ref	-
Collision with motor vehicle in transport	207	497	2.71	1.09–8.30	.049
Harmful event location					
On roadway	228	515	1.00	Ref	-
In parking lane/zone	3	47	0.45	0.08–2.02	.316
Off roadway	15	515	0.64	0.32–1.23	.190

*Each odds ratio is the odds of the risk factor in a crash resulting in an injury divided by the odds of the risk factor occurring when there was no injury.

a US highway saw an increased risk of injury by a factor of 1.74 and 1.60 respectively, in comparison to county highways. Crashes with a sideswipe and an impact from an angle resulted in significantly decreased odds of injury by a factor of 0.25 and 0.49 compared to the front-to-rear crashes, respectively. The event of a collision with a moving motor vehicle showed an increased risk of injury by a factor of 2.71, in comparison with a parked motor vehicle.

Lastly, a Generalized Additive Model was employed to examine any nonmonotonic relationship between injury status and the temporal variables (month and time of day). The results show no significant result for the variable of the month of the year. However, the time of day (hours) variable revealed significant results. The result of the time of day plot reveals an increase in the effect on injury during the 5th and 19th hours of the day (Figure 3).

Discussion

This study is the first to analyze FV and FLTV crashes in Florida. Although the number of FV and FLTV vehicle-related crashes is low, when comparing the crash fatality rates, we see that 2.1% of the FV and 2.9% of the FLTV-involved crashes resulted in fatalities. The overall crash fatality rate in Florida is less than 1% (0.45 fatalities per 100 crashes),[27] meaning that FV and FLTV-involved crashes are 4.7 and 6.4 times more fatal than all other crashes, respectively.

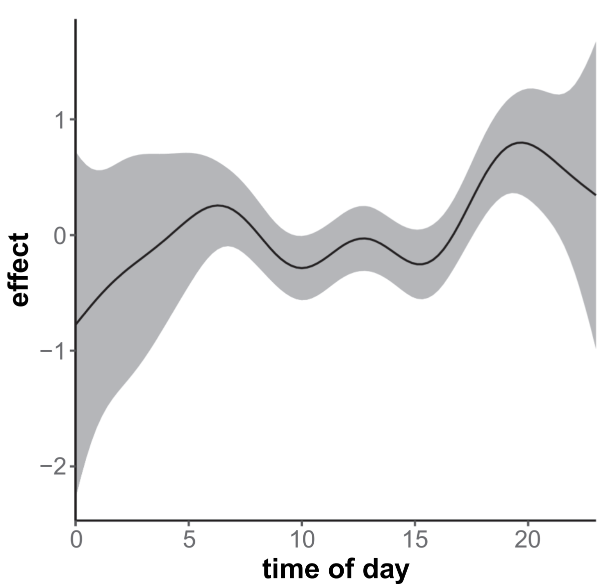

Figure 3. Effect of time of day on injury outcome.

The time of day affects the outcome of injury from these crashes. The crashes during dark hours were more injurious than the crashes occurring during daylight. The monthly distribution of agricultural roadway crashes in Florida did not have a significant effect on the amount of injury outcomes. This follows from the fact that agricultural work is performed year-round due to the climate in Florida.[28]

Similar to the previous studies from the other states, we found that the most contributing driver actions for both FV and FLTV-involved crashes were the careless operation of the vehicles.[4] We observed that the proportion of non-FV and non-FLTV drivers who operated their vehicles carelessly was higher than the FV and FLTV vehicle drivers. Unlike the other studies,[4,17] only a very small percentage of crashes were reported due to driving too fast for the conditions.

More than half of the FV-involved crashes occurred on roads where the posted speed limit was higher than 56 km/h (35 mph). Speed was a main concern reported by many researchers for farm vehicle operations on roadways. Similar to other studies, we found that speed differences between non-FVs and FVs were high, but the average closing speed (47 km/h) was a lower than the one reported by Gorucu et al.[4] which was 51 km/h. Our study also suggested that only a small portion (27 of 749 FVs, 3.6%) of the FVs had violated the lighting and marking-related Florida statutes.

A study by Cordner[21] analyzing FLTV crashes in California indicated that drivers of the FLTV lacked proper licenses. In our study, 11% ($n = 23$) of the FLTV drivers either had no license or no proper license at the time of the crashes. The study revealed that over 40% of the occupants of the FLTV were not wearing their seatbelt. A properly inspected FLTV must have safety belts for the migrant and seasonal workers, therefore it is the choice of the passenger not to employ the seat belt.

In our study, we found that FV and FLTV crashes are spatially related and occur mostly in South Florida. Safety emphasis should be made in the Miami-Dade, Palm Beach, and Polk counties. The largest counties of agriculture value and employment contributions in the state of Florida are Miami-Dade and Palm Beach.[29] Therefore, hotspots for FV and

FLTV crashes are in counties in which there are large agricultural presences. The results imply that additional safety recommendations and education should be made for farm vehicles and farm labor transport vehicles on roadways in these areas, especially for the operators of the other vehicles.

As described by Cordner,[21] a successful problem-oriented policing project to address farm labor vehicle transportation safety conducted by the California Highway Patrol (CHP) might be adopted to ensure the safety of farm labor vehicles on roadways. The CHPs initiative included the Safety and Farm Labor Vehicle Education (SAFE) program as well as increased enforcement and inspections for vehicles, drivers' licenses, seat belts, equipment, etc. In a news release by the US Department of Labor,[30] agricultural industry employers and workers were urged to act to decrease transportation-related deaths and injuries. Safety measures such as vehicle inspections, proper licensing of the farm labor vehicle drivers, and seat belt usage proved to be effective in preventing crashes and reducing the outcome of injury severities.

Conclusions

In Florida, agricultural-related crashes are much more dangerous on average than the overall crash rate in the state. Therefore, extra care should be taken by the driver of the other vehicle when driving near these vehicles. These results demonstrate the importance of safety needs surrounding FV and FLTVs on public roadways.

The strengths of this study are that it explored FV and FLTV crashes in the state of Florida which has not previously been studied. A major limitation of this study was that the database was frequently miscoded. The miscoding led to many misclassified vehicles as Farm Vehicles or Farm Labor Transport Vehicles. Additional efforts such as keyword searches were made to ensure that no cases were missed.

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APPENDICES

Table A1. Event Level Variables

Variable	Description	Range/Levels
Crash year	Year that crash occurred	2013–2021
Total Numbers of Vehicles	The total number of vehicles involved in the crash	1–4
Total Number of Persons	The total number of persons involved in the crash	1–64
Rural or Urban	The crash location type	Rural, Urban
Road System Identifier	The type of roadway that the crash occurred	State Highway, County Highway, Local Highway, Parking Lot
Type of Shoulder	The type of shoulder of the roadway in which the crash occurred	Paved, Unpaved, Curb
Type of Intersection	The type of intersection in which the crash occurred	Four-Way, T-Intersection
Type of Impact	The type of impact because of the crash	Front to Rear, Front to Front, Angle, Sideswipe
Light Condition	The light at the time of the crash	Daylight, Dusk/Dawn, Dark
Weather Condition	The weather at the time of the crash	Clear, Cloudy/Rain
Road Surface Condition	The road condition due to weather at the time of the crash	Dry, Wet/Ice/Frost
First Harmful Event	The main cause of the crash	Motor Vehicle in Transport/Parked Motor Vehicle
Harmful Event Location	The location where the first harmful event	On roadway, off roadway, in a parking lane or zone
Time of Day	The time of day that the crash occurred	1–24
Injury	Whether or not the individual involved in the crash was injury	Injury, no injury
Month	The month that the crash occurred	1–12
County	The county in which the crash occurred	All 67 counties in Florida

Table A2. Vehicle Level Variables

Variable	Description	Range/Levels
Type of Vehicle	The description of the vehicle involved in the crash	Farm labor transport vehicle, Farm vehicle, passenger cars, pickup trucks, sport utility vehicles, medium/heavy trucks, other light trucks
Disabling functional damage	The extent of the damage from the crash	Disabling, Functional, Minor
Most Harmful Event	The event that caused the most harm from the crash	Collision with Non-Fixed Object, Non-Collision, Collision with Fixed Object

Table A3. Person Level Variables

Variable	Description	Range/Levels
Age	Ages of the individuals involved in the crash	1–99
Injury Severity	The injury severity of the individuals involved in the crash	None, Possible, Non-Incapacitating, Incapacitating, Fatal
Driver Actions	The driver action that could be the cause of the crash	None, Motor vehicles operated carelessly, improper backing, followed too closely, failed to yield right-of-way, improper turn, ran red light, drove too fast for conditions