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Economic Damages of Wild Pigs in Non-Traditional Areas: From the Fairway to the After Life

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Economic Damages of Wild Pigs in Non-Traditional Areas: From the Fairway to the After Life

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Abstract

Invasive wild pigs are widely known to cause damage to agricultural properties and commodities, but less has been reported about damages to other types of property. A survey was distributed to golf courses and cemeteries across Texas to explore the extent of damage these properties experience. While both property types reported significant damages, golf courses were found to experience more damage than cemeteries. Using average reported costs and predicted county-level damage, total costs for all golf courses and cemeteries across the state were estimated to exceed $1.6 million USD per year.

Key words: cemetery, damage estimates, feral swine, golf course, invasive species, property damage

Introduction

Invasive species are one of the leading threats to ecosystems in the United States (U.S.) causing damage and economic losses to many sectors of the U.S. economy. They are responsible for over $120 billion in damage and control costs annually and these losses are expected to increase (Pimental 2007, Early et al. 2016). An important aspect of invasive species control and management is understanding economic losses and control costs. Understanding these impacts allows managers to weigh control costs and damage mitigation results to inform damage mitigation decisions improving prioritization of control resources.

One of the most important invasive species in the U.S. are wild pigs (*Sus scrofa* Linneaus), also known as feral swine, feral hogs, wild hogs, and wild boar (Keiter et al., 2016). Over $1.5 billion in annual damage is attributed to invasive wild pigs in the U.S. and has resulted in significant policy activity to mitigate damages to natural ecosystems, residential developments, agriculture, and rangelands (Miller et al., 2018). To date, most existing damage estimates have been for agricultural resources. Annual damage to six crops across ten U.S. states with large wild pig populations was

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estimated to be $200 million (Anderson et al., 2016) and $272 million for another set of six crops across 12 states (McKee et al., 2020). In Florida, one of the largest cattle production states in the U.S., damage to pasture by feral swine was estimated to result in losses greater than $2 million annually in five counties (Bankovich et al., 2016).

Little is known about damages caused by feral swine to non-traditional sectors of U.S. agriculture such as the turfgrass industry, of which golf courses and cemeteries are an important component. Cemeteries and, to a larger extent, golf courses, represent a very high category of land development and require the use of many high value horticultural products and services. The golf sector is the largest component of the turfgrass industry, representing nearly half (44%) of the industry (Haydu et al., 2006). Golf courses generate $33.2 billion in gross output and employ nearly 500,000 people on nearly 16,000 courses nationwide (Haydu et al., 2008). Four states - Florida, California, Texas, and Illinois – disproportionately contribute to golf course output. One of these states, Texas, has over 800 golf courses and 80 stand-alone driving ranges that generated over $6 billion in annual revenue employing more than 80,000 people that accounts for wage income of over $2 billion (Haydu et al., 2008). Areas that remain moist throughout the year – such as golf courses and cemeteries, which are commonly irrigated - are essential to good wild pig habitat (Graves 1984). Typically reported feral swine damages include rooting, compacting soil, wallowing, and trampling. In golf courses and cemeteries, this expands to include damage to physical structures like toppling headstones and irrigation systems. The juxtaposition of feral swine and well-to-do golfers has generated some clever headlines and snickers. However, despite the economic importance of the turfgrass industry, particularly for golf courses and cemeteries, there are no studies currently available describing the frequency of damage or the total costs associated with damage from wild pigs.

Our objectives in this study were to characterize the economic impact of wild pigs to Texas golf courses and cemeteries and to identify those areas of Texas with a greater likelihood of damage. Specifically, we sought to understand the seasonality of damages, changes in frequency and severity of impacts, and factors associated with damage. To accomplish these objectives, we conducted a survey of golf courses and cemeteries in Texas. Then, we developed a statistical model which predicted the probability of damage to cemeteries and golf courses in every Texas county. We further estimated the total cost for the golf course and cemetery based on the predicted probability and the number of properties. Our results provide the first estimates of damage to an important sector of the turf grass industry.

Methods
*Survey Instrument and Implementation*
A survey was implemented by Texas A&M University-Commerce and New Mexico State University. Links to the questionnaires are available are https://tinyurl.com/feralswine for cemeteries and https://tinyurl.com/GolfandSwine for golf courses. The Texas A&M University-Commerce Institutional Review Board (IRB) reviewed all survey materials and approved the survey[8]. Cemetery listings were obtained through the Texas Cemeteries and Crematories Association. Their membership list included 175 cemeteries. The Texas Golf Association provided a list of member golf courses. Surveys were sent to 389 golf courses or associations. Member golf courses and cemeteries were

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[8] IRB ID number 1822

contacted through a mailed letter which included a web address to take the survey online, or a paper survey to return. After the responses were received, non-responses were contacted by phone with a final request to complete the survey online. The surveys were initially mailed in October 2019 and non-respondents were contacted by phone during the summer of 2020.

Texas was divided into seven regions (Fig 1) and respondents were asked to select the location of their property. Additionally, the physical location of the properties was estimated using the latitude/longitude point from the location of the computer that was used to complete the online survey, or from the centroid of the zip code of the mailed survey.

Figure 1: Survey Regions
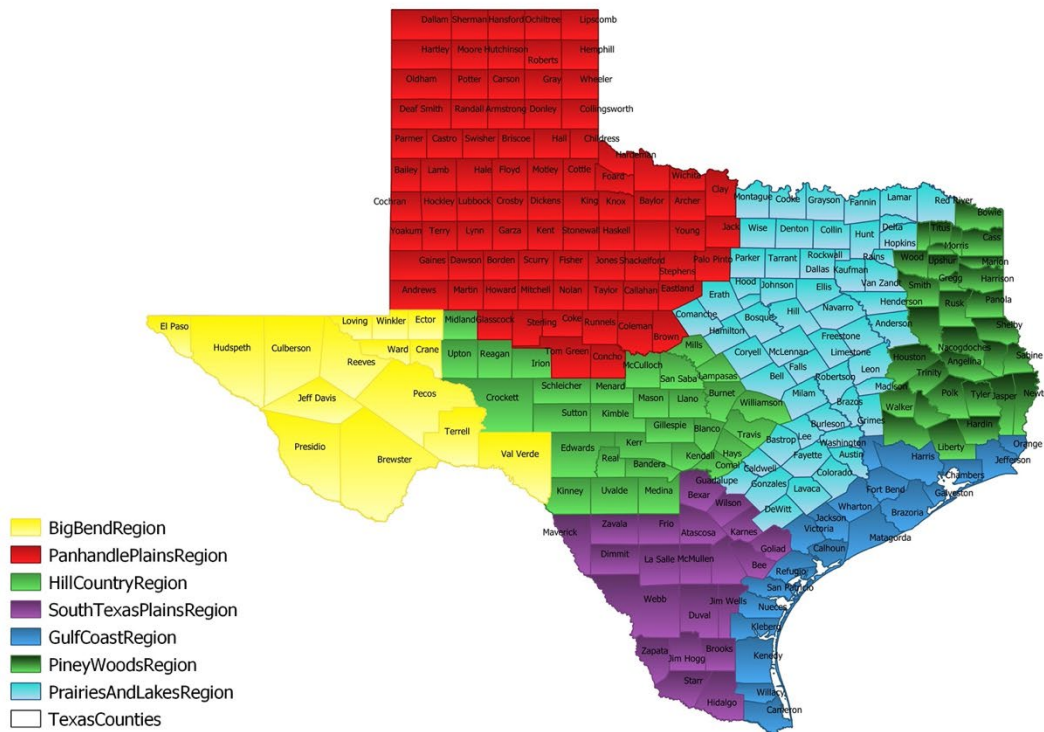
Survey Questions and Analysis

Respondents were asked whether they had ever observed damage from feral swine on the property they manage, and their level of concern about potential damage. Analysis of subsequent questions related to damage were restricted to respondents who had observed damage. Respondents who reported concern were asked what types of damage were caused (or possibly caused) by feral swine and what measure(s) they took to repair feral swine damage. They were asked to report the quarterly costs of feral swine damage from October 2018 to September 2019, the frequency of damage events, and how the frequency of damages has changed in recent years. Analysis of variance (ANOVA) was used to analyze the differences among mean reported quarterly costs. Respondents who reported concern were also asked what preventative measures they take, the annual costs of those measures for the past three years, and their effectiveness. They were offered the opportunity to write in any

management advice they had for other landowners dealing with feral swine and any other information they would like to share. The questionnaire is provided in Appendix A, and responses to the survey in Appendices B and C.

Logistic regression analysis was performed to determine relationships between reported damage observations and possible influencing factors. (Eq. 1). The dependent variable was observed damage (binary responses). We expected the probability of damage in a county to increase with the density of feral swine[9], and with extreme temperatures (expressed as the number of months in a county above the average temperature plus one standard deviation (NOAA 2021))[10], as wild pigs thermo-regulate by accessing shade and water resources (Choquenot & Ruscoe, 2003).

We also hypothesized that the type of property (modeled as a binary variable golf or cemetery) would be an influencing factor, due to differences in management, average sizes and layout.

$$Observed\ Damage = \alpha + \beta_1 * Density + \beta_2 * Temperature + \beta_3 * Property\ Type + \epsilon \qquad (Equation\ 1)$$

To generate measures of feral swine density, data describing the nationwide distribution (presence/absence) of feral swine at the county level were compiled from APHIS-Wildlife Services and the Southeastern Cooperative Wildlife Disease Study (SCWDS) (Corn and Jordan 2017). These data represent the known nationwide distribution of feral swine over the past 38 years and have been used to forecast the spread of feral swine (Snow et al., 2017), estimate the probability of occurrence (McClure et al., 2015), determine agricultural producers at risk of damage from wild pigs (Miller et al., 2017), and predict corresponding policy activity (Miller et al., 2018). These occurrence data were used with county level predictions of feral swine density produced using a Bayesian Catch-Effort Model (Miller et al. Unpublished data). The catch-effort model is similar to that described by Davis et al. (2016) and uses feral swine removal data collected as part of the APHIS National Feral Swine Damage Management Program to generate predictions of feral swine density for each county at monthly scale while accounting for differing removal methods, habitat, climate, and other factors effecting either population growth or probability of capture.

Regression results were used to predict potential damage by county across the state using the total number of cemeteries and golf courses in each county. Regression analysis was performed using R version 3.5.3 (R Core Team 2019). The model's accuracy was evaluated using Area Under Curve (AUC). Predicted probability (risk) of damage was mapped by county.

Results

Surveys were returned from 38 cemeteries and from 85 golf courses for a respective response rate of 20.6 percent and 21.9 percent. Most surveys were returned from the Gulf Coast (n=30) and Prairies and Lakes (n=32) Regions. The most frequent reports of observed damage came from the Gulf Coast Region (Figs 2 & 3).

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[9] Mean feral swine density: 0.897 head/km² – standard deviation 0.673 head/km²
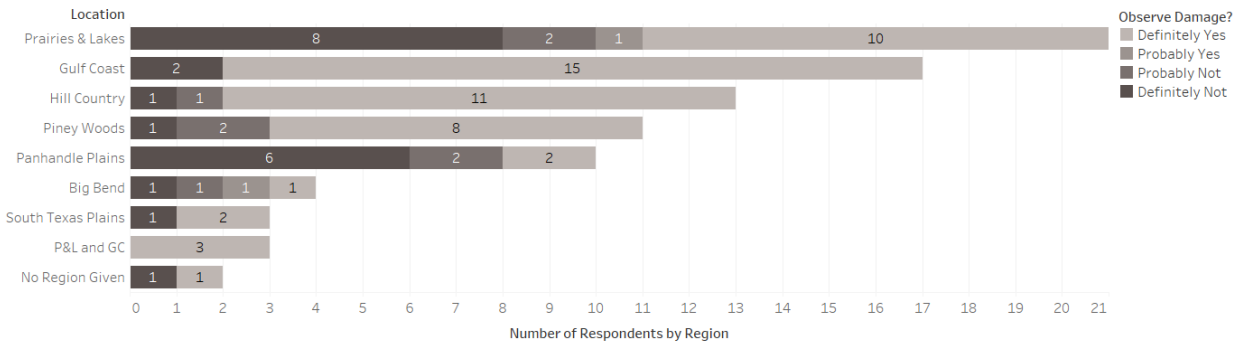
[10] Threshold temperature: 80.24°F

Figure 2: Damage Observation

Have you ever observed any damage to the cemetery property you manage that was caused by feral swine?
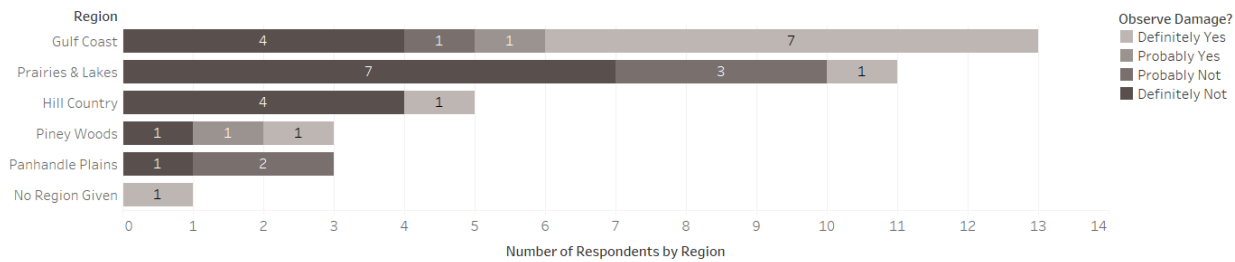
Have you ever observed any damage to the golf course property you manage that was caused by feral swine?

The majority of golf course respondents had observed damage (64.7%) and were concerned about potential damage (72.9%). A minority of cemetery respondents had observed damage (38.9%), but half were concerned about potential damage (50.0%).

Respondents overwhelmingly reported damage to vegetation on their properties, including damage to greens and landscaping (Fig 3).

Figure 3: Types of Damages

Based on your observation, what are the types of damages caused (or possibly caused) by feral swine on the cemetery property you manage?
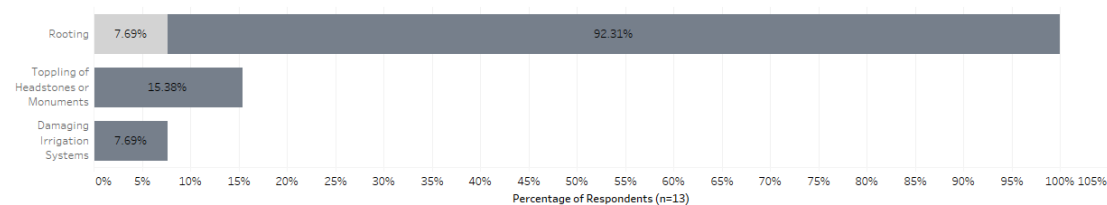
Based on your observation, what are the types of damages caused (or possibly caused) by feral swine on the golf course property you manage?
Damage to...

Fewer respondents reported damage to irrigation and other structures. Consequently, almost all reported repairs were for greenery (sod) and very few repairs were for irrigation or structures (Fig 4).
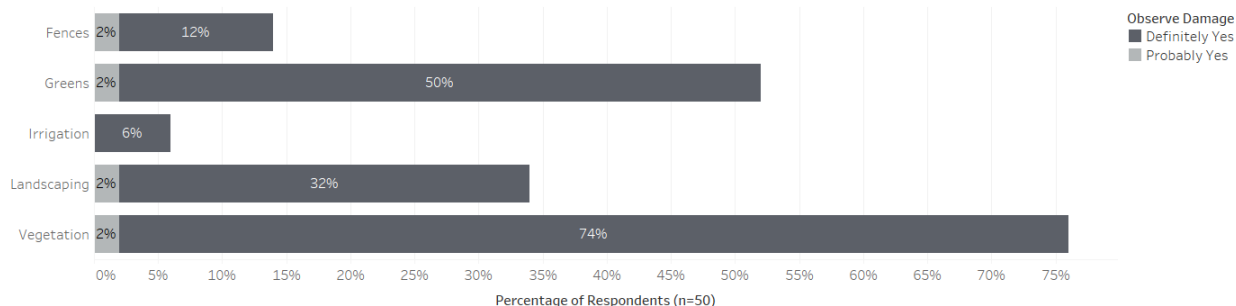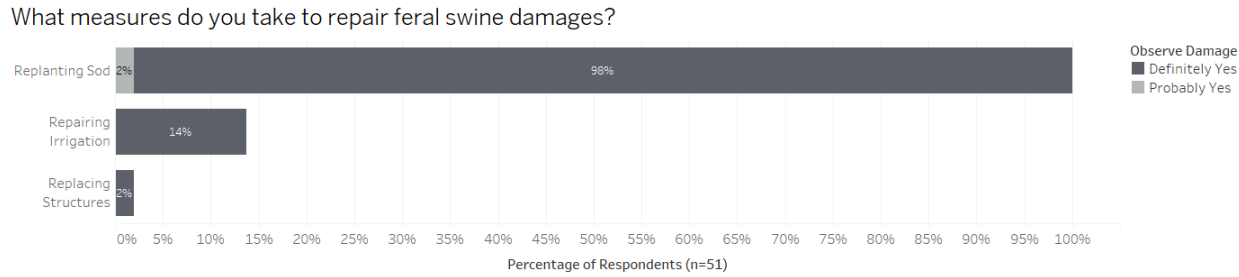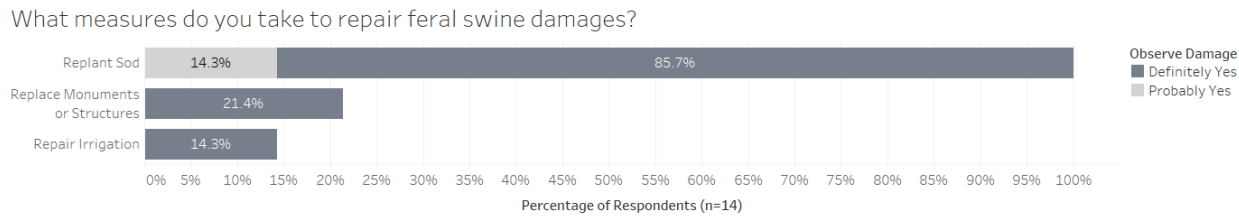
Figure 4: Repair Measures

What measures do you take to repair feral swine damages?

			Observe Damage
Replant Sod	14.3%	85.7%	■ Definitely Yes
Replace Monuments or Structures	21.4%		□ Probably Yes
Repair Irrigation	14.3%		

Percentage of Respondents (n=14)

What measures do you take to repair feral swine damages?

			Observe Damage
Replanting Sod	2%	98%	■ Definitely Yes
Repairing Irrigation	14%		■ Probably Yes
Replacing Structures	2%		

Percentage of Respondents (n=51)

Reported damage costs appeared mostly uniform over the year for both property types, except for the April – June 2019 quarter for cemeteries, which had lower damage (Table 1).

Table 1. Damage Costs

		Oct-18	Jan-19	Apr-19	Jul-19
Cemetery	Mean	$1,704.17	$1,566.67	$466.67	$1,433.33
n=12	Std Error	$1,137.06	$1,177.59	$255.94	$1,034.87
	Median	$350.00	$0	$0	$0
Golf Course	Mean	$1,513.68	$1,458.96	$1,191.98	$1,404.25
n=53	Std Error	$315.58	$344.72	$337.45	$380.55
	Median	$500.00	$200.00	$125.00	$500.00

However, ANOVA analysis did not reveal significant differences among the annual quarters. Both cemetery and golf course respondents reported using trapping for mitigation most frequently (Table 2).

Table 2. Costs of Mitigation Methods

		Fencing	Trapping	Hunting	Guard Dogs	Other
	Average	$4,325	$1,825	$2,067	$2,000	$367
Cemetery	Median	$650	$1,125	$2,000	$2,000	$400
	n	4	8	3	1	3
	Average	$5,037	$5,415	$5,990	$125	$16,575
Golf Course	Median	$2,000	$2,500	$300	$0	$0
	n	19	36	30	12	16

For both property types, damage frequency was most often reported as "sporadic" (Fig 5).

Figure 5: Highest Amount of Damage

In the quarter with the highest amount of damage, how often do damages occur?
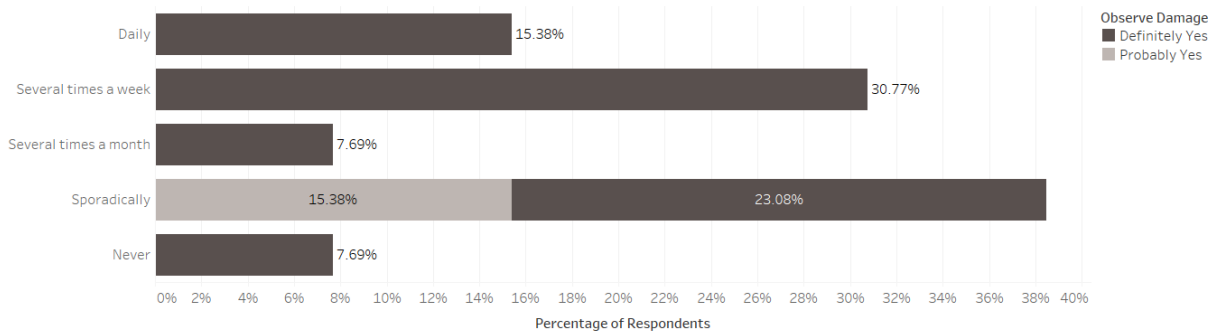
Daily	15.38%
Several times a week	30.77%
Several times a month	7.69%
Sporadically	15.38% 23.08%
Never	7.69%

Observe Damage
- Definitely Yes
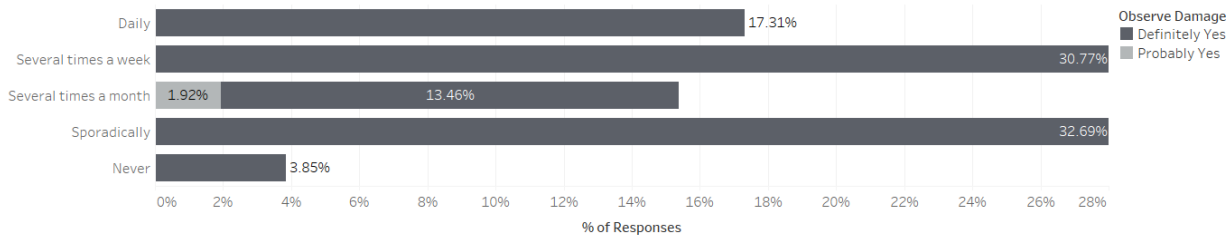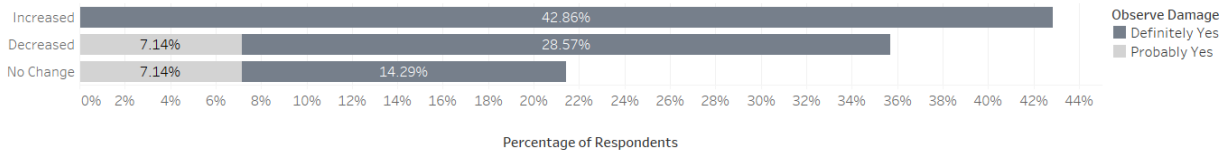- Probably Yes

Percentage of Respondents

In the quarter with the highest amount of damage, how often do damages occur?

Daily	17.31%
Several times a week	30.77%
Several times a month	1.92% 13.46%
Sporadically	32.69%
Never	3.85%

Observe Damage
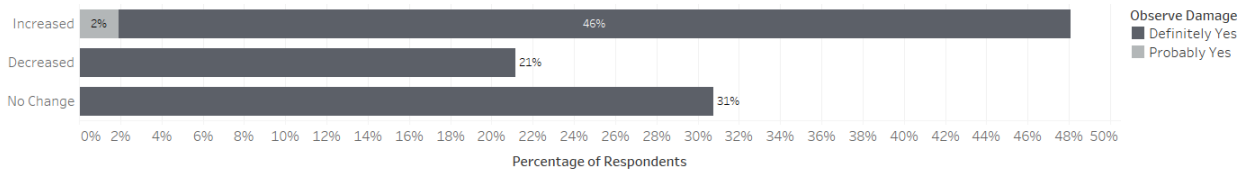- Definitely Yes
- Probably Yes

% of Responses

A plurality of both golf course and cemetery respondents reported that damages had increased over the past three years (Fig 6).

Figure 6: Changes in the Frequency of Damage

How has the frequency of damage changed in the past three years?

Increased	42.86%
Decreased	7.14% 28.57%
No Change	7.14% 14.29%

Observe Damage
- Definitely Yes
- Probably Yes

Percentage of Respondents

How has the frequency of damage changed in the past three years?

Increased	2% 46%
Decreased	21%
No Change	31%

Observe Damage
- Definitely Yes
- Probably Yes

Percentage of Respondents

Golf course respondents perceived more of their property at risk of feral swine damage than cemetery respondents (Fig 7).

Regression analysis (AUC: 0.798) revealed significant positive relationships between observed damage and feral swine density and average temperature (Table 3).

Table 3. Logistic regression results.

|	Coefficients				Marginal Effects		
	Estimate	Std. Error	p-value		dF/dx	Std. Error	p-value
Intercept	-4.965	1.451	0.001				
Feral Swine Density	1.359	0.403	0.001		0.334	0.099	0.001
Golf Course	1.408	0.519	0.007		0.338	0.115	0.003
Temperature	0.325	0.147	0.027		0.080	0.037	0.030

Golf courses are more likely to experience damage than cemeteries. Regression results were used to predict damage probability for each county using the complete golf and cemetery listings. For each county and each property type, the predicted probability was multiplied by the total number of properties in that county and the average cost of feral swine damage. These estimates were then aggregated to estimate the total costs of feral swine damage to all golf courses and cemeteries in Texas (Table 4).

Table 4. Predicted Total Cost of Feral Swine Damage Across TX.

Total Costs	Average	Statewide	Count
Cemeteries	$5,171	$282,523	133
Golf Courses	$5,569	$1,389,683	389
Total		**$1,672,206**	522

Total predicted costs for cemeteries were $282,500 for 133 properties. Golf courses had predicted cost of $1,390,000 for 389 properties. Maps illustrating probability of feral swine damage indicated the greatest risk was on the southeast side of the state (Fig 7).

Figure 7: Percent of Property Acreage Susceptible to Damage

Risk Index

Cemeteries   Golf Courses
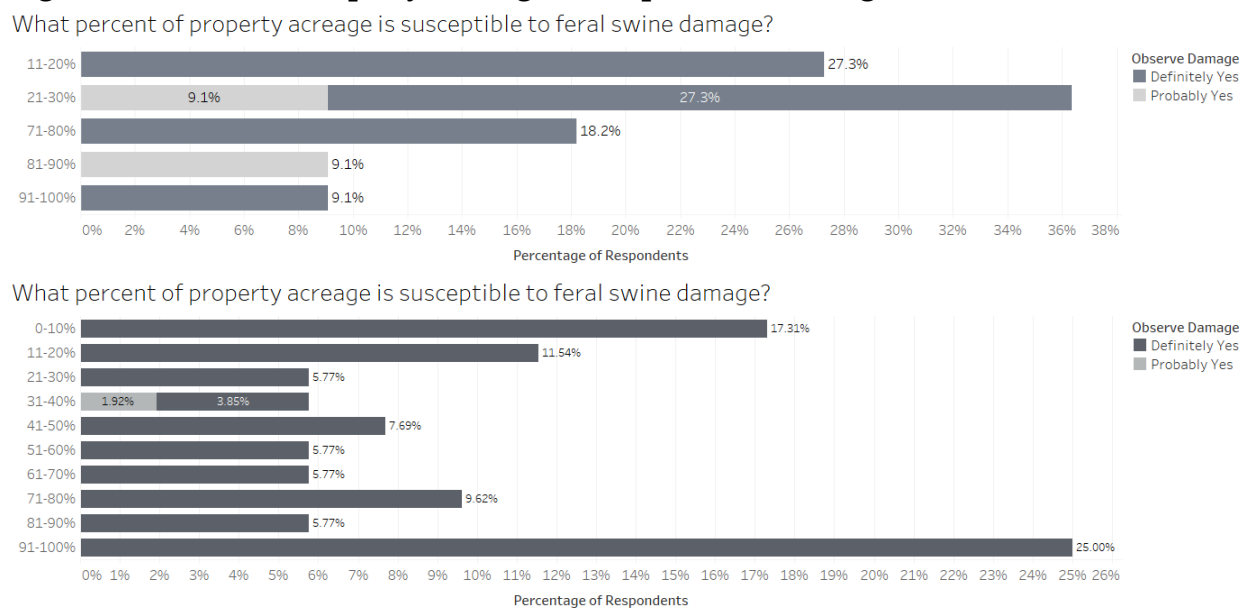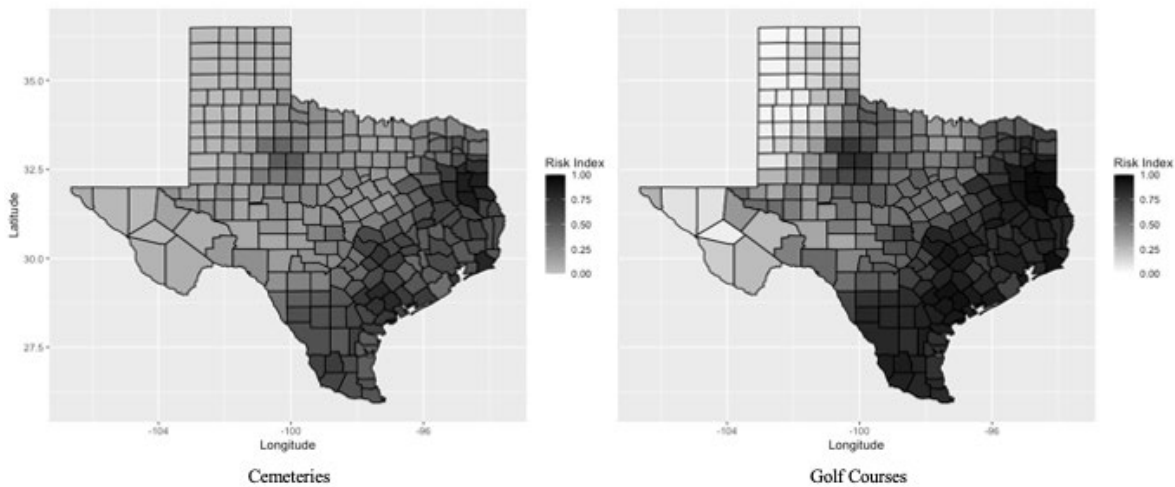
Discussion

While feral swine are increasingly recognized as a serious threat to agricultural land and wildlife habitat, this paper provides the first estimate of damages to two types of land uses that are not commonly recognized as at-risk by this invasive species. Respondents reported most damage to vegetation, greens, and other landscaping, and less damage to structures. As a result, most repair costs accrued to repairing or replanting sod. Regression analysis revealed the expected positive relationship between damage and feral swine density. The analysis also showed that counties with more months of above average temperatures were more likely to experience damage, perhaps because feral swine seek out the irrigated grounds of these properties when temperature rises. Cemeteries are less likely to experience damage than golf courses possibly because they are almost always fenced and are typically smaller. Possibly for the same reasons, more golf course respondents reported 91-100 percent of their property at risk from feral swine than cemetery respondents. Golf courses may also report damage more often than cemeteries because they are more consistently managed so damage is more likely to be noticed.

The total cost of damage to these property types is estimated to exceed $1.6 million annually in Texas. This is a conservative estimate, since it does not include damage mitigation costs. Certainly, there are more golf course and cemetery properties in Texas than were in our mailing list. The estimate also omits the diminished visitor experience to golfers and cemetery visitors, which could translate into loss of revenues for golf courses. Moreover, because Texas' future climate is likely to feature drier summers and decreasing water supplies for much of the state for the remainder of the 21st century (Nielsen-Gammon et al. 2020), we can expect damages to increase over time.

This work should be followed by further research into other non-traditional areas in the United States, such as roadways and parks, including the estimation of willingness to pay for

mitigation strategies aimed at reducing wild pig damages. Special attention should be given to the areas that receive extra run-off or irrigation and create green spots in arid climates. The work supports efforts to broaden the interest groups involved in funding the removal of wild pigs and changing policies to limit their spread.

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	Appendix A. What management advice do you have for other land managers dealing with feral swine?
Cemetery	Trapping is by far the best.
	Once we put up a commercial 6" chain link around the back of our cemetery they never came back in. So fencing is what I would say is the best.
	Take measures ASAP because they get bad quickly.
	We were about to call in some hunters to help, but then trapped 17 hogs in one corral trap with a guillotine trap door. The box trap has only caught a couple. Game cameras are a must.
	Hunt & kill. Do not use poison, trap & kill.
	Use game cameras to help learn their patterns to make it easier to hunt/trap.
	Get a reputable trapper/hunter on the property overnight during peak season. Remove as many as possible before the sows deliver.
	Keep areas of brush and high grass well-trimmed. Maintain exterior fencing as well as possible.
Golf Course	Remove/exterminate as quick as possible they multiply fast.
	Try to use every tool available to pattern them as much as you can. Patience and persistence are key because hogs do whatever they want. They are also intelligent and trainable.
	If possible control moisture level in soil. Treat for grubs if possible, observe surrounding areas and talk to other surrounding properties to see if they have observed any feral swine and what they are doing about it.
	Nutsedge+Grub control.
	Rake up all acorns if possible. Kill all grubs if possible. Spray herbicides to eradicate nutgrasses + kylenga.
	Kill them all.
	Hunting + Trapping
	Keep them out of property at all costs.
	Hunting with fogs and killing the feral swine has been our best action taken at this time. Trapping has not been as successful. Don't wait to take an action.
	Eliminate access to creek and river bottoms.
	As soon as you see damage, have someone out there the next night to hunt. Eventually, the hogs will be trained to avoid your property.
	The best way to disrupt wild hogs is to continually have hunters or trappers be present.
	Food source provided in acceptable area, add traps, then hunt.
	Stay active and constant. Help your adjoining properties.
	Trapping tends to be very effective.
	Hunting with dogs has been more effective than any other method.
	Treat your property for the insects and weeds that the hogs are seeking.
	Be proactive and persistent in trapping, hunting, or other measures.

Identify what feral swine are food sources they are rooting for and take preventative steps to control those food sources. Such as grubs, nutsedge tubbers. In rural areas without topography challenges, a 2-strand electric fence can work with high success rate. In populated city areas using dogs to catch feral swine would be best yet the trained dog owners have told me it is to high risk for the safety of the dogs because they could pursue the feral swine into private property.

Dogs seem to be the most effective in keeping them off the golf course, but you have to almost have hunters every night, which is not cost effective.

Our facility is on an Air Force Base. Obviously, the entire base is protected by various types of fencing that is constantly monitored and well maintained. While we do have unexplained damage to the course, I do not believe this to be swine due to the fence. I have yet to see any swine on the base. If possible, I'd recommend protecting the property with fencing.

Keep a trap available and managed.

For us, fencing and a trapping service with remote monitoring has been successful in our urban environment. when using fence, leave open a portion of the fence to create a pinch point in which you can direct them towards the trap. Be quick to relocate traps when activity is present elsewhere.
I also find it peculiar that they have not disturbed greens, tees or fairways. I was told several years ago by a biologist/trapper that this would be the case. So far it's true.

Use of insecticides to control food source is highly recommended to reduce amount of food available to swine.

Dogs seem to be the most effective, but to be effective, they would need to hunt daily non-stop, which is not feasible. Our property is 3500 acres and fenced but it would take a game fence to keep them out which is to cost prohibitive.

It must be addressed in Texas. Our Ownership and Property Owners Association do a very good job planning each year on feral hog hunting and trapping. We have had only nominal damage to the course over the last 6 years. However, some owners out on the further, more rural edges of the ranch have had massive landscape damage. The plan is to keep them as far away from the course as possible. Basically, trap and hunt the lowlands and congregation points in the less residential areas of the property.

Act quickly as soon as you see evidence of hog damage.

Cameras on the course. When the hogs arrive, the camera sends a picture to an experienced hunter who goes immediately and shoots the hogs.

Be diligent in finding where they sleep during the day. If you can afford it, hire a helicopter hunter to eradicate the herds. We cannot afford this measure.

Traps seem to be the best, but homeowners complain about the cruelty of animals.
Most of the complaints come from non-golfers.

Shoot them all.

Hire a night hunter.

Shoot them.

Dogs are the most effective measure to hunt.

	Fence inside the tree line, and call wildlife authorities to inform them you are having issues. They may come to assist. They may also have recommendations for your particular area and can inform you on why occurrences may be increasing in your area.
	Start eradication measures as early as possible. Do not wait on the problem to come to you, expect it to come and take action even before it does.
	Deal with the issue as soon as possible. Find the most suitable way to eradicate or deter the population from the course.
	Haven't done enough to give advice.
	Get them early!! Don't wait.

	Appendix B. Do you have any additional information on feral swine or suggestions on the survey that you would like to share?
Cemetery	Our damage took place in 2015 at our cemetery. We do see feral rooting near our basketball complex.
	No damage so far at my cemetery.
	If there is any help you can give on eradicating or info would be great.
	Qs #8 I answered several times a week. It may be 2 months before they come back, but they seem to stay for a week or so. Summer is worst when it is very dry because we irrigate so much.
	City owned cemeteries have not looked into any costs yet.
	We're within the city limits inside the loop. No feral swine reported.
	Our property damage happened only once in the spring of 2018, which was not one of the time periods on the survey.
Golf Course	I am a hunter and I understand hunting but until there is no value in feral hog hunting, we will not be able to win the war. It is amazing how those without hog knowledge think it's a "silly game" until they witness the damage and stress these animals cause.
	Local farmers have used helicopter hunting.
	On and around green spray a chemical that will kill grubs. Grubs attract feral swine.
	Eliminating the need for a hunting license is a good start but it's an access problem. No one is going to pay a landowner hundreds of dollars to help them with their so-called "problem". If landowners really wanted them gone, hunts would be free.
	The golf course I manage is in an urban area with lots of housing. I have not seen any swine in 9 years, but I would not be surprised if they show up at some point.
	Please develop/approve a poison that can be used. No present methods will ever eradicate this epidemic.
	Armadillos cause similar damage as far as cost goes.
	Amount of acreage damaged would be good to know.
	Consideration should be given to legalizing the poison used in Australia.
	Control the food source and never let them get comfortable being on the property.
	Drastically impacts the value of the course... lower the property taxes.
	Thank you for doing this. The dry weather and new construction have them on the move. They have nowhere to go and they need water. Golf courses have water!