Research article

Using an online survey to assess the spatial distribution of wild boar (*Sus scrofa* L.) crop damage and factors influencing this distribution and severity in Limburg province, Belgium

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Abstract. Wild boar (*Sus scrofa* L.) reappeared in Flanders (northern Belgium) in 2006 after almost half a century of absence. Interactions between wild boar and human activities are frequent due to extensive fragmentation of the landscape in Flanders. Complaints about agricultural damage are increasing but the actual extent of crop damage remains unknown. The goal of this study was to assess the current risk and the spatial distribution of crop damage, as well as factors influencing damage distribution in the province of Limburg (eastern Flanders). An online survey was sent to farmers by email. Moreover, as we expected potential respondent bias towards farmers that already experienced damage, we also conducted a follow-up non-respondent check by telephone. Our study showed that the current crop damage probability on a farm lies between 42% (likely an overestimation due to respondent bias in the online survey) and 22% (an underestimation based on the non-respondent check). There is considerable geographical variation in the proportion of farms that report boar damage; probability for crop damage due to wild boar is relatively high for farmers in Limburg but shows a geographically heterogeneous spread. Factors explaining the crop damage probability differed strongly between the online survey and the non-respondent check and no consistent results could be found. Our results show that using the online survey, it was possible to get an initial insight in the geographical distribution of crop damage. However, as we found differences between the results of the online survey and the non-respondent check, taking management decisions based solely on online survey results without conducting a non-respondent check could lead to misguided actions.

Keywords. Human-Wildlife Conflict, online survey, damage probability, respondent bias.

Introduction

The success of many wildlife populations depends on their capacity to coexist with humans (CARTER & LINELL 2016). Resolving human-wildlife conflicts is therefore seen as a major challenge for conservation (TREVES *et al.* 2006). Species that re-establish in their former distribution area can typically be a source of conflict due to human safety risks or damage to crops, livestock, buildings, infrastructure, gardens, cars, etc. (TROUWBORST 2010). One such re-established species causing conflicts in Europe is the wild boar, *Sus scrofa* (Linnaeus, 1758; Mammalia, Chordata). Wild boar populations have been increasing all over Europe since the 1960s (SAEZ-ROYUELA & TELLARIA 1986; BIEBER & RUF 2005; ACAVEDO *et al.* 2007) and their expansion is still ongoing in most European countries (MASSEI *et al.* 2015). A combination of environmental and agricultural changes have triggered the revival of the wild boar, mainly due to 1- increased piglet survival due to rising winter temperatures and 2- a lower age of first reproduction and increased average litter size related to increasing food availability. The latter factor is caused by more frequent mast years, agricultural intensification, decrease of grasslands and an increase in rapeseed and maize cultivation (MASSEI *et al.* 2015; MORELLE *et al.* (2016).

The return of wild boar to Flanders (the northern part of Belgium) since 2006, after more than half a century of absence, rapidly developed from a few sightings to a now settled population. This is in line with the observed expansion in the rest of Europe (SCHEPPERS *et al.* 2014) and is of interest because of the intense intertwinement of urbanised, agricultural and natural areas leading to close contact of wildlife with human activities. Flanders is currently one of the most densely populated areas in Europe (462 persons per km²) (LINELL *et al.* 2001). Forests represent a mere 11.4% of the total surface area (CASAER & LICOPPE 2010; DEMOLDER *et al.* 2014) and the dense road network (5.2 km/km²) results in highly fragmented natural areas.

The key to successful wildlife management is to include both ecological and human dimensions (KEULING *et al.* 2016) into the decision making process in order to achieve positive impacts that are valued by all stakeholders (RILEY *et al.* 2003). This is particularly true for the management of conflict species such as wild boar. Wild boar impacts can result in large costs and can be unacceptable for multiple stakeholders, with crop damage (including rooting in grasslands) as the primary impact (CAHILL *et al.* 2012). In the Netherlands, France, Luxembourg and Wallonia (Southern Belgium), the economic impact of crop damage by wild boar can be large (SCHLEY *et al.* 2008; CARNIS & FACCHINI 2012; FAUNAFONDS 2014; WIDAR & LUXEN 2016). In Flanders, compensation for wild boar damage is only paid by the authorities in the exceptional case where damage is done by wild boar originating from a nature reserve or forest where there is no hunting or culling program. In all other cases the hunter himself is responsible for paying for damage directly to the farmer. One of the consequences is that currently there is no centralised database covering damage paid annually. During annual meetings of wild boar management units, the need for better knowledge on the current extent of wild boar damage is stressed consistently by both farmers and hunters as well as nature administrators. Consequently there is an urgent need for a first assessment of current wild boar damage risk, its geographic distribution and factors driving it.

In this study, we aimed to assess:
– the probability of a farmer suffering wild boar damage given the current distribution of wild boar in Flanders.
– the spatial distribution of damage probability and factors influencing this distribution.

For this purpose, an online survey was implemented. Online surveys related to wildlife issues are used extensively as they can be easily implemented and they provide almost immediate results (STONE 1973; FREDERIK 1998; MOORE *et al.* 1999; REITER *et al.* 1999; LARD *et al.* 2002; SIGNORILLE & EVANS 2007; WHITE *et al.* 2005). Online surveys are also an inexpensive data-collection method (DUDA & NOBILE 2010; SEXTON *et al.* 2011) and sending an online survey by email allows for flexibility as respondents can participate when it is convenient (EVANS & MATHUR 2005). Moreover, online surveys allow for direct data transfer into databases, eliminating manual input from questionnaires (EVANS & MATHUR 2005; LEFEVER *et al.* 2007). However, online surveys also present some drawbacks that call for caution.

Sample validity, respondent and stakeholder bias and unverified respondents could all lead to inaccurate, unreliable and biased results (WHITE *et al.* 2005; DUDA & NOBILE 2010; EVANS & MATHUR 2005, LEFEVER *et al.* 2007). Respondent bias occurs when the population of non-respondents differs from the respondent population. In this study respondent bias could have important consequences if farmers who had already suffered crop damage were more keen to respond than those that did not. Therefore we also conducted a non-respondent check.

Material and methods

Study area

At the onset of this study in 2015, the distribution of wild boar in Flanders was mostly limited to the province of Limburg (Fig. 1), i.e., the eastern part of Flanders near the Dutch border (SCHEPPERS *et al.* 2014). The geographical scope of this study was therefore limited to Limburg. With 23.6% of its surface area covered by forest, Limburg is the most forested province in Flanders (DEMOLDER *et al.* 2014; MOORS 2014), although still highly fragmented. Arable land in Limburg is dominated by maize (44.7%), grassland (32.3%) and cereal crops (23.0%) (Flanders: 40.8% - 38.0% - 21.2%) (report Federale Overheidsdienst Economie (FOD) 2015).

Data collection

Online survey

The online survey was conducted in collaboration with Boerenbond, the largest cooperative farmers' organisation in Flanders, who provided farmer contact details. Of the 2824 farmers in Limburg (data STATBEL), 1282 are members of Boerenbond, 904 of whom had a known email address. Since we expected no correlation between damage probability, Boerenbond membership and whether or not an email address was known, we assumed the sampling population as representative for the total Limburg

Fig. 1 – Study province of Limburg (dark grey), in the Northern part of Belgium (Flanders, light grey). Dashed lines: distribution area in Flanders of wild boar in 2014 (from hunting bag data (SCHEPPERS *et al.* 2014).

farmer population. In order to avoid an unverified responder bias, typically linked to an open access online survey, we sent farmers a personal invitation using their email-address to participate. All farmers with a known email address received the online survey invitation in March 2015. Reminders were sent after one and after two weeks to increase the response rate. The survey consisted of eleven questions (see Appendix) and was estimated to take about 10 minutes to complete. Only the answers to three questions (damage/no damage, municipality and farm size) were used for this research.

Non-Respondent check

In our study we acknowledged the possibility that farmers who had suffered crop damage would be more keen to respond than would those who had not. Moreover, a non-respondent check should always be conducted in cases where low response rates are expected (Duda & Nobile 2010; Sexton *et al.* 2011). Therefore, for each of the 43 municipalities, we randomly selected three farmers among the non-respondents from the online survey, contacted them by telephone and asked two questions from the questionnaire used for this study (damage/no damage and farm size).

Statistical analysis

All analyses were performed using R software R CORE TEAM (2016).

Survey sample

A series of Kendal rank correlation tests were conducted. Firstly to control whether the distribution of the farmers who received the online survey matched the distribution over the different municipalities of the target population (all farmers of Limburg). Next, we tested the spatial representativeness of our respondents to the online survey by comparing the distribution over municipalities of respondents and the distribution of the entire Limburg farmer population. Also the distribution of farm sizes of the respondents was compared to the total distribution of farm sizes in the province of Limburg.

Damage probability and its spatial distribution

Damage probability was defined as the proportion of farms that had experienced damage over the total number of farms per municipality and these values were displayed on a map to visualise spatial patterns. We conducted a Chi-square test to see whether damage probability differed between those who answered the online survey and the participants of the non-respondent check.

Factors influencing crop damage probability

The following analyses were done both for the online survey and for the non-respondent check. Doing this parallel analysis, we were able to assess a potential respondent bias and its impact on our findings.

To explore the factors influencing crop damage probability, apart from farm size (which was included as an offset factor to account for size effects) and the random effect of municipality, four additional potential explanatory factors were selected (Table 1).

Forest cover was included as wild boar is a forest-dwelling species (Briedermann 1990). Previous research has also shown that forest cover influences wild boar distribution (Morelle *et al.* 2016) and serves as a good predictor of crop damage (Ficetola *et al.* 2014; Lombardini *et al.* 2016). The percentage of arable land (agriculture cover) was included as it has been shown to be the most important factor next to population density and forest edge length in modelling crop damage probability (Bleier *et al.* 2012). There are various suggested methods to estimate population densities of wild boar (Focardi *et al.* 2001, 2002; Massei *et al.* 1997; Acevedo *et al.* 2007), however finding a reliable method to estimate population densities at the municipality scale remains difficult (Scheppers & Casaer 2012; Engeman *et al.* 2013). We therefore included both the number of years in which wild boar were shot in a given municipality over the period 2007–2014 (Scheppers *et al.* 2014), and the number of wild boar shot in that period, as proxies for the abundance of wild boar. We consider these proxies as reliable given

TABLE 1

Potential factors influencing crop damage probability.

Variable	Abbreviation	Description
Crop damage	CD	Did farmers experience damage (Yes-No)
Farm size	FS	Three categories such as used in the survey: 0-40 ha, 40-60 ha, >60ha
Municipality	MUN	Municipality in which most of the cropland of the farm is situated
Forest cover	FC	Percentage of forest cover per municipality (mean = 21.1%, SE = 13.1%)
Agriculture cover	AC	Percentage of agriculture cover per municipality (mean = 43.5, SE = 20.8)
Years of hunting of wild boar	YH	Number of years in which wild boar were shot in a municipality over the period 2007 – 2014 (mean = 2.74, SE = 0.15)
Number of wild boar shot	NS	Log (x+1) of number of wild boar shot over the period 2007-2014 (mean = 11.9, SE = 1.9)

that no temporal or spatial variation of culling or hunting effort was expected, no quotas for wild boar hunting exist, no large areas are exempted from hunting, and hunting takes place year-round.

We screened these four potential factors for collinearity combining Variance Inflation Factors (VIF) (FOX & MONETTE 1992) in which we allowed a maximum VIF value of 2 and a correlation of which we set the maximum at 0.7. This revealed that forest and agriculture cover were strongly negatively correlated. We opted to select forest cover in further analysis following the findings of (FICETOLA *et al.* 2014; LOMBARDINI *et al.* 2016). The number of years in which wild boar were shot and the number of animals shot were also highly correlated. We opted to include the number of wild boar shot as a factor in the model based on the fact that the number of years wild boar were shot showed the highest VIF (VIF = 5.19). The remaining factors forest coverage and number of wild boar shot had VIF values below 2 and a correlation below 0.7.

We defined four linear mixed effect models for crop damage probability (Table 2). All models included farm size as an offset factor and the random effect of municipality. Model 1 was the null model in which no additional factors were included. In models 2 and 3 we additionally included forest cover or the number of wild boar shot respectively. Finally, in model 4, the full model, both forest cover and the number of wild boar shot were included.

AIC values (Akaike Information Criterion) HU (2007) were used for model selection: in cases where the AIC values between two models differed by more than 2, the model with the lowest AIC values was selected as the best model. Effect size (mean divided by standard error) was calculated for each covariate in the final model. When the online survey and the non-respondent check would have comparable results, the AIC values should return the same a priori model, and the influence of covariates should be comparable.

Results

Survey sample

Of the 904 farmers contacted, 182 (20%) completed the online survey and an additional 122 farmers were contacted by telephone for the non-respondent check.

TABLE 2

Four *a priori* models. All models include Farm Size (FS) as an offset variable and the random effect of municipality (f_{MUN}). Covariates Forest Cover (FC) and number of wild boar shot (NS) are also included in hypothesized model 2, 3 and 4.

Hypotheses	Model structure
Model 1	$CD \sim FS + f_{MUN}$
Model 2	$CD \sim FS + FC + f_{MUN}$
Model 3	$CD \sim FS + NS + f_{MUN}$
Model 4	$CD \sim FS + FC + NS + f_{MUN}$

The correlation coefficient between the spatial distribution of the total population of farmers over the different municipalities in Limburg and the one of the members of the Boerenbond who received the survey was 0.95 (p<0.001). The correlation coefficient between the total population of farmers and farmers who responded to the online survey was 0.65 (p<0.001). The distribution of farm sizes among the online survey respondents was not correlated with that of the total population of farmers (-0.84, p>0.05) as survey respondents included mostly smaller farm sizes.

Damage probability and its spatial distribution

We found that 42% (76 out of 182) of the respondents to the online survey reported damage, whereas only 22% (27 out of 122) of the non-respondents reported damage. Damage probability differed significantly between the two groups of respondents (online survey and non-respondent check) (chi-
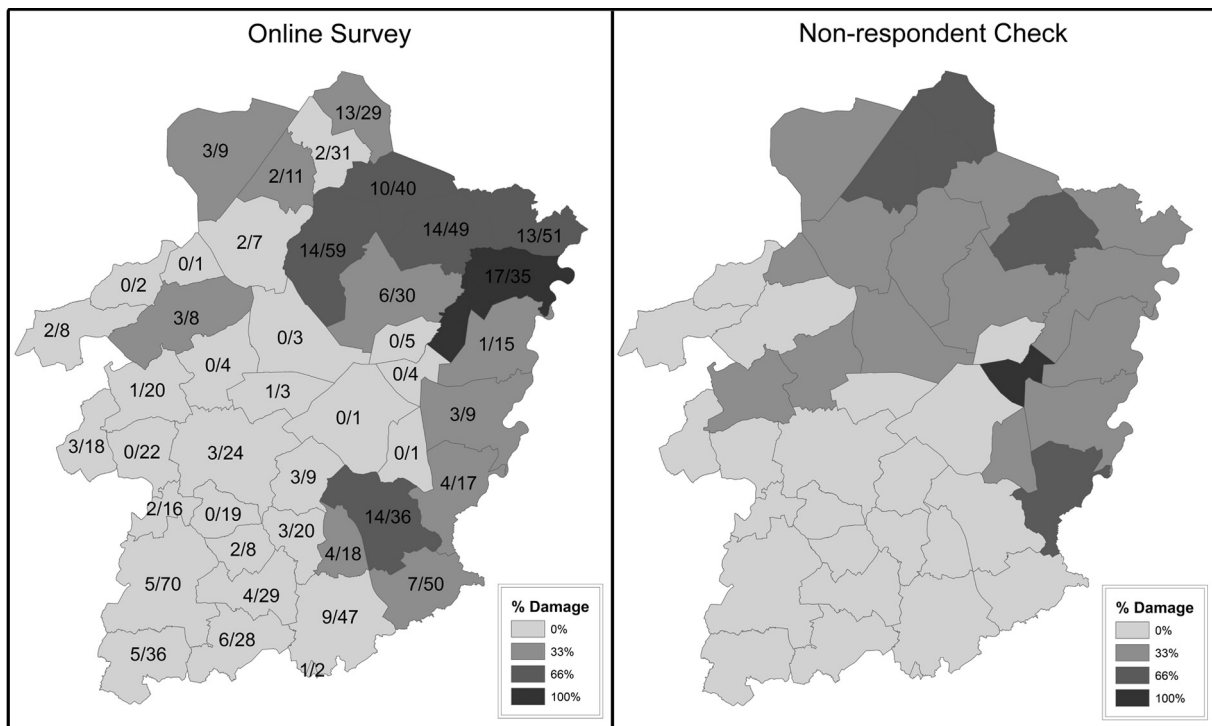

Fig. 2 – Spatial distribution of reported damage probability. Left: overview of number of farmers who responded to the online survey/who received the online survey; grey scale gradient represents percentage of reported damage. Right: percentage of damage reported in the non-respondent check with three contacted farmers per municipality.

TABLE 3

Model selection. AIC (Akaike Information Criterion) and p-values of Log likelihood Test for all four *a priori* hypotheses. * is the selected model.

Hypotheses	Online survey		Non-respondent check	
	AIC	p-value	AIC	p-value
Model 1	201,13		115,77	
Model 2	194,56	0,003	102.16*	<0.001
Model 3	180.99*	<0.001	108,84	1
Model 4	182,94	0,81	103,84	0,008

square test, p<0.001). Therefore, spatial distribution maps were made separately for the online survey and the non-respondent check (Fig. 2). The highest reported damage prevalence was found in the north of the province of Limburg, according to both the online survey and the non-respondent check. Southern municipalities showed low to no damage probability.

Factors influencing crop damage probability

The model selection results are shown in Table 3. For the online survey, model 3 (including number of boars shot) was the most informative (lowest AIC value); for the non-respondent check, this was the case for model 2 (including forest cover). However, in both cases, the difference in AIC-values with model 4 (combining farm size with both hunting and forest cover) was very small (<2) so the quality of that model is not significantly lower but model 4 showed forest cover to be non-significant for the online survey, and number of boars shot to be non-significant for the non-respondent check. Therefore, model 3 was selected as the best model for the online survey and model 2 for the non-respondent check.

Damage probability increases as farm size increases for both the model of the online survey and the non-respondent check, confirming our size effect expectation (Table 4). For the online survey the number of boars shot was positively correlated with damage probability. The model for the non-respondent check showed increasing damage probability with increasing forest cover.

Predictions based on the final models (for intermediate farm size (40–60 ha), Fig. 3) show that according to the model from the online survey, the predicted crop damage probability increases considerably with
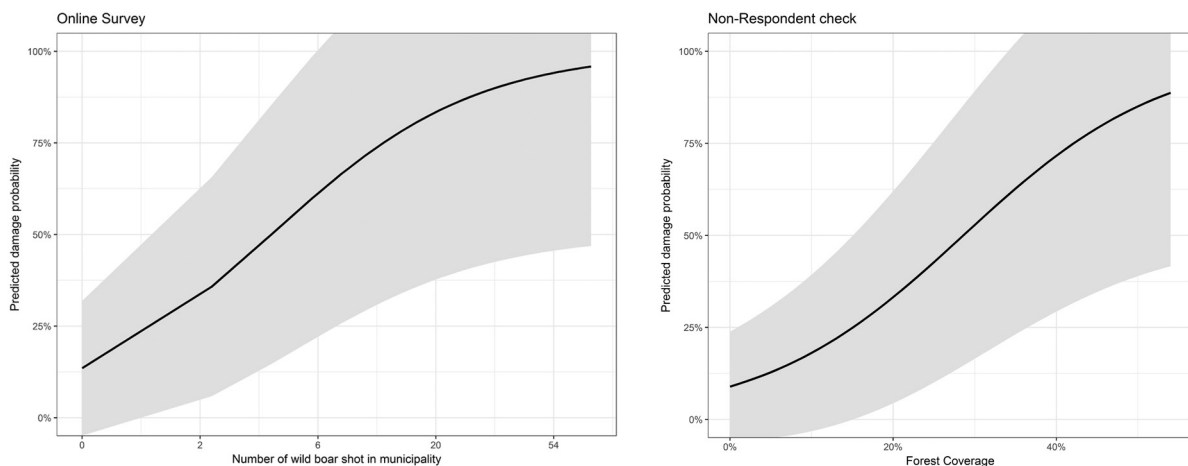

Fig. 3 – Prediction for damage probability based on final model of the online survey (left) and of the non-respondent check (right) for intermediate farm size (40–60 ha).

TABLE 4

Model parameters of model 3 for the online survey and model 2 for the non-respondent check: Mean, standard error (SE), confidence intervals and effect size of the fixed effects describing the relationship between crop damage, farm size (FS), forest cover (FC) or number of wild boar shot (NS). * are significant parameters, p-value < 0.05.

	Online survey				Non-respondent check			
	Mean	**SE**	**Effect size**	**p-value**	**Mean**	**SE**	**Effect size**	**p-value**
Intercept	-3,25	0,76	4,28	<0.001*	-4,56	0,83	5,49	<0.001*
Farm Size:								
FS 40-60 ha	1,39	0,5	0,28	0.005*	2,23	0,69	3,23	0.001*
FS >60 ha	1,44	0,55	2,62	0.009*	2,14	0,68	3,15	0.001*
Forest Coverage (FC)	/	/	/	/	0,08	0,02	4	0.01*
Number wild boar shot (NS)	1,16	0,29	4	<0.001*	/	/	/	/

a higher number of boars shot. According to the model from the non-respondent check, the damage probability curve increases with forest cover.

Discussion

As the socio-cultural context of wildlife management has changed in recent decades (RILEY *et al.* 2003), successful wildlife management more than ever implies including both ecological as well as human dimensions (KEULING *et al.* 2016). With wild boar causing more and more human-wildlife conflicts in Flanders, there was a need for a fast and simple method to collect information on the most important impact: crop damage. By using an online survey we aimed to gain an initial overview of the actual damage levels and their spatial distribution in the province of Limburg, Flanders.

Damage probability according to the online survey was 42%, whilst the non-respondent check returned a lower damage probability of 22%. We assume actual damage probability to be situated between these two values. As we consider farmers who already suffered crop damage to be more keen to respond than those that did not- introducing a respondent bias- we believe that the online survey resulted in an overestimation. However, we also consider the non-respondent check to be an underestimation as the surveyed population of this non-respondent check is based on farmers who did not respond to the online survey and consequently excludes those farmers who already experienced and reported crop damage using the online survey.

We consider the correlation between the spatial distribution of the online survey respondents and of the total farmer population high enough to be spatially representative of the population of interest. Both the online survey and the non-respondent check show a clear spatial differentiation of the crop damage risk within the province with northern municipalities showing higher damage probabilities compared to southern municipalities. These findings illustrate the usefulness of an online survey -although generally overestimating damage probability- to get a quick scan of the actual spatial distribution of damage in a region when no other information sources are available. These results on spatial distribution of crop damage were therefore used in the research of RUTTEN *et al.* (2018) to delineate a study area in which damage cases were photographed to develop a drone based method to objectively assess damaged area in a field.

The online survey and the non-respondent check models resulted in divergent conclusions with respect to factors explaining the crop damage probability. According to the online survey the number of wild

boar shot can best explain damage probability while forest cover was not included in the final model. However, the model of the non-respondent check showed a clear positive effect of forest cover on damage probability and the effect of the number of wild boar shot was not retained in the final model. These opposite findings made us conclude that our approach does not allow any reliable conclusions to be drawn for this question.

Possible explanations for the opposite findings of the models may be our small sample size on the one hand and the correlation between forest coverage and the number of wild boar shot on the other hand; or a combination of both elements. The relation between increasing wild boar numbers with increasing forest coverage has been found in previous studies (BIEBER & RUF 2005; MELIS *et al.* 2006). In our study, the correlation between forest coverage and number of wild boar shot was 0.68. Given that this value is smaller than the set threshold value of 0.7 used for eliminating variables from the model building, both variables were included as factors in the model selection. Regarding the small sample size, we needed email addresses and telephone numbers of farmers, thus the collaboration with farmers' organisation Boerenbond was essential. This resulted in a total of 904 email-addresses, equalling 32% of the total farmer population in Limburg. However, we only achieved a response rate of 20% for the online survey.

While the goal of surveys like ours is to collect information beneficial for efficient management of human–wildlife conflicts (BROWNE-NUNEZ & JONKER 2008), authors too often ignore the problem of respondent bias. According to a review on surveys in ecology by WHITE *et al.* (2005) only 12.5% of surveys included any form of non-respondent check. Studies like that of BARKER (1991) who did conduct such a check on the scope of hunter harvest of waterfowl in New Zealand, found that harvest estimates were about 20% higher according to respondents when compared to non-respondents; obviously, this can have large implications when bias is not accounted for when setting up survey-based harvest quotas. Potential consequences of not validating respondent bias also became clear in the present study: not only did factors influencing the spatial distribution differ between the online survey and the non-respondent check models, but we also found an overall higher damage probability according to predictions of the online survey model compared to the non-respondent check. This can lead to misguided conclusions and therefor misinformed decisions on management actions should they be based on these results only.

Conclusions

 Using the online survey followed by a non-respondent check, we found clear spatial differentiation of crop damage risk within the province of Limburg; the online survey and the non-respondent check concurred in the geographic distribution of this risk. However we could not determine unambiguously the factors influencing damage probabilities as we found opposite results between the online survey and the non-respondent check. For future studies we recommend caution with the use of online surveys, certainly in cases where the risk for a low response rate is high. We suggest a focus on increasing sample size as much as possible. This can be achieved by providing rewards for completing the survey, persuading respondents that their responses will be used, providing frequent reminders, keeping the survey short or enhancing the survey with visual elements (NULTY 2008; DEUTSKENS *et al.* 2004). However, we want to stress that at all times a non-respondent check should be conducted to assess the validity of online survey results.

Acknowledgements

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Appendix

Online survey

1. **In which agricultural sector is your farm situated?**
   - a. Cattle farming
   - b. Pig farming
   - c. Chicken farming
   - d. Arable farming
   - e. Fruit culture
   - f. Vegetable cultivation
   - g. Floriculture
   - h. Others

2. **In which municipality is the largest part of the farm situated?**
   Fill in

3. **What is the total surface of your farm?**
   - a. 0 – 10 ha
   - b. 10 – 20 ha
   - c. 20 – 40 ha
   - d. 40 – 60 ha
   - e. More than 60 ha

4. **Do you have crops which can be sensitive for wild boar damage (grasslands are regarded as crops)?**
   - a. Yes
   - b. No

5. **Did you already experience damage by wild boar?**
   - a. Yes
   - b. No

6. **Which crops have already been damaged?**
   - a. Grassland
   - b. Wheat
   - c. Rye
   - d. Barley
   - e. Triticale
   - f. Oats
   - g. Maize
   - h. Sugar beets
   - i. Potatoes
   - j. Fodder beets
   - k. Other

7. **What is the damaged surface for each of the damaged crops?**
   Fill in

8. **Did you already take preventive measures to prevent damage from wild boar? And which ones did you take?**
   Fill in

9. **Did you already request damage compensation?**
   - a. Yes
   - b. No

10. **Why did you not request damage compensation?**
    Fill in

11. **Score the following statements**
    a. **I would take preventive measures because:**

	I totally agree	I agree	Neutral	I do not agree	I totally do not agree
I think the damage compensation in Flanders is insufficient					
I don't think the current hunting pressure has a positive effect on the population					
Wild boar numbers and damage will increase					
Investing in preventive measures is advantageous					
I don't have to worry about future damage					
I can prevent discussions with hunters and other farmers					

   b. **I don't take preventive measures because:**

	I totally agree	I agree	Neutral	I do not agree	I totally do not agree
There are no wild boar in this area					
There is no damage in this area					
The investment is too high compared to the damage					
Measures should be taken by hunters, not by farmers					
Measures should be taken by owners of nature areas, not by farmers					