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Environmental Quality and Compliance with Animal Welfare Legislation at Swedish Cattle and Sheep Farms

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Abstract: Conflicts between different goals can obstruct progress in sustainability, but interests may also coincide. We evaluated relationships between environmental quality and animal welfare on Swedish farms with grazing livestock, using publicly available databases. Data were collected from 8700 official animal welfare inspections on 5808 cattle farms and 2823 inspections on 2280 sheep farms in 2012–2017. Compliance with three animal-based checkpoints was modeled using logistic regression, including a random farm effect to account for repeated inspections. Compliance was regressed on semi-natural grassland area, participation in the National Meadow and Pasture Inventory, Agri-Environmental Scheme (AES) grassland payments, presence of indicator plant species, and the presence of Natura 2000 habitats. Cattle farms complied more often if they received AES payments for grasslands of special values compared with if they did not apply for them (OR = 1.55–1.65; $p \leq 0.0001$) and there was a similar tendency for cattle farms that applied for but were denied such payments (OR = 1.29; $p = 0.074$). There was also a strong tendency for Natura 2000 habitats on cattle farms to be associated with higher compliance (OR = 1.36; $p = 0.059$). These results suggest a direct or indirect causal effect of biodiversity on cattle welfare. The same associations could not be shown in sheep.

Keywords: biodiversity; farm animal; grassland; meat production; pasture; sustainability

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1. Introduction

Discourse on environmental, social, and economic sustainability is widespread across the public and private sectors and at different levels of society, both regionally and globally. Concerns arise about the impact of agriculture on, for example, biodiversity, public health, and animal welfare [1–7]. Regulatory requirements, societal desires, and market demands change and increasingly require that farms are monitored for the impacts of their production on issues such as food safety, environmental values, and animal welfare [8].

There are sometimes conflicts when trying to achieve several different sustainability goals simultaneously, which is demonstrated by the different indicator-based methods that have been developed to assess sustainability in a holistic way [8–12]. The widely used tool Sustainability Assessment of Food and Agriculture (SAFA) [11], not only includes the environmental dimension, but also sustainability performance for economy, social (including animal welfare), and governance dimensions. Conflicts of interest and conflict resolution are discussed; yet, it is not identified where these conflicts occur. Comparative studies on environmental performance in egg and dairy production systems, for example, showed that the systems perform differently for different sustainability indicators [13–16].

It, therefore, matters which sustainability issue is emphasized and which indicators are used. Assessment gets even more complicated when issues and indicators of several sustainability domains (such as social and economy) are involved [17]. For example, conflicts might arise when trying to maintain a good body condition of the animals when no additional food is provided and they are expected to graze less nutritious shrubs or wetland vegetation. This can lead to a polarized debate about which sustainability goals are the most important, and hamper progress in the area.

On the other hand, interests can coincide and even create synergies, although this is less often discussed. For example, improvements in animal health, welfare, and longevity, or more efficient production, are likely to have positive effects on the environment [18–21] and farming profitability [22–24]. Such win-win situations could be targeted more effectively to speed up progress for both goals.

Recently developed innovative husbandry systems often take different aspects of sustainability into account [25,26], but the majority of animal production systems are traditional and may be more or less good in the different areas [13,27–29]. In addition to these inherent limitations of animal production systems, landowners and farmers themselves may vary in their management, making it difficult to predict sustainability results even when regulations on infrastructure design and management are enforced.

Swedish Agri-Environmental Schemes (AES) under the European Union's (EU's) Common Agricultural Policy [30] provide information about payments to protect the environmental values of semi-natural grasslands on individual farms. The data are available in the AES subsidies database [17]. The two main categories of grassland AES concern general or special environmental values. General values describe the basic AES level for all grasslands. Management prescriptions for grasslands with special values are more detailed and demanding with regard to landowner engagement compared to general values. Grasslands with special values often have vascular plant communities that include red-listed species and indicate long continuity of high grazing levels and unimproved grass swards. Landowners can also apply for, and be fully or partly granted, higher-level grassland AES payments (special values or other higher-level AES payments linked to, for example, mountain pastures or buffer zones by water). Grasslands for which the landowner applied but was denied special values are considered to have only general values. Farms with no semi-natural grasslands are not eligible for AES payments linked to special and general values [31].

In addition, Natura 2000 [32] is a network of core breeding and resting sites and habitats for rare and threatened species across the EU. Natura 2000 habitat types are listed in Annex 1 of the EU Habitat Directive 92/43/EEC. These natural habitat types are considered natural or near-natural and of high conservation interest.

There is considerably less data available related to animal welfare. Historically, resource- and management-based measures of animal welfare, i.e., descriptors of the animal environment and management routines, have been used to describe animal welfare [33], but are nowadays seen as more important for assessing the risk of impaired welfare. According to the European Food Safety Authority, animal-based measures, i.e., those relating directly to the physical health, behavior, and mental state of the animal, are considered more valid indicators of welfare [34].

In EU Member States, official animal welfare control is executed by competent authorities, according to the Official Controls Regulation (EU) 2017/625, through inspections of farms and other animal premises to check compliance with current legislation. In Sweden, county administrative boards carry out all animal welfare inspections using standardized species-specific checklists, and each checkpoint refers, in principle, to a separate paragraph in the legislation. Inspections may be conducted for different reasons, for example high-risk animal activities, complaints, cross-compliance inspection, directed campaigns or projects, follow-up of previous violations, or random selection. Following each inspection, the results are reported and saved in the official Swedish Animal Welfare Control Database, as regulated by the animal welfare control register act (SFS 2009:619). The database is administered by the Swedish Board of Agriculture. By an epidemiological approach, Hitchens et al. [35,36] used the register to determine the prevalence of non-compliance with animal welfare regulations, as well as to identify resource- and management-based factors associated with non-compliance with checkpoints concerning animal-based measures in equines, and circus, and zoo animals.

Of particular importance for sustainable agriculture are grazing cattle and sheep. In 2017, there were approximately 1.50 million cattle on 16,700 farms and 606,000 sheep on 9300 farms in Sweden [37]. From 2013 to 2017, the total number of cattle decreased by 2%, while the number of cattle farms dropped by 12%. In the same period, the number of sheep and sheep farms increased by 5%. Consequently, the average herd size increased from 79 to 90 cattle and from 32 to 33 ewes/rams. Official control is risk-based and prioritizes inspections of premises with a high risk of non-compliance, which means that the control frequency varies greatly. Overall, far from all cattle and sheep farms are inspected every year.

With a view to future decisions for improved sustainability in farm animal production, this study aimed to investigate synergies and conflicts between measures of environmental quality and compliance with animal welfare legislation. More specifically, we studied compliance with animal-based measures at official inspections on Swedish cattle and sheep farms. We used data from public databases and chose an exploratory approach, but predicted positive or negative associations between compliance and semi-natural grassland area, participation in the National Meadow and Pasture Inventory, Agri-Environmental Scheme subsidies for special values in semi-natural grasslands, the presence of plant species that indicate long-standing grazing and unimproved grass swards, and the presence of Natura 2000 habitats.

2. Materials and Methods

In this study, ‘animal welfare’ refers to the physical and mental state of an animal in relation to its environment. By ‘environmental quality’, we mean the presence on individual farms of grassland with natural or cultural values.

Land use and environmental quality data linked to the farms’ production place numbers (PPNs) and obtained from the Swedish Board of Agriculture as Geographic Information System shape files, were extracted from the Land Parcel Database [31] 2016, the AES subsidies database 2016, and the Swedish National Meadow and Pasture Inventory [38] (database TUVA) 2017, with polygons delineating arable fields and semi-natural grasslands. Agricultural land was broadly divided into semi-natural grassland and arable land. Semi-natural grassland was defined as land that was not suitable for ploughing, but could be used for grazing livestock, with specific restrictions regarding shrub or tree cover, whereas arable land was suitable for ploughing and growing crops. Grasslands not suitable for ploughing are often described as semi-natural because fertilizers and reseeding are prohibited; however, the level of naturalness varies from very little recent agricultural improvement to borderline cases that are difficult to distinguish from old arable fields [39–41].

Geographical coordinates were translated to PPNs by a separate register, also obtained from the Swedish Board of Agriculture. Land areas were defined as either semi-natural grassland or arable. The land was characterized with regard to the cultivation of cereal crops, oil crops, forage crops (including grass leys), or miscellaneous crops. The total agricultural land area on each farm in the Land Parcel Database was used as a proxy of farm size. Information about the presence of one or more Natura 2000 habitats and the number of vascular plant species that indicated unimproved, semi-natural grasslands were extracted from the TUVA as indicators of environmental quality of farms with grasslands. AES management level was characterized as: (1) applied for general values only, (2) applied for special values, all of which were granted, (3) applied for special values, some of which were granted, (4) applied for special values, none of which were granted, (5) applied for other values only, or (6) no semi-natural grassland in the Land Parcel Database linked to the PPN. TUVA data were obtained for 59% of the farms with cattle inspections and 50% of the sheep farms; remaining farms had no land included in the inventory.

Complete Animal Welfare Control data were obtained from the Swedish Board of Agriculture as Excel files (Microsoft Corp., Redmond, Washington, USA). All cattle and sheep farm inspections from 2012 to 2017 were selected and results were extracted for the only three animal-based checkpoints, which were related to the animals' (1) body conditions (–the animals' body conditions are acceptable), (2) cleanliness (–the animals are kept sufficiently clean), and (3) hoof care (–the animals' hooves are inspected regularly and trimmed as necessary). Farms were identified by their PPNs. In total, 23,019 farm inspections were identified, of which 76% covered one or several of the mentioned checkpoints for cattle, 32% for sheep, and 8.1% for both cattle and sheep on the same farm. For each checkpoint, the result was coded as (1) yes—compliant, (2) no—not compliant, (3) not inspected, or (4) not relevant. Due to the structure of the database and missing data, it was not possible to distinguish the type of production within species, for example cattle kept for beef or dairy production. Nor did the data include herd size information.

All available animal welfare and environmental quality data were merged at the level of animal welfare inspection, using PPN as farm identifier. The merger resulted in data from 10,456 cattle and 3357 sheep inspections, or totally 12,835 inspections on 8138 farms, of which 742 farms had inspections of both species. Merging and subsequent statistical analysis were made in Stata/IC 15 (StataCorp., College Station, TX, USA).

Relationships between different measures of environmental quality at farm level were assessed by Spearman rank correlation. Associations between indicators of environmental quality and compliance with animal welfare legislation were analyzed by mixed-effects logistic modeling. A binary dependent variable was defined to denote compliance at inspection, coded as 0 if at least one of the animal-based checkpoints was non-compliant and 1 if all three were compliant. Inspections where it was not possible to assign a code because there were less than three checkpoints inspected, all of which were compliant, were excluded. Cattle and sheep were analyzed separately (using the combined farms in both analyses). For each species, two models were constructed to evaluate different effects and avoid multicollinearity. Model 1 used all the available observations to test associations with semi-natural grassland area, percentage TUVA land, and type of AES, while Model 2 used the subset of inspections of farms with TUVA land to test relationships with indicator plant species and Natura 2000 habitats (Table 1).

When building the models, the independent variables were divided into three categories, following the recommendations of Dohoo et al. [42]: (1) Primary predictors, which were the studied effects, relating to study predictions, (2) *A priori* confounders, which were known influential factors assumed to improve the models and most likely confound the studied effects, and (3) Potential confounders, which may or may not have confounded the studied effects (Table 1). Primary predictors and *a priori* confounders were forced into the models, while potential confounders were included only if significant at $p \leq 0.05$ or found to confound a primary predictor, as indicated by a >10% change in a regression coefficient when they were excluded. Primary predictors were land area with semi-natural grassland, percentage of TUVA land, AES values, average number of indicator plant species, and the presence of Natura 2000 habitats. Continuous variables were categorized with four roughly equally sized levels to handle nonlinear relationships. In all models, farm identity was included as a random intercept to account for clustering.

Table 1. Independent variables [1] considered in two mixed-effects logistic models [2] of the probability of complying with three animal-based checkpoints at official animal welfare inspections on Swedish cattle and sheep farms.

Variable Description	Levels	Model 1	Model 2
Semi-natural grassland area	*0–1; >1–5; >5–15; >15 ha*	Primary	*A priori*
TUVA land percentage [3]	*0; >0–3; >3–12; >12–100%*	Primary	*A priori*
AES level [4]	*Applied for general values only; Applied for special values, all granted; Applied for special values, partly granted; Applied for special values, not granted; Applied for other values only; No semi-natural grassland*	Primary	*A priori*
Indicator plant species [5]	*0–4; 5–8; >8*	-	Primary
Natura 2000 land [6]	*No; Yes*	-	Primary
Total agricultural area	*1–20; >20–50; >50–100; >100 ha*	*A priori*	*A priori*
Cereals or oilseeds area	*0; >0–7; >7–27; >27 ha*	Potential	Potential
Lay area	*0–10; >10–25; >25–50; >50 ha*	Potential	Potential
Geographical region [7]	*South; Middle; North*	*A priori*	*A priori*
Landscape type [8]	*Arable-dominated; Mosaic; Forest-dominated; No agricultural land*	Potential	Potential
Inspection type [9]	*Random; Risk; Complaint; Follow-up; Cross-compliance; Other*	*A priori*	*A priori*
Inspection year	*2012; 2013; 2014; 2015; 2016; 2017*	*A priori*	*A priori*
Inspection season [10]	*Spring; Summer; Autumn; Winter*	*A priori*	*A priori*
Both species inspected [11]	*No; Yes*	Potential	Potential

[1] Primary = primary predictor, forced into models; *A priori* = *a priori* confounder, known influential effect, most likely also confounding a predictor, forced into models; Potential = potential confounder, included in models only if significant at $p \leq 0.05$ or found to confound a predictor. [2] Model 1 was based on all the available observations; Model 2 was based on inspections of farms in a database originating from the Swedish Meadow and Pasture Inventory, TUVA [38]). [3] Percentage of total agricultural land area found in the database originating from the TUVA. [4] Environmental value of the land based on Swedish Agri-Environmental Scheme prescriptions. [5] Vascular plant species that indicate long continuity of good grazing levels and unimproved grass swards. [6] Core breeding and resting sites or habitats for rare and threatened species across the European Union [32]; *No* = no Natura 2000 land; *Yes* = some Natura 2000 land. [7] *South* = counties corresponding to the Götaland region of Sweden; *Middle* = Svealand region; *North* = Norrland region. [8] Based on the predominant land character of a 5 × 5 km landscape square at the farm location, or the geographical midpoint if the production place number was linked to several locations; *Arable-dominated* = a large proportion of arable land; *Mosaic* = varying proportions of forest, grassland and arable land; *Forest-dominated* = a large proportion of forest and some small proportion of mainly arable land. *No agricultural land* = no or extremely small occurrence of arable land or semi-natural grassland. [9] *Random* = random selection; *Risk* = risk-based; *Complaint* = warranted complaint by, e.g., the general public, a veterinarian, the police or an animal-welfare organization; *Follow-up* = follow-up on a previous violation; *Cross-compliance* = Cross-compliance control according to EU legislation; *Other* = specific project or campaign initiated by the control authority, unwarranted compliant (where non-compliance could not be verified), or an application for a permit for a commercial operation or public exhibition. [10] *Spring* = March–May; *Summer* = June–August; *Autumn* = September–November; *Winter* = December–February [11] *No* = only one species inspected, either cattle or sheep; *Yes* = both cattle and sheep inspected at same time.

Initially, simple associations were estimated in univariable models. Independent variables were considered as eligible for further analysis only if significant at $p \leq 0.25$. Subsequently, all eligible variables were included in a full model, which was reduced stepwise by excluding and re-introducing potential confounding effects until all of them remaining were either significant or confounded a primary predictor, as explained above. Interactions that were considered illogical or too difficult to interpret were disregarded. The joint significance of model effects was assessed using the Wald test. The number of observations (and farms) offered to Models 1 and 2 was 8700 (5808) and 5110 (3448) in cattle, respectively, and 2823 (2280) and 1404 (1144) in sheep.

The final models were validated by examining residuals, calculating the Pearson goodness-of-fit statistic and estimating the discriminatory ability by calculating the area under the receiver operating characteristic (ROC) curve. To determine the relative importance of farms vs. repeated inspections within farms, the proportion of the variance in the dependent variable residing at the farm level (the intraclass correlation coefficient) was calculated taking the latent-variable approach [43], based on the assumption that the residual variance was $\pi^2/3$ (=3.29). Regression coefficients were exponentiated to obtain odds ratios (OR), which were presented with 95% confidence intervals.

3. Results

In cattle, there was a maximum of 16 (mean 1.49; median 1) inspections per farm, and 4234 (48.7%) and 2456 (48.1%) of the observations were from farms with only one inspection in Models 1 and 2, respectively. In sheep, there were up to 9 (mean 1.23; median 1) inspections per farm, and 1911 (67.7%) and 965 (68.7%) of the observations were from farms with only one inspection in Models 1 and 2, respectively. Repeated inspections were generally due to follow-up of established deviations in one or more checkpoints. The data are summarized in Table 2. Comparing with cattle farms, sheep farms were characterized by higher compliance (and, consequently, fewer follow-up inspections), smaller semi-natural grassland areas, but larger semi-natural grassland percentages (not in table), larger TUVA percentages, slightly lower environmental values (based on AES payments), less total land, smaller areas with cereals or oilseeds or with lay, and less often pure arable land. Judging by the distribution of inspections across categories of AES values, indicator plant species, and Natura 2000 habitats, grassland quality and biodiversity were similar on cattle and sheep farms.

Rank correlation revealed that, while the number of indicator plant species and presence of Natura 2000 habitats on cattle farms were strongly associated with each other (ρ = 0.91; n = 5808), they were negatively correlated with TUVA land area ($\rho = -0.60$ and -0.73, respectively; n = 5808) and only weakly correlated with special AES values (compared to no special values; $|\rho| < 0.35$; n = 4694). The amount of semi-natural grassland was moderately positively correlated with TUVA land area, special AES values, number of indicator plants, and Natura 2000 habitats (ρ = 0.69, 0.48, -0.43 and -0.49, respectively). Similar results were obtained for sheep farms.

The complete final models are found in Tables S1–S4. Model estimates for studied effects are shown in Table 3. At cattle inspections, the probability of compliance with the three animal-based checkpoints was significantly higher on farms that received grassland AES payments for special values compared with if they did not apply for special values (OR = 1.55–1.65; $p \leq 0.0001$; Model 1), and there was a similar tendency for cattle farms that applied but were denied special values (OR = 1.29; p = 0.074). Cattle farms complied more often if they received grassland AES payments for special values compared with if they did not apply for special values (OR = 1.55–1.65; $p \leq 0.0001$), and there was a similar tendency for cattle farms that applied but were denied special values (OR = 1.29; p = 0.074). Similar associations were not found in sheep.

Table 2. Distribution (%) of observations across different variable levels considered in two mixed-effects logistic models [1] of the probability of complying with three animal-based checkpoints at official animal welfare inspections on Swedish cattle and sheep farms.

Variable	Level	Cattle		Sheep	
		Model 1 (n = 8700)	Model 2 (n = 5110)	Model 1 (n = 2823)	Model 2 (n = 1404)
No. of inspected animal-based checkpoints [2]	*1*	2.5	2.4	2.4	2.8
	2	7.4	7.4	4.4	4.4
	3	90.1	90.2	93.2	92.8
No. of compliant animal-based checkpoints [2]	*0*	5.3	5.0	4.5	4.2
	1	10.5	10.7	5.7	6.0
	2	18.5	18.5	9.7	8.9
	3	65.7	65.8	80.0	80.9
Compliance [3]	*No*	34.3	34.2	20.0	19.1
	Yes	65.7	65.8	80.0	80.9
Semi-natural grassland area, ha	*0–1*	25.6	8.4	27.0	9.2
	>1–5	21.6	18.1	32.9	28.3
	>5–15	24.9	30.3	24.3	34.1
	>15	27.9	43.3	15.8	28.4
TUVA land percentage [4], %	*0*	41.3	-	50.3	-
	>0–3	20.1	34.2	13.1	26.4
	>3–12	20.9	35.5	13.7	27.6
	>12–100	17.8	30.3	22.9	46.1
AES level [5]	*Applied for general values only*	37.6	31.5	42.2	35.3
	Applied for special values, all granted	16.5	26.4	16.8	29.1
	Applied for special values, partly granted	15.3	24.1	11.0	18.3
	Applied for special values, not granted	6.5	7.4	7.0	7.3
	Applied for other values only	3.5	4.3	3.3	4.5
	No semi-natural grassland	20.6	6.3	19.7	5.6
Indicator plant species [6]	*0–4*	-	32.8	-	34.9
	5–8	-	37.3	-	37.8
	>8	-	29.9	-	27.3
Natura 2000 land [7]	*No*	-	10.6	-	10.3
	Yes	-	89.4	-	89.7
Total agricultural area, ha	*1–20*	15.8	19.8	51.9	37.8
	>20–50	26.7	23.6	25.2	27.6
	>50–100	27.6	29.9	13.4	18.9
	>100	29.8	36.7	9.56	15.7
Cereals or oilseeds area, ha	*0*	32.3	28.5	63.5	56.3
	>0–7	20.2	19.3	18.1	19.4
	>7–27	24.0	24.1	11.6	13.8
	>27	23.4	28.1	6.9	10.6
Lay area, ha	*0–10*	15.1	12.8	47.6	40.7
	>10–25	27.4	25.2	29.8	29.1
	>25–50	26.6	28.6	13.9	17.5
	>50	30.9	33.5	8.7	12.7
Geographical region [8]	*South*	54.2	61.6	47.7	54.9
	Middle	22.4	21.7	28.7	28.3
	North	23.4	16.8	23.6	16.8

Table 2. *Cont.*

Variable	Level	Cattle		Sheep	
		Model 1 (*n* = 8700)	**Model 2 (*n* = 5110)**	**Model 1 (*n* = 2823)**	**Model 2 (*n* = 1404)**
Landscape type [9]	*Arable-dominated*	36.3	38.1	29.3	30.5
	Mosaic	27.0	34.2	28.6	37.7
	Forest-dominated	35.9	27.0	40.8	30.8
	No agricultural land	0.8	0.8	1.3	1.0
Inspection type [10]	*Random*	7.0	6.9	9.4	10.6
	Risk	39.6	38.3	48.1	44.6
	Complaint	9.1	9.0	7.4	7.3
	Follow-up	17.9	18.1	9.9	10.2
	Cross-compliance	9.7	9.6	10.2	10.9
	Other	16.7	18.2	15.1	16.4
Inspection year	*2012*	16.1	16.6	13.3	13.3
	2013	16.3	15.8	14.5	14.5
	2014	14.5	14.0	16.3	15.0
	2015	17.9	17.1	19.2	18.3
	2016	17.0	17.7	16.4	17.7
	2017	18.2	18.9	20.3	21.2
Inspection season [11]	*Spring*	34.3	34.2	25.4	33.4
	Summer	9.3	8.3	10.2	10.5
	Autumn	21.8	21.5	24.2	23.9
	Winter	34.6	36.1	30.2	32.2
Both species inspected [12]	*No*	90.3	89.3	72.4	64.7
	Yes	9.7	10.7	27.6	35.3

[1] Model 1 was based on all the available observations; Model 2 was based on inspections of farms with TUVA land in the Swedish Meadow and Pasture Inventory, TUVA [38]. [2] Checkpoints concerning animal body condition, cleanliness, and hoof care. [3] *No* = at least one animal-based checkpoint non-compliant; *Yes* = all three animal-based checkpoints compliant. [4–12] Explanations for these terms are given in the footnotes of Table 1.

In cattle, the presence of TUVA land seemed to reduce compliance, but the association was statistically significant only for a TUVA land coverage between 3 and 12% of the farm land (OR = 0.79; $p = 0.040$; Model 1). Furthermore, presence of Natura 2000 habitats on cattle farms tended to be associated with higher compliance (OR = 1.36; $p = 0.059$; Model 2). No statistically significant effects of indicator plant species were seen. For both cattle and sheep, compliance was highest on farms with less than 20 ha of agricultural land, and by far the lowest at inspections motivated by warranted complaints (95–98% lower odds), or follow-up of previous violation (76–93% lower odds). In sheep Model 1, compliance was significantly higher in the middle than in the south region of Sweden, and higher in mosaic than in arable-dominated landscapes. There was a gradual increase in compliance from 2012 to 2016 and compliance was generally highest during summer and autumn, compared to spring and winter.

Model fit was acceptable, with Pearson goodness-of-fit p values of 0.32, 0.22, 0.033, and 0.24 for cattle models 1 and 2 and sheep models 1 and 2, respectively, although some standardized residuals (absolute values) exceeded 2. Areas under the ROC curve were 0.76, 0.76, 0.79, and 0.82, respectively, which is consistent with a fair discriminative ability. Intraclass correlation coefficients of the empty models were 0.49, 0.52, 0.61, and 0.64, respectively, which indicated that there was substantial correlation between inspections on the same farm. Judging from likelihood-ratio tests, the random effect of farm improved the models significantly ($p < 0.001$).

Table 3. Results from mixed-effects logistic Models 1 and 2 [1] of compliance with three animal-based checkpoints (body condition, cleanliness, and hoof care) at official animal welfare inspections on Swedish cattle and sheep farms in 2012–2017; odds ratios (OR) and *p* values.

Variable	Level	Cattle Model 1 (*n* = 8700)		Cattle Model 2 (*n* = 5110)		Sheep Model 1 (*n* = 2823)		Sheep Model 2 (*n* = 1404)	
		OR	*p*	OR	*p*	OR	*p*	OR	*p*
Semi-natural grassland area, ha	*0–1*	1 (base)		1 (base)		1 (base)		1 (base)	
	>1–5	0.87	0.40	0.50	0.037	0.64	0.11	0.62	0.42
	>5–15	1.02	0.90	0.64	0.19	1.14	0.68	1.16	0.81
	>15	1.12	0.54	0.69	0.29	1.01	0.97	1.27	0.73
TUVA land percentage [2], %	*0*	1 (base)		-		1 (base)		-	
	>0–3	0.87	0.15	1 (base)		1.15	0.50	1 (base)	
	>3–12	0.79	0.040	0.90	0.39	0.99	0.97	0.78	0.39
	>12–100	0.82	0.11	0.91	0.48	0.96	0.84	0.79	0.43
AES level [3]	*Applied general values only*	1 (base)		1 (base)		1 (base)		1 (base)	
	Applied special values, all granted	1.65	<0.0001	1.53	0.0009	1.29	0.23	1.03	0.90
	Applied special values, partly granted	1.55	0.0001	1.43	0.0087	1.09	0.74	0.93	0.83
	Applied special values, not granted	1.29	0.074	1.36	0.086	0.94	0.80	1.29	0.54
	Applied other values only	1.11	0.57	1.21	0.41	0.78	0.49	0.45	0.090
	No semi-natural grassland	0.87	0.41	0.59	0.14	0.58	0.060	0.48	0.27
Indicator plant species [4]	*0–4*	-	-	1 (base)		-	-	1 (base)	
	5–8	-	-	1.03	0.80	-	-	0.98	0.95
	>8	-	-	1.00	0.99	-	-	0.63	0.10
Natura 2000 land [5]	*No*	-	-	1 (base)		-	-	1 (base)	
	Yes	-	-	1.36	0.059	-	-	1.44	0.30
Totalagricultural area, ha	*1–20*	1 (base)		1 (base)		1 (base)		1 (base)	
	>20–50	0.82	0.065	0.99	0.97	0.55	0.0005	0.66	0.10
	>50–100	0.71	0.0028	0.75	0.11	0.40	0.0003	0.50	0.034
	>100	0.80	0.075	0.81	0.27	0.42	0.014	0.80	0.57
Cereals or oilseeds area, ha	*0*	-	-	-	-	1 (base)		-	-
	>0–7	-	-	-	-	1.19	0.31	-	-
	>7–27	-	-	-	-	1.61	0.039	-	-
	>27	-	-	-	-	2.77	0.0050	-	-
Geographical region [6]	*South*	1 (base)		1 (base)		1 (base)		1 (base)	
	Middle	1.52	0.14	1.20	0.11	1.78	0.0009	1.40	0.16
	North	1.26	0.12	1.04	0.75	1.43	0.071	1.17	0.58
Landscape type [7]	*Arable-dominated*	-	-	-	-	1 (base)		-	-
	Mosaic	-	-	-	-	1.46	0.039	-	-
	Forest-dominated	-	-	-	-	1.02	0.93	-	-
	No agricultural land	-	-	-	-	0.42	0.081	-	-
Inspection type [8]	*Random*	1 (base)		1 (base)		1 (base)		1 (base)	
	Risk	1.00	0.98	0.94	0.71	0.84	0.48	0.72	0.39
	Complaint	0.06	<0.0001	0.05	<0.0001	0.03	<0.0001	0.02	<0.0001
	Follow-up	0.24	<0.0001	0.20	<0.0001	0.12	<0.0001	0.07	<0.0001
	Cross-compliance	1.20	0.25	1.05	0.81	1.12	0.72	0.86	0.76
	Other	1.32	0.053	1.12	0.54	0.93	0.79	0.98	0.96
Inspection year	*2012*	1 (base)		1 (base)		1 (base)		1 (base)	
	2013	1.09	0.40	1.15	0.32	0.99	0.95	1.25	0.52
	2014	1.17	0.16	1.07	0.65	0.96	0.85	1.23	0.55
	2015	1.37	0.0033	1.33	0.041	1.72	0.017	1.67	0.14
	2016	1.50	0.0002	1.62	0.0007	1.47	0.094	1.79	0.098
	2017	1.37	0.0032	1.40	0.016	1.28	0.26	1.34	0.38

Table 3. *Cont.*

Variable	Level	Cattle Model 1 (*n* = 8700)		Cattle Model 2 (*n* = 5110)		Sheep Model 1 (*n* = 2823)		Sheep Model 2 (*n* = 1404)	
		OR	*p*	OR	*p*	OR	*p*	OR	*p*
Inspection season [9]	*Spring*	1 (base)		1 (base)		1 (base)		1 (base)	
	Summer	2.13	<0.0001	2.21	<0.0001	1.73	0.013	2.01	0.034
	Autumn	1.90	<0.0001	1.85	<0.0001	1.79	0.0005	2.57	0.0006
	Winter	0.73	<0.0001	0.67	<0.0001	1.44	0.013	1.36	0.16
Both species inspected [10]	*No*	1 (base)		1 (base)		-	-	-	-
	Yes	1.35	0.16	1.39	0.024	-	-	-	-

[1] Model 1 was based on all the available observations; Model 2 was based on inspections of farms with TUVA land in the Swedish Meadow and Pasture Inventory, TUVA [38]. [2] Percentage of total agricultural land area found in database originating from the TUVA. [3–10] Explanations for these terms are given in the footnotes of Table 1.

4. Discussion

Using publicly available databases, this study highlights apparent synergies and conflicts between sustainability goals relating to animal welfare and environmental protection on Swedish cattle and sheep farms. More synergies than conflicts were found.

In this study, on cattle farms, we found a significant positive association between compliance with animal-based measures in animal welfare legislation at official farm inspections on the one hand, and Agri-Environmental Scheme (AES) payments for special environmental values on the other, as well as a tendency for a similar association with AES payments for general values when special values were applied for, but not granted (evaluated in Model 1). AES for special values were likely to reflect both high grassland biodiversity and farmer commitment to environmental protection (Glimskär et al., unpublished data). Situations where farmers had applied for AES payments for special values, but were only granted payments for general values, may indicate farmer commitment, even if environmental values were not sufficiently high. Absence of semi-natural grasslands with AES for general values, on the other hand, may reflect that the farmer applied for payment but did not receive any, or did not apply even though grasslands existed. The fact that we found a significantly stronger association only with AES payments for grasslands with special values indicates that animal welfare compliance was primarily linked to biodiversity, rather than farmer commitment. Similar associations, however, could not be shown in sheep. This may, at least partly, be explained by the smaller sample, since the magnitude of ORs according to the different AES values was similar to that of cattle. Alternative, less plausible, and possibly less attractive, explanations are that biodiversity differed between cattle and sheep farms, or that applications for AES payments were evaluated differently depending on the animal species. We have found no support in previous research for any of these claims.

In cattle, there was some evidence of an association between the presence of TUVA land and low animal welfare compliance (evaluated in Model 1). However, the TUVA database does not cover all agricultural land that could fulfil the demands for valuable grasslands, which makes it partly incomplete [44,45] and may have weakened this association. There was also a tendency for higher compliance when Natura 2000 habitats were present on cattle farms. TUVA coverage on farms is thought to indicate high biodiversity, although the presence of Natura 2000 habitats is an even stronger indication, based on specific expert judgment without any relationships with the farmer.

From a general perspective, it may be argued that associations between environmental quality measures and animal welfare compliance are due to either a direct causal link (environmental quality affecting animal welfare compliance, or the opposite) or an effect of a common factor, such as farm or farmer characteristics. For example, an organized and aware farmer can be expected to do better in terms of both environmental and animal protection. We had no records of farmer characteristics or farm management. Nevertheless, these results speak in favor of a direct causal link between environmental quality and animal welfare compliance. All significant associations found, except for the relatively low compliance at cattle inspections on farms with 3–12% of TUVA land, were positive, indicating synergies between sustainability goals. No significant conflicts, other than the one mentioned, were found.

The fact that both AES payments for special values and Natura 2000 habitats were significantly, or nearly significantly, related to animal welfare compliance in a multivariable model (cattle Model 2) indicates that these measures of environmental quality have independent effects and, therefore, suggests that they reflect different aspects of biodiversity. This was supported by rank correlation.

Some influential and confounding factors deserve to be mentioned. Sheep Model 1 revealed an association of geographical location and landscape type with compliance, with a higher probability of compliance in the middle compared to the south of Sweden, and in mosaic compared to arable-dominated landscapes, regardless of the values of other covariates. Similar associations were not seen in Model 2, or in cattle, which may indicate a difference between the species regarding farm management.

Compliance was also higher in March to August, compared to September to February. Swedish regulations since 1988 require that dairy cattle are kept on pasture in the summer, and several studies have shown a positive effect of grazing or exercise on lameness and hoof health [46–48]. This is probably partly due to a cleaner and drier environment outdoors [49–51]. On the other hand, studies have reported that dairy cows lose body condition more on pasture than in confinement [52,53], which might counteract the positive effects of grazing on animal welfare compliance. However, we did not find animal welfare compliance, of which body condition was one of the measures, to be significantly related to semi-natural grassland area with general values per se.

In all four models, compliance was lowest at inspections motivated by warranted complaints and follow-up of previous violations, which is to be expected. The probability of compliance appeared to increase gradually over the study period, at least up to 2016, with 47–79% higher odds in 2016 than in 2012. The time trend accords well with the yearly rates of discrepancies reported by the Swedish Board of Agriculture [54], which showed that deficiencies in animal husbandry of farm animals generally decreased from 2013, and that this was probably due to increased knowledge among animal keepers and control staff.

Unregistered factors may have influenced the results. For example, there is a possibility that more remote, poorer, and/or larger land areas were selected for grazing, perhaps by necessity, which may have influenced, for example, the animals' body conditions, cleanliness, and general health and, thus, biased the estimated relationships. Animals kept on remote pastures may also have been inspected more seldom or less completely. In that case, this may also have confounded the studied effects.

Large samples extracted from databases allow the exploration of different combinations of actions and of the relative importance of different sustainability indicators. Nordic countries have a long tradition of databases concerning animal farming and primary food production and some of these are readily available for research. We utilized publicly available databases, which is an advantage considering future research with the same focus. However, some of the data were not readily available to anyone, but had to be extracted and provided by the administrative body, in this case the Swedish Board of Agriculture. The Swedish databases are probably rather unique; to our knowledge, similar data are not gathered systematically in other countries, at least not outside the Nordic region. However, originally, these databases were created for other purposes and, therefore, have some shortcomings, which reduce their usefulness for research purposes.

The TUVA inventory was started in 2002 as a governmental initiative to identify and classify grasslands with high natural or cultural heritage values, and field data were mainly collected in 2002–2004. The database is continuously updated as objects are added, restored, or deemed as no longer fulfilling criteria as valuable semi-natural grasslands. The TUVA has become a major tool for government agencies and researchers [17,55–58].

The Swedish Animal Welfare Control Database was created when official control was transferred to the regional level in 2009, which aimed to improve planning and documentation of inspections, as well as facilitate statistics extracts for reporting and evaluation. Data on animal welfare inspections are partly incomplete and important information on, for example, herd size or grazing management are not included. It is also important to recognize that the database reflects compliance with current legislation, rather than animal welfare per se. As a consequence, the information on animal-based measures was scant and contained in only three checkpoints. Moreover, merging of the databases was complicated by the fact that farms and land areas had different identifiers. Still, this study has shown that merging of the databases and subsequent statistical analyses using epidemiological methods are possible.

5. Conclusions

There is strong evidence of positive associations between sustainability goals concerning environmental quality and compliance with legislation on animal-based measures of animal welfare at official control inspections on Swedish cattle farms. There are indications of a causal effect of biodiversity on animal welfare compliance on cattle farms. As a consequence, we conclude that efforts for environmental sustainability are likely to also have positive effects on the welfare of grazing livestock.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su14031095/s1, Table S1: Complete estimates from a mixed-effects logistic model of compliance with three animal-based checkpoints at official animal welfare inspections on Swedish cattle farms in 2012–2017; n = 8700 inspections; Table S2: Complete estimates from a mixed-effects logistic model of compliance with three animal-based checkpoints at official animal welfare inspections on Swedish cattle farms with TUVA land in 2012–2017; n = 5110 inspections; Table S3: Complete estimates from a mixed-effects logistic model of compliance with three animal-based checkpoints at official animal welfare inspections on Swedish sheep farms in 2012–2017; n = 2823 inspections; Table S4: Complete estimates from a mixed-effects logistic model of compliance with three animal-based checkpoints at official animal welfare inspections on Swedish sheep farms with TUVA land in 2012–2017; n = 1404 inspections.

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