Projektbeskrivelse

Projekttitel

Benchmarking af dyrlægers ordination af antibiotika til svin og kvæg

Projektperiode

1. februar 2022 til 31. August 2022

Sagsnr./Journal nr.

I3RG10 i AP2022. Selvstændigt projekt men det ligger i direkte forlængelse af projekt I3RG6 i AP2021 (2020-15-25-00236)

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Formål med og afgrænsning af projektet

Opgaven til DK-VET var formuleret som følger:

”Baggrunden for dette projekt er, at der fortsat er politisk fokus på ansvarlig og bæredygtig anvendelse af antibiotika i husdyrproduktionen.

Datagrundlaget er et opdateret dataudtræk fra VetStat samt CHR fra perioden 01-01-2020 til og med 31-12-2021. Desuden inddrages viden og erfaringer fra tidligere projekt ”Deskriptiv analyse af dyrlægers ordinationer af antibiotika i svine- og kvægbesætninger”.

Der skal udarbejdes en rapport om overordnet benchmarking af kvæg- og svinedyrlæger.

Der skal fokuseres på at udvikle en simpel model og fremlægge fordele og ulemper ved en sådan model versus en mere kompliceret model for henholdsvis svin og kvæg.

Modellen kan gøres simpel ved f.eks. at:

1. Lave en model, hvor man bruger gennemsnittet af det samlede forbrug i alle dyrlægens SRA-besætninger indenfor aldersgrupper.
2. Lave en model, hvor man sammenligner dyrlæger på median af forbrug i deres SRA-besætninger indenfor aldersgrupper.

Der sættes i analysen fokus på betydningen af aldersgrupper, besætningsstørrelse og estimerede brugsarter samt antal af rådgivningsaftaler for den enkelte dyrlæge. Der kan yderligere fokuseres på antibiotikakategorier (fra antibiotikavejledningerne) samt administrationsveje og sygdomsindikationer. I dette tilfælde målrettes analysen mod at kunne klarlægge udbredelsen af oral behandling af fravænningsgrise og kalve.”

Resumé

Denne rapport indeholder opgørelser af antibiotika udskrevet til brug på forskellige aldersgrupper af grise og kvæg samt beskrivelse og illustration af simple benchmarking modeller med illustrationer, der ville kunne implementeres i nyt VetStat. Formålet er øge dyrlægers opmærksomhed på og forståelse af egne antibiotikaudskrivningsmønstre sammenlignet med andre dyrlægers.

De visuelle værktøjer vil endvidere kunne bruges i forbindelse med Fødevarestyrelsens supervision af sundhedsrådgivende dyrlæger. Interessenters ønsker og idéer til benchmarking-modellen er indhentet ved tre møder med arbejdsgruppen ledet af Fødevarestyrelsen (FVST) og med repræsentanter fra Den Danske Dyrlægeforening (DDD) (Faggruppe Kvæg og Faggruppe Svin), Landbrug & Fødevarer (L&F) og SEGES Innovation (SEGES).

I modsætning til Dansk Veterinær Konsortiums (DK-VET) forudgående arbejde med udvikling af benchmarking-modeller for dyrlægers udskrivning af antibiotika til svin og kvæg fra 2021, er datagrundlaget for nærværende rapport baseret på data udtrukket fra nyt VetStat, der blev iværksat i juni 2021. Dataformatet og mulighederne for fletning af data fra forskellige tabeller i nyt VetStat adskiller sig fra de tidligere udtræk. Det har derfor været nødvendigt med et større datahåndteringsarbejde og omkodning af eksisterende softwareprogrammer, og der er stadig enkelte udfordringer, der ikke er løst endnu. Datagrundlaget er det samme, som anvendes i VetStat ved rapportering af månedligt antibiotikaforbrug på besætningsniveau.

Opgørelserne i denne rapport tager udgangspunkt i beregnet gennemsnit procent behandlede dyr per dag ('average daily dosis' (ADD)/100 dyr/dag) baseret på standard daglige doser anvendt i VetStat. Det vil sige, at de tager højde for antal dyr i besætningen (baseret på CHR-data med antal stipladser angivet for svinebesætninger og antal dyr i forskellig aldersgrupper baseret på enkeltdyrsregistreringer for kvæg). Ejendomme hvor antal dyr ikke er angivet eller er nul er frasorteret. Alt antibiotika udskrevet til besætningen er i benchmarkingen tilskrevet den dyrlæge, der stod opført som besætningens sundhedsrådgivende dyrlæge på udskrivningstidspunktet, da denne ifølge lovgivningen er ansvarlig for rådgivning omkring antibiotikabehandlingsstrategier i besætningen.

Data blev modtaget i marts 2022. Studieperioden blev oprindeligt aftalt som en 2 års periode hen over implementeringen af det nye VetStat. Der måtte dog fraviges denne studieperiode grundet udfordringer med datamanagement relateret til skiftet fra ejendomsniveau (CHR-nummer) til besætningsniveau (besætningsnummer) i indberetningerne med opdateringen af VetStat. I den endelige analyse er der således inddraget data fra 2,5 år op til implementeringen af det nye VetStat. Da DK-VET i arbejdet med data havde fordel af at arbejde med data for hele år (2019 og 2020) blev studieperioden forlænget fra 2 til 2½ år. De udarbejdede benchmarkingmodeller kan oversættes fra CHR-niveau til besætningsniveau på et datagrundlag efter 1. juni 2021. Fremlæggelsen af baggrund og tekniske forklaringer er nedenfor skrevet på engelsk af hensyn til senere publicering med peer-review.

Der er udarbejdet illustrationer af følgende sammenhænge: procent antibiotikabehandlede dyr per dag opsummeret for studieperioden eller på årsbasis fordelt på dyreart, aldersgruppe samt status for rådgivningsaftale. Der er desuden lavet opgørelser af procent antibiotikabehandlede dyr per dag sammenholdt med ejendomsstørrelse (aldersgruppestørrelse) og ejendomstyperne anvendt i rapporten fra 2021. Der er ved regressionsanalyse fundet en statistisk signifikant sammenhæng i et mønster med stigende antibiotikaforbrug ved stigende aldersgruppestørrelser for alle aldersgrupper.

For dyrlæger med sundhedsrådgivning er der lavet opgørelser over gennemsnitlig procent antibiotikabehandlede dyr per dag opsummeret for studieperioden versus antal af

sundhedsrådgivningsaftaler samt en årlige opgørelser over fordeling af dyrearter i sundhedsrådgivningsprofilerne. Der er ved regressionsanalyse af data for hele året 2020 fundet en statistisk signifikant sammenhæng mellem antal sundhedsrådgivningsaftaler og mængden af ordineret antibiotika (givet som gennemsnit for dyrlægens besætninger med sundhedsrådgivning) for alle aldersgrupper undtagen gruppen af kvæg under 2 år gamle.

I henhold til ønsker fra arbejdsgruppen blev der valgt en simpel benchmarkingmodel med grafiske illustrationer til dyrlæger, der har sundhedsrådgivningsaftaler med hhv. svinebesætninger og kvægbesætninger, da den blev vurderet umiddelbart gennemskuelig. Modellen, som demonstrerer kontinuert benchmarking over et år, justerer ikke for produktionstype, besætningsstørrelses-kategorier, antal eller typer af sundhedsrådgivningsaftaler eller andre forhold, der kunne have en betydning for dyrlægernes udskrivningsmønstre inden for hver af aldersgrupperne i selve grundlaget for benchmarkingen. Modellen som viser benchmarking per måned tager dog delvist højde for antal sundhedsrådgivningsaftaler ved at gruppere dyrlæger grafisk, men ikke de øvrige faktorer.

De største udfordringer med benchmarkingen var, foruden dem relateret til data og data management, opsætning af en benchmarkingmodel med anvendelse af median. Da intervallet mellem ordinationer, særligt for svin, ofte er længere end en måned vil mange måneder være registreret uden et forbrug på den enkelte ejendom. Dette kan resultere i en median, som ligger på nul i en given måned. Derfor er de udarbejde modeller baseret på gennemsnit samt 3-måneders rullende gennemsnit.

Kort om materialer og metoder

Analysen baseres på dataudtræk fra VetStat og CHR.

Data fra VetStat er udtrukket og udleveret i marts 2022 af Fødevarestyrelsen (FVST). Data blev udleveret som R-filer til DK-VET, Københavns Universitet, Institut for Veterinær- og Husdyrvidenskab. Studieperioden dækkede en 2,5-års periode frem til 1. juni 2021.

I løbet af projektperioden har der været løbende kommunikation af datateknisk karakter mellem FVST og DK-VET. De udleverede data var i et for DK-VET nyt format, da der ikke har været arbejdet med udtræk fra VetStat efter implementeringen af nyt VetStat siden idriftsættelsen i juni 2021.

Databehandling, analyser og udarbejdelse af grafisk materiale inkluderet i rapporten er foretaget ved hjælp af R-Studio og statistikprogrammet R.

Yderligere beskrivelser af data og metoder kan ses i afsnittene ”VetStat description and data structure” og ”Data used by the DK-VET”.

Baggrund, relevans og perspektiv

Politisk ønske om fortsat fokus på ansvarlig og bæredygtig anvendelse af antibiotika i husdyrproduktionen

Arbejdsplan inkl. milepæle

Februar 2022: Opstartsmøde og forventningsafstemning mellem FVST og DK-VET

Marts 2022 – Maj 2022: Dataudlevering. Data management og udarbejdelse af databeskrivelser samt oprensning af rådata.

April 2022: Arbejdsgruppemøde med deltagere fra FVST, DK-VET, Den Danske Dyrlægeforening samt Landbrug & Fødevarer

Maj 2022: Opfølgningsmøde mellem FVST og DK-VET efter arbejdsgruppemøde. Faglig erfaringsudveksling om benchmark af dyrlægers brug af antibiotika i svin og kvæg med deltagere fra FVST, DK-VET, Den Danske Dyrlægeforening samt Landbrug & Fødevarer

Juni 2022 – Juli 2022: Deskriptiv statistik og dataanalyse. Opfølgningsmøde mellem FVST og DK-VET

August - September 2022: Udfærdigelse af rapport

Resulterer projektet i rådgivningsprodukter til Fødevarestyrelsen
(sæt kryds): X Ja, __ Nej

Hvis ja:

Hvilke *(rapport, notat, model, seminar…)***:** Rapport

Påtænkt leverancetermin *(md/år)***:** Ultimo August 2022 (rapport afleveret til FVST 29.9.2022)

Kontaktperson i Fødevarestyrelsen: Katrine Løvenbalk Lundsby og Pia Holm Jul

Contents

Background

Previous work

Antimicrobial use (AMU) is of global concern. Many countries are developing, implementing and evaluating National Action Plans (NAPs) against antimicrobial resistance development. In this report, AMU is measured as antibiotics prescribed by veterinarians for use in pig or cattle herds, i.e. excluding anthelmintica.

An increase in AMU for pigs in Denmark led to a statement from the Danish Advisory Committee on Veterinary Medicines in 2019 recommending increased research of "good clinical practice" amongst primarily pig veterinarians[1]. Following this recommendation, the Danish Veterinary and Food Administration (DVFA) included, amongst other initiatives, benchmarking of veterinarians' antibiotic prescriptions (APs) in the Danish NAP AMR in production animals[2]: "Danish Veterinary and Food Administrations national action plan for antibiotic resistance in production animals and food 2021-2023".

In 2020, the DVFA commissioned the Danish Veterinary Consortium (DK-VET)[3] to carry out a research project with the working title "Deskriptiv analyse af dyrlægers ordinationer af antibiotika i svine- og kvægbesætninger"[4] (Descriptive analysis of veterinarians' prescriptions of antibiotics in pig- and cattle herds). In the project, the DVFA requested an analysis of patterns in the veterinarians' APs for pigs and cattle, with focus on distribution by antibiotic classes, disorders the antibiotics were prescribed for, and route of administration.

The majority (84.6%) of the total APs for production animals in Denmark in 2021 (85,551 kg active compounds) were for pigs while cattle accounted for the second largest amount (11%) (Figure 1).

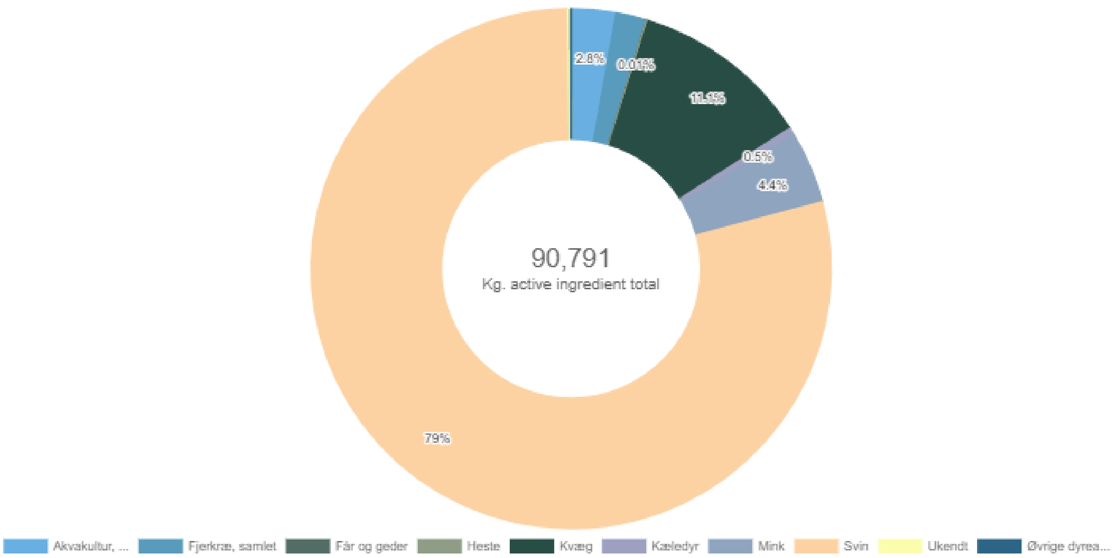

Figure 1. *Pie chart showing the distribution of the total of antibiotics in kilo active ingredient prescribed for use in production animals (AMU) in 2019, divided into species groups. Yellow represents the AMU in pigs and dark green represents cattle. The other colours include poultry and other species. The source webpage www.vetstat.dk was accessed 29th of September 2022.*

Thus, these two species were the focus in the development of a benchmarking model for veterinarian's AP. The DVFA requested a quantitative analysis of how the veterinarians were distributed with regard to biomass-adjusted amounts prescribed for pigs and cattle. After dialogue and general expectation alignment in the winter 2020/2021, it was decided to focus on developing a benchmarking model for Danish pig and cattle herd health consulting veterinarians.

The approach to creating a Danish benchmarking model for veterinarians was partly inspired by the Dutch "Veterinary Benchmark Indicator" described in 2014 by Heederick et. al.[5]. The resulting Danish model from 2021 compared veterinarians holding Veterinary Advisory Service Contracts (VASCs)[6] with pig and cattle herds. Only veterinarians with VASC were included for several reasons, e.g. that they are obliged to advice about AMU on a farm in accordance with Danish legislation[7,8]. That benchmarking model was based on the percentage of farms with "high" AMU in the veterinarians VASC profile. In the model, a "high" AMU farm was a farm with a use in the fourth quartile when compared with other Danish farms within the same age group and within the same farm type. In Denmark, AMU is reported by species and age groups[9] and not by production type as in the Netherlands. Therefore, estimated farm types were developed for the 2021 model based on available register data. Hence, farm types were based on species, the age groups present on a farm, and for cattle also the proportion of young stock. The AMU was corrected for number of animals by using animal daily doses (ADD) per 100 animals per day[10], also referred to as percentage treated animals per day. The model was demonstrated for the total AMU. However, it would be possible to run that model for specific antibiotic classes or routes of administration.

The analyses of AMU in Denmark are primarily done using data from VetStat, which is a relational database on an Oracle Platform[11]. It is managed by the DVFA and contains data on all reported use, dispensing and prescription of medicine for animals authorized by a veterinarian. In June 2021, the updated version of VetStat was implemented. This resulted in changes in the data structure. An important change was that AMU went from being reported at farm level (i.e. a property with specific geographical location) to being reported at herd level (i.e. herd of animals with one species in one production type e.g. dairy herd or veal herd or beef herd).

Follow-up analyses and new benchmark model in 2022

In the autumn 2021, a second analysis was commissioned by the DVFA from the DK-VET. Planning began in February 2022 and the working title of the project was "Benchmarking af dyrlægers ordination af antibiotika til svin og kvæg" (Benchmarking of veterinarians' antibiotic prescription for pigs and cattle). Data were delivered by the DVFA in March 2022. The received data were in the new VetStat format, as opposed to the data used in the previous report, which were in the old format.

Input from the working group

The DVFA gathered a working group with stakeholders to evaluate the possibility of benchmarking Danish veterinarians after receiving the analysis from DK-VET in 2021. The working group included representatives from Den Danske Dyrlægeforening (The Danish Veterinary Association)[12], Landbrug & Fødevarer (Danish Agriculture & Food Council)[13], SEGES Innovation P/S[14], and the University of Copenhagen. The first meeting was held in June 2021. Professor Dick Heederik, Chair of the Expert panel of the Netherlands Veterinary Medicines Authority (SDA) gave a presentation of the Dutch benchmarking system, which has been updated since 2014 in favour of a simpler model similar to the one used to compare Dutch farms. The working group also received the DK-VET report from the previous work described above and was encouraged to reflect upon it until next meeting.

A second working group meeting was held in April 2022. It was emphasized that benchmarking should be implemented as a tool used in a dialogue during supervisory visits from the DVFA and as an awareness-raising (or nudging) tool where veterinarians can compare themselves with others on the VetStat online platform. The responses to the proposed benchmarking model from the previous work were generally positive, but the model was considered too complex. A simpler model was suggested and approved by the working group representatives.

VetStat description and data structure

The veterinarians' prescription, use, and dispensing of antibiotics enters VetStat via three main pathways. The pharmacies report the details from the veterinary prescription when the farmer buys the medicine. The veterinarian must report their own use and dispensing of antibiotics to VetStat. Many veterinarians report via their billing system, for cattle these typically upload to the Danish Cattle Database managed by SEGES, where data is adjusted according to certain criteria before it is sent to VetStat. The remaining veterinarians report directly to VetStat via an online platform.

Data made available to the DK-VET

The data available in this project were extracted in the new Vetstat format with the goal of creating a dataset corresponding to the one forming the basis for analysis in the previous report. However, some differences were unavoidable. The updated VetStat database has an increased complexity. Additional information has been added and existing information has to some extent been rearranged to ensure uniformity in reporting and better support the expected future demands and the functions in the online VetStat platform. Details regarding the received data, adjustments and a few encountered challenges can be found in Appendix I.

Data used by the DK-VET

Originally, the study period was set to include data from before and after the implementation of new VetStat. Due to multiple challenges with data management, amongst others handling the transition from records at farm level to herd level, the study period was moved from 01-12-2018 to 31-05-2021, which marks the implementation of new VetStat. The study period was extended to 2½ year to include records from two full years. The principles demonstrated in this report can be translated from farm- to herd-level, when the current data challenges have been resolved.

The data analyses in this report are based on the AMU data aggregated per month per farm in VetStat, similar to the previous report. These data are the same that are used to generate the continuous reports on the online platform www.vetstat.dk. The AMU data were combined with data on VASC, which limited the benchmarking to veterinarians holding VASCs. Data on number of animals were added for information on number of animals present in all months – not only months with reported AMU. In accordance with instructions from the DVFA, monthly records with equal to or more than 100 percent treated animals per day were excluded as they most likely represent technical errors. For the initial descriptive analyses, data from months with animals recorded as present at farm-level were kept. For the data used for the benchmarking models, monthly registrations without an active VASC were excluded. Observations in the dataset with no animals recorded present in the farm were deleted.

Descriptive analyses

Basic AMU description

The status in AMU for pigs and cattle during the study period is described in this section to improve the understanding of the benefits and shortcomings in the proposed benchmark models. As requested, the section focuses on the relevance of correcting for age groups, herd size/age-group size) and estimated herd production types when comparing AMU at farm-level. For veterinarians, the relevance of the number of VASCs versus AMU was investigated. The annual distribution of veterinarians' VASC profiles as either single species or mixed were also summarised.

Age groups

As seen in prior analyses, significant differences between the age groups were found, when the AMU given as percentage treated animal per day was calculated per age group (Figure 2). This was most apparent for pigs, where the average for weaners across the whole study period was 7.10 ADD/100 animals/day higher than for slaughter pigs. For cattle, the differences were smaller, but showed a lower use reported for young stock compared to adult cattle.

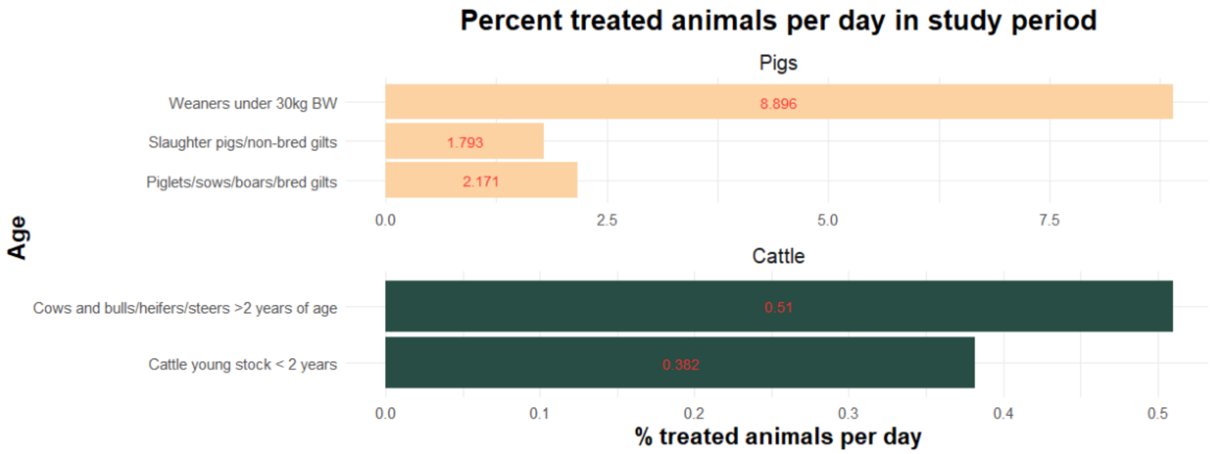

***Figure 2**. Percent treated animals per day during the study period summarised for three age groups of pigs and two age groups of cattle across all farms with these age groups recorded in the Central Husbandry Register. The red numbers gives the exact percent treated animals per day for each age group.*

Veterinary Advisory Service Contracts

VASC distribution by species

For each year over a four-year period from 2018 to 2021, the number of unique VASCs was summarised per species (Figure 3). The majority of VASCs were registered for pigs followed by cattle. The remaining species with VASCs, e.g. mink, poultry and fish, were grouped together and accounted for only 3-3.4%.

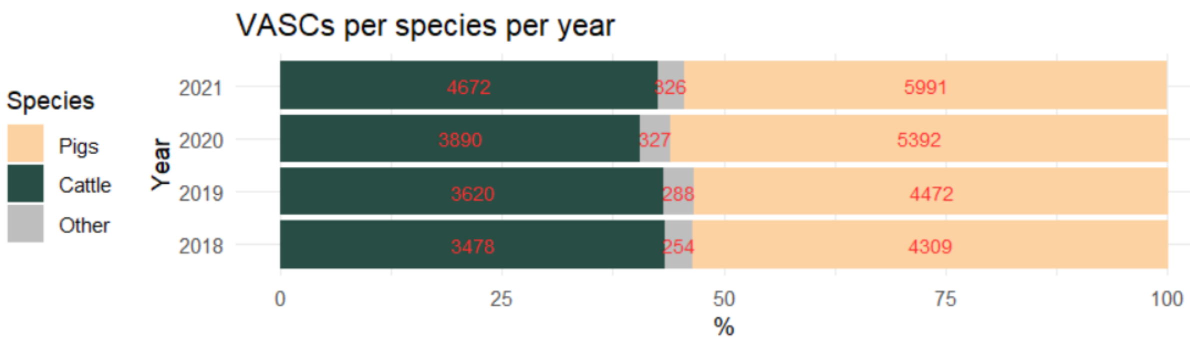

***Figure 3.** Number of Veterinary Advisory Service Contracts (VASCs) per animal species for each of the years 2018 to 2021. The red numbers are the unique VASCs registered per species per year. The data for this figure is the received datasets covering VASCs – See Appendix I for further information.*

VASC status and VASC requirement

VASC is obligatory for farms of a certain size[7,8]. The number of farms required to have VASCs was calculated annually based on the average number of animals per month and farm VASC status was determined. The number of age groups on farms per year is summarised by their VASC status in Table 1. All farms without VASCs were excluded from the study data. Some farms required an obligatory VASC according to the records, but had none. The reasons for this were not further investigated, but likely reasons include recording errors or errors arising from merging or aggregation of data. The number of farms without obligatory VASC decreased over the study period.

***Table 1.** Status of presence of Veterinary Advisory Service Contract (VASC) for farms and age groups in study data*

	Age group	VASC Status	Nr. of farms with the age group		
			2019	**2020**	**2021**
Included in study	Weaners under 30kg BW	Obligatory VASC	167	182	198
	Slaughter pigs/non-bred gilts	Obligatory VASC	245	258	286
	Piglets/sows/boars/bred gilts	Obligatory VASC	1236	1251	1265
	Cows and bulls/heifers/steers >2 years of age	Obligatory VASC	2084	2040	2040
	Cattle young stock < 2 years	Obligatory VASC	979	1015	1080
	Weaners under 30kg BW	Voluntary VASC	2234	2228	2247
	Slaughter pigs/non-bred gilts	Voluntary VASC	3920	3984	4100
	Piglets/sows/boars/bred gilts	Voluntary VASC	356	340	331
	Cows and bulls/heifers/steers >2 years of age	Voluntary VASC	540	494	504
	Cattle young stock < 2 years	Voluntary VASC	1916	1772	1711
Excluded from study	Weaners under 30kg BW	No VASC	338	286	233
	Slaughter pigs/non-bred gilts	No VASC	927	785	672
	Piglets/sows/boars/bred gilts	No VASC	339	313	304
	Cows and bulls/heifers/steers >2 years of age	No VASC	10011	9794	9513
	Cattle young stock < 2 years	No VASC	10724	10453	10116
	Weaners under 30kg BW	W/O obligatory VASC*	11	6	3
	Slaughter pigs/non-bred gilts	W/O obligatory VASC*	15	10	2
	Piglets/sows/boars/bred gilts	W/O obligatory VASC*	56	34	13
	Cows and ulls/heifers/steers >2 years of age	W/O obligatory VASC*	142	123	75
	Cattle young stock < 2 years	W/O obligatory VASC*	75	66	44

W/O = Without, The reasons for a farm not having an obligatory VASC have not been investigated further but likely reasons could be errors in recording or data merging.

Proportion of prescription for farms with/without VASC

Records of AMU registered as animal doses (ADD) were combined with information on farm VASC status on a monthly basis. Figure 4 illustrates the distribution of total animal doses prescribed during the entire study period.

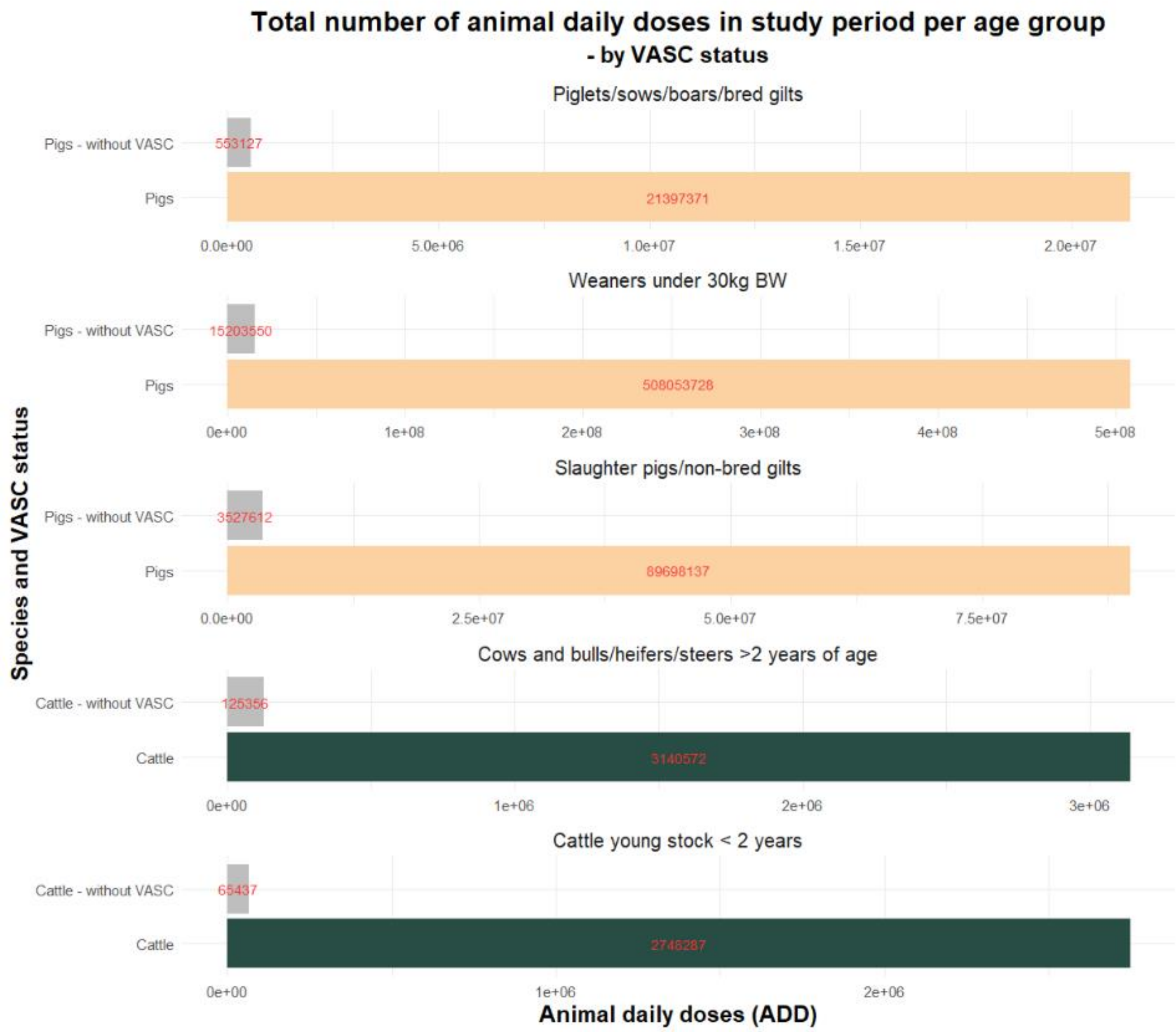

Figure 4. *Total number of standard animal daily doses (ADD) prescribed for different age groups of pigs and cattle in farms with and without Veterinary Advisory Service Contracts (VASCs) for the full 2½ year study period. Note that the scales vary between age groups. The red numbers are the total number of animal daily doses per group in the study period*

The proportion of ADD prescribed during the study period to farms without VASCs ranged from 2.5% to 3.8% of the total number of animal doses prescribed for pigs and 2.3% and 3.8% of the total number of animal doses prescribed for adult and young cattle, respectively. The proportions can be seen in Appendix III, Table A2.

Average AMU for farms with/without VASC

When the average AMU was calculated per species and age group for farms with and without VASCs, the farms without VASCs had a lower average AMU during the study period. This was most pronounced for cattle. In Figure 5, this is illustrated for 2020. Figures illustrating the remaining study period are shown in Appendix III.

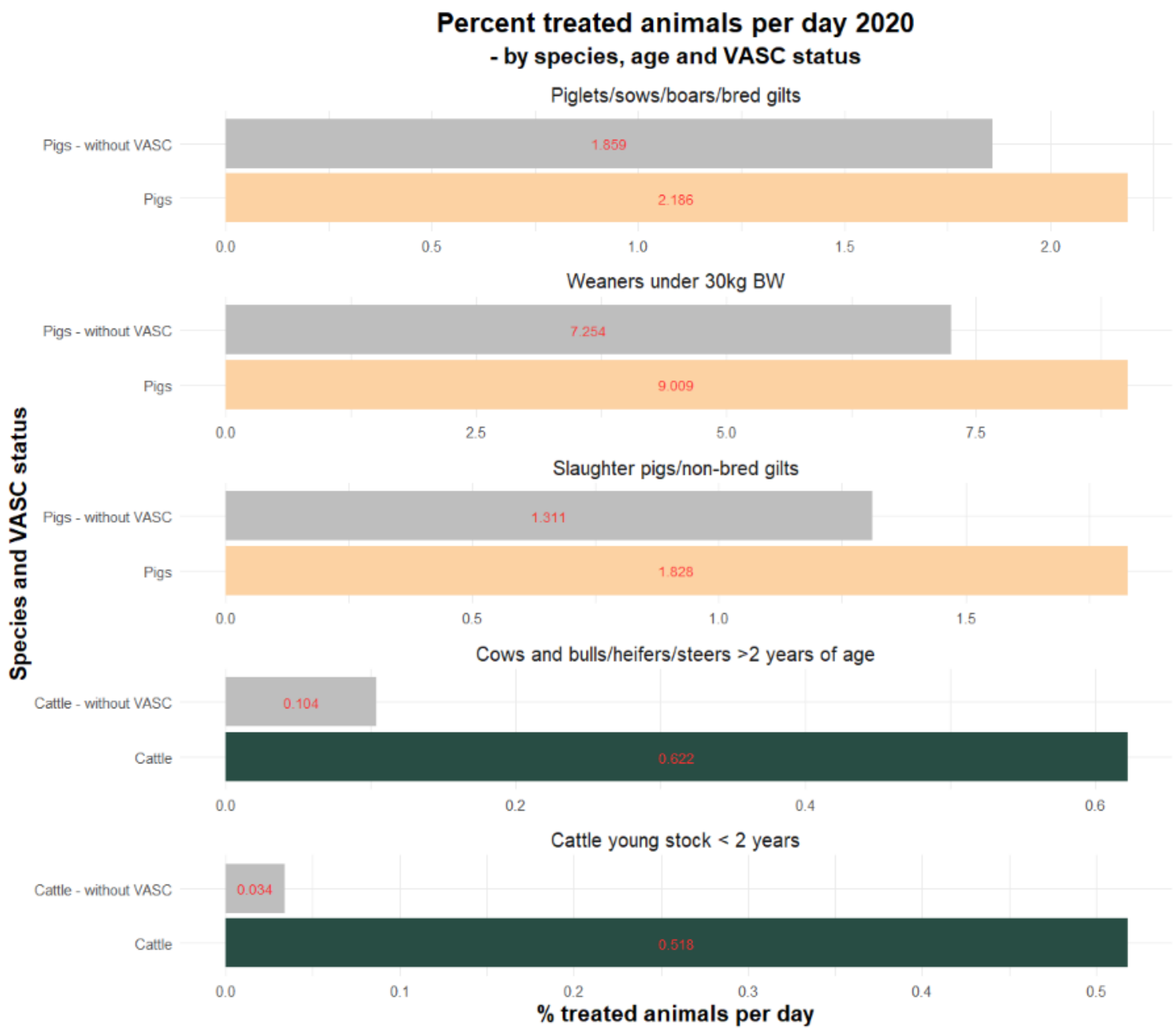

Figure 5. *Percent treated animals per day in 2020 for different age groups of pigs and cattle in farms with and without Veterinary Advisory Service Contracts (VASCs). Note that the scales vary between age groups. The red numbers are the percent treated animals per day for each group.*

When the same calculations were carried out for only AMU given as flock medication[1], defined as oral treatments, the findings were similar. However, the use of flock treatment was very similar between non-VASC farms and VASC farms for the age group “Slaughter pigs/non-bred gilts”.

The use of flock medication was investigated using data from old and new VetStat for 2020. In the old data 82.8% of the animal daily doses for weaners were prescribed as flock treatment. In the new data there were some inconsistencies in the level of flock medication that could not be resolved with the available data. Therefore, flock medication was not included in analyses or benchmarking in this report, but it could be done in future work. The reasons for changes in flock medication proportions have therefore not been further studied.

[1] Flock medication is defined in VetStat as medicine for oral use

Farm size

Dot plot of farm size versus AMU

For farms, the annual mean number of animals was compared to percentage of animals treated per day. In Figure 6, the results are shown for weaned pigs.

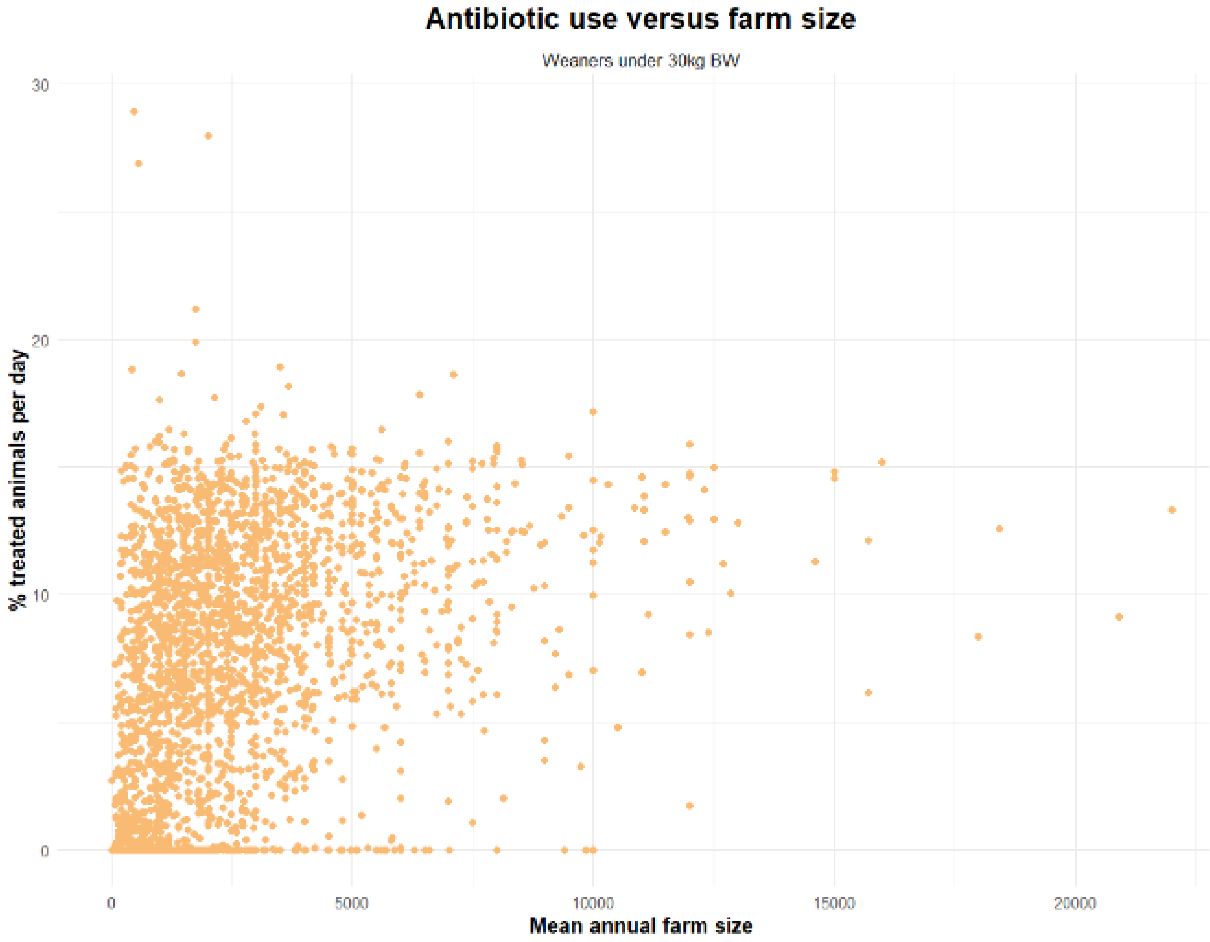

Figure 6. *Farm size based on annual mean number of animals versus annual percent treated animals per day for farms with weaners in 2020.*

Figure 6 shows a tendency of an increase in the average AMU with increasing farm size. This was most pronounced for weaners. This tendency is less clear for cattle - See Appendix III, Figures A4-A10 for illustrations of all age-groups plotted as scatter plots and boxplots.

Statistical analysis of association between farm size and AMU

A statistical analysis of associations between the outcome '% treated animals per day per farm in 2020' and age-group size was performed as a regression model for each age-group including observations from all properties with data for at least 9 months in 2020 aggregated to one row in the datasets per property. Age-group size was categorised into 10 groups of quantiles (Q) within each species-age group combination. No data were available to adjust for e.g. organic status, OUA or productivity in the properties.

The number of animals (or pen places recorded on the property) was significantly associated with the percent treated animals per day in 2020 for all age-group/species combinations. However, the difference between the age-group sizes was larger for some age groups than for others. For instance, the properties with the biggest 'Piglet/Sows/Boars/Bred gilts' and 'Slaughter pigs/Non-bred gilts' age groups had on average 1.6%-point higher % treated animals per day than the properties with the smallest size of that age-group. The same pattern was seen for weaned pigs, however with 7.7%-point higher % treated animals per day in the largest properties compared to the smallest properties.

For cattle the differences were smaller, but still statistically significant overall. The largest young stock group differed in the treatment level by 0.54% animals treated per day (2-3 times more treatments) compared to all the other groups, which were very similar in the levels of treatment.

For the adult cattle, the three largest groups of farms treated on average 0.5-0.7%-points more animals per day than the smallest reference group in the model.

The statistical results are included in Appendix III, Table A3.

Farm types

When reported as quantiles across the study period for VASC farms, the AMU appears to be affected by the composition of age groups on a farm for pigs and the proportion of young stock and size of the farm for cattle. This is most notable for weaners for pigs and young stock for cattle. See Appendix III, Figure A11. This association was not tested statistically.

Number of VASCs per veterinarian

The association between the number of VASCs and AP was investigated. A statistical analysis of associations between the outcome 'average % treated animals per day per farm in 2020 per veterinarian' and the number of VASCs per veterinarian was performed using a regression model for each age group in 2020 aggregated to one row in the datasets per veterinarian. The variable 'Number of VASCs' was categorized into three approximately equally sized categories.

The analyses showed that a higher number of VASCs per veterinarian was significantly associated with a higher average percentage of treated animals per day per farm in 2020 for all other age-group/species combinations than young cattle under 2 years old. In the young cattle group there was no difference detected between the VASC categories. The biggest difference between VASC categories were seen for the 'Weaner' and 'Slaughter pigs/Non-bred gilts' age groups.

The distributions are illustrated in Figures A12-A16, and the statistical results are included in Table A4 in Appendix III.

VASC profiles – Prevalence of mixed profiles

The composition of the VASC veterinarians' VASC profiles with regards to species included were summarized per year. The results are shown in Table 2. Mixed profiles account for 10.4% to 13.1% of the total profiles.

Table 2. *Distribution of veterinarians' Veterinary Advisory Service Contract profiles by year*

VASC profile	2019	2020	2021
Mixed cattle and pigs	51 (13.1 %)	49 (12.5 %)	38 (10.4 %)
Only Cattle	243 (62.0 %)	242 (61.5 %)	228 (62.3 %)
Only Pigs	104 (25.9 %)	102 (26.0 %)	100 (27.3 %)

Benchmarking models

Dashboard view

Inspired by the online VetStat platform a dashboard view was created for each veterinarian stratified by age groups. Each veterinarian will have AMU reported for multiple farms, i.e. all his/her farms with a VASC. AP per veterinarian can be reported in the proposed model for continuous benchmarking as either the median or the average percentage treated animals per day across all the veterinarians VASC farms with the age group for a given month. The national median or mean AMU and the corresponding 75% and 90% quantiles for the VASC veterinarians with the age groups can be included. This is similarly to the included national average AMU in the farm dashboard on vetstat.dk. In this report, the dashboard views are given for the same veterinarian plotted over a one year period from December 2018 to November 2019. The age group is "Weaners under 30kg BW". For six out of twelve months, the veterinarian has a median AP of zero. When the mean is used there are no months with zero AP, there are however, large fluctuations. When a moving average calculated over 3 months is used, the fluctuations are smaller. In Figure 7, the dashboard view can be seen with mean and moving average. The corresponding figure based on median is in Appendix IV, Figure A17.

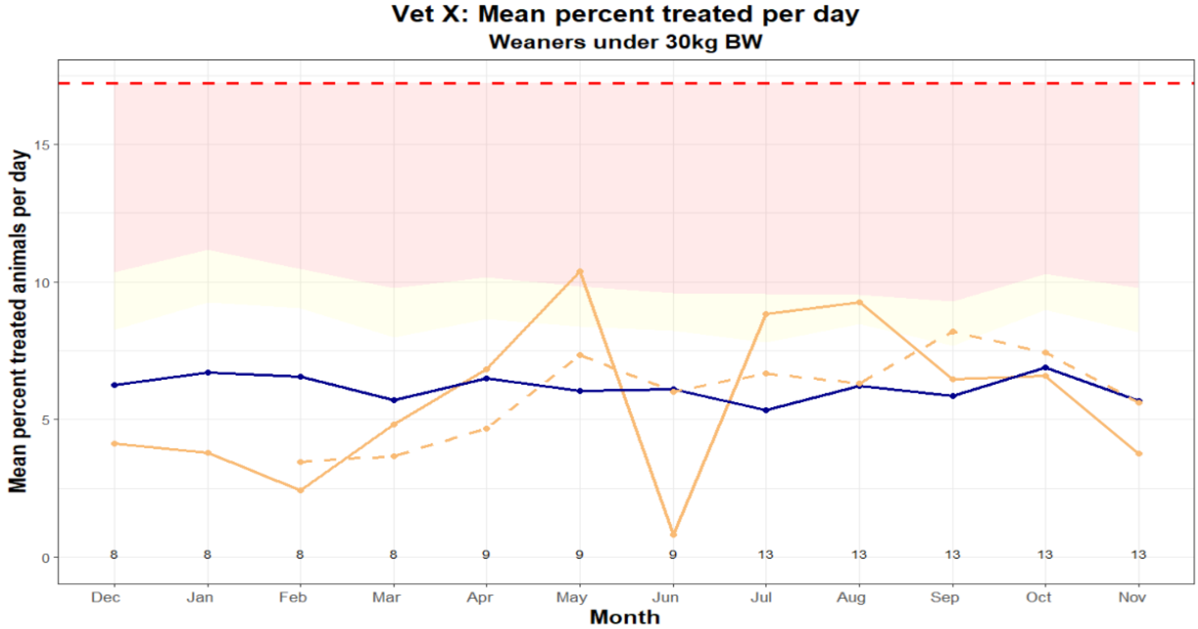

Figure 7*. Illustration of a continuous benchmarking of one veterinarian's mean/moving average antibiotic prescriptions across his/her Veterinary Advisory Service Contract farms with the pig age group "Weaners under 30kg BW"*
The orange line shows the veterinarian's mean percent treated animals per day across all VASC-farms in a month. The dashed orange line is the 3-month moving average for Vet X. The numbers above the x-axis show the number of VASCs the mean is based on.

The mean based on monthly mean antibiotic prescription for the population of VASC veterinarians with weaners is shown in blue along with the interval from the 75% quantile to 90% quantile (in pale yellow) and the interval from 90% quantile to the threshold in "Yellow Card" (pale red). The threshold is the red dashed line.

Benchmarking can also be done at a monthly level. Figure 8 illustrates benchmarking within a month for the veterinarian. The benchmarking is stratified by groups of veterinarians with different number of VASCs for weaners and the results are given both based on the monthly mean and the moving average for the veterinarian. Using the monthly mean results in a placement above the 75% quantile within the group with 5-35 VASCs in July 2019 for the veterinarian. However, using the moving average results in a placement roughly in the middle of the group. The figure illustrates the spread of the veterinarians with AP ranging from 0% to around 12%.

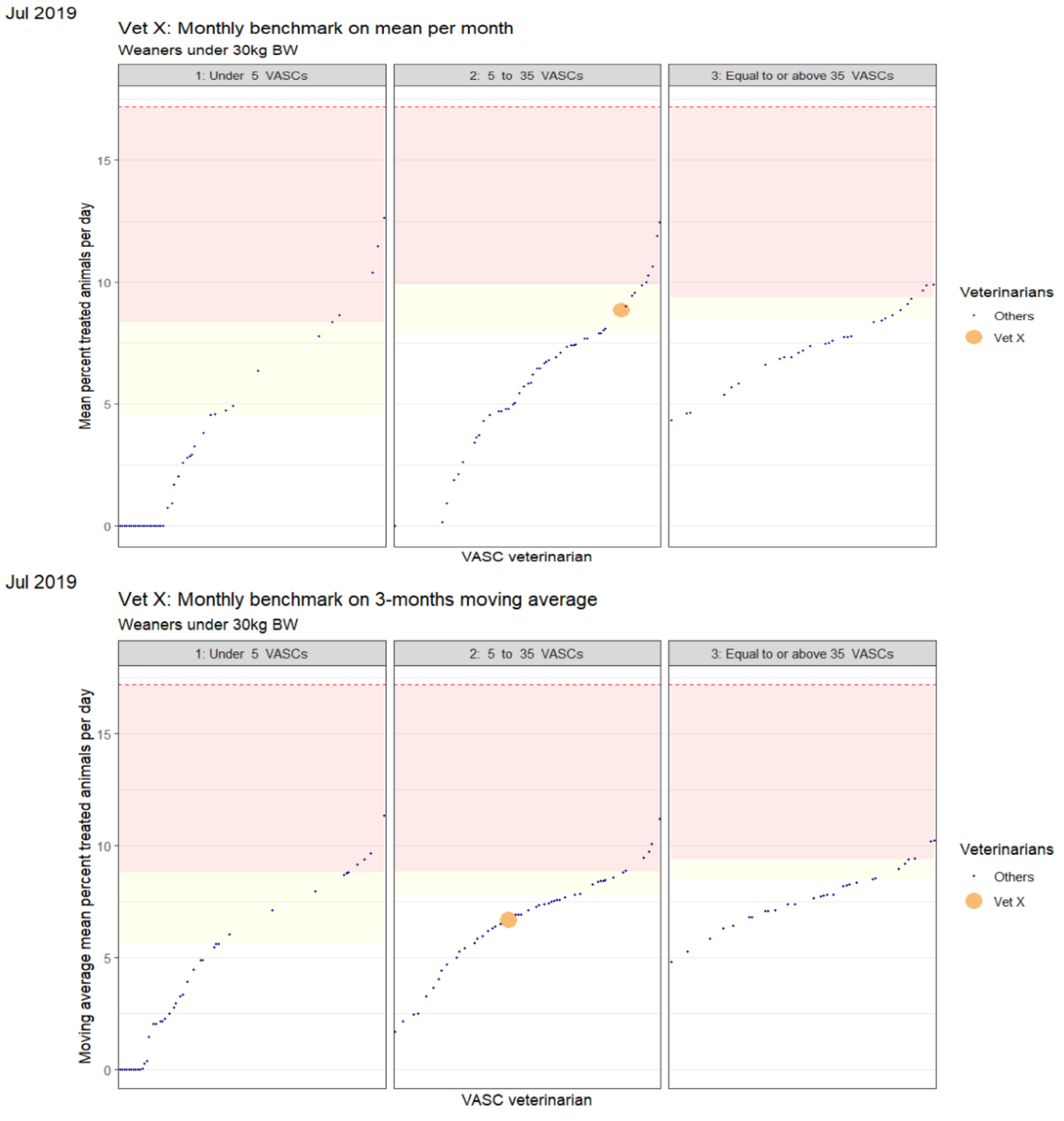

Figure 8. *Illustration of a monthly benchmark of one veterinarian's mean/moving average antibiotic prescriptions across all his/her herds with the pig age group "Weaners under 30kg BW" with Veterinary Advisory Service Contracts (VASCs).*

The orange dot shows the Vet Xs' mean and moving average percent treated animals per day across all VASC-farms in July 2019.

The pale yellow indicates the 75% quantile to 90% quantile for antibiotic prescription mean (top pane) moving average (bottom pane) of the population of VASC veterinarians with the age group "Weaners under 30kg BW". The pale red indicates the interval from 90% quantile to the threshold in "Yellow Card" (pale red). The threshold is the red dashed line.

Discussion

Comments on implementation of the benchmark model

Relevance

Developing relevant graphic illustrations of the veterinarians' prescription patterns and practices is important, as it can promote constructive dialogue between stakeholders.

Data for analyses

The proposed benchmark models are based on data tables identical to the ones used to generate the herd dashboard views on www.vetstat.dk. This should ease implementation of the models in the existing system. The benchmark models are based on farm-level data but can be easily converted to herd-level with inclusion of only new VetStat data.

Median versus mean

Using median antibiotic prescription per month for continuous benchmarking in VetStat is challenging when the frequency of prescriptions for a given farm exceeds one month. A veterinarian with a prescription pattern with less frequent prescriptions per farm can end up with many months with a median prescription equal to zero. This challenge also applies to the population median and quantiles especially for the age group containing slaughter pigs.

The mean antibiotic prescription per month can show large fluctuations between months. This can be counteracted by introducing a moving average. In this model, a 3-month moving average was chosen in collaboration with the DVFA. A benefit with 3-months versus e.g. nine and twelve months is that seasonal changes can be captured and illustrated. This is primarily relevant for cattle. If a similar model to the one presented in this report is to be implemented we propose basing it on the mean and the moving average.

Further development

In this report, the focus has been developing an overall benchmark model for VASC veterinarians based on mean antibiotic prescription per month. However, further details can be added to the benchmarking. Relevant areas could be benchmarking on proportion of flock medication prescribed or proportion of selected antibiotic classes. This is feasible as the information is already present in the data extracted for this report.

During an internal presentation of the benchmark work in the Section Animal Welfare and Disease Control at University of Copenhagen the implementation of Statistical Process Control (SPC) along with the benchmarking was suggested. SPC can help detect sudden large fluctuations or steady increases in prescribed antibiotics by a veterinarian. This could be useful, e.g. when the DVFA select veterinarians for obligatory supervision.

Challenges with the proposed model

Factors influencing farm-level AMU

In the chapter "Basic AMU description" a few of the factors, which can influence farm-level AMU are presented. The age of the animals is one of the most important factors and the model corrects for this by benchmarking by age groups instead of species. However, this also results in multiple benchmarking groups per veterinarian. Universal benchmarking across age groups and species is not possible with the proposed, relatively simple model.

A few of the factors that the model does not correct for is farm size (as a potential factor affecting the AMU), farm type (e.g. production type, organic or OUA-production) and productivity. Productivity is mainly an issue for pigs, where the number of animals is derived from the number of pen places. When comparing two farms, who treat the individual animal with the same amount of antibiotics, a farm which produces more pigs per pen place per year, will tend to have a higher AMU. This is especially important for weaners as the youngest pigs receive most treatments.

According to our analyses, farm size or age group size within farm is associated with AMU. This can be important when comparing veterinarians with small farms in their VASC profile with veterinarians with primarily large farms in their profile, and is not taken into account in the simple benchmark model.

Farm type might also impact AMU, but this has not been investigated in detail, as the information is not currently readily available in VetStat. Previously, farm types based on composition of animal on a farm has been investigated and visually there are differences between the types; most notably for weaners for pigs and young stock for cattle. Farms with a high proportion of cattle young stock will often have significantly higher % treated animals per day than farms with more older animals. The simple model cannot correct for this, and benchmarking of VASC veterinarians with primarily one age group against veterinarians with primarily the other age group distribution risk being perceived as inappropriate by the veterinarians.

The significance of a farms status as organic or conventional has not been studied due to lack of access to that information in VetStat, but it may have a significant impact on farm AMU. Many smaller organic farms may have been excluded in the benchmark model due to lack of VASC.

Veterinarian factors influencing AMU

The number of VASCs the veterinarian is holding seems affect the level of AMU. There is a partial correction for this in the model with the within month-based benchmark dashboard. The continuous benchmark models can be based on data from only the group, which a veterinarian belongs to, but it increases the number of graphs generated and thus the complexity of the model. This could be further studied, when deciding on a model to implement.

The composition of VASC profiles concerning species and age groups has not been extensively studied, but mixed profiles account for 10.4% to 13.1% of the total profiles during the study period. This may be relevant and could be further studied.

Assigning responsibility for AMU

According to Danish legislation, veterinarians holding VASCs are responsible for advising about AMU in their respective VASC farms. This is one of the reasons for placing the prescriptions made by other veterinarians to a VASC farm on the VASC veterinarian. However, the proportion and significance of AMU prescriptions made by other veterinarians should be further investigated to ensure fair comparison. In the previous report from 2021, it was shown that around 25% for pigs and up to 50% of antibiotics for cattle were prescribed by a veterinarian not responsible for the VASC with the farm.

Lowering or optimising farm AMU can take time. This may be relevant if a veterinarian signs a VASC with a new farm. In this model, the farm is included in the veterinarians mean antibiotic prescriptions the month the VASC is signed. It might be relevant to discuss a grace period for new farms before they are included in the veterinarians mean.

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Appendix I – Data and data management

Received data

Table A1. *Received data for this and the previous report*

Data received in 2022	Data received in 2021	Content
vetstat_SUNDHEDSRAADGIVNINGSAFTALE **vetstat_KONVERTERING_CHR_SRA_kvæg** **vetstat_KONVERTERING_CHR_SRA_svin** **vetstat_AFTALETYPE** **vetstat_REL_AFTALETYPE_DYREART**	VTS_SRAFTALE	Data providing information on veterinary advisory service contracs
vetstat_beregn_doser_pr_dag_chr **vetstat_beregn_doser_pr_dag_chr_gns**	VTS_DOSER VTS_DOSERPERDAG	The antibiotic use data aggregated per month by the Danish Veterinary and Food Administration
vetstat_BEREGN_DYREDAGE	VTS_DAGE	Number of animals per month given for each farm/herd dived into species and age groups
VetStat_indberetning	VTS_APO_MED_REG VTS_DYRL_MED_REG VTS_FODERREG	The "raw" registrations as they are entered into VetStat. Before June 2021 the raw data was divided into three data tables based on who entered them.
vetstat_DYREAEKVIVALENT	VTS_DYREEKVIVALENT	The assigned daily doses for relevant products. Typically given as amount per kilo body weight.
vetstat_AKTIVTSTOF **vetstat_ANTIBIOTIKA** **vetstat_ATCGRUPPER** **vetstat_ATC_KODE** **vetstat_ATC_NIVEAUNAVN** **vetstat_DISPENSERINGSFORM** **vetstat_DISPENSERINGSGRUPPE** **vetstat_STANDARDENHED** **vetstat_STYRKEENHED** **vetstat_PAKNINGSTYPE** **vetstat_VARE**	VTS_AKTIVT_STOF VTS_VARE VTS_VARE_AKTIVT_ST OF **Received in 2015**: VTS_ANTIBIOTIKAGRU PPE VTS_DISPENSERING VTS_DISPGRUPPE	Data on products covering active ingredients, pharmaceutical form, route of administration, strength of the product and packaging. In addition, ATC codes [15] and antibiotic classes can be added.
vetstat_ALDERSGRUPPE **vetstat_CHR_DYREART** **vetstat_ORDINATIONSGRUPPE**	**Received in 2015**: VTS_ALDERSGRUPPE VTS_ORDINATIONSGR UPPE	Supplementary data connecting the used ID's from registrations with text labels for species, age groups and areas of disorder.
vetstat_CHR_BEAETNING	-	A key connecting herds with farm ID's

Data changes with the updated VetStat

Sales data

Raw sales data is now combined in one data frame in opposition to three before. Another change is that records included in the basis for generation reports are clearly marked.

Product data

A marked change from the previous data is product, which is now based on extracts from the National Service Platform (NSP), where a national register of approved products is stored, as opposed to being manually entered into VetStat by the DVFA employees before. There have been issues with units for records with specific products entered into VetStat via the Danish Cattle database.

VASC data

The VASC data were provided in multiple data sets with a set of converted files, one per species, covering the historical VASCs at farm level before the implementation of the new VetStat and a data set covering the VASCs at herd level after June 1st 2021. In addition to the latter, were a couple of supplementary data sets.

Number of animals

The DAYS data is delivered to VetStat from the CHR register and contains calculated animal days per herd, which was aggregated at farm level for this report.

Adjustments to study data

Years with uninterrupted seasons

Seasons were added to the data to investigate season changes in AMU – mainly relevant for cattle. During this process the concept "season years" was introduced. Season years covers the months January to November in a given year plus December in the previous year to avoid splitting the winter season. All data on AMU given in animal doses or percentage treated animals per day is using season years as the time variable.

Merging challenges

The new VetStat operates largely with both herd and farm numbers as registered in the CHR data base and corresponding ID's added in VetStat. In June, the DK-VET received an additional data table containing the link between the herd numbers and CHR ID's. The DK-VET has used data made available for the previous report to create a key containing the link between recorded herd numbers, herd IDs, CHR numbers and CHR IDs. The key is however incomplete.

Appendix II – The www.vetstat.dk dashboard view

Figure A1 shows the dashboard view of AMU from www.vetstat.dk for the age group "Cow, bulls/heifers/steers >2 years of age" from a random cattle farm over a one year period. July is still open for corrections to data and August has not yet been reported. The second panel shows the distribution of antibiotic classes for the same period.

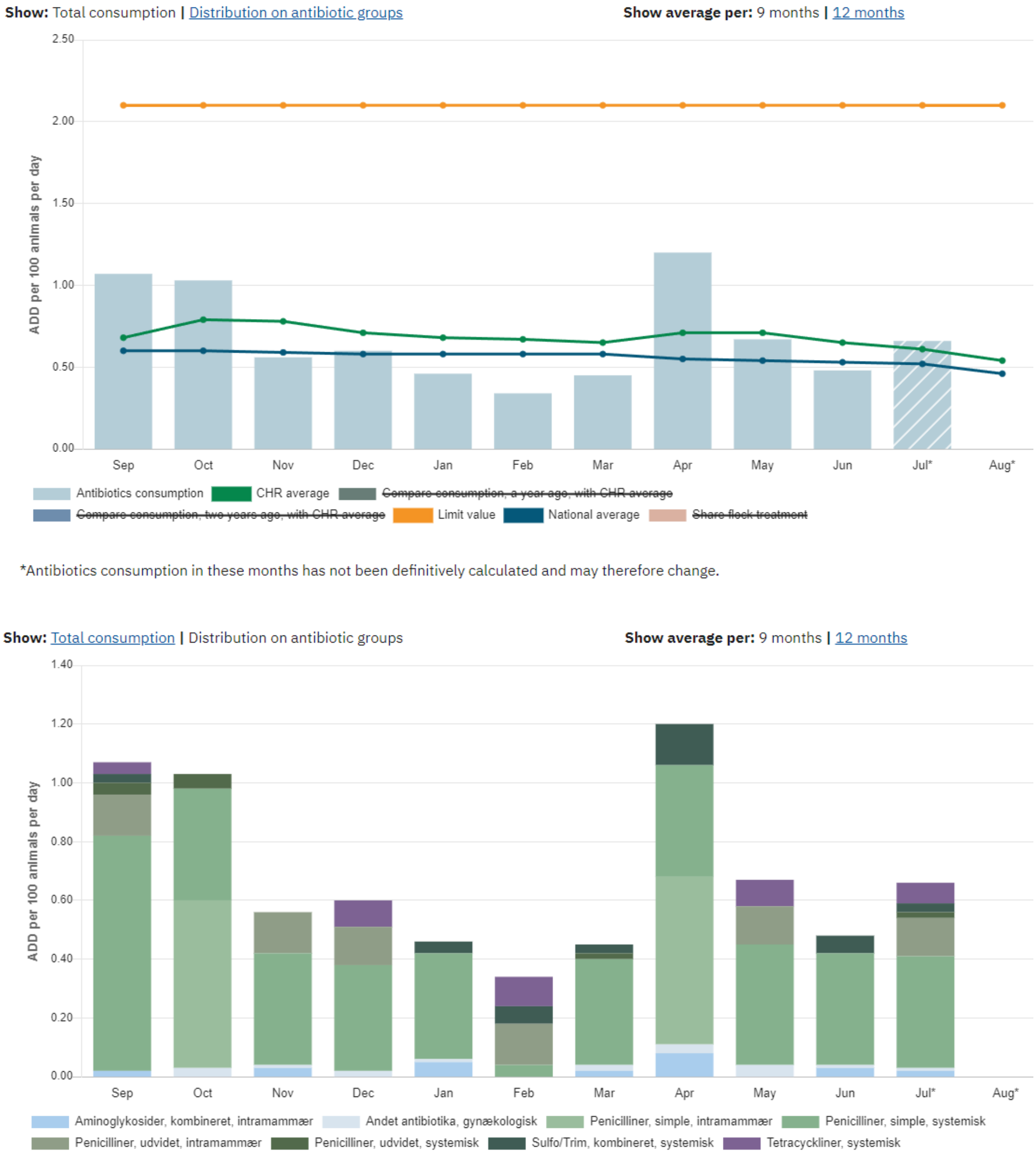


***Figure A1**. Dashboard view on www.vetstat.dk for random cattle farm*

Appendix III – Additional figures from analyses

Average percentage treated animal per day by VASC status

Average AMU for farms with/without VASC

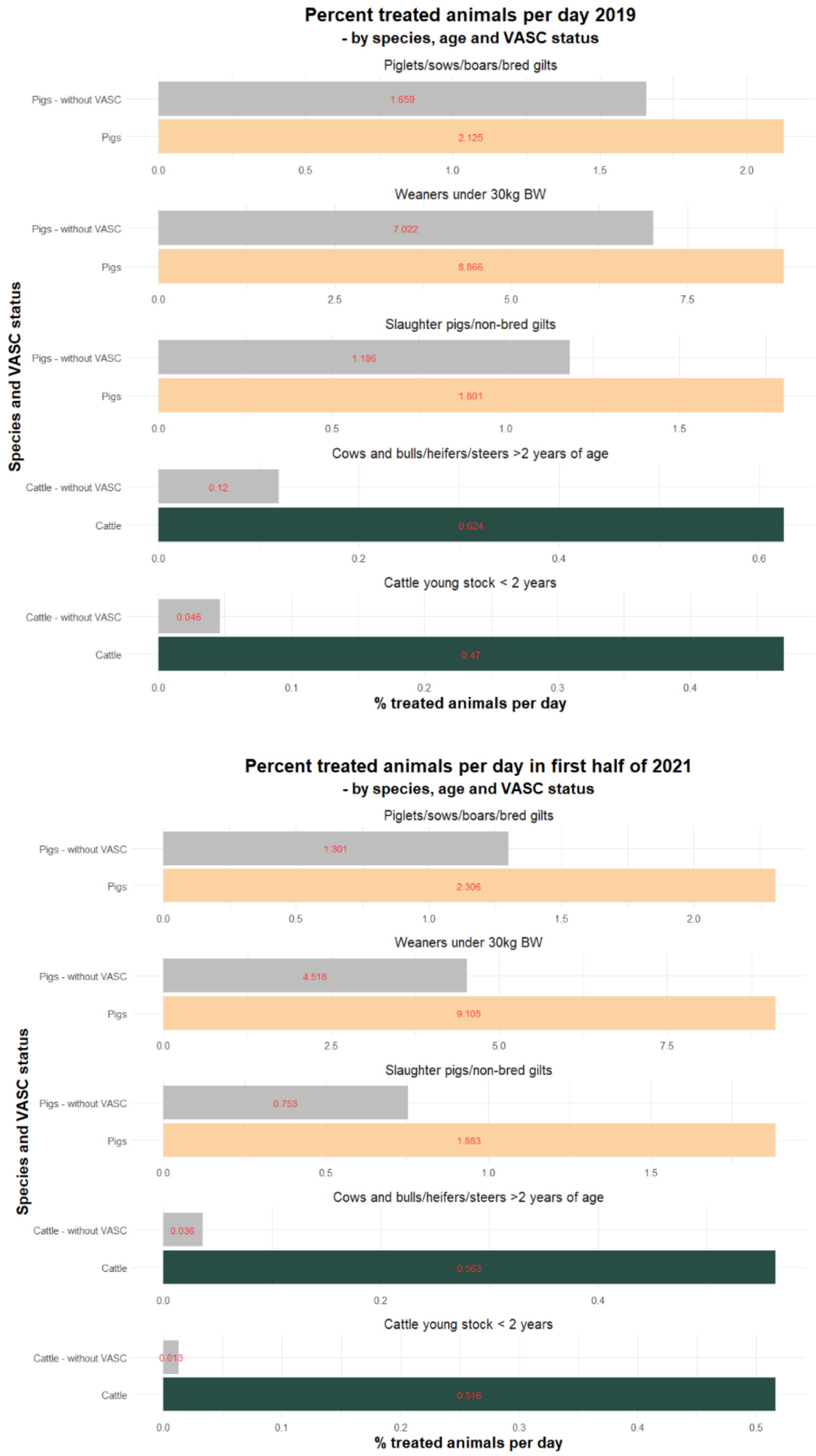


Figure A2. *Percent treated animals per day in 2019 and first half of 2021 for different age groups of pigs and cattle in farms with and without Veterinary Advisory Service Contracts (VASCs).*
Note that the scales vary between age groups. The red numbers are the percent treated animals per day in the groups.

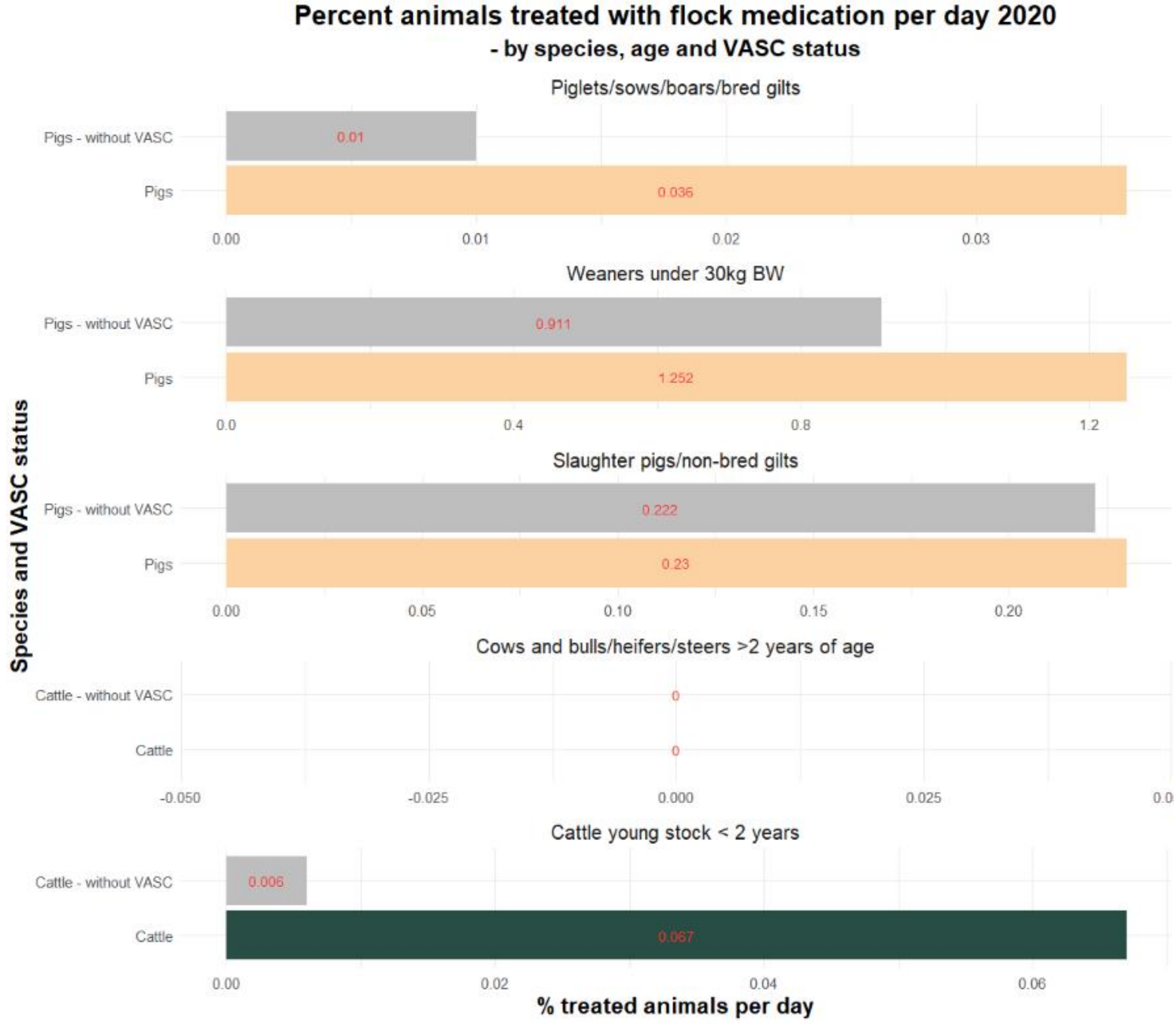


Figure A3. *Percent animals treated with flock medication per day in 2020 for different age groups of pigs and cattle in farms with and without Veterinary Advisory Service Contracts (VASCs)Note that the scales vary between age groups. Flock treatment is not used in adult cattle. The red numbers are the percent treated animals per day in the groups.*

Veterinary Advisory Service Contracts

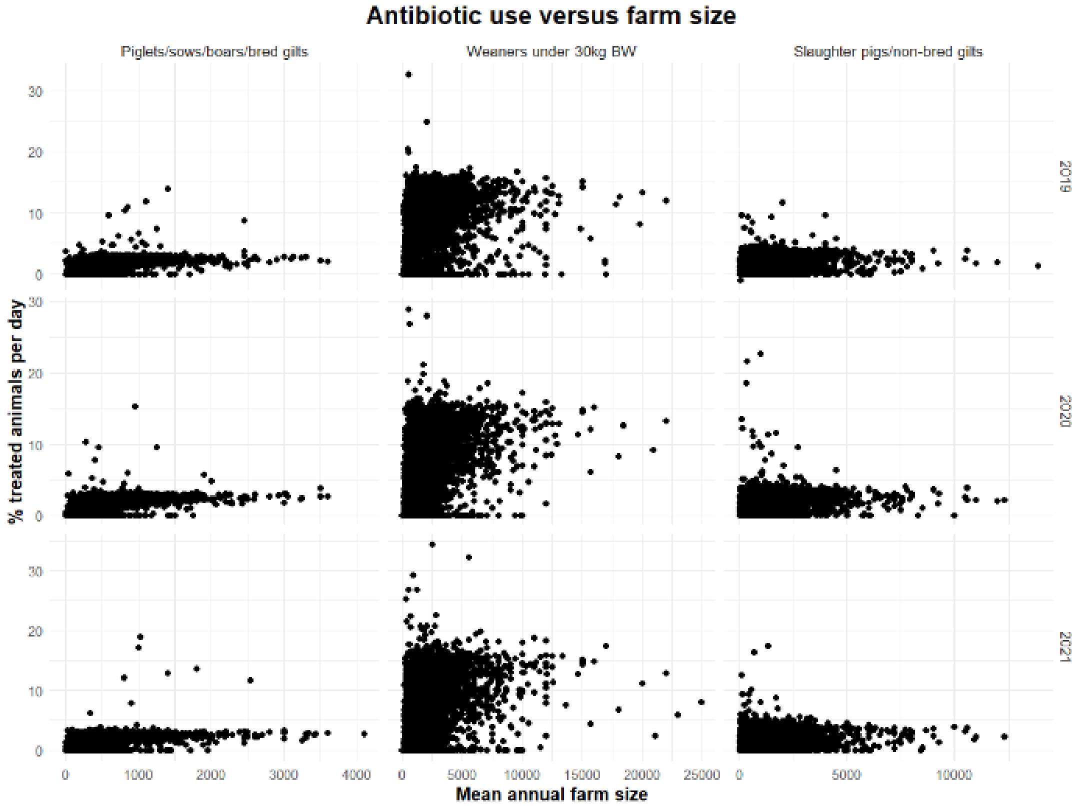
VASC status and VASC requirement

Table A2. *Percent of total number of animal daily doses (ADD) prescribed for farms without Veterinary Advisory Service Contracts (VASC) in 2020.*

Age group	% ADD prescribed for farms without VASC
Piglets/sows/boars/bred gilts	2.52 %
Slaughter pigs/non-bred gilts	3.78 %
Weaners under 30kg BW	2.91 %
Cattle young stock < 2 years	2.33 %
Cows and bulls/heifers/steers >2 years of age	3.84 %

Farm size

Dot plot of farm size versus AMU



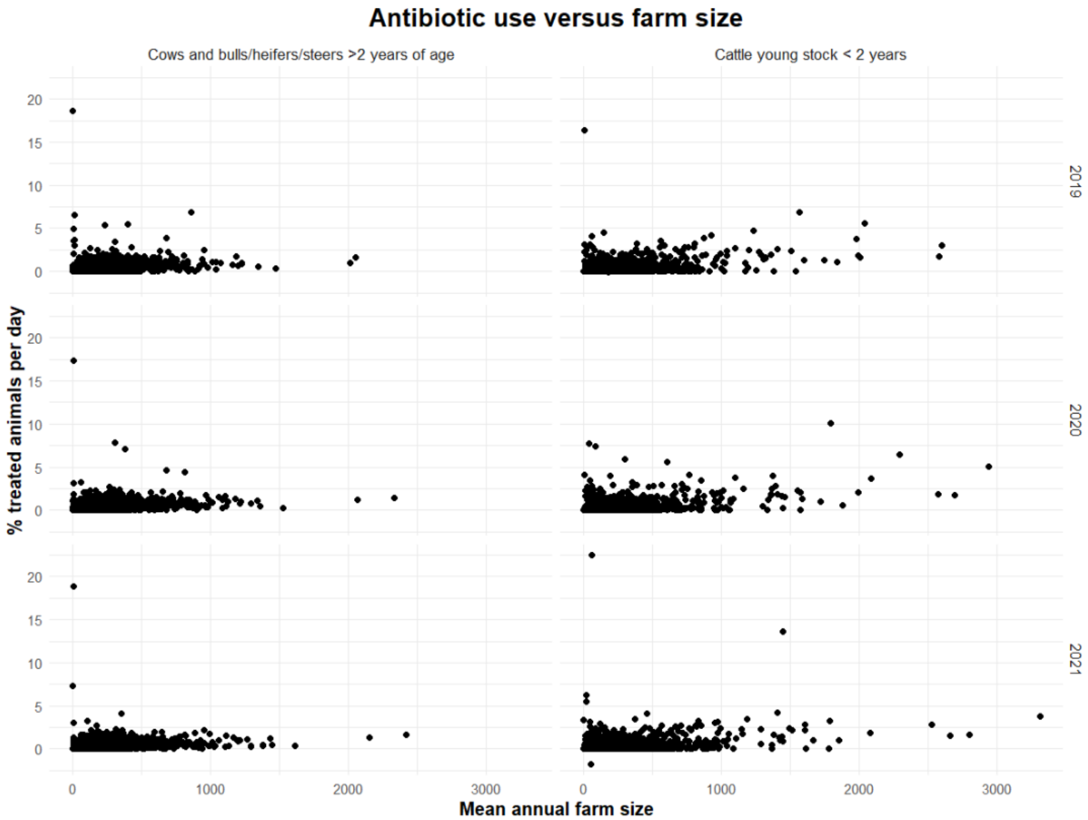


Figure A4. *Farm size based on annual average number of animals versus annual percent treated animals per day by year and age group*

Figure A5*.* Percent treated sows*/piglets/boars/bred gilts per day per herd in 2020, stratified by the following herd size groups, 0: up to the 10th percentile (Q10), 1: Q10-Q20, 2: Q20-Q30, 3: Q30-Q40, 4: Q40-Q50, 5: Q50-Q60 6: Q60-Q70, 7: Q70-Q80, 8: Q80-Q90, 9: Q90-Q100.*

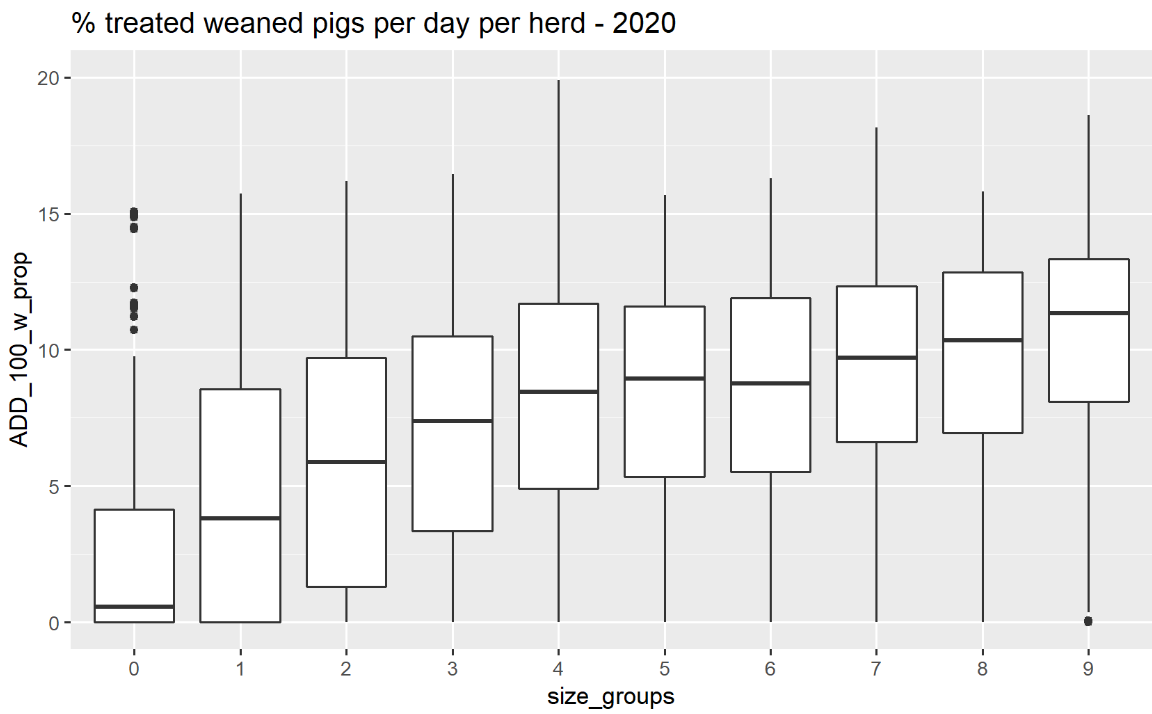


Figure A6*.* Percent treated weaned pigs per day per herd in 2020, stratified by the following age-group size categories, 0: up to the 10th percentile (Q10), 1: Q10-Q20, 2: Q20-Q30, 3: Q30-Q40, 4: Q40-Q50, 5: Q50-Q60 6: Q60-Q70, 7: Q70-Q80, 8: Q80-Q90, 9: Q90-Q100.

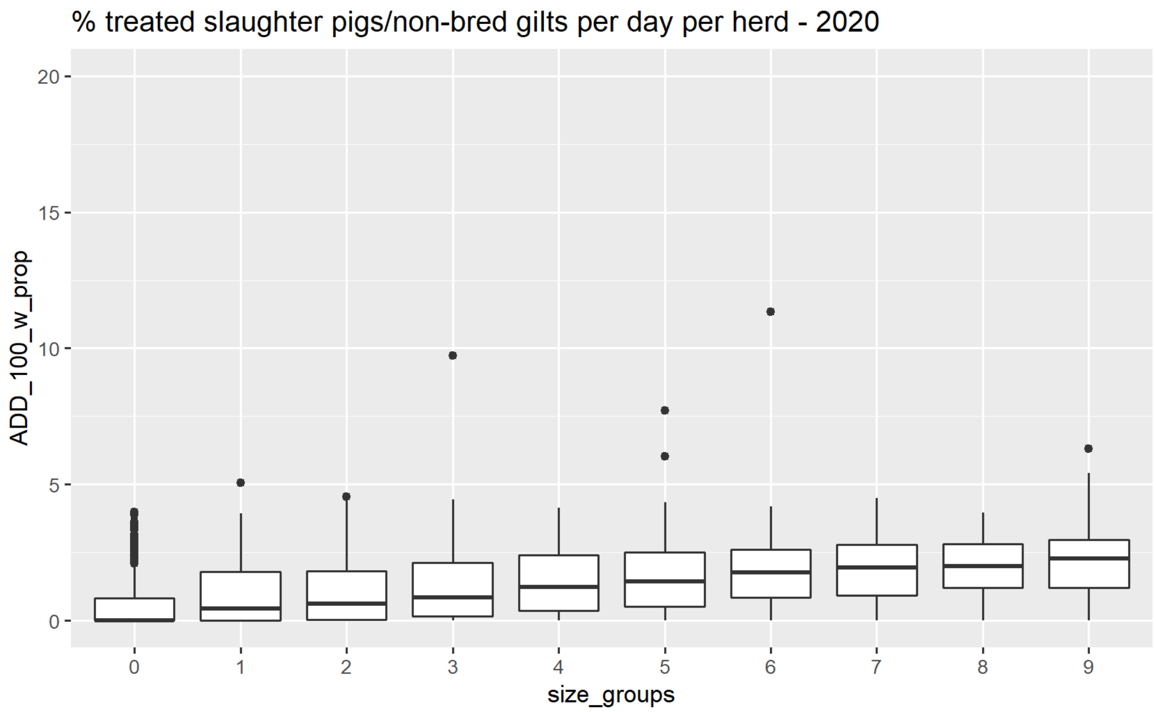


Figure A7. *Percent treated slaughter pigs and non-bred gilts per day per herd in 2020, stratified by the following age-group size categories, 0: up to the 10th percentile (Q10), 1: Q10-Q20, 2: Q20-Q30, 3: Q30-Q40, 4: Q40-Q50, 5: Q50-Q60 6: Q60-Q70, 7: Q70-Q80, 8: Q80-Q90, 9: Q90-Q100.*

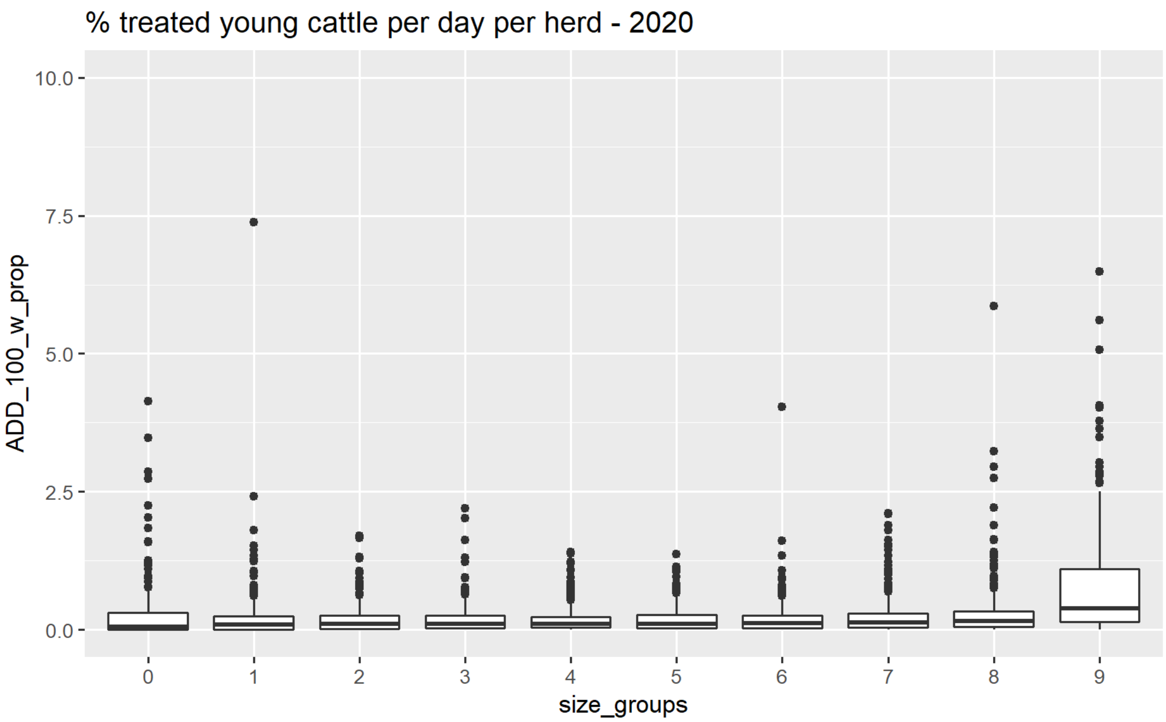


Figure A8. *Percent treated young cattle < 2 years old per day per herd in 2020, stratified by the following age-group size categories, 0: up to the 10th percentile (Q10), 1: Q10-Q20, 2: Q20-Q30, 3: Q30-Q40, 4: Q40-Q50, 5: Q50-Q60 6: Q60-Q70, 7: Q70-Q80, 8: Q80-Q90, 9: Q90-Q100.*

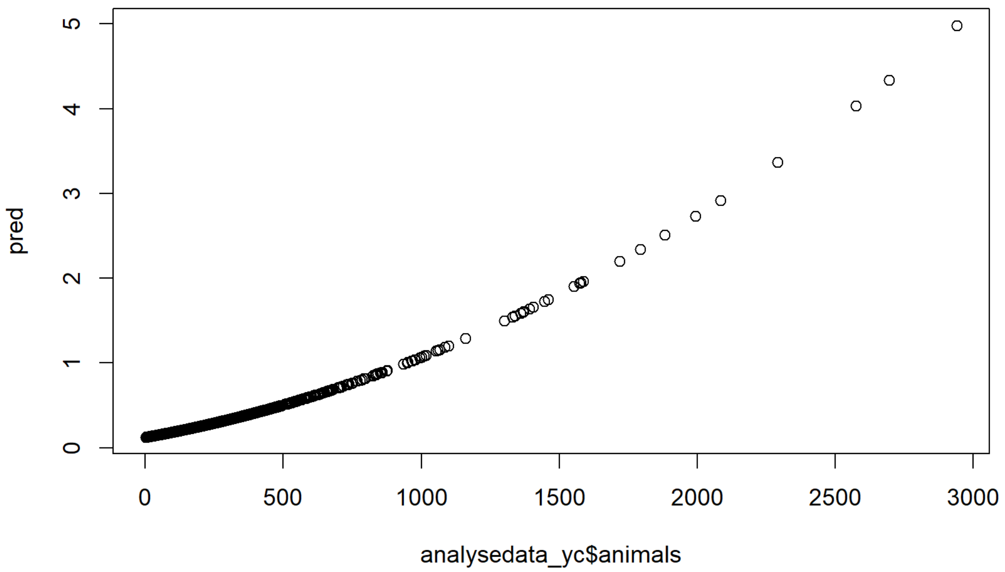


Figure A9. *Model predicted percent treated young cattle < 2 years old per day per herd in 2020 vs. number of animals in the young stock group below 2 years old in the analysed properties.*

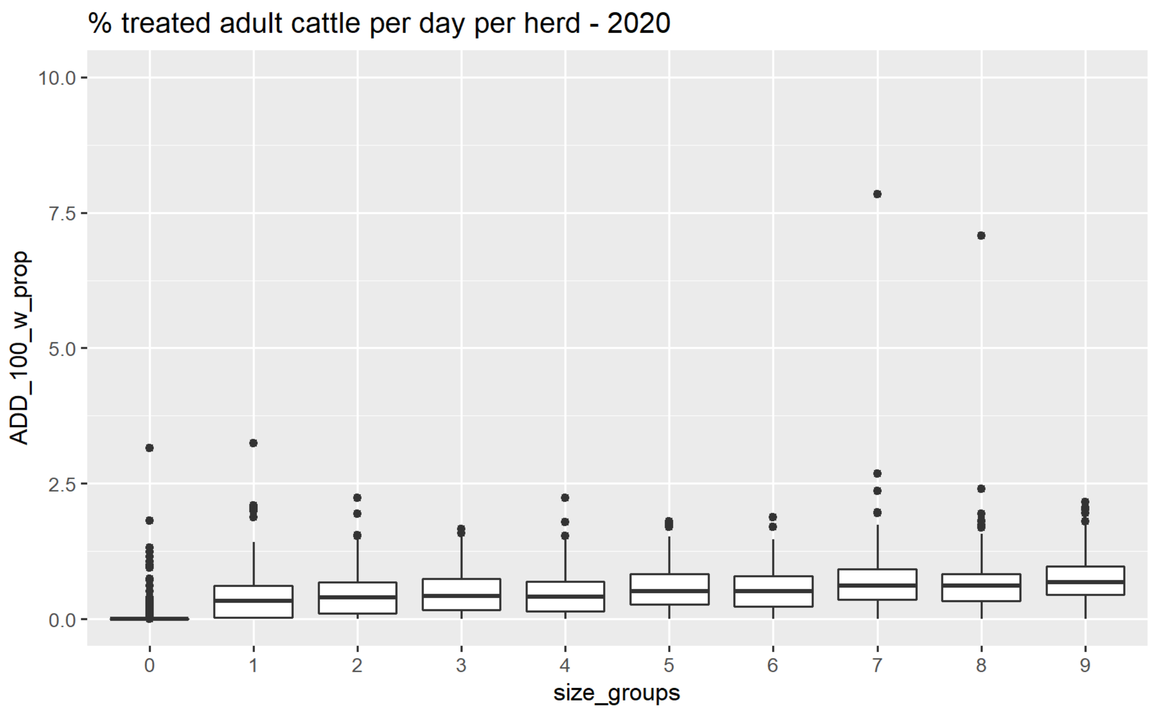


Figure A10. *Percent treated adult cattle > 2 years old per day per herd in 2020, stratified by the following age-group size categories, 0: up to the 10th percentile (Q10), 1: Q10-Q20, 2: Q20-Q30, 3: Q30-Q40, 4: Q40-Q50, 5: Q50-Q60 6: Q60-Q70, 7: Q70-Q80, 8: Q80-Q90, 9: Q90-Q100*

Statistical analysis of association between farm size and AMU

The statistical analysis of associations between the outcome 'average % treated animals per day per herd in 2020' and age-group size was performed as a regression model for each age-group including observations from all properties with data for at least 9 months in 2020 aggregated to one row in the datasets per property. Age-group size was categorized into 10 groups of quantiles (Q) within each species-age group combination. No data were available to adjust for e.g. organic status, OUA or productivity in the properties.

Table A3. *Statistical analysis of association between farm size and AMU*

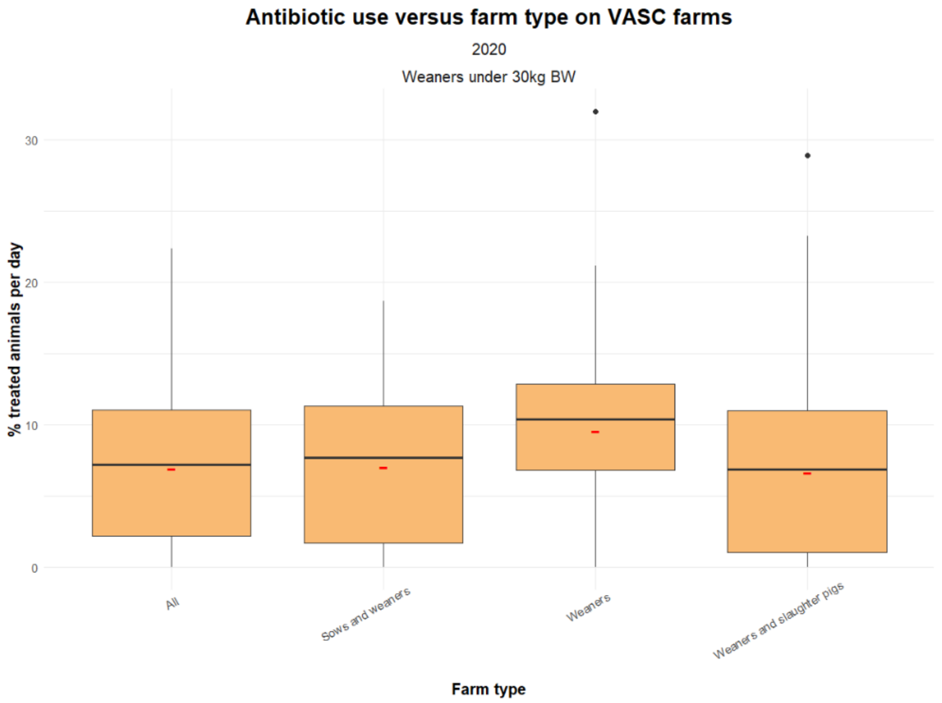
Variable	Category (n animals)	N properties	Estimate*	95% CI of estimate	p-value**
	Piglets/Sows/Boars/Bred gilts				
Age-group size					< 0.0001
	0: <Q10 (2-178)	158	0.849	0.71-0.99	a
	1: Q10-20 (179-299)	155	0.587	0.39-0.79	b
	2: Q20-30 (300-395)	159	0.877	0.68-1.08	b, c
	3: Q30-40 (398-483)	156	1.121	0.92-1.32	c, e
	4: Q40-50 (485-575)	156	1.164	0.96-1.36	c, d, e
	5: Q50-60 (580-661)	159	1.190	0.99-1.39	d, e,
	6: Q60-70 (663-761)	157	1.258	1.06-1.46	e, f, g, h
	7: Q70-80 (762-990)	157	1.491	1.29-1.69	g, h
	8: Q80-90 (991-1282)	157	1.532	1.33-1.73	h
	9: Q90-100 (1284-3600)	158	1.563	1.36-1.76	h
	Weaned pigs				
Age-group Size					< 0.0001
	0: <Q10 (9-395)	207	2.629	2.04-3.22	a
	1: Q10-20 (400-750)	267	2.183	1.39-2.97	b
	2: Q20-30 (752-1095)	222	3.285	2.46-4.11	b
	3: Q30-40 (1100-1495)	235	4.565	3.76-5.38	c, d
	4: Q40-50 (1500-1960)	254	5.218	4.42-6.01	c, d, e
	5: Q50-60 (1972-2496)	237	5.534	4.73-6.34	d, e, f
	6: Q60-70 (2498-2990)	194	5.666	4.82-6.52	d, e, f, g
	7: Q70-80 (3000-3793)	271	6.492	5.71-7.28	f, g, h
	8: Q80-90 (3800-5417)	243	6.942	6.14-7.75	h, i
	9: Q90-100 (5500-22000)	240	7.695	6.89-8.50	i
	Slaughter pigs/Non-bred gilts				
Age-group size					< 0.0001
	0: <Q10 (5-136)	406	0.561	0.45-0.67	a
	1: Q10-20 (138-298)	414	0.404	0.25-0.56	b
	2: Q20-30 (300-499)	363	0.496	0.33-0.66	b, c
	3: Q30-40 (500-748)	466	0.673	0.52-0.83	c, d
	4: Q40-50 (750-998)	413	0.867	0.71-1.03	d, e
	5: Q50-60 (1000-1245)	428	1.002	0.85-1.16	e, f
	6: Q60-70 (1250-1596)	413	1.213	1.06-1.37	f, g
	7: Q70-80 (1600-1999)	405	1.353	1.19-1.51	g, h
	8: Q80-90 (2000-2491)	395	1.386	1.23-1.55	g, h
	9: Q90-100 (2500-12300)	457	1.559	1.41-1.71	h

(Continued on the next page)

Variable	Category (n animals)	N properties	Estimate*	95% CI of estimate	p-value**
Cows and bulls/heifers/steers >2 years of age					
Age-group size					< 0.0001
	0: <Q10 (1-51)	245	0.089	0.03-0.14	a
	1: Q10-20 (52-107)	248	0.331	0.25-0.41	b
	2: Q20-30 (108-135)	246	0.359	0.28-0.44	b, d
	3: Q30-40 (136-153)	243	0.406	0.33-0.49	b, e
	4: Q40-50 (154-178)	243	0.392	0.31-0.47	b, e
	5: Q50-60 (179-209)	247	0.487	0.41-0.57	c, e, f
	6: Q60-70 (210-251)	248	0.461	0.38-0.54	c, d, e
	7: Q70-80 (252-316)	252	0.605	0.53-0.68	f, g
	8: Q80-90 (317-421)	246	0.581	0.50-0.66	f, g
	9: Q90-100 (423-2334)	247	0.639	0.56-0.72	g
Cattle young stock < 2 years old					
Age-group size					< 0.0001
	0: <Q10 (2-68)	266	0.261	0.20-0.32	a
	1: Q10-20 (69-95)	267	-0.037	-0.12-0.05	a
	2: Q20-30 (96-117)	279	-0.065	-0.15-0.02	a
	3: Q30-40 (118-137)	270	-0.067	-0.16-0.02	a
	4: Q40-50 (138-161)	275	-0.061	-0.15-0.03	a
	5: Q50-60 (162-186)	273	-0.072	-0.16-0.02	a
	6: Q60-70 (187-223)	271	-0.053	-0.14-0.04	a
	7: Q70-80 (224-290)	271	0.000	-0.09-0.09	a
	8: Q80-90 (291-397)	275	0.049	-0.04-0.14	a
	9: Q90-100 (398-2941)	272	0.539	0.45-0.63	b

** The estimate for the first category (<Q10) represents the average of that age-group size.*
The estimates of the other categories indicate how much higher the average % treated animals per day per herd were for each of those categories compared to category 0: <Q10.
*** Different letters indicate groups that are statistically different at the 0.05-significance level*

Farm types



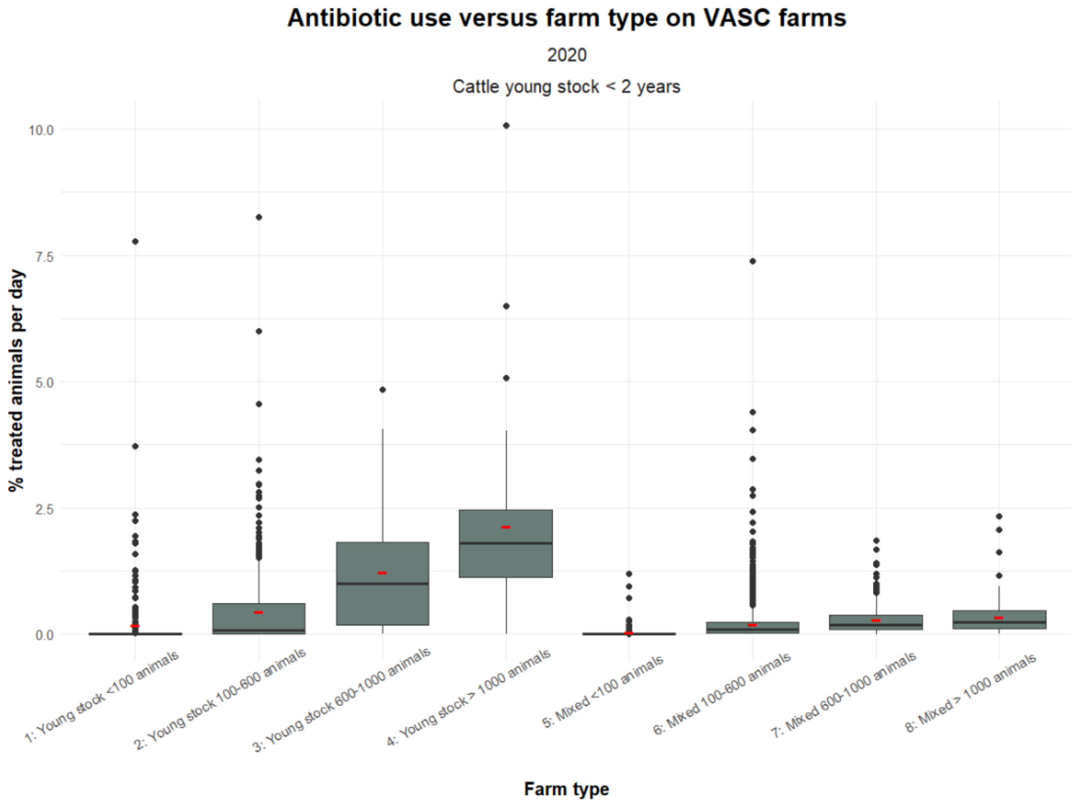


Figure A11. *Antibiotic use versus farm type for weaners and cattle young stock in 2020.*
For each age group the percentage of treated animals per day was calculated per farm for 2020. The farms were then grouped by the farm types defined in the 2021 report. The results are given as boxplots for the pig age group "Weaners under 30 kg BW" in yellow and the cattle age group. T "Cattle young stock < 2 years" in green. The mean percentage treated animals per day for the group is marked with a red line (-)

Number of VASCs per veterinarian

Table A4. *Statistical analysis of association between the number of VASCs and mean AP in 2020*

Variable	Category (n animals)	N veterinarians	Estimate*	95%CI of estimate	p-value**
Piglets/Sows/Boars/Bred gilts					
Number of VASCs					< 0.0001
	1: Below 4	38	1.274	1.05-1.50	a
	2: 4 to 18	43	0.401	0.10-0.71	b
	3: Equal to or above 18	41	0.695	0.39-1.00	b
Weaned pigs					
Number of VASCs					< 0.0001
	1: Below 5	44	4.086	3.33-4.85	a
	2: 5 to 27	41	2.135	1.04-3.23	b
	3: Equal to or above 27	42	3.593	2.50-4.68	c
Slaughter pigs/Non-bred gilts					
Number of VASCs					< 0.0001
	1: Below 6	50	0.643	0.48-0.80	a
	2: 6 to 36	50	0.591	0.37-0.82	b
	3: Equal to or above 36	51	0.861	0.64-1.09	c
Cattle young stock < 2 years old					
Number of VASCs					0.47
	1: Below 5	99	0.253	0.20-0.31	a
	2: 5 to 12	94	-0.014	-0.09-0.06	a
	3: Equal to or above 12	98	0.033	-0.04-0.11	a
Cows and bulls/heifers/steers >2 years of age					
Number of VASCs					< 0.0001
	1: Below 5	99	0.360	0.31- 0.41	a
	2: 5 to 11	90	0.060	-0.01- 0.13	a
	3: Equal to or above 11	98	0.174	0.10- 0.25	b

** The estimate for the first category represents the average of that VASC-category.*
The estimates of the other categories indicate how much higher the average % treated animals per day per farm per veterinarian were for each of those categories compared to category 1.
*** Different letters indicate groups that are statistically different at the 0.05-significance level*

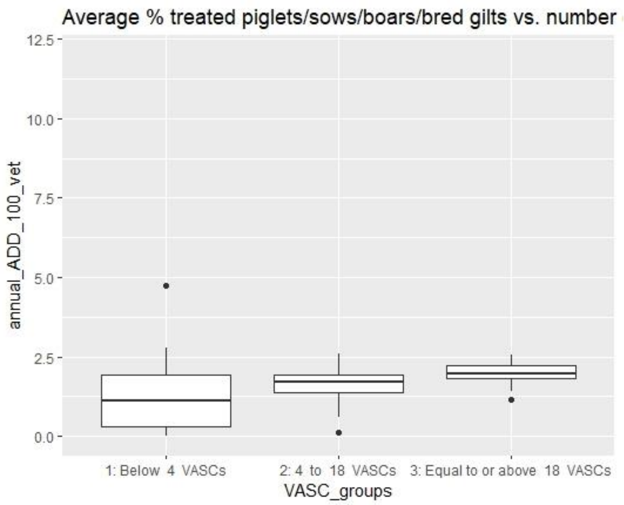


Figure A12. *Average percent treated sows/piglets/boars/bred gilts per day per farm in 2020, stratified by categorized number of VACSs per veterinarian.*

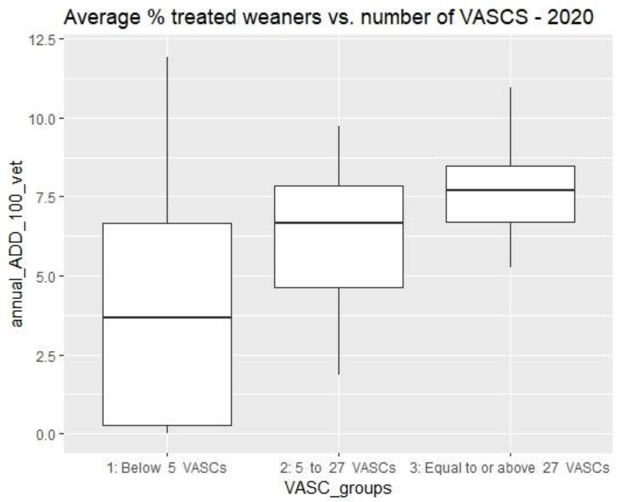


Figure A13. *Average percent treated weaned pigs per day per farm in 2020, stratified by categorized number of VACSs per veterinarian.*

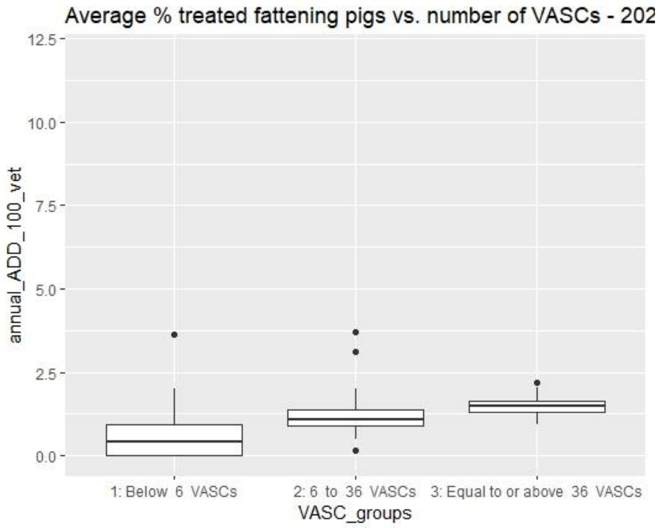


Figure A14. *Average percent treated fattening pigs per day per farm in 2020, stratified by categorized number of VACSs per veterinarian.*

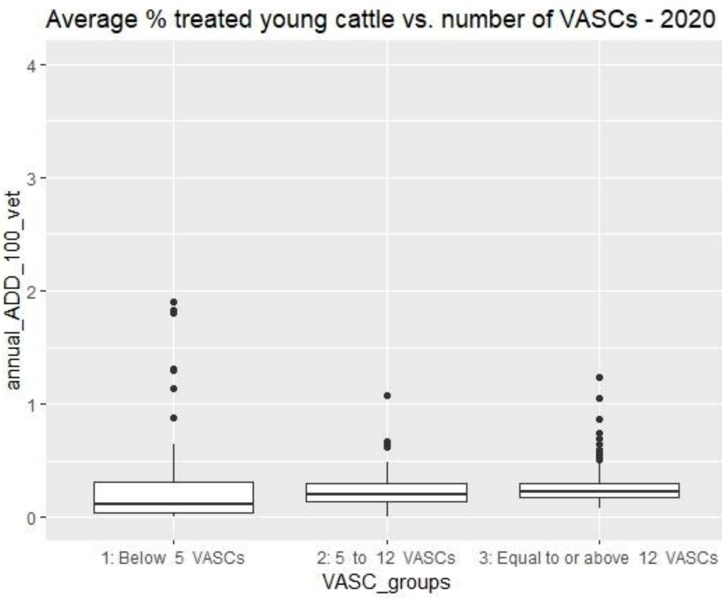


Figure A15. *Average percent treated young cattle per day per farm in 2020, stratified by categorized number of VACSs per veterinarian.*

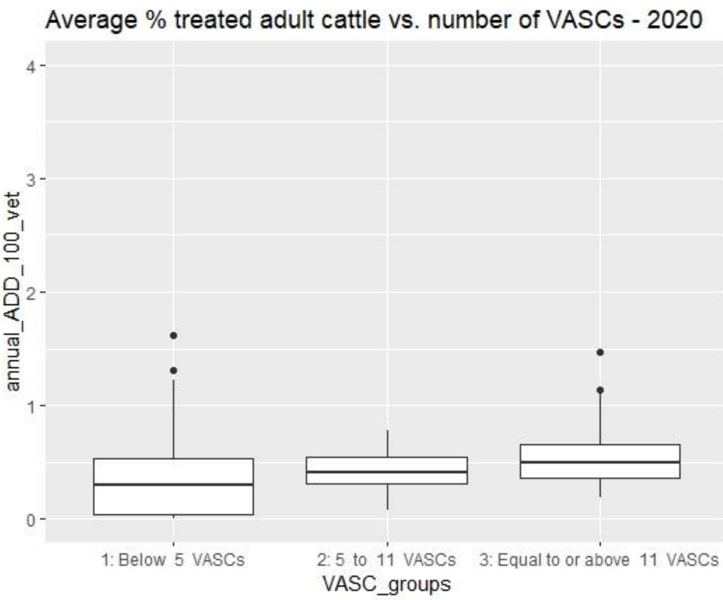


Figure A16. *Average percent treated adult cattle per day per farm in 2020, stratified by categorized number of VACSs per veterinarian.*

Appendix IV – Benchmarking models

Dashboard view

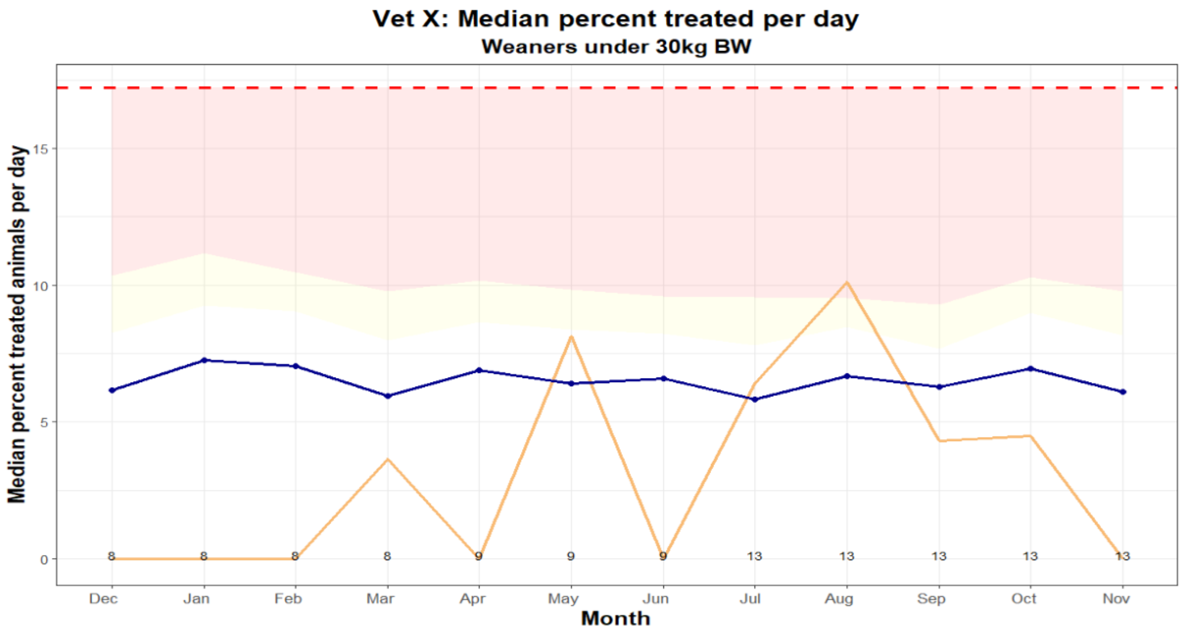


Figure A17. *Illustration of a continuous benchmarking of one veterinarian's median antibiotic prescriptions across all his/her Veterinary Advisory Service Contract farms with the pig age group "Weaners under 30kg BW"*

The orange line shows the veterinarian's median percent treated animals per day across all VASC-farms in a month and the numbers above the x-axis show the number of VASCs the median is based on.

The median based on monthly mean antibiotic prescription for the population of VASC veterinarians with weaners is shown in blue along with the interval from the 75% quantile to 90% quantile (in pale yellow) and the interval from 90% quantile to the threshold in "Yellow Card" (pale red). The threshold is the red dashed line