Based on the two new evaluations, the manuscript can be accepted subject to properly addressing the following comments listed by referee #5:

We would like to acknowledge the editor for his feedback and the reviewer 5 for providing the additional comments.
We have addressed his comments with our response hereafter and the corrections in the manuscript, both written in red.

Major comments:
1. Lack of uncertainty or sensitivity analysis
The manuscript does not include a formal uncertainty or sensitivity analysis. This is a major limitation given the complexity of the modelling framework, which combines emission measurements and inventory data, a regional chemical transport model (CMAQ), a local dispersion model (ADMS) and multiple mitigation scenario assumptions.

Each of these components introduces significant uncertainty. While the manuscript briefly acknowledges uncertainties in emission measurements and modelling assumptions, these are not quantified or propagated through the analysis.

Because the study aims to evaluate mitigation strategies and their impacts on PM2.5 concentrations, it is essential to demonstrate that the predicted changes are robust relative to modelling uncertainty. At minimum, the authors should provide:
- a sensitivity analysis of key parameters (e.g., emission factors, meteorology, deposition velocities), or
- a structured uncertainty discussion quantifying expected ranges in model outputs.

Either targeted sensitivity analysis or ideally Monte Carlo simulation would be a strong option. Without such analysis it is difficult to determine whether the reported scenario impacts represent meaningful physical signals or fall within the uncertainty of the modelling system.

We thank the reviewer for highlighting the importance of uncertainty and sensitivity considerations. We fully recognise that integrated modelling systems such as the one used here (WRF/CMAQ & ADMS) inherently involve multiple sources of uncertainty.
However, a comprehensive quantitative uncertainty or sensitivity analysis, such as Monte Carlo simulations as suggested, lies outside the intended scope of the present study, which is focused on evaluating the relative impacts of mitigation scenarios within a coherent modelling framework.

However, it is worth reminding the meteorology used in the study was evaluated (see the companion study: https://doi.org/10.3390/atmos16040353) showing it was fit for purpose.
We have not tested the change in the deposition scheme in CMAQ or changes in the deposition velocities in ADMS. These parameters used the recommendations published in the literature as cited in the manuscript. It is right saying these parameters can impact the NH_3 and $PM_{2.5}$ concentrations, but these tests should be undertaken in a dedicated study.

We have added this text (bold) in Section 4 "Discussion":
"Limitations of the local modelling include uncertainties related to **the model parametrisation**, emission measurement data and the associated farm activity data. **A targeted local-scale modelling study can be developed to evaluate how variations in parameters such as emission factors, turbulence, and deposition velocities influence pollutant dispersion in the vicinity of the farms.**"

2. Model bias relative to reported scenario effects

The evaluation of the regional model shows a substantial negative bias in simulated PM2.5 concentrations, with an underestimation of approximately 50%. The manuscript acknowledges this bias but mainly justifies it by citing similar biases reported in previous modelling studies.

However, the key issue is that the predicted impacts of mitigation measures on PM2.5 concentrations are extremely small (on the order of 1–1.5%). When model error is significantly larger than the predicted signal, the reliability of the conclusions becomes uncertain.

The authors should therefore discuss more explicitly:
- how this systematic model bias affects the interpretation of the scenario results
- whether the predicted reductions exceed the expected uncertainty of the modelling framework.

We acknowledge that the small magnitude of the simulated changes means that the results should be interpreted as indicative rather than as precise quantitative estimates.

We did not perform a formal propagation of model uncertainty and therefore cannot conclude that the simulated $PM_{2.5}$ reductions clearly exceed the full uncertainty range of the modelling system; but we have included this text at the end of Section 3.1.2:

“The evaluation of CMAQ has shown a substantial negative bias in simulated $PM_{2.5}$ concentrations affecting confidence in the absolute concentration levels. This also requires caution when interpreting the mitigation scenarios, because the simulated $PM_{2.5}$ responses are small. Since the baseline and scenarios simulations use the same modelling framework, some systematic errors may partially cancel when scenario differences are calculated. These scenarios results should therefore be interpreted as indicative of the direction and likely limited regional influence of NH_3-focused mitigation on $PM_{2.5}$, rather than as precise quantitative estimates of change.”

3. Scenario design and attribution of mitigation effects

The modelling scenarios incorporate 20 mitigation measures simultaneously, with varying uptake levels across scenarios. While this may represent realistic policy combinations, it introduces a large number of interacting variables.

Because the measures are applied simultaneously, it is difficult to attribute the resulting changes in emissions or concentrations to specific mitigation strategies. This limits the interpretability of the results, particularly from a policy perspective.

The authors should justify why individual measures or smaller groups of measures were not evaluated separately, or provide sensitivity tests that identify which measures contribute most strongly to the observed changes.

The reviewer recognizes the limited impact of the package of measures, so his comment contradicts his previous comment on the small changes and the bias in the modelled results.

Indeed, looking at individual measure will produce marginal changes.

Moreover, it was not the scope of the study and project to estimate the impact of each individual measure. As mentioned by the reviewer, the study looked at realistic mitigation strategies and so at packages of measures.

This type of analysis, on each individual measure, will also obviously lead to an important increase of simulations, from 3 simulations corresponding to the 3 scenarios (low, medium, high) to 60 (20 measures ×3 scenarios) simulations.

4. Interpretation of near-field dispersion results

The conclusions regarding near-field dispersion around farms rely heavily on results from ADMS simulations. However, Gaussian plume models such as ADMS are known to have increased uncertainty very close to emission sources due to factors such as:

- plume development near the source
- building-induced turbulence
- highly variable emission rates.

Since the analysis focuses on distances within a few hundred metres of farms, the authors should discuss the limitations of the modelling framework in the near-field and provide a clearer assessment of how model uncertainty may influence the reported dispersion distances.

The model simulations carefully accounted for the configuration and type of emission sources such as building vents, including details like temperature and flow rate, as well as the potential influence of nearby buildings on local pollutant concentrations.

This configuration considered the recommendations in the ADMLC review. This review indicates that ADMS-based conclusions in the first ~100 m from agricultural sources should be treated cautiously. The report states that near-field concentrations are highly sensitive to source geometry, release height, buoyancy, and initial momentum.
Predictions beyond ~100 m are less sensitive to source dimensions but can still depend strongly on efflux conditions and building effects.

We have added this text (in bold) in Section 3.2:
"Across the existing and mitigation scenarios the greatest distance for concentrations of NH_3 and $PM_{2.5}$ to reach 10% of the maximum is 700 metres (Figs. 6a & 6b). The distance at which concentrations reach 10% of the maximum varies depending on many local scale dispersion parameters at the farm and meteorology, such as air flow release rate (m/s), temperature (ºC), wind speed (m/s) and direction (º) and impact of building downwash**. Indeed, such near-source concentrations in local modelling are highly sensitive to source geometry, release height, buoyancy, and initial momentum. Predictions beyond ~100 m are less sensitive to source dimensions but can still depend strongly on efflux conditions and building effects (Stocker et al., 2015).**"

With the corresponding reference:
Stocker, J., Ellis, A., Smith, S., Carruthers, D., Venkatram, A., Dale, W., Attree, M.: A review of the limitations and uncertainties of modelling pollutant dispersion from non-point sources, UK Atmospheric Modelling Liaison Committee, 2015, https://admlc.com/wp-content/uploads/2014/05/fm1019_cerc_admlc_final_mar16.pdf#:~:text=ADMLC/2015/06.%20 This%20study%20was%20funded%20by%20the,in%20this%20report%20are%20those%20of%20the (last access: 15.04.2026).

5. Conceptual link between local dispersion and regional PM2.5 formation

The manuscript suggests that rapid local dispersion of ammonia emissions helps explain the small regional PM2.5 response observed in the CMAQ simulations.
This reasoning is not entirely convincing. Even if ammonia concentrations decrease rapidly near farms, transported ammonia can still contribute to secondary aerosol formation over much larger spatial scales. The authors should clarify the conceptual link between local dispersion patterns and regional PM2.5 formation processes.

This is an important comment, and we agree that our previous wording did not sufficiently distinguish between (i) the rapid decline in local NH_3 concentrations around farms and (ii) the ability of emitted NH_3 to be transported and contribute to regional secondary $PM_{2.5}$ formation.

We have revised the text to clarify that the ADMS results should not be interpreted as showing that NH_3 becomes irrelevant beyond the near-field. A steep decline in local NH_3 concentration with distance reflects dilution of the plume and strong spatial gradients in near-source exposure, but it does not mean that transported NH_3 cannot participate in secondary inorganic aerosol formation further downwind. The CMAQ results therefore are not explained solely by rapid local dispersion.
Our interpretation is instead that the two models inform different spatial scales and processes. ADMS indicates that the largest incremental primary $PM_{2.5}$ and NH_3 concentrations occur close to farms, highlighting the importance of near-source exposure. CMAQ shows that the response of regional $PM_{2.5}$ to NH_3 mitigation measures is relatively small, which is more plausibly related to the non-linear chemistry of secondary aerosol formation and the likely NH_3-rich conditions over much of the UK, meaning that regional $PM_{2.5}$ formation may be limited more strongly by the availability of other precursors than by NH_3 alone. Thus, the ADMS and CMAQ findings are complementary rather than directly causal.

We have revised the manuscript accordingly (in bold) in the Section 4 "Discussion":
"Although CMAQ is state of the art and widely used in scientific research and policy development, the model also has uncertainties. The analysis presented in this study rely on the accuracy of the simulation which is subject to any uncertainties in the model's specific parameterization of atmospheric processes, as well as uncertainties in the emission inventory and meteorology input. It has been shown that CMAQ does not perfectly model the interactions between NH_3 emissions. **In addition, the local processes cause the majority of NH_3 to be dispersed near the studied farms as highlighted by ADMS results. The ADMS results showed a steep decline in farm-scale NH_3 and primary $PM_{2.5}$ concentrations, with concentrations decreasing by around 90% within 700 metres of the studied farms. This indicates strong near-source concentration gradients and highlights the importance of local exposure close to farms.**
The limited impact of the mitigation measures at a regional scale, which mainly target the NH_3 emissions, on $PM_{2.5}$ concentrations can be due to an NH_3-rich atmosphere in the UK and highlights that other precursor of these $PM_{2.5}$ and the primary $PM_{2.5}$ emissions need to be tackled. **This confirms the findings from Pan et al. (2024) arguing for more collocated aerosol and precursor observations for better characterization of SIA formation.** This also highlights that exposure on secondary $PM_{2.5}$ near the farms needs also to be investigated while most air quality studies focus on total $PM_{2.5}$ concentrations."

Minor Comments:
1. Meteorological representativeness
The simulations use meteorological conditions from a single year (2019) to represent the 2030 scenarios. While this approach is common in scenario studies, the authors should discuss how interannual meteorological variability could influence the results.
It is right that the solely the 2019 meteorology has been used in this study. As initially stated in the manuscript "The future scenarios solely focused on change in emissions and no climate projection has been undertaken. Consequently, there is no analysis on changes in meteorological conditions."
If a climate scenario should be applied, it means, at least 2 sets of data should be analysed: emission scenarios, emission scenarios + climate scenario, and potentially a third dataset with solely the climate scenario.

However, we have added these following texts in Section 2.2.1:
"The use of a single year meteorology is a common approach in emission-driven scenario assessments. Nevertheless, interannual meteorological variability can influence secondary PM2.5 formation and dispersion, meaning that results based on one year may not capture the full range of possible outcomes. As the study is designed to evaluate relative differences between emission scenarios under consistent meteorological conditions, the scenario-to-baseline contrasts are expected to be less sensitive to this limitation."
And in the conclusions:
"Finally, the simulations were performed using meteorological fields from a single year (2019) and future work could incorporate multi-year or climate-perturbed meteorological datasets to better characterise the influence of meteorological variability on agricultural PM2.5 formation."

2. Representativeness of local farm modelling
The local analysis is based on five farms. Although the authors acknowledge limitations in data availability, it would be useful to discuss how representative these farms are of the broader UK livestock sector.
The farms were not intended to be representative of all UK agriculture, but were intended to provide example data, to be used alongside data from literature review. The farms included dairy, pig and poultry farms, providing a focus on housed livestock systems.

3. PM2.5 / PM10 conversion factor
The use of a constant PM2.5/PM10 ratio (0.58) derived from background monitoring stations may introduce additional uncertainty, as the particle size distribution of agricultural emissions can vary substantially depending on housing systems and farm management practices.
We acknowledge that the use of a constant PM2.5/PM10 ratio introduces some uncertainty, as particle size distributions from agricultural activities can vary depending on housing systems and management practices. However, the assumed ratio (0.58), derived from background AURN observations, lies within the range typically reported for agricultural sources.
Given that our analysis focuses on annual mean concentrations and relative changes across scenarios, the use of a fixed ratio is expected to have a limited influence on the interpretation of scenario-driven differences, as systematic uncertainties affect all scenarios consistently. We note that developing source-specific PM2.5/PM10 ratios based on new measurement datasets would be a valuable extension for future work.

We have added this text in the manuscript and the following references:
"This assumed ratio (0.58), derived from background AURN observations, lies within the range typically reported for agricultural sources (Gladding et al. 2020), even if lower values were found by Demmers et al. (2010) (0.16 for broilers, 0.26 free-range layers, and 0.41 for caged layers). A high variability in PM2.5/PM10 emission factors for UK poultry farms was also highlighted in a review study (Defra, 2012)."

Demmers, T., Saponja, A., Thomas, R, Phillips, G.J, McDonald, A. G., Stagg, S., Bowry, A., Nemitz, E.: Dust and ammonia emissions from UK poultry houses: XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering, 2010

Gladding, T.L. , Rolph, C.A., Gwyther, C.L., Kinnersley, R., Walsh, K., Tyrrel, S.: Concentration and composition of bioaerosol emissions from intensive farms: Pig and poultry livestock, Journal of Environmental Management, 272, https://doi.org/10.1016/j.jenvman.2020.111052, 2020.

Defra: Review of Air Quality Impacts Resulting from Particle Emissions from Poultry Farms, https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1511251444_AQ0926_Report_PM_Emissions_from_Poultry_Farms_Final_BV_AECOM_Nov_2012.pdf, 2012.

4. Emission data sources

Some sources rely on direct measurements while others use inventory estimates. The authors should clarify how these different data sources were harmonized and whether their uncertainties differ.

We have clarified in the manuscript how emission inputs from different sources were harmonized before use in ADMS and how their uncertainties differ.

In the local modelling with ADMS, farm-specific measurements were used wherever possible and were the preferred source of emission information. In our methodology, measured NH3 and PM2.5 concentrations were combined with hourly ventilation rates to derive source-specific hourly emission rates. Where direct measurements were not available, SCAIL emission factors were used to estimate source-specific annual emissions from source area or animal numbers. For PM, SCAIL PM10 values were converted to PM2.5 using the fixed factor of 0.58. All inputs were then expressed in a form compatible with ADMS using consistent pollutant definitions, source geometry and emission units.

We have also clarified that harmonization involved both emission magnitude and temporal allocation. Where a source lacked direct measurements but was comparable to a measured housing unit, the SCAIL-derived annual emission magnitude was combined with a farm relevant measured diurnal profile. Where no activity or measurement data were available to support a time-varying profile, a constant annual-average emission rate was applied.

We agree that the uncertainties differ between these data sources. Measurement-based emissions are more representative of individual farms but remain uncertain due to measurement error, ventilation-rate estimation and extrapolation from monitored periods to full animal cycles or the full year. SCAIL-based emissions have greater structural uncertainty because they rely on generic emission factors, scaling by source area or animal numbers, the PM10 to PM2.5 conversion, and, in some cases, simplified temporal allocation.

We now state explicitly that the confidence is highest for fully measured hourly profiles, intermediate for measured profiles extrapolated in time or applied to analogous sources, and lowest for fully inventory-based annual-average emissions.

Thus, we have added this following paragraph at the end of Section “2.3.2 Emissions”:

“In summary, emission inputs from different data sources were harmonized before their use in ADMS by converting all source terms to a consistent pollutant-specific emission format. Farm-specific measurements were used preferentially and combined with hourly ventilation rates to derive hourly NH3 and PM2.5 emission rates. Where measurements were unavailable, SCAIL emission factors were converted to source-specific annual emissions using source area or livestock numbers; SCAIL PM10 emissions were converted to PM2.5 using a fixed factor.

Temporal allocation was harmonized separately from emission magnitude: where appropriate, SCAIL-derived housing emissions were assigned a measured diurnal profile from a comparable farm source, while sources lacking supporting activity or measurement data were assigned constant annual-average emissions. This hierarchy also reflects relative confidence in the inputs, with fully measured hourly emissions considered most robust and fully inventory-based annual-average emissions the most uncertain.”

Recommendation: Major revisions

The manuscript addresses an important question and uses an interesting modelling framework combining regional and local approaches. However, several methodological aspects require further clarification before the results can be interpreted with confidence. In particular, the absence of uncertainty analysis and the large model bias relative to the reported scenario effects raise concerns about the robustness of the conclusions.

Addressing these issues would significantly strengthen the manuscript.

The corrections have been added in the manuscript and detailed in our replies above.