Machine learning models for diagnostics and risk analysis

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31st October 2023

bTB diagnostics project

- Goal:
  - Augment the results of the Single Intradermal Comparative Cervical Tuberculin (SICCT) test with surrounding epidemiological risk factors:
    - to improve herd-level test sensitivity,
    - thus improve early detection and reduce onward transmission.
- Outcomes:
  - Integration of a large number of risk factors, including:
    - Farm characteristics, movements, testing, *vet practice*, *tuberculin batch*, ...
  - Herd-level prediction of bTB breakdowns using a machine learning model.
  - Risk factor breakdown using feature importance
    - and deeper analysis.

Foundation

- Initial idea from:

Article | Open Access | Published: 26 January 2021

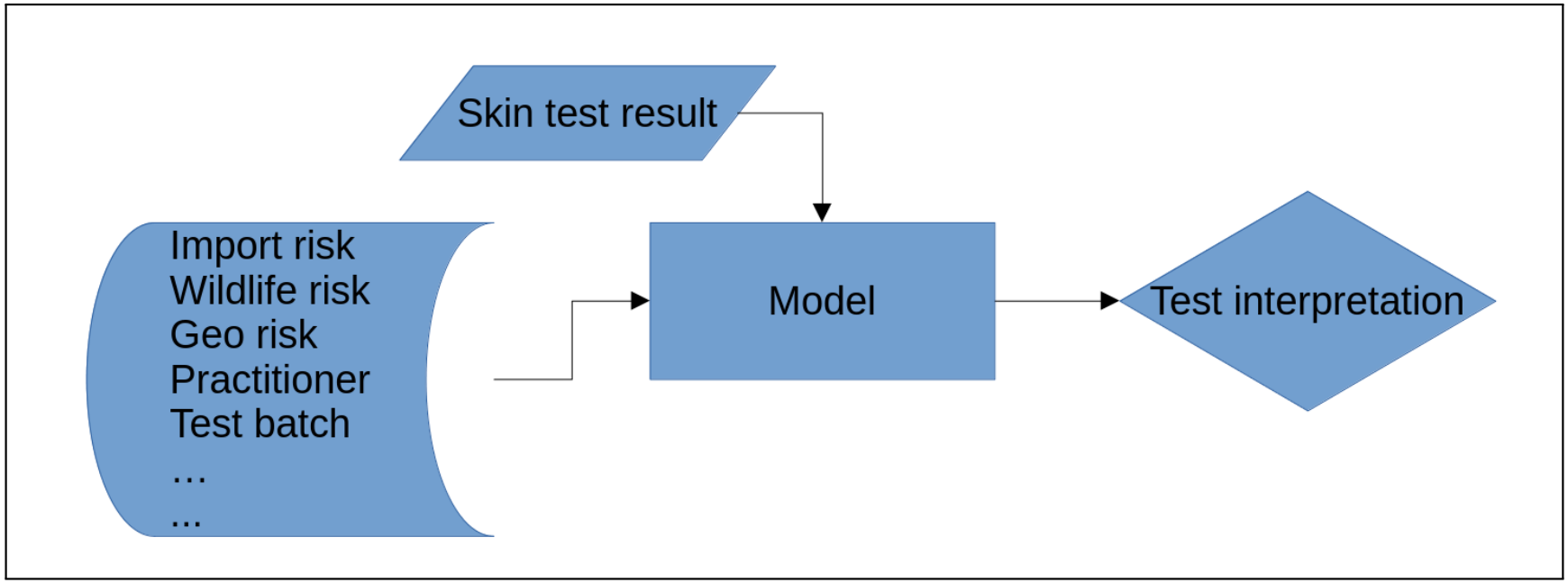
Using machine learning improves predictions of herd-level bovine tuberculosis breakdowns in Great Britain

K. Stański, S. Lycett, T. Porphyre & B. M. de C. Bronsvoort

Scientific Reports **11**, Article number: 2208 (2021) | Cite this article

- Improved by:
  - Fewer (streamlined) risk factors, more historical data
  - Histogram-based Gradient Boosted Tree model:
    - Tuned and cross-validated model performance
    - Simplifying the treatment of missing data
  - Including new data from UK Farmcare (Vet practice and tuberculin batch).

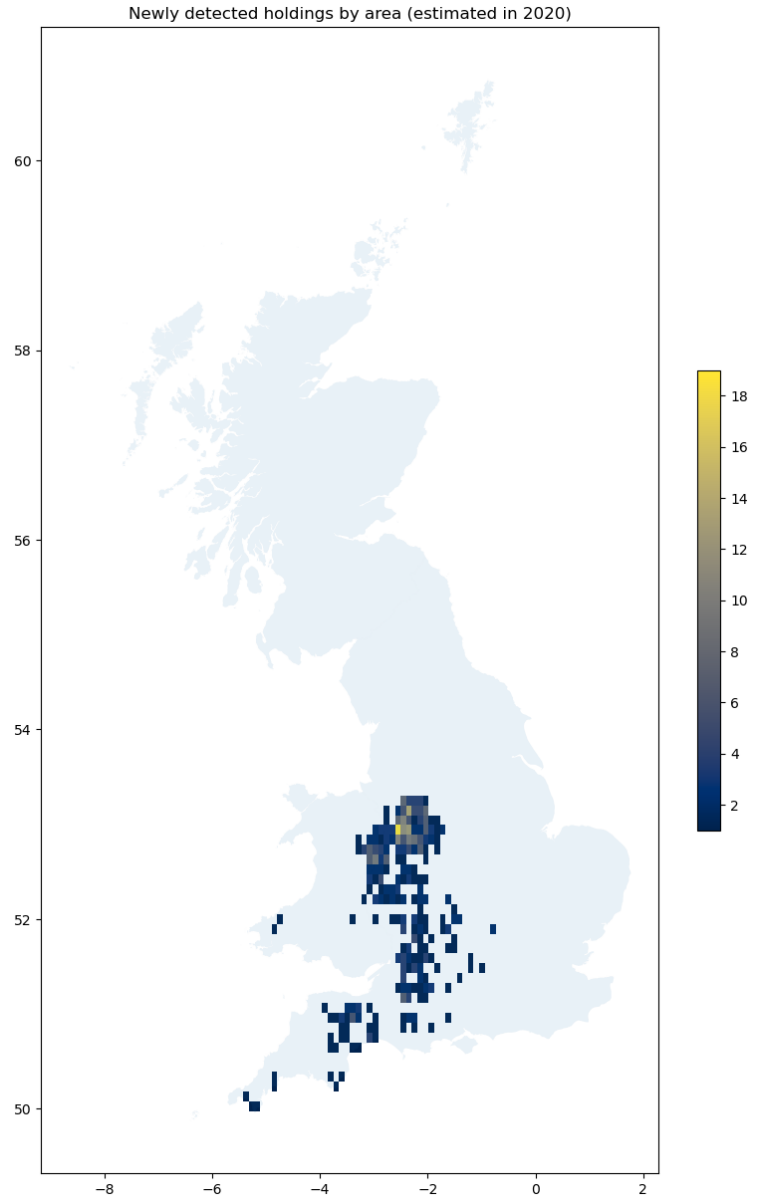
Model and Data



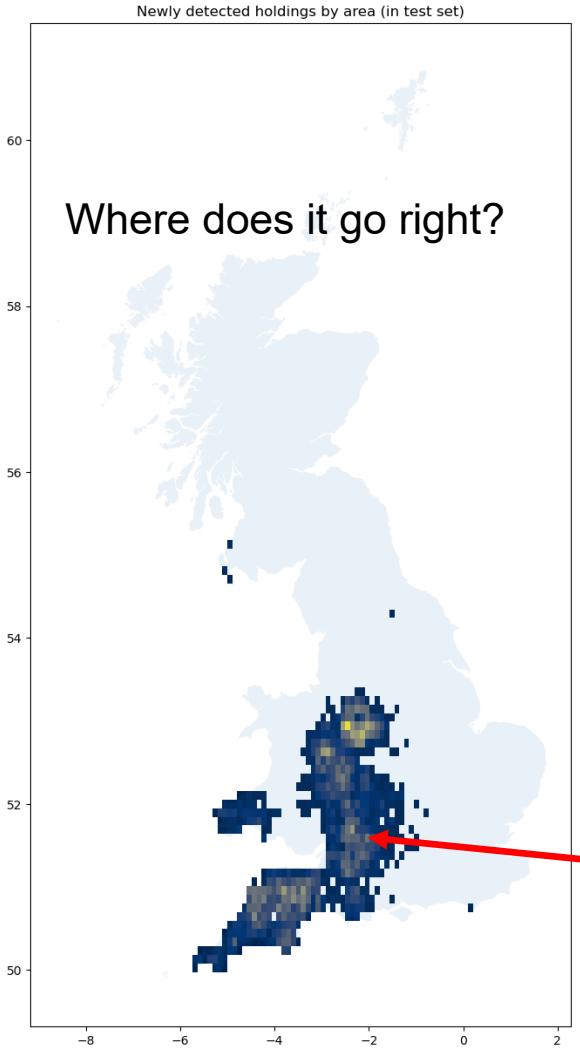
- Data extracted from APHA bTB surveillance database (SAM) and the Cattle Tracing System (CTS) database.
  - Every recorded SICCT test event between January 2012 and September 2021 (1.3m records)
  - Metadata on herd, location, movements, . . .
- Data from UKFarmcare on vet and tuberculin batch for some tests:
  - 400 vet practices, covering 120k tests
  - 650 tuberculin batches, covering 57k tests

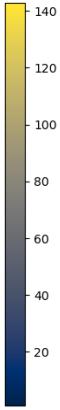
Results

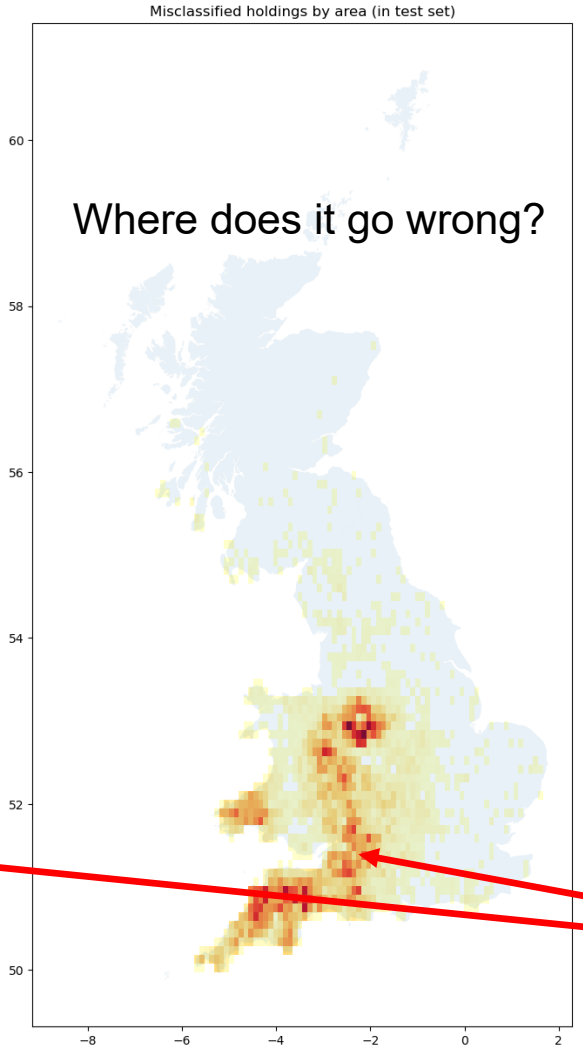
- Model goal is to predict a new breakdown within 90 days of testing.
- Balance of sensitivity vs. specificity can be tuned in the model.
- Here we take the same herd-level specificity as the skin test alone, maximising sensitivity.
- **Increase in herd-level sensitivity 12%.**
- Over one year (2020) we find **around 400** negative herd-level tests, that went on to have breakdowns, but were **identified as positive by the model**.

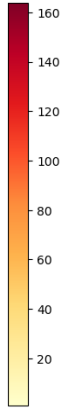


Results – Spatiotemporal

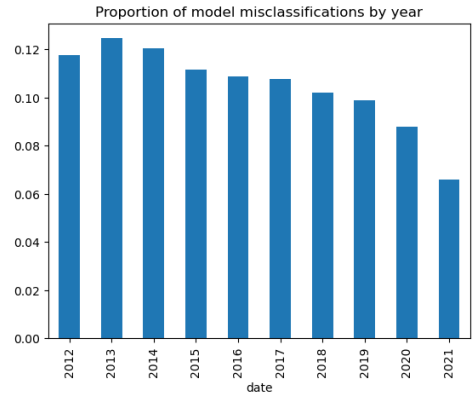




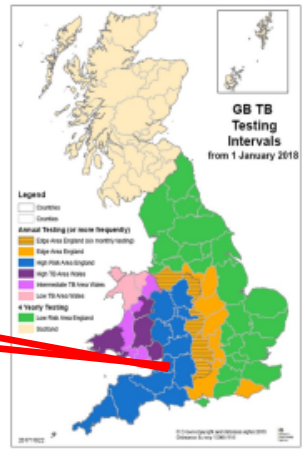




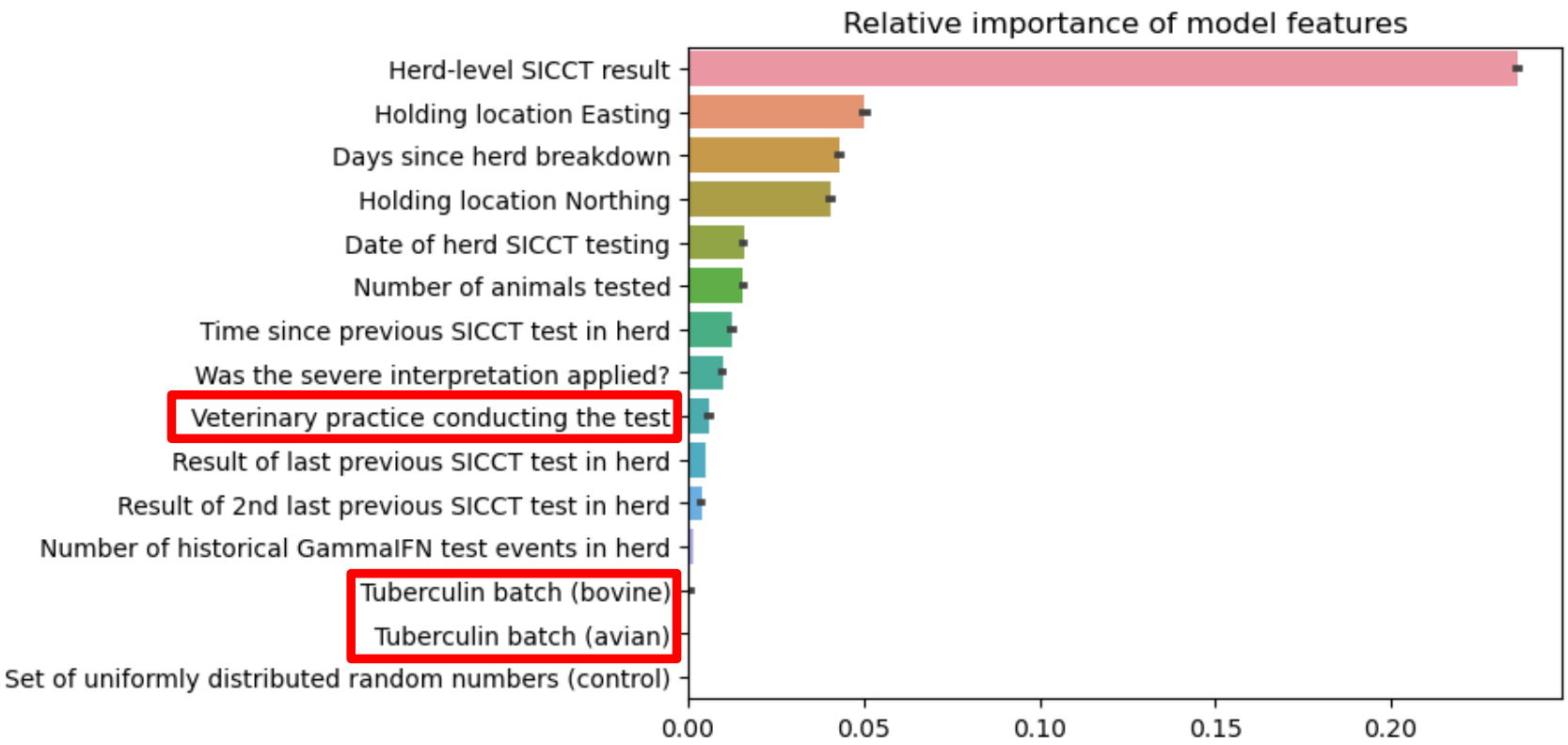
When does it go wrong?



HRA



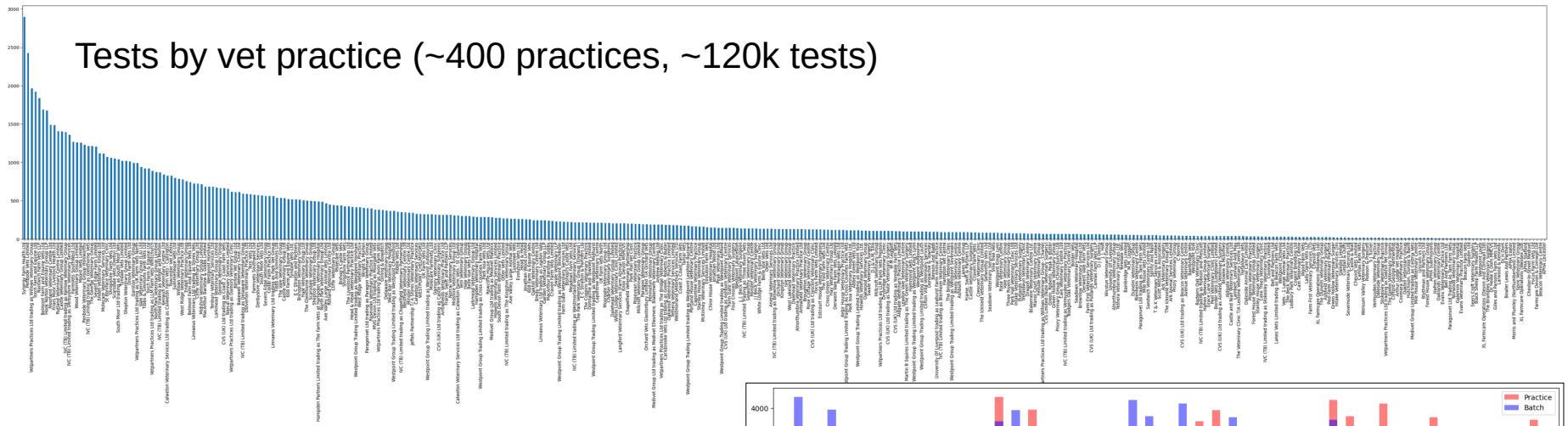
Analysis – Risk factor importance

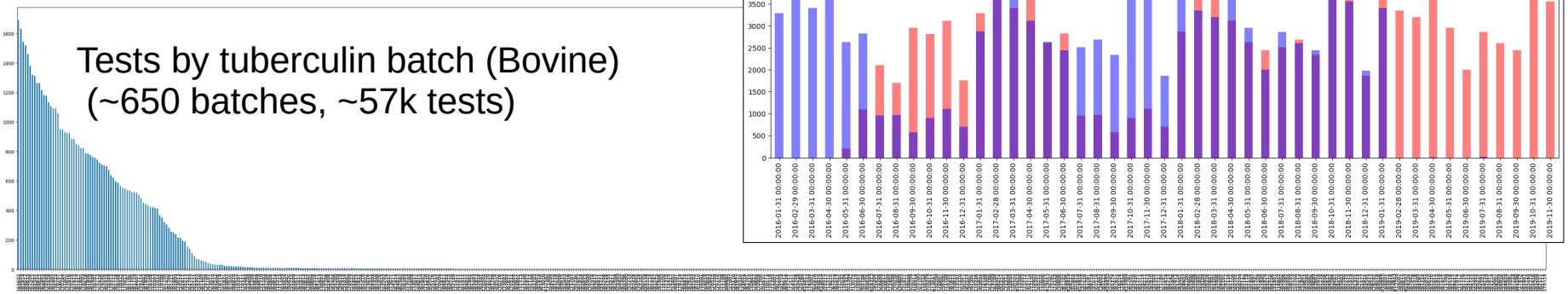


- Risk factors ranked by permutation-based importance testing.
- Bar length shows accuracy reduction when factor removed from model.

Vet data – Coverage

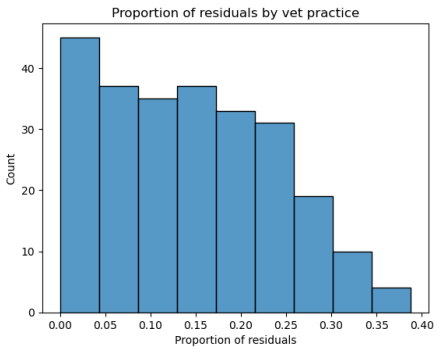
- Can we further explain risk factor importance of vet data?
- Data coverage may be reducing effectiveness:



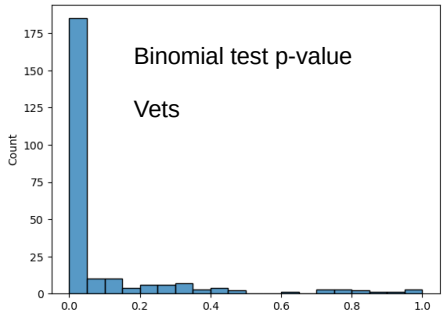


Vet data – Vet/tuberculin accuracy

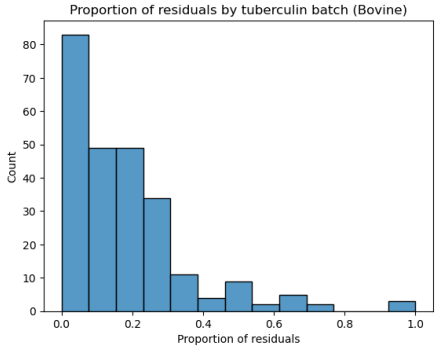
- What can we say about vet / tuberculin performance?



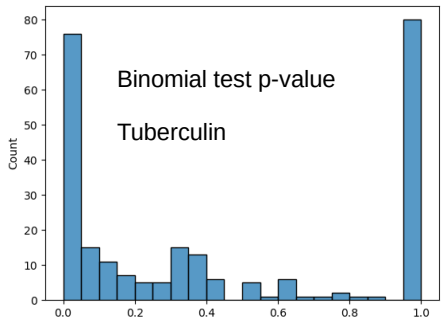
Fairly wide distribution of vet performance



74% perform outside expected range



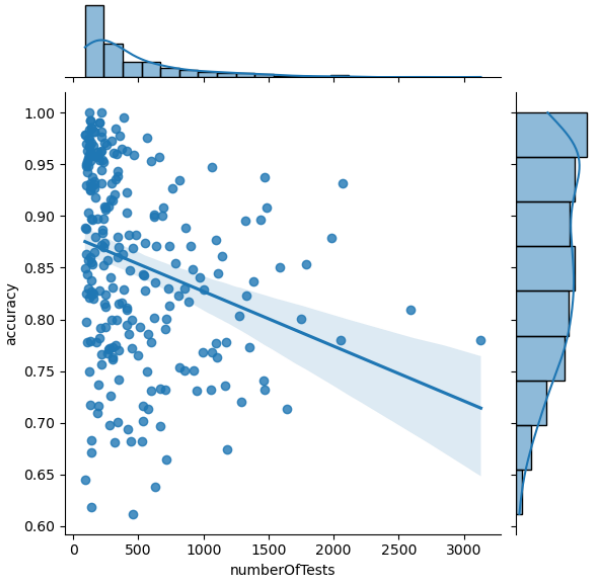
Longer tailed distribution of tuberculin performance (small number very bad)



30% perform outside expected range

Vet data – Performance by practice type

- Which practices perform worse?



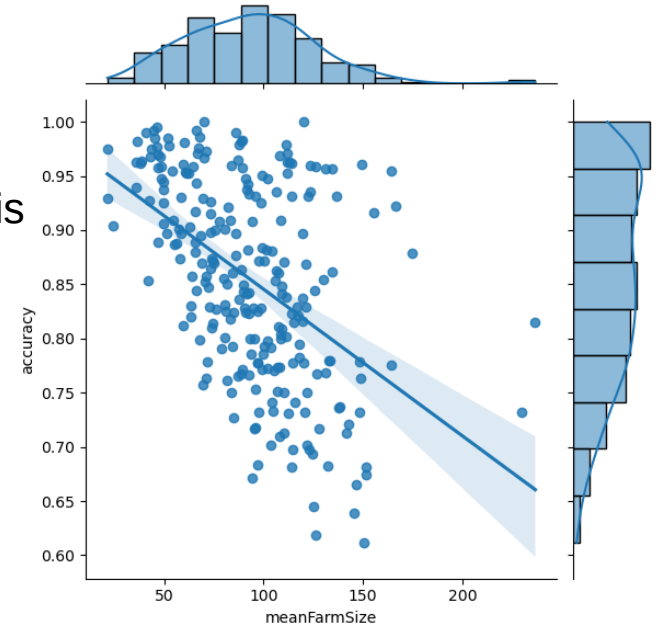
Size of vet practice by number of tests conducted has a weak correlation

r = -.27

Mean size of herd dealt with by the vet is reasonably well correlated

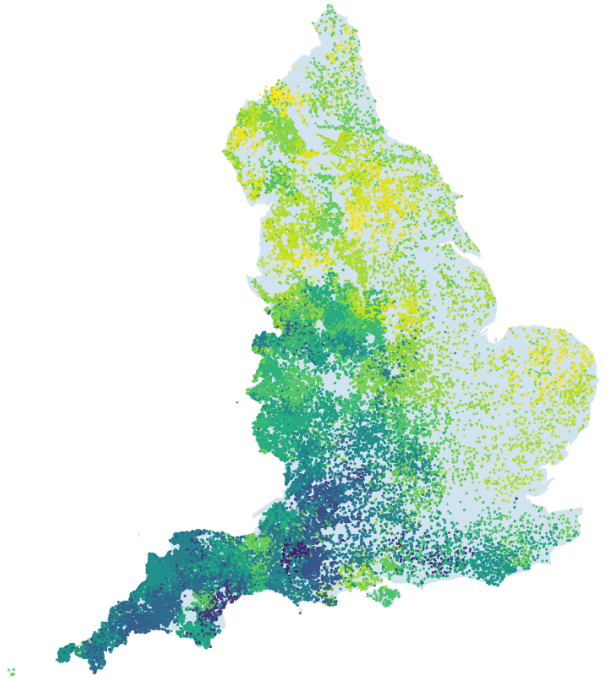
r = -.48

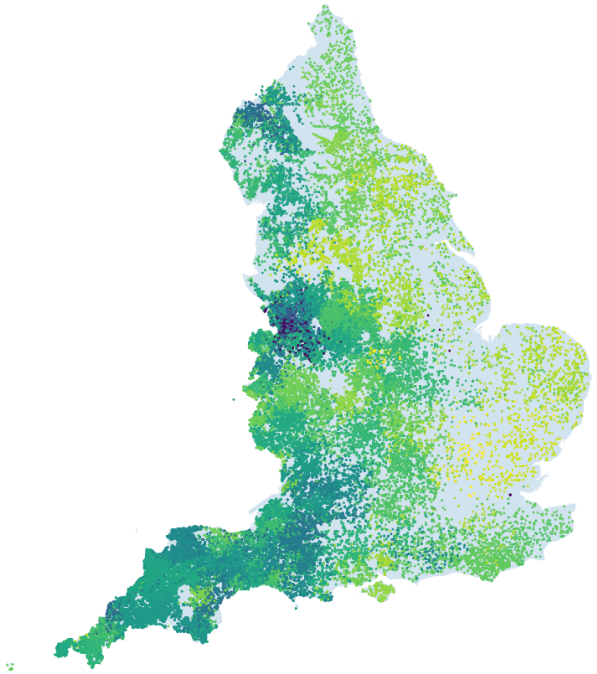
Vets that deal with larger herds perform worse



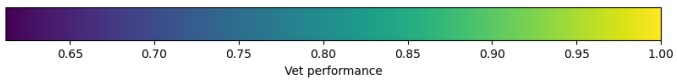
Vet data – Performance by practice type

- Geographically?

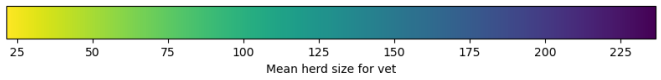




Best performing vets (top 250)



Largest herds

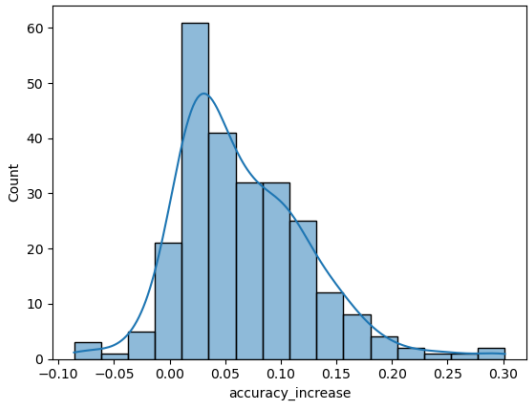


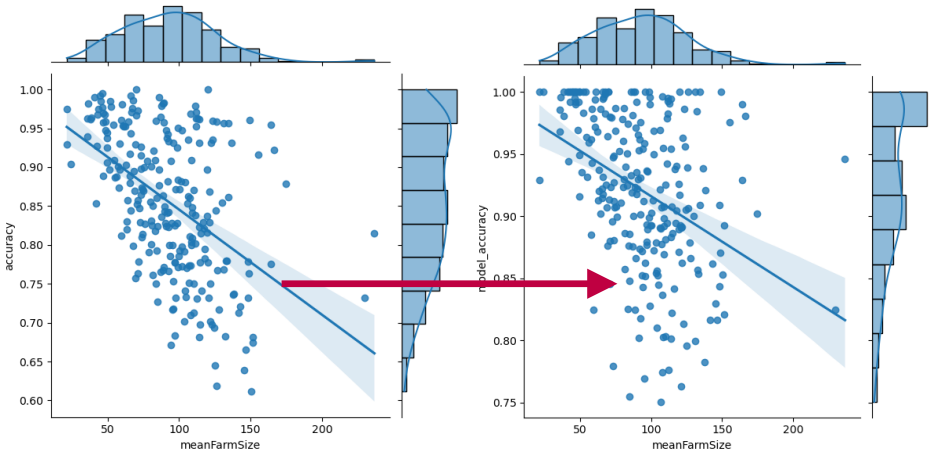
What is the point of all this?

How does the model help?

Model augmented testing improves accuracy for most vets.

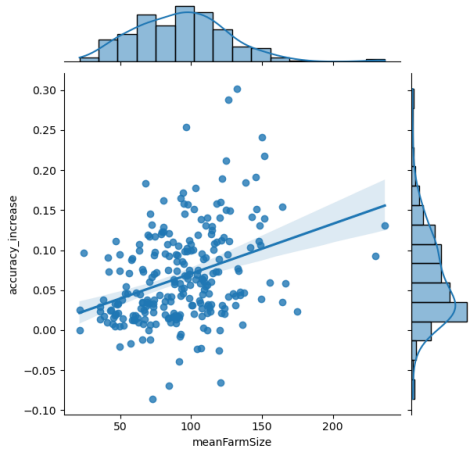
Some up to 30%:





Model reduces accuracy corelation with mean farm size from r=-.48 to r=-.38

It increases performance with larger herds:



Where next?

- UK Farmcare to conduct further analysis on vet results
- Possible extension to use skin test measurements instead of binary results
- How could this be used in the field?
  - App interface to model for vets to use at testing?
  - A guide to re-testing high-risk herds?
- Other situations: BVD, Johne's.