# In-abattoir 3D measurements of beef carcasses for the prediction of saleable meat yield and novel carcass traits

Nisbet, H., Lambe, N., Miller, G., Doeschl-Wilson, A., Barclay, D., Wheaton, A., Duthie, C.-A.

Holly Nisbet
PhD Student
Scotland's Rural College (SRUC)
The University of Edinburgh



Tuesday 3rd September 2024

# Curernt Carcass Assessment

**EUROP conformation and fat class**

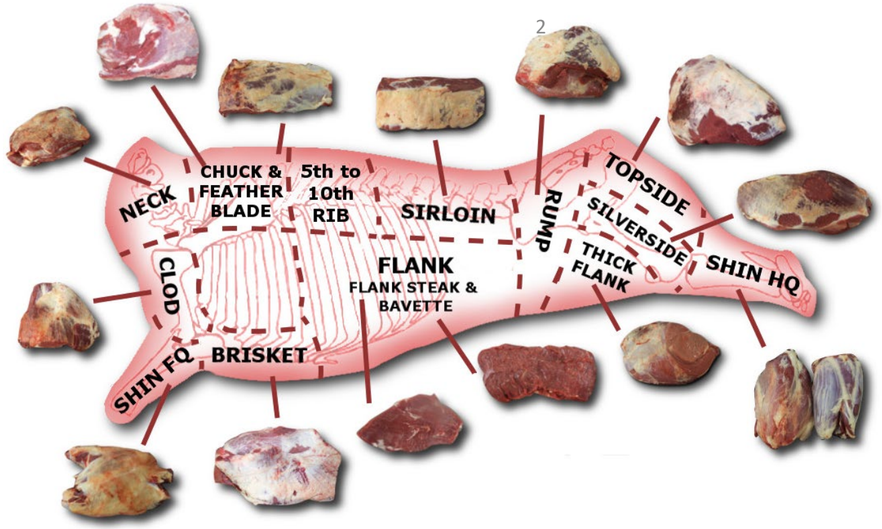
- Price in pence/kg
- Generally subject assessment

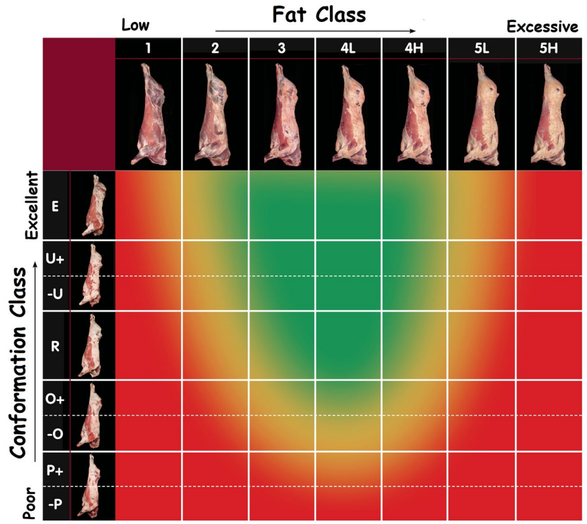
**Need for objective classification**

- Imaging technology with limited infrastructure

**Opportunity for addition traits of value**

- Saleable meat yield (SMY)
- Quantifiable

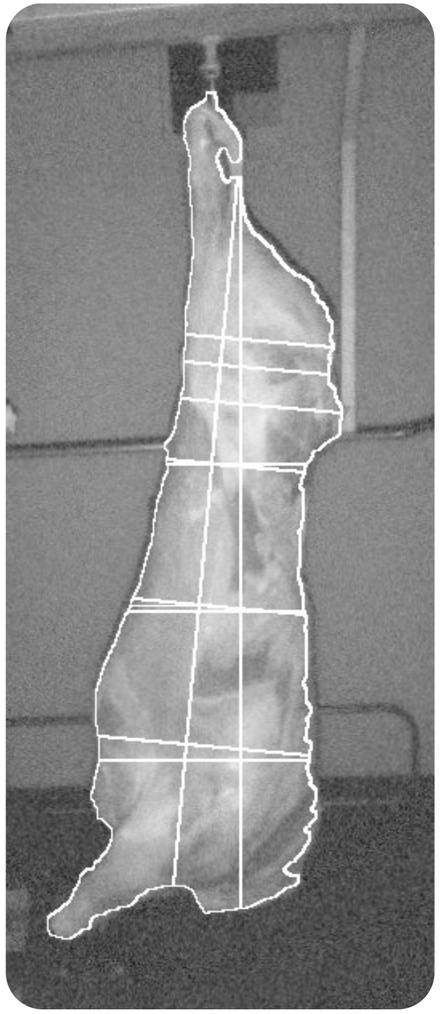


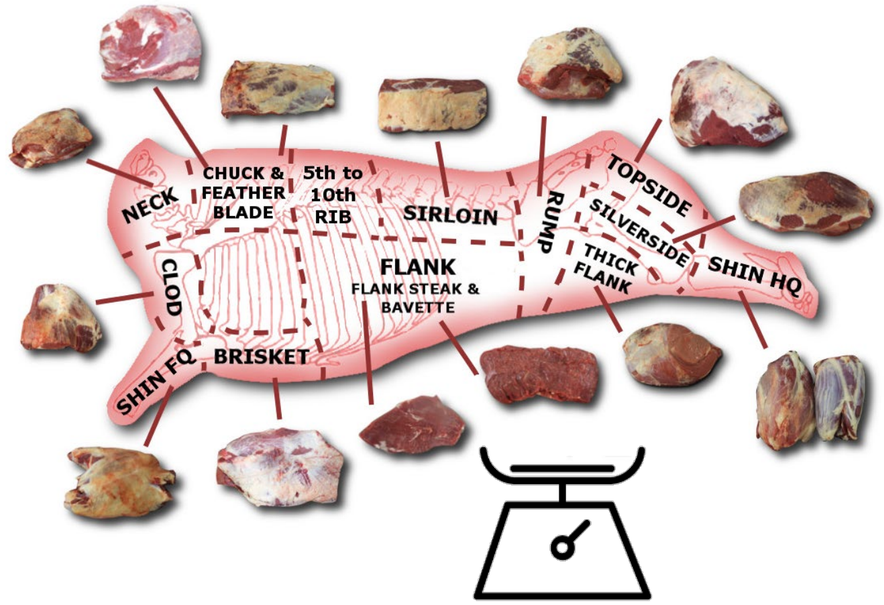

Adapted from J. Fredenbrugh (2016)

# Aim of study

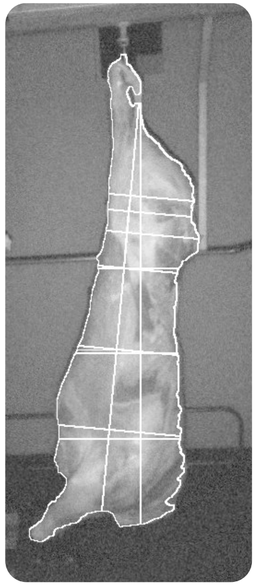
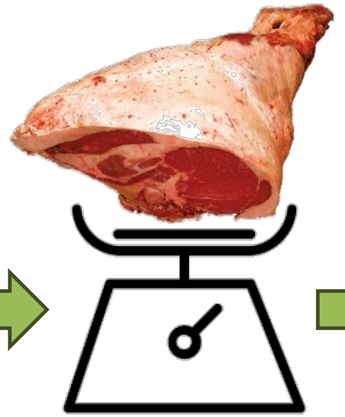
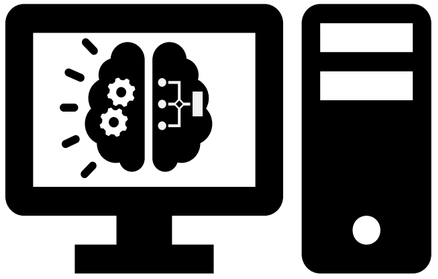
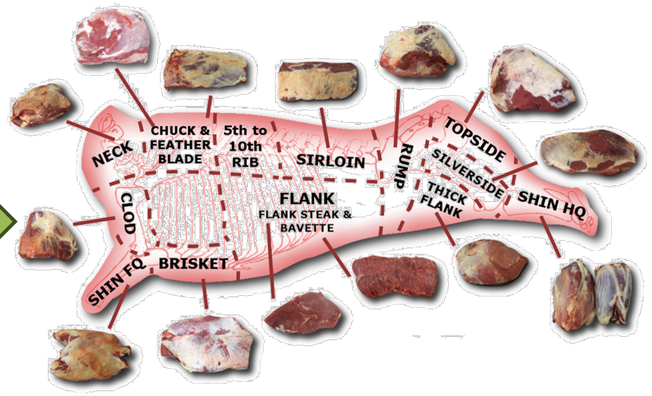
- Predict saleable meat yield traits and primal cut weights
  - 3D measurements of beef carcasses and other carcass information
  - multiple linear regression (MLR)
  - machine learning (ML) techniques (random forest; RF, and artificial neural networks; ANN)





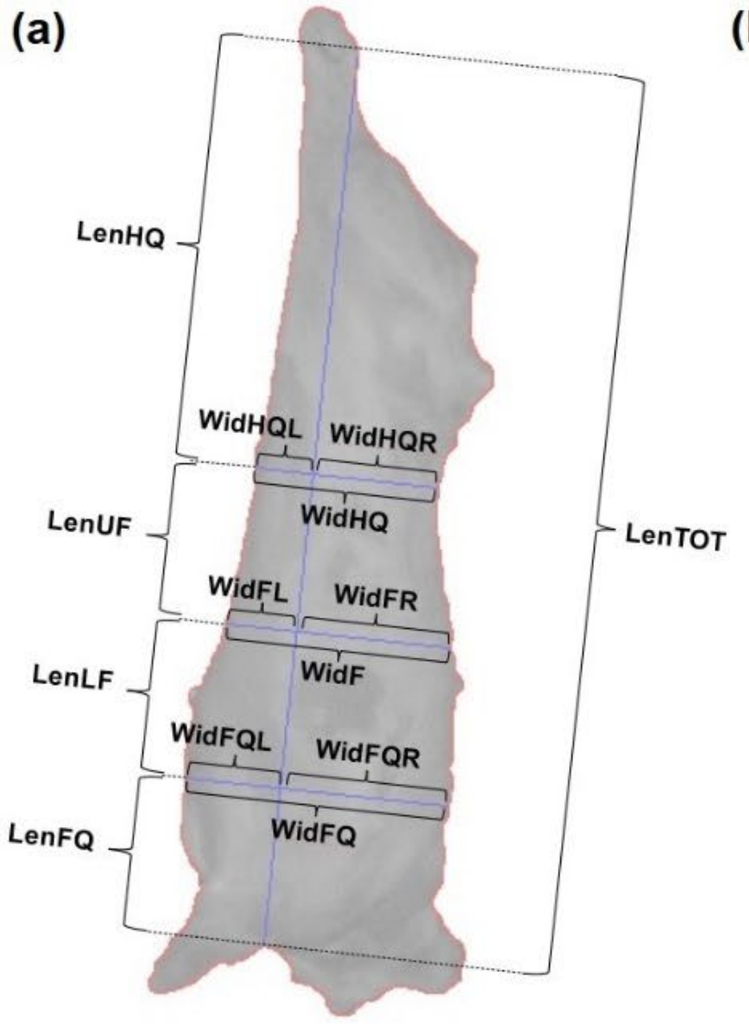


# Data collection

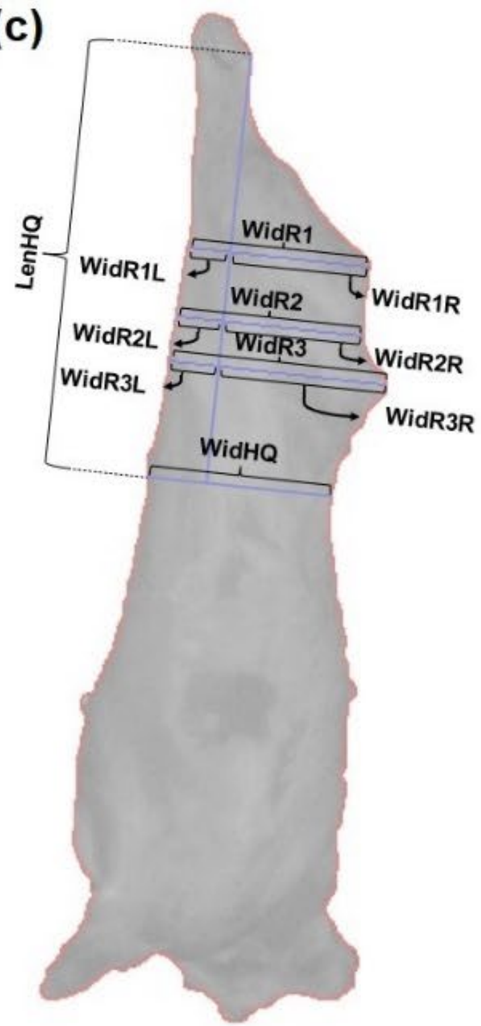






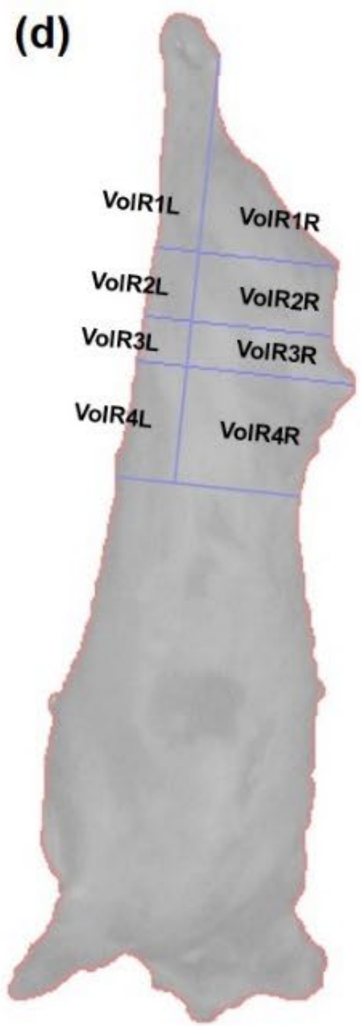

- 44 3D measurements extracted from 484 beef carcasses
  - 2 commercial abattoirs
- Individual primal cuts, trim and fat recorded from each carcass
- Four SMY weights calculated
  - hindquarter, flank and forequarter and total SMY
- Four high value primal cuts
  - Sirloin, ribeye, topside and rump
- Predicted using MLR and ML techniques

# 3-Dimensional Measurements







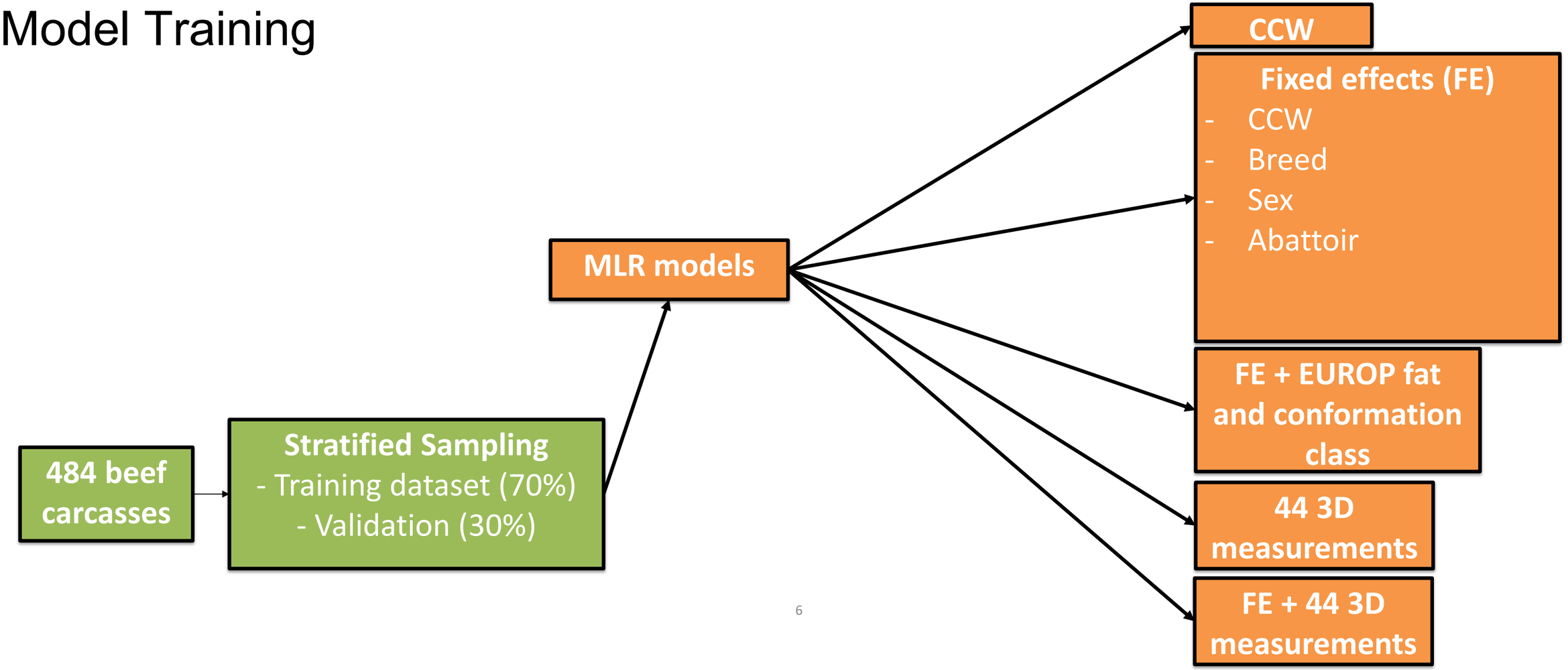

**5 lengths and 9 widths** **13 volumes** **9 rump widths** **8 rump volumes**



Adapted from Nisbet et. al. (2024)

Nisbet, H., Lambe, N., Miller, G., Doeschl -Wilson, A., Barclay, D., Wheaton, A., Duthie, C. -A., 2024. Using in -abattoir 3 -dimensional measurements from images of beef carcasses for the prediction of EUROP classification grade and carcass weight. Meat Sci. 209, 109391. https://doi.org/10 .1016/j.meatsci.2023.109391

# Model Training



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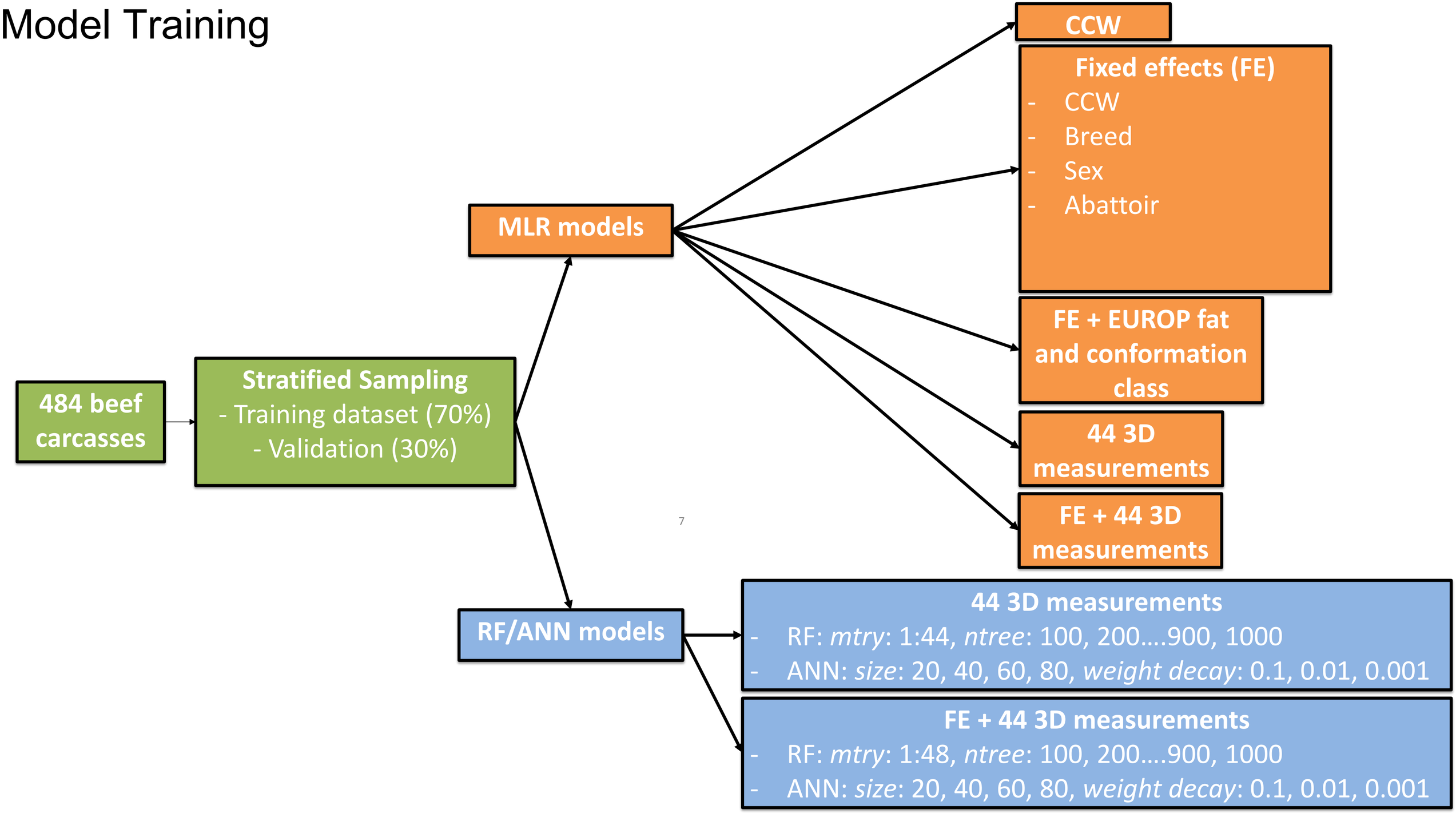

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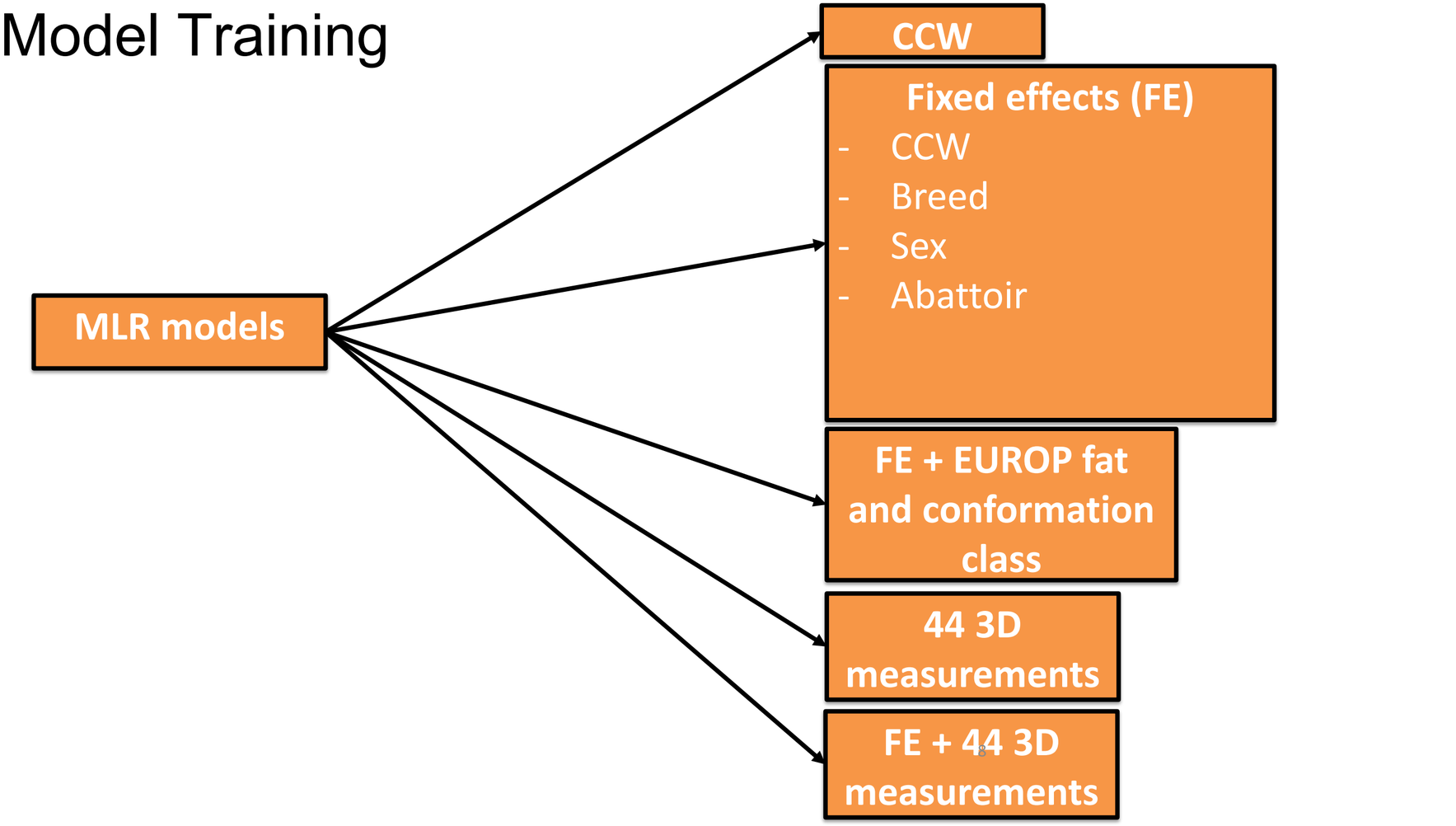


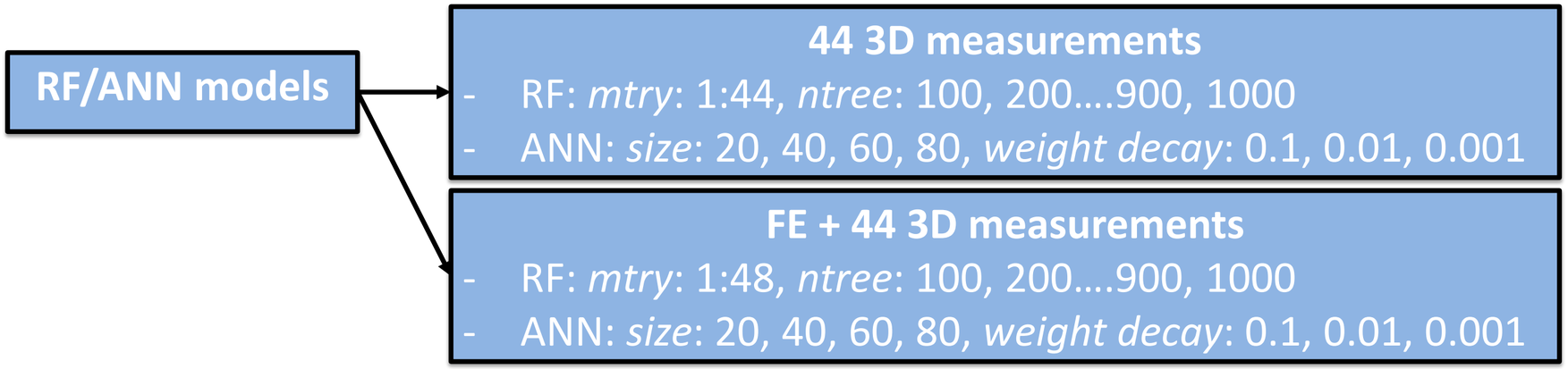

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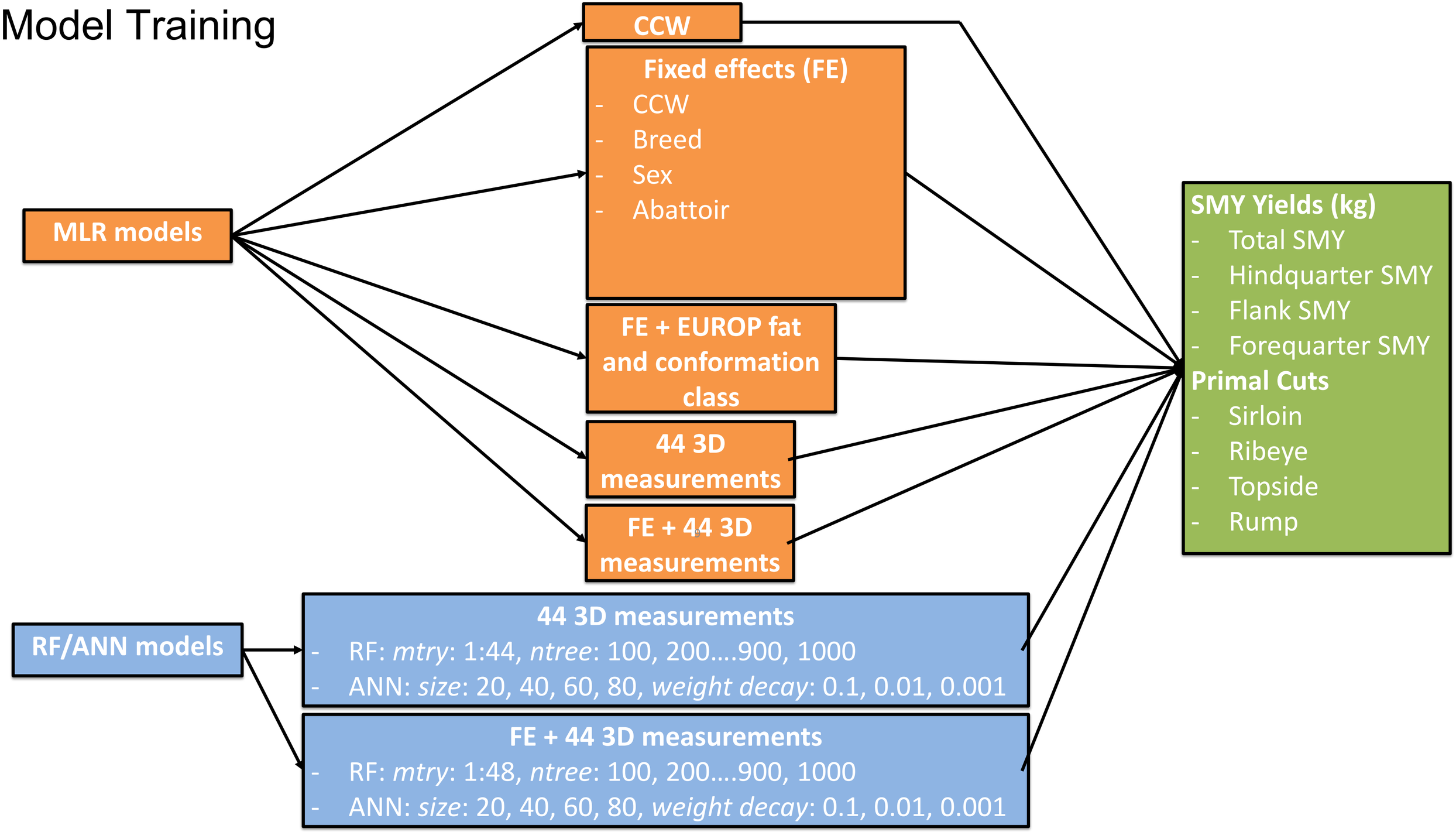
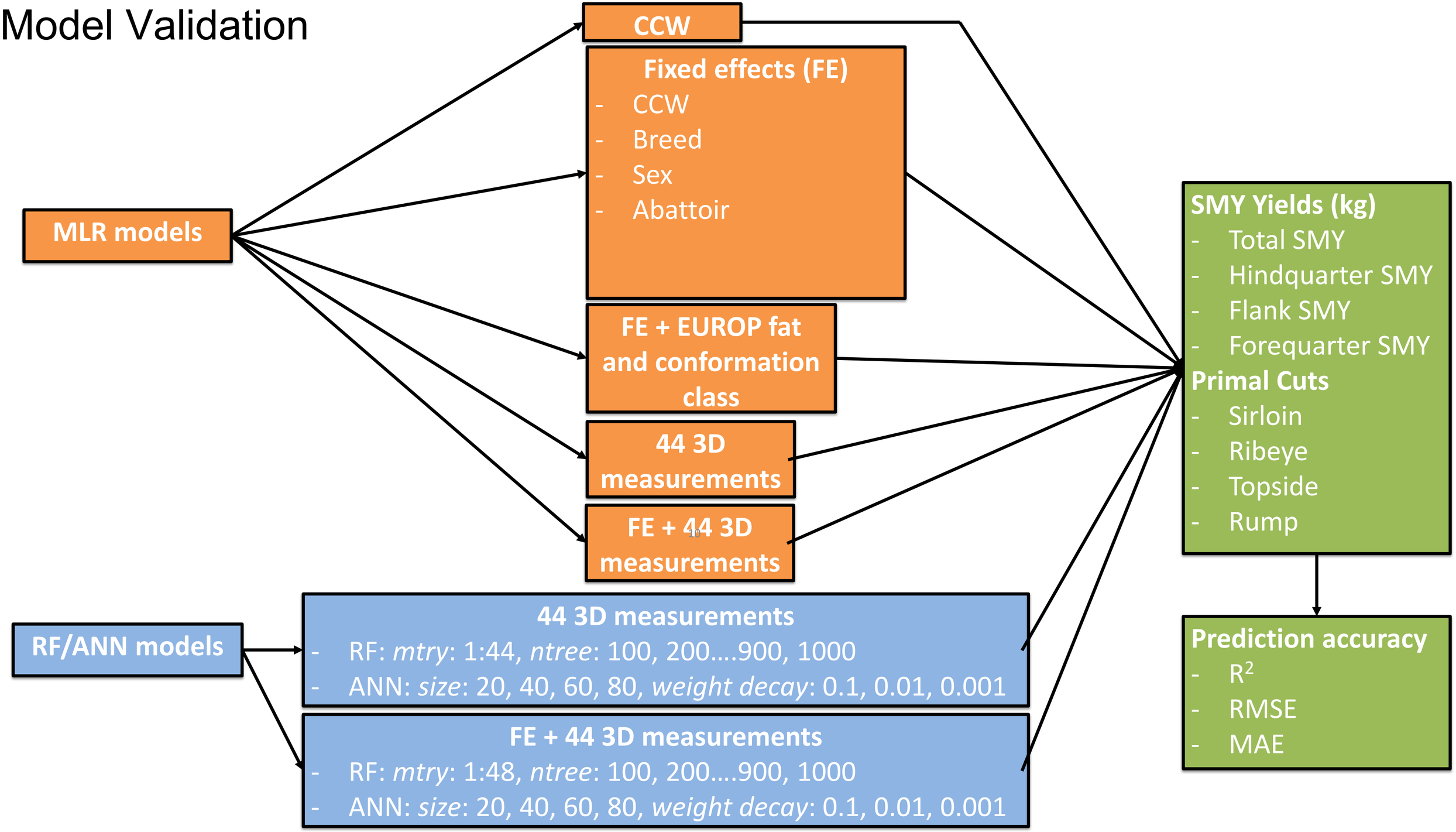
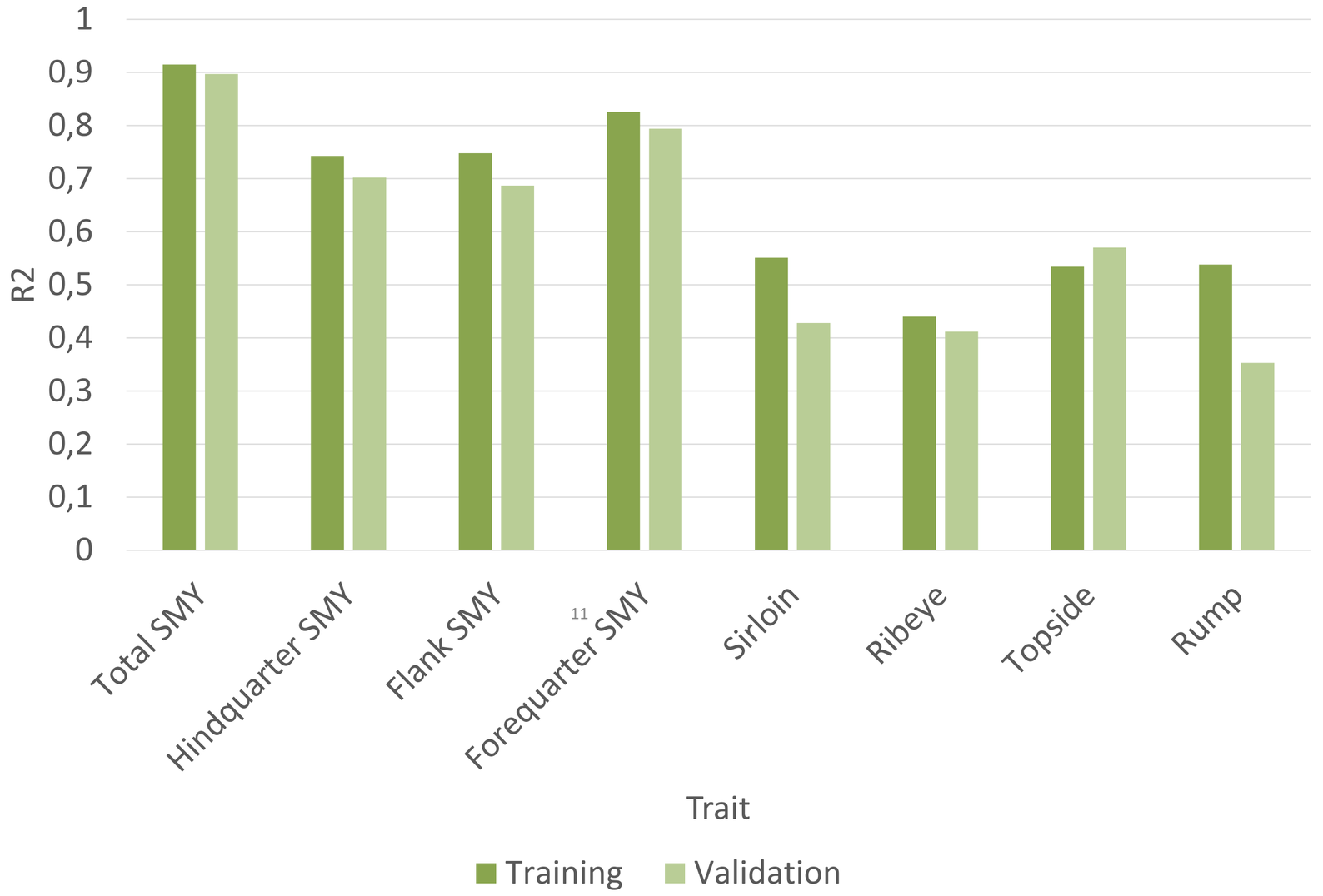


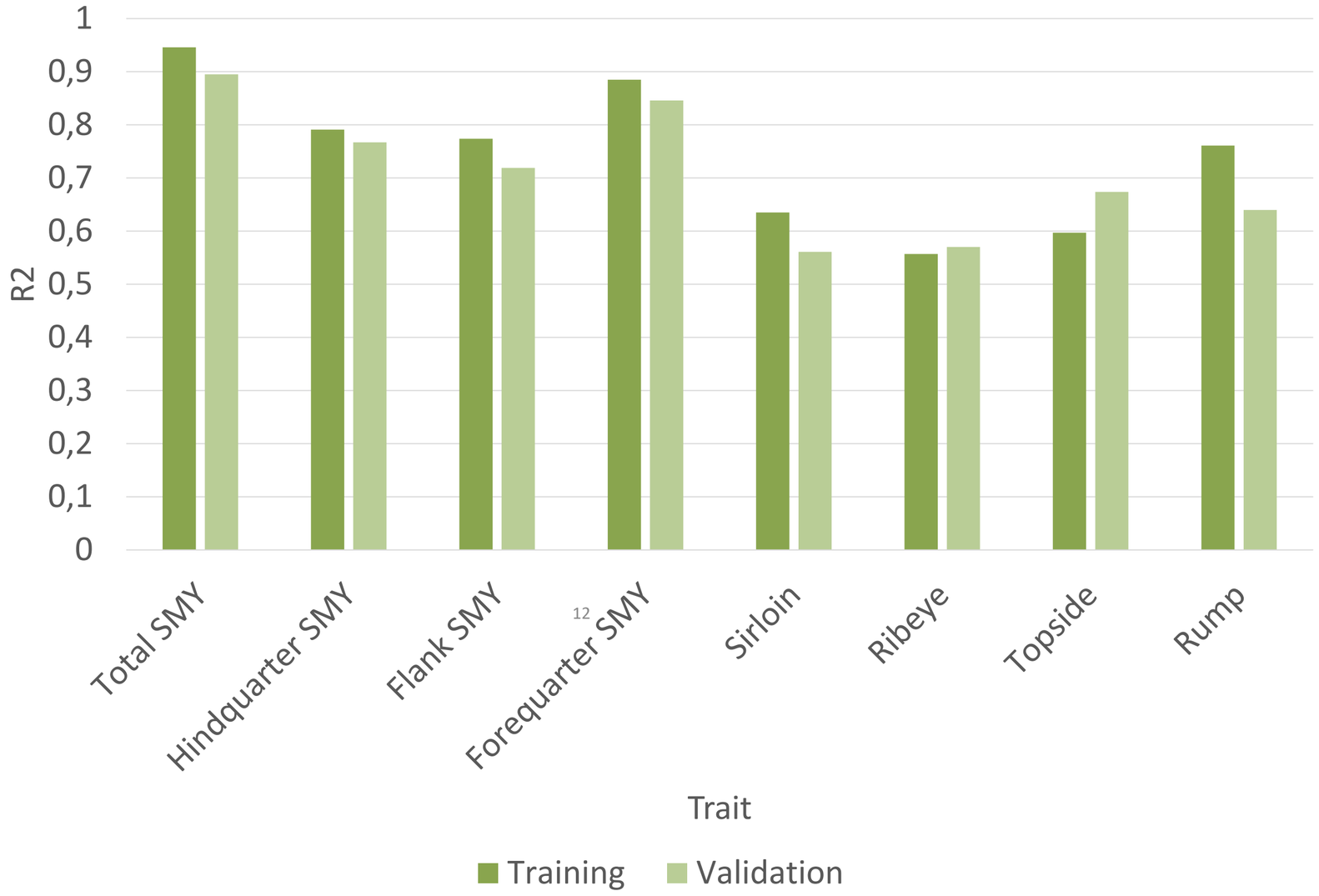
# Model Validation



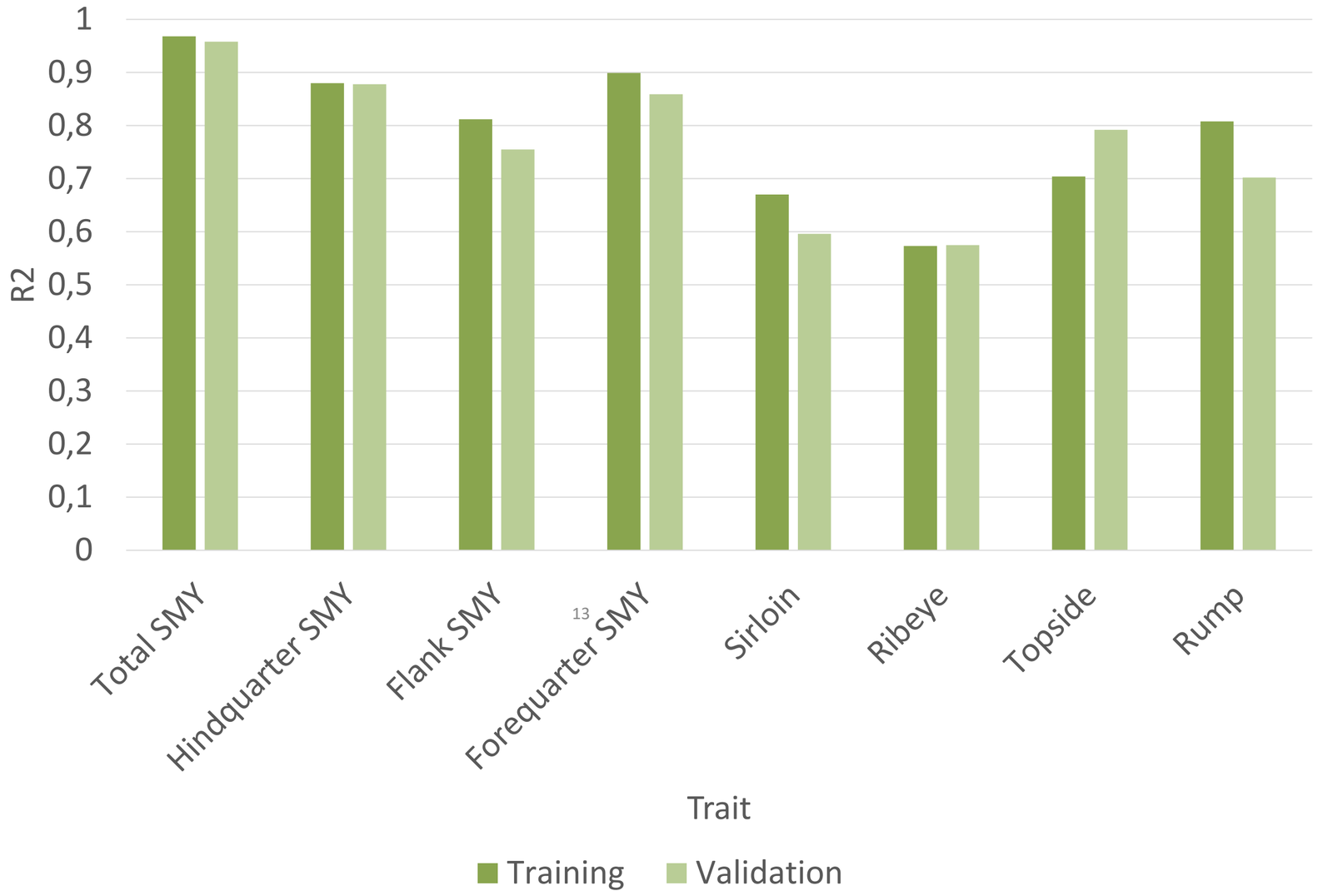
# CCW for the prediction of SMY traits and primal cut weights



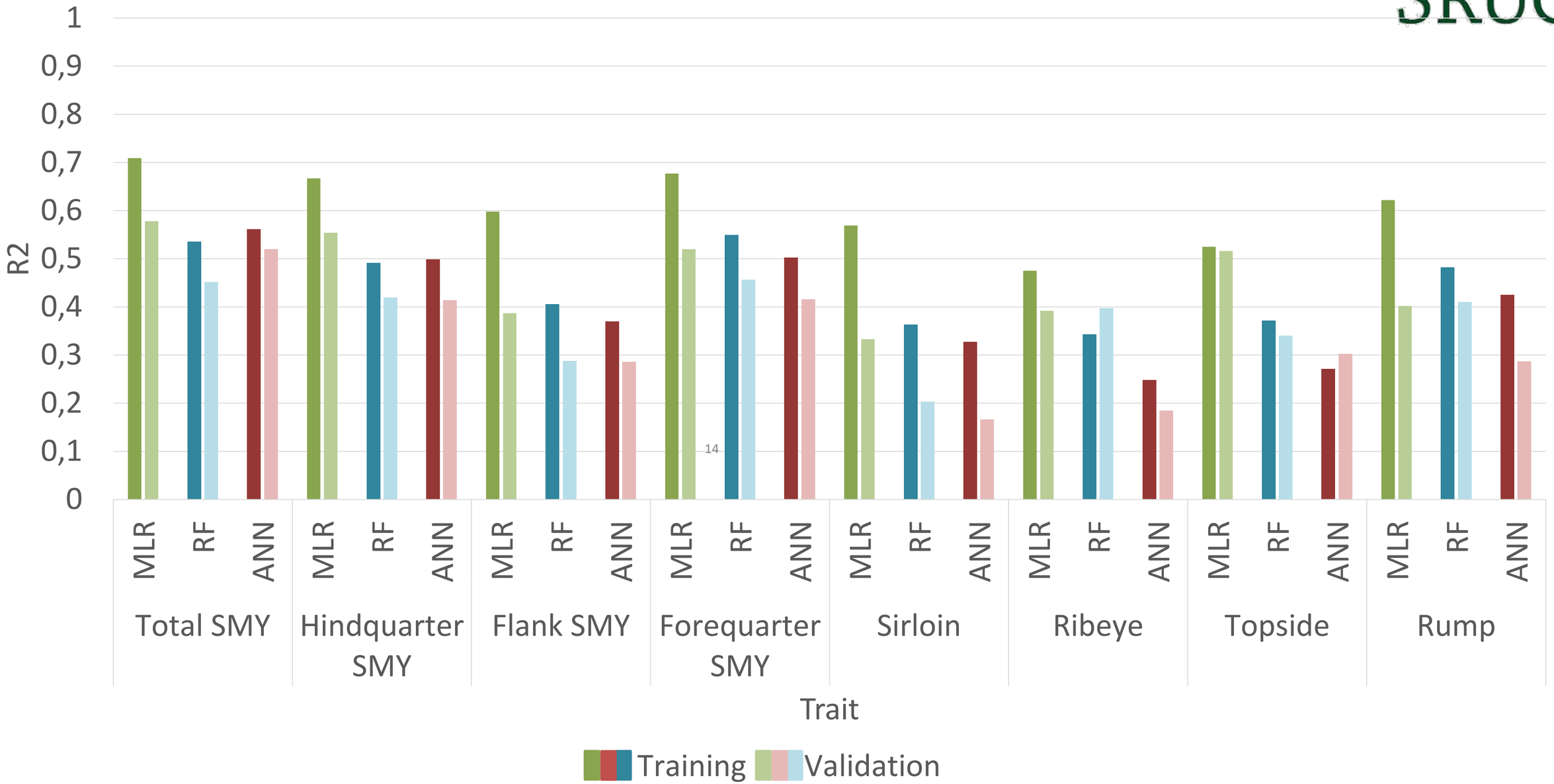
# Fixed effects for the prediction of SMY traits and primal cut weights



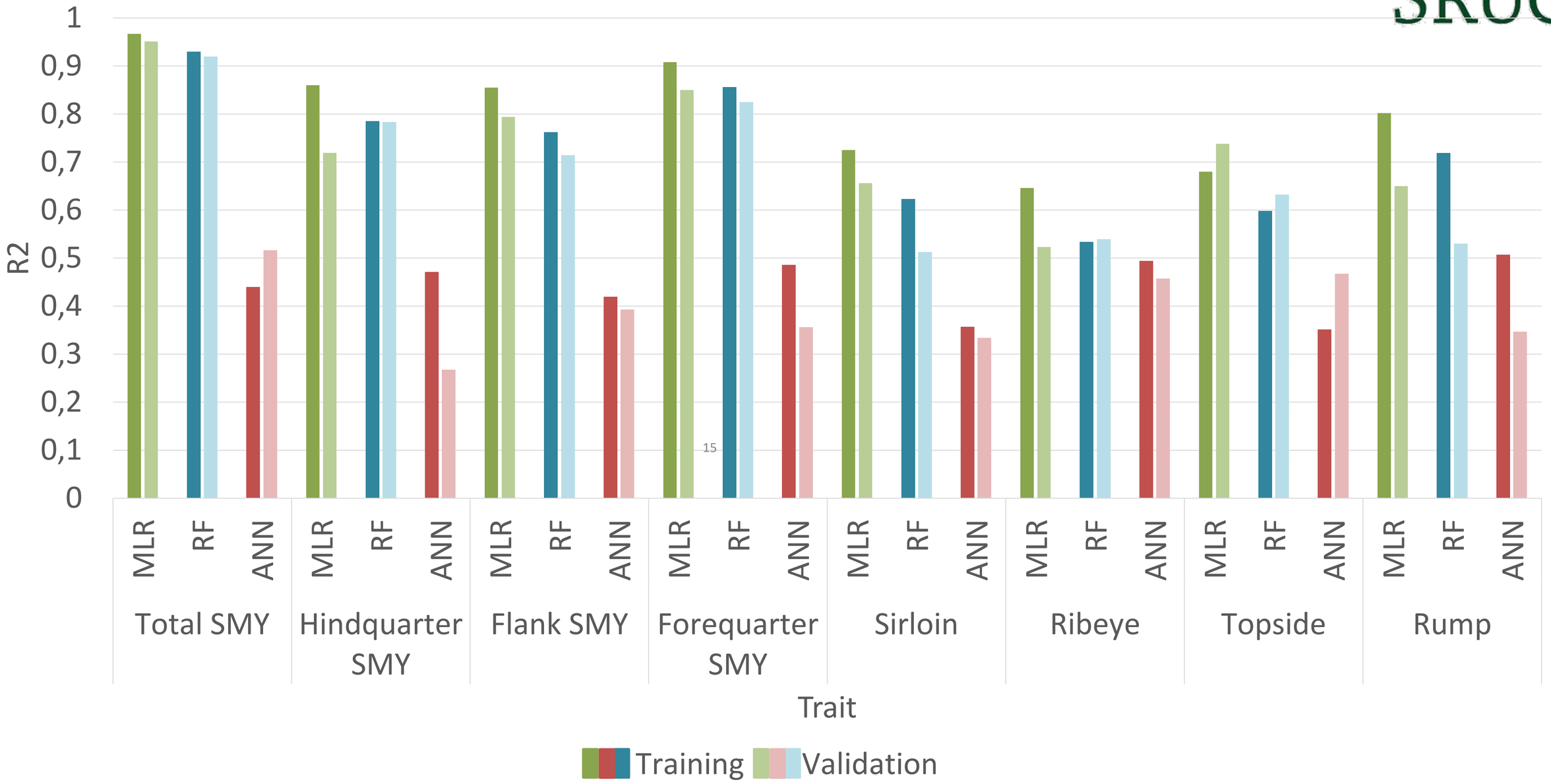
# Fixed effects and EUROP for the prediction of SMY traits and primal cut weights



# 3D measurements for the prediction of SMY traits and primal cut weights



# Fixed effects and 3D measurements for the prediction of SMY traits and primal cut weights



# Conclusion

The 3D measurements were capable of predicting the SMY traits with high accuracy and primal cut weights with moderat-high accuracy

MLR methods resulted in superior accuracies compared to the ML methods



Great potential for this commercially within the industry.

# Thank you for listening.

Prof. Carol-Anne Duthie

Dr. Gemma Miller

Dr. Nicola Lambe

Prof. Andrea Doeschl-Wilson

SRUC technicians and abattoirs

Funded by SRUC and AHDB



# Data Cleaning and analysis

- Up to 35 images per carcass
- Thresholds – 5 standard deviation points above/below mean of each measurement
- Coefficient of variation <0.3 for all measurements
- Datapoints per carcass averaged
- Final dataset of 484 carcasses
- Used to build MLR, random forest (RF) and artificial neural network (ANN) models

# CCW or FE

| | | Training | | Validation | | |
|---|---|---|---|---|---|---|
| Trait | Number of predictors in final model | Adjusted $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Total SMY | 1 (CCW) | 0.915 | 4.690 | 0.897 | 4.864 | 3.642 |
| | 4 (Fixed effects) | 0.946 | 3.742 | 0.895 | 3.957 | 2.991 |
| Hindquarter SMY | 1 (CCW) | 0.743 | 3.309 | 0.702 | 3.527 | 2.664 |
| | 4 (Fixed effects) | 0.791 | 2.970 | 0.767 | 3.101 | 2.360 |
| Flank SMY | 1 (CCW) | 0.748 | 2.253 | 0.687 | 2.234 | 1.746 |
| | 3 (Fixed effects) | 0.774 | 2.125 | 0.719 | 2.121 | 1.623 |
| Forequarter SMY | 1 (CCW) | 0.826 | 2.718 | 0.794 | 2.908 | 2.158 |
| | 3 (Fixed effects) | 0.885 | 2.201 | 0.846 | 2.499 | 1.863 |
| Sirloin | 1 (CCW) | 0.551 | 0.860 | 0.428 | 0.938 | 0.771 |
| | 4 (Fixed effects) | 0.635 | 0.772 | 0.561 | 0.817 | 0.658 |
| Ribeye | 1 (CCW) | 0.440 | 0.413 | 0.412 | 0.419 | 0.328 |
| | 4 (Fixed effects) | 0.557 | 0.366 | 0.570 | 0.358 | 0.287 |
| Topside | 1 (CCW) | 0.534 | 1.155 | 0.570 | 1.045 | 0.788 |
| | 4 (Fixed effects) | 0.597 | 1.070 | 0.674 | 0.908 | 0.671 |
| Rump | 1 (CCW) | 0.538 | 0.801 | 0.353 | 0.983 | 0.779 |
| | 6 (Fixed effects) | 0.761 | 0.574 | 0.640 | 0.733 | 0.551 |

# EUROP and FE

| | | Training | | Validation | | |
|---|---|---|---|---|---|---|
| Trait | Number of predictors in final model | Adjusted $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Total SMY | 6 | 0.968 | 2.853 | 0.958 | 3.112 | 2.294 |
| Hindquarter SMY | 6 | 0.880 | 2.243 | 0.878 | 2.281 | 1.732 |
| Flank SMY | 4 | 0.812 | 1.938 | 0.755 | 2.001 | 1.542 |
| Forequarter SMY | 6 | 0.899 | 2.051 | 0.859 | 2.391 | 1.796 |
| Sirloin | 5 | 0.670 | 0.733 | 0.596 | 0.785 | 0.639 |
| Ribeye | 6 | 0.573 | 0.358 | 0.575 | 0.357 | 0.284 |
| Topside | 6 | 0.704 | 0.915 | 0.792 | 0.729 | 0.547 |
| Rump | 6 | 0.808 | 0.513 | 0.702 | 0.669 | 0.510 |

# 3D measurements (SMY traits)

| | | | Training | | Validation | | |
|---|---|---|---|---|---|---|---|
| Trait | Technique | Model structure | $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Total SMY | MLR | 21 | 0.709 | 8.426 | 0.578 | 10.308 | 7.448 |
| | RF | 26, 500 | 0.536 | 11.209 | 0.452 | 11.331 | 8.493 |
| | ANN | 80, 0.1 | 0.561 | 10.859 | 0.520 | 11.106 | 8.633 |
| Hindquarter SMY | MLR | 22 | 0.667 | 3.645 | 0.554 | 4.482 | 3.310 |
| | RF | 29, 400 | 0.491 | 4.741 | 0.420 | 4.960 | 3.754 |
| | ANN | 80, 0.001 | 0.499 | 4.755 | 0.414 | 5.279 | 4.216 |
| Flank SMY | MLR | 23 | 0.598 | 2.750 | 0.387 | 3.262 | 2.515 |
| | RF | 11, 100 | 0.406 | 3.501 | 0.288 | 3.382 | 2.688 |
| | ANN | 80, 0.01 | 0.370 | 3.816 | 0.286 | 3.804 | 3.000 |
| Forequarter SMY | MLR | 27 | 0.677 | 3.554 | 0.520 | 4.568 | 3.241 |
| | RF | 28, 100 | 0.549 | 4.457 | 0.456 | 4.709 | 3.506 |
| | ANN | 80, 0.1 | 0.502 | 4.741 | 0.416 | 5.253 | 4.048 |

# 3D measurements (primal cuts)

| | | | Training | | Validation | | |
|---|---|---|---|---|---|---|---|
| Trait | Technique | Model structure | $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Sirloin | MLR | 19 | 0.725 | 0.654 | 0.656 | 0.725 | 0.575 |
| | RF | 44, 300 | 0.623 | 0.795 | 0.513 | 0.862 | 0.693 |
| | ANN | 20, 0.1 | 0.357 | 1.126 | 0.334 | 1.101 | 0.883 |
| Ribeye | MLR | 25 | 0.646 | 0.317 | 0.523 | 0.403 | 0.308 |
| | RF | 46, 400 | 0.534 | 0.382 | 0.539 | 0.373 | 0.299 |
| | ANN | 80, 0.1 | 0.494 | 0.494 | 0.457 | 0.413 | 0.316 |
| Topside | MLR | 8 | 0.680 | 0.948 | 0.738 | 0.814 | 0.614 |
| | RF | 36, 600 | 0.598 | 1.093 | 0.632 | 0.968 | 0.741 |
| | ANN | 40, 0.01 | 0.351 | 1.501 | 0.467 | 1.287 | 1.016 |
| Rump | MLR | 19 | 0.802 | 0.510 | 0.650 | 0.725 | 0.540 |
| | RF | 40, 600 | 0.719 | 0.634 | 0.530 | 0.840 | 0.633 |
| | ANN | 60, 0.1 | 0.507 | 0.919 | 0.347 | 1.078 | 0.853 |

# 3D measurements and FE (SMY traits)

| | | | Training | | Validation | | |
|---|---|---|---|---|---|---|---|
| Trait | Technique | Model structure | $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Total SMY | MLR | 20 | 0.967 | 2.855 | 0.951 | 3.424 | 2.517 |
| | RF | 48, 600 | 0.930 | 4.344 | 0.920 | 4.308 | 3.176 |
| | ANN | 60, 0.1 | 0.440 | 12.979 | 0.516 | 11.011 | 8.614 |
| Hindquarter SMY | MLR | 24 | 0.860 | 2.357 | 0.719 | 2.524 | 1.934 |
| | RF | 42, 200 | 0.785 | 3.084 | 0.783 | 3.039 | 2.339 |
| | ANN | 20, 0.1 | 0.471 | 5.048 | 0.268 | 7.840 | 5.682 |
| Flank SMY | MLR | 22 | 0.855 | 1.652 | 0.794 | 1.808 | 1.417 |
| | RF | 39, 200 | 0.762 | 2.215 | 0.714 | 2.122 | 1.656 |
| | ANN | 80, 0.1 | 0.420 | 3.677 | 0.393 | 3.385 | 2.716 |
| Forequarter SMY | MLR | 17 | 0.908 | 1.929 | 0.850 | 2.483 | 1.783 |
| | RF | 45, 200 | 0.856 | 2.522 | 0.825 | 2.678 | 2.040 |
| | ANN | 60, 0.1 | 0.486 | 4.983 | 0.356 | 5.285 | 3.863 |

# 3D measurements and FE (primal cuts)

| | | | Training | | Validation | | |
|---|---|---|---|---|---|---|---|
| Trait | Technique | Model structure | $R^2$ | RMSE | $R^2$ | RMSE | MAE |
| Sirloin | MLR | 20 | 0.569 | 0.819 | 0.333 | 1.041 | 0.804 |
| | RF | 11, 200 | 0.363 | 1.040 | 0.203 | 1.115 | 0.884 |
| | ANN | 80, 0.1 | 0.327 | 1.173 | 0.166 | 1.387 | 1.053 |
| Ribeye | MLR | 24 | 0.475 | 0.386 | 0.392 | 0.443 | 0.356 |
| | RF | 12, 300 | 0.343 | 0.450 | 0.397 | 0.426 | 0.332 |
| | ANN | 80, 0.1 | 0.248 | 0.557 | 0.185 | 0.593 | 0.463 |
| Topside | MLR | 19 | 0.525 | 1.135 | 0.516 | 1.143 | 0.850 |
| | RF | 13, 700 | 0.372 | 1.353 | 0.340 | 1.303 | 1.007 |
| | ANN | 60, 0.1 | 0.271 | 1.664 | 0.303 | 1.589 | 1.304 |
| Rump | MLR | 20 | 0.622 | 0.704 | 0.402 | 0.961 | 0.750 |
| | RF | 33, 500 | 0.482 | 0.859 | 0.410 | 0.951 | 0.735 |
| | ANN | 60, 0.1 | 0.425 | 1.016 | 0.287 | 1.167 | 0.896 |