



Evaluating the Robustness of Cumulative Milk Yield Estimation Methods under Limited Test-Day Availability in Italian Mediterranean Buffalo

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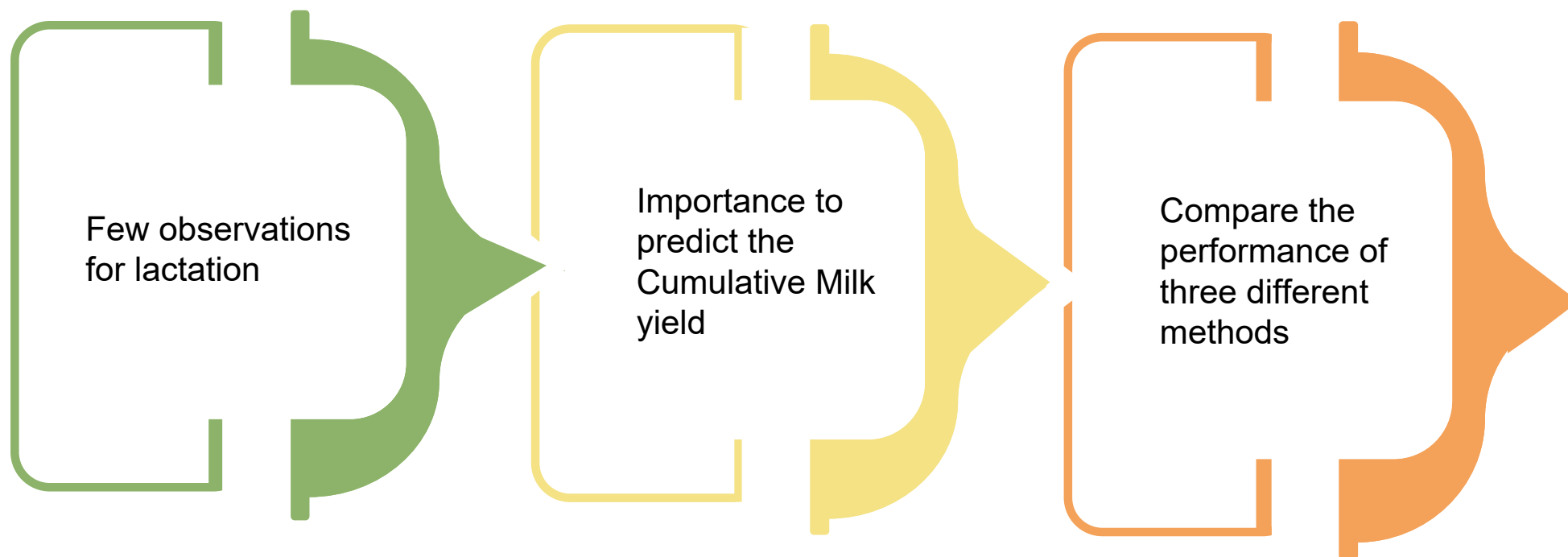
Agenda



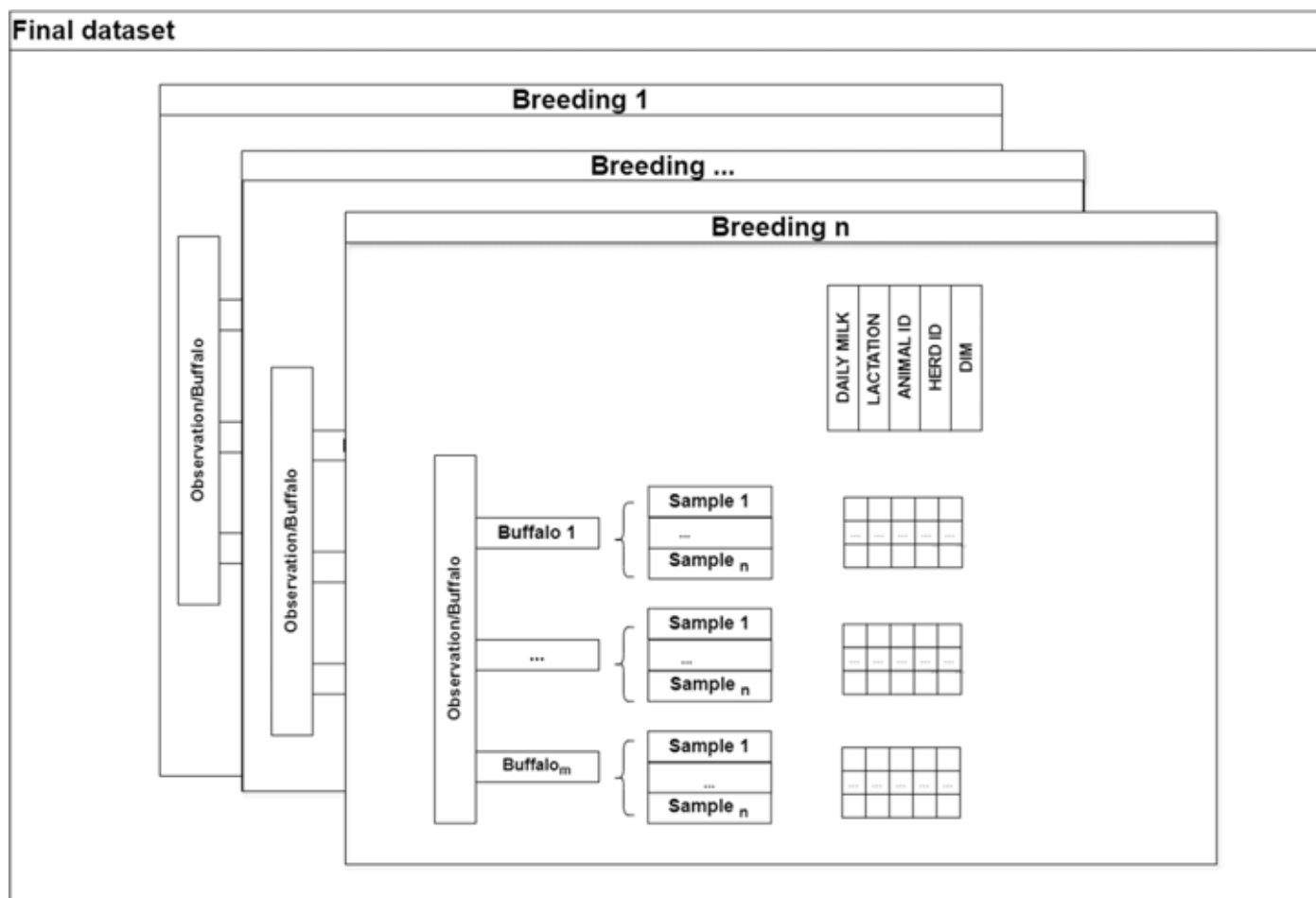
Background

- Buffalo sector has been constantly growing in the last years and are important producers of milk and dairy products;
- From 1996 until now, there has been a growth of 173% of heads. The number of buffaloes in Italy amounts to about 429000;
- Recording daily milk yield is often logistically and economically difficult for many farms. Usually, they rely on the National Breed association with one observation per month.

Aim of the work



Dataset



Dataset:

- 329 herds
- 2013 -2023
- 130531 animals
- 1957430 TD

TD configuration

To simulate routine monthly recording systems, **nine test-day** measurements per lactation were selected, corresponding to approximately one control per month, as commonly performed by the national recording association.

The **same nine Days in Milk (DIM) and milk yield records were used across all three methods** to ensure a consistent comparison of their performance.

Moreover, **four alternative configurations were designed to evaluate the robustness of the methods under different recording patterns using the same methodology.**

	Test-Day (TD)	Days in milk (DIM)	
Balance configuration	9 (each 30 days)	7, 37, 67, 97, 127, 157, 187, 217, 247	
	6 (each 45 days)	7, 52, 97, 142, 187, 232, 277	
	4 (each 70 days)	7, 77, 147, 217	
	4 (early lactation)	7, 37, 67, 97	
	4 (late lactation)	157, 187, 217, 247	Unbalance configuration

Test Interval Method

$$MY = I_0M_1 + I_1*\frac{(M_1 + M_2)}{2} + I_2 * \frac{(M_2 + M_3)}{2} + I_{n-1} * \frac{(M_{n-1} + M_n)}{2} + I_nM_n$$

Where:

M_1, M_2, M_n are the weights in kilograms, given to one decimal place, of the milk yielded in the 24 hours of the recording day.

I_1, I_2, I_{n-1} are the intervals, in days, between recording dates.

I_0 is the interval, in days, between the lactation period start date and the first recording date.

I_n is the interval, in days, between the last recording date and the end of the lactation period.

Equations

- Wood equation (Wood, 1967)

$$Y_w(t) = at^b e^{-ct}$$

- Y_w = milk yield,
- t = days in milk,
- a = magnitude,
- b = time to peak
- c = the decay.

Wood. (1967). Algebraic Model of the Lactation Curve in Cattle. *Nature*, 216 (5111), 164–165. <https://doi.org/10.1038/216164a0>

- MilkBot equation (Ehrlich, 2013)

$$Y_{mb}(t) = a \left(1 - \frac{e^{\frac{c-t}{b}}}{2} \right) e^{-dt}$$

- Y_{mb} = milk yield,
- t = days in milk,
- a = magnitude,
- b = time to peak
- c = offset
- d = decay

Ehrlich, J. L. (2013). Quantifying inter-group variability in lactation curve shape and magnitude with the MilkBot[®] lactation model. *PeerJ*, 1, e54. <https://doi.org/10.7717/peerj.54>

Evaluation metrics

BIAS

Measures the average tendency of predictions to systematically overestimate or underestimate the observed values



Cumulative milk yield at 270 days

R²

Measures how well the model explains the variability of the observed data

RMSE

Measures the average magnitude of prediction errors, giving more weight to larger errors. Lower values indicate better model performance

MAPE

Measures the average percentage error between predicted and observed values. Lower values indicate higher prediction accuracy

Results - 1

- In **balanced TD schemes**, bias ranged from -1.85% to -0.04% across models and parities, indicating **good agreement** between predicted and observed cumulative milk yield.
- In contrast, **unbalanced TD schemes** showed larger discrepancies between predicted and observed values.
- The late TD configuration showed marked **instability**, particularly for the **Wood model**.

TD	Parity	TIM %	Wood %	MilkBot %
Balanced TD				
9	1	-0.70	-0.71	-0.75
	2	-0.66	-0.65	-0.34
	3+	-0.54	-0.51	-0.22
6	1	-0.80	-0.60	-0.73
	2	-1.03	-0.88	-0.22
	3+	-1.10	-0.85	-0.26
4	1	-1.56	-0.47	-0.04
	2	-1.85	-0.93	-1.13
	3+	-1.46	-0.49	-0.74
Unbalanced TD				
4 Early	1	14.00	-4.70	-3.27
	2	17.70	-3.72	-3.03
	3+	18.62	-3.15	-5.00
4 Late	1	-13.40	103.00	-6.34
	2	-9.23	4.86	-6.66
	3+	-12.86	5.92	-5.95

Results - 2

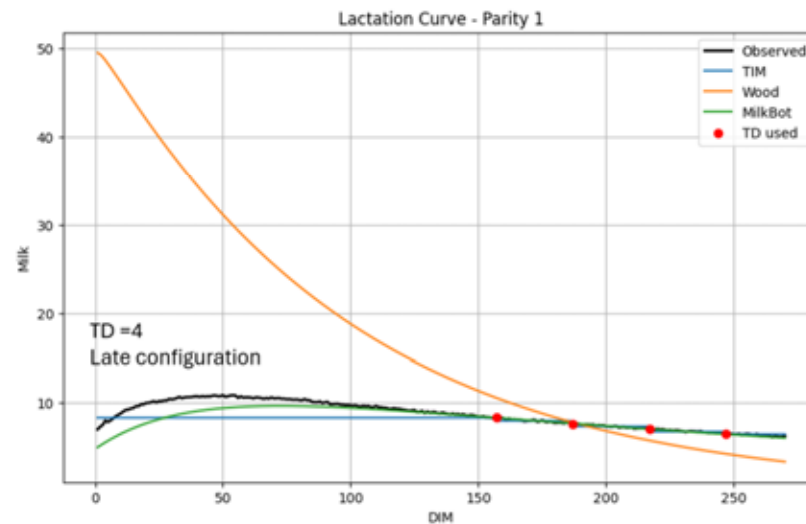
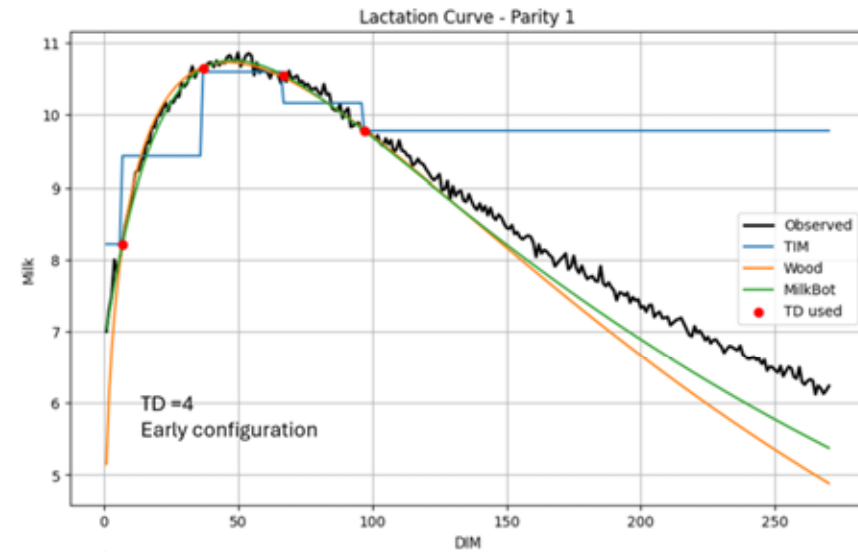
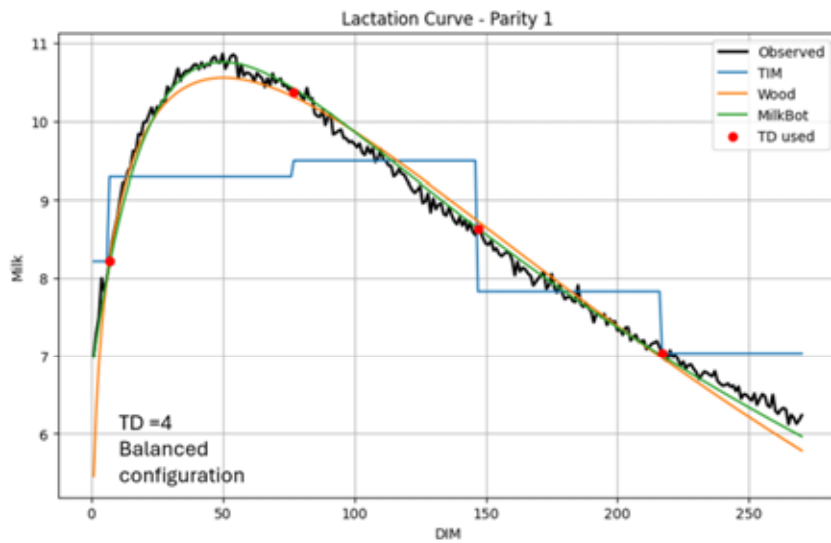
Balance TD schemes

- R^2 ranged between **0.97 – 0.99** for both methods denoting that the models were able to capture the overall shape of the curve.
- This is confirmed by **RMSE** that ranged from **0.18 to 0.26** and **0.11 to 0.33** for Wood and Milkbot, respectively.

Unbalance TD schemes

- **Performance varied between the early and late configuration.**
- In the early one, the Wood model achieved R^2 values of **0.83 - 0.96**, while the Milkbot model ranged from **0.92 - 0.96**.
- Late configuration showed a strong **degradation in performance**, with the Wood model dropping to an R^2 value of -102.48 for parity 1.
- The **Milkbot model also experienced a decline in performance**, although less severe, obtaining R^2 values of 0.60, 0.71, and 0.78.

Results - 3



Results - 4

Discussion and conclusion

- Overall, **TIM displayed a consistent behavior across unbalanced sampling schemes**; however, this was associated with **lower accuracy**, as reflected by bias in both early and late configurations
- **Degradation in unbalance configuration** occurs because when TD records are concentrated toward the end of lactation, the early phase of the LC is not adequately captured, limiting the ability of the models to correctly reconstruct the overall curve shape
- Finally, future studies could evaluate the models by stratifying data at the animal level rather than by parity. In addition, the use of a more robust gold standard, such as a very dense TD dataset or data generated from automatic milking systems (milking robots), could further improve the assessment of model accuracy and reliability.

THANK YOU

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