

Bayesian Modeling of Lactation Curves in Italian Mediterranean Buffalo Using the MilkBot Equation

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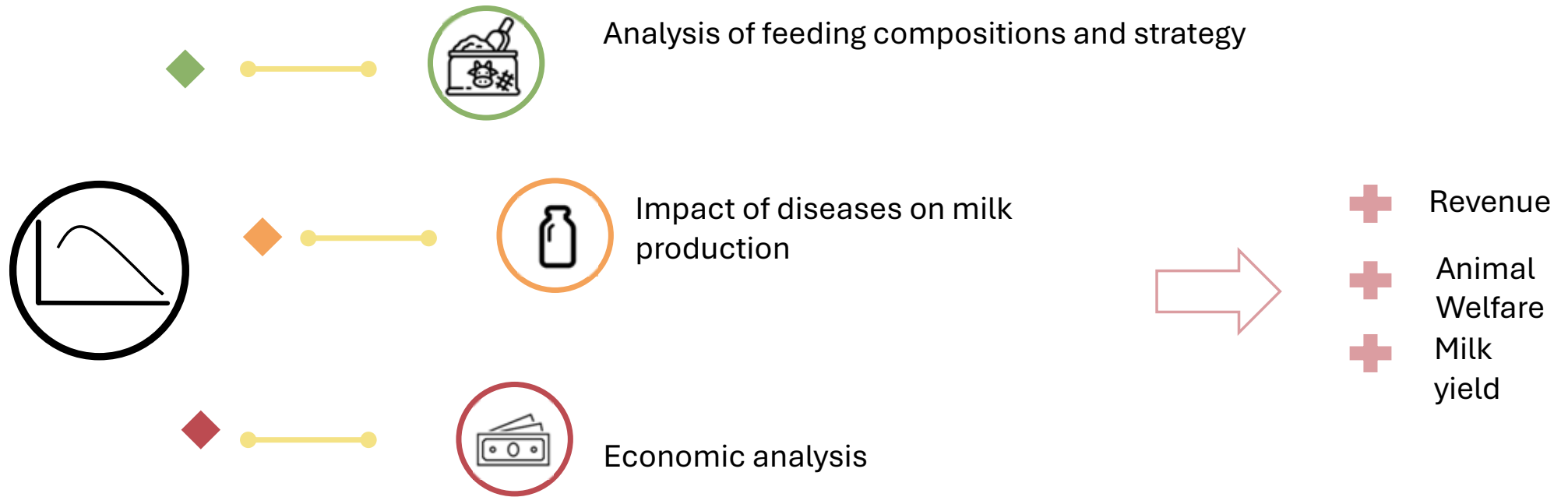
Agenda



Background

- Buffaloes contribute about 15% of global milk production, with Italy being the leading producer in Europe.
- In Italy, approximately 429000 Italian Mediterranean buffaloes were reared.
- Buffalo milk is a high-value product and the key raw material for traditional dairy products, such as the PDO Mozzarella di Bufala Campana.
- The modernization of Italian buffalo farming has increased milk yield, making lactation curve analysis an essential tool for monitoring production performance, supporting efficient herd management decisions.

Background



Aim of the work

Higher production levels require more organized and structured management systems

It is important to predict the Cumulative Milk yield and lactation curve characteristics

Bayesian Modelling using Milkbot equation to find suitable priors

Why the Bayesian Approach?

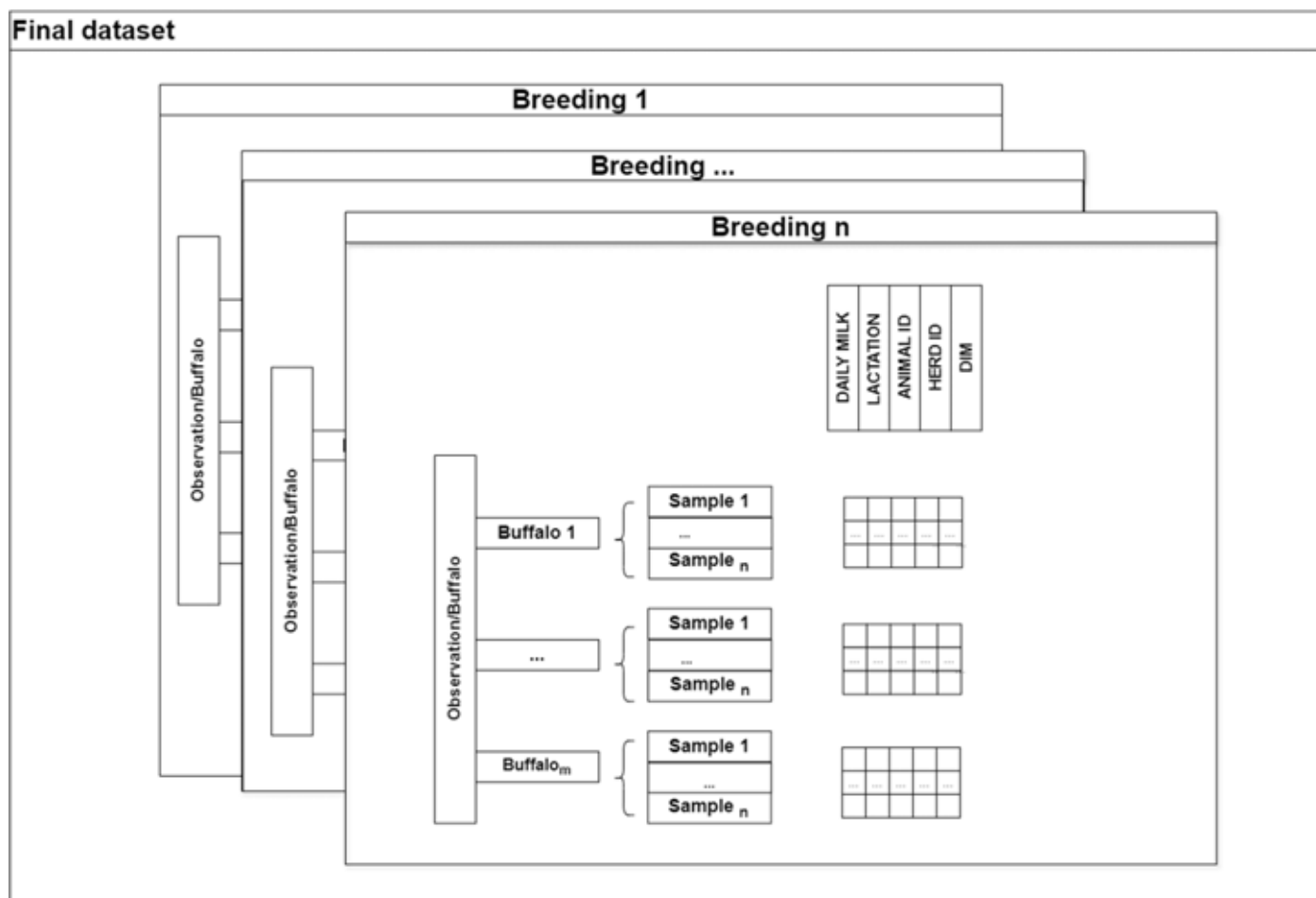
Real scenario

- Sparse Data Challenge in Buffalo; data relies on monthly test-days.
- Limited observations per lactation make curve fitting highly sensitive to outliers[?] reducing estimation accuracy.

Bayesian Solution

- It incorporates prior biological knowledge on lactation into the parametric MilkBot function.
- Significantly improves lactation curve estimation under sparse data conditions.

Dataset



Dataset:

- 328 herds
- 2018 -2023
- 92493 animals
- 384964 TD

Equation

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>

Workflow

Step 1

- Split data in train (80%) and test (20%)
- Stratify the dataset in parity 1 (P1) and parity 2+ (P2+)

Step 3

- Posterior-based estimates used to predict mean lactation curves.
- Evaluate model performance on test datasets.

Step 2

- Posterior distributions were estimated using MCMC sampling (6 chains)
- Select the draw with the highest log-posterior density.
- Provide an approximate Maximum A Posteriori (MAP) estimate within the sampled space

Evaluation metrics

R^2

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

MSE

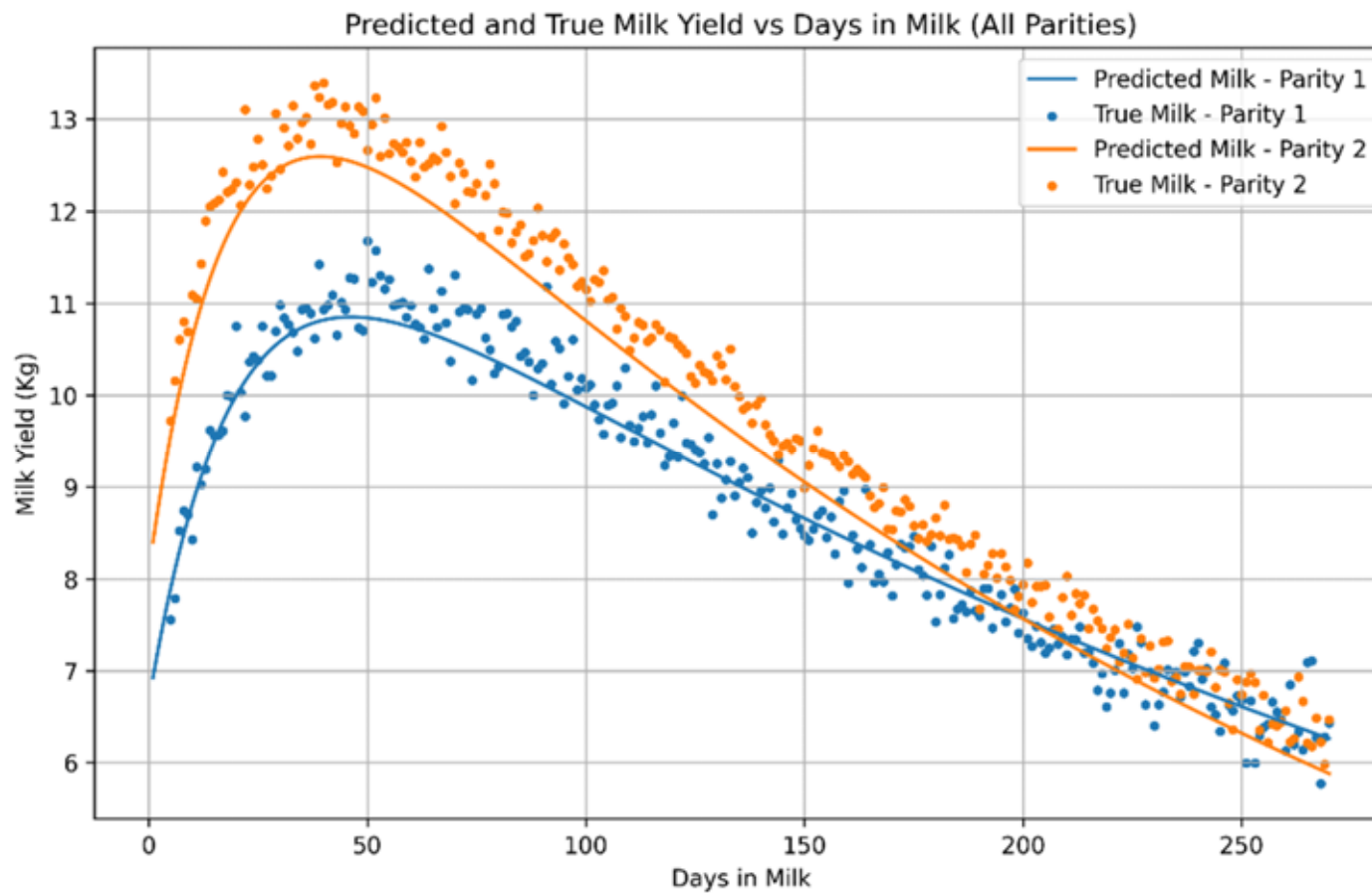
Measures the average squared difference between the actual observed values and the values predicted by the model

Results - 1

Parity	Posteriors			
	Scale (a)	Ramp (b)	Offset (c)	Decay (d)
P1	13.00 ± 0.03	20.94 ± 0.44	-0.50 ± 0.01	0.003 ± 0.00
P2 +	15.54 ± 0.03	19.86 ± 0.25	-0.78 ± 0.00	0.004 ± 0.00

Parity	MSE	RMSE	MAPE (%)	R ²
P1	0.09	0.29	2.66	0.96
P2+	0.20	0.45	4.25	0.96

Results - 2



Discussion and conclusion

Higher scale (a) in multiparous (P2+) reflected mammary gland maturation and greater productive capacity.

Decay (d) denoted higher persistence in primiparous (P1).

Primiparous buffaloes showed a higher ramp (b) meaning a more pronounced lactation peak confirming literature trends.

Biological meaning

Performance estimation

The model showed slightly higher prediction errors (RMSE, MSE, MAPE) and a tendency to underestimate the lactation curve for P2+.

High heterogeneity within the P2+ group which pooled animals from the 2nd up to the 6th lactation (where the highest variance in production usually occurs).

The Bayesian MilkBot framework proved highly robust and accurate ($R^2 = 0.96$ for both parities) under sparse data conditions.

Future Step: Moving from a general P2+ category to a more refined stratification of pluriparous animals to improve biological interpretability.

THANK YOU

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