Resilience indicator phenotypes based on daily milk yield in Nordic Red cows

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BACKGROUND

- Resilience is the ability of an animal to remain largely unaffected by disruptions or to quickly return to its normal state after experiencing a disturbance.

- Resilience cannot be directly measured but can be utilized to assess resilience.

Research Goals:

- Develop indicators of resilience by analyzing the dynamics of milk yield over lactation using data from milking robots available in Finland.

- Compare resilience phenotypes to evaluate their correlation and validate these phenotypes.

- Understand the genetics behind resilience phenotypes and their associations with fertility and energy status as well as health related traits.

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Materials&Methods

- ✓ Data from 52 dairy cows, spanning 2 to 449 days in milk (310 ± 43), at Luke Maaninka research farm in Finland were used to evaluate the methods.

- ✓ Plans to extend the comparison to a larger dataset of over 70,000 cows (> 107 million per-visit records) to confirm the results.

- ✓ The study will also focus on identifying correlated or redundant variables to refine the phenotypes for more precise analysis.

- ✓ Several methods to detect and characterize disturbances/perturbations have been developed such as:
  - Simple statistics: variance of curve
  - Time series statistics (e.g., smoothing)
  - More theoretical: idealized curve fitting

- ✓ The perturbed lactation model (**PLM**) and differential smoothing (**DS**) methods were implemented to detect and characterize disturbances in the lactation curves using R software.

Table 1
List of potential variables to describe and quantify animal resilience. These variables can be adapted for any species.

Item	Definition	Examples
Magnitude of perturbation	Maximum of the difference between the theoretical trajectory of performance and the actual perturbed performance	(Codrea et al., 2011) Dairy cows
Time of recovery	The time between the minimum value of performance reached and the time of complete recovery (return to the theoretical trajectory).	(Sadoul et al., 2015) Rainbow trout
Surface	The area between the theoretical trajectory and the actual performance during the perturbation interval	(Revilla et al., 2019) Piglet
Intensity	• Speed of the decrease during the collapse phase • speed of the increase during the recovery phase	(Friggens et al., 2016; Macé et al., 2020; Ben Abdelkrim et al., 2021a) Meat sheep, dairy goats, dairy cows
Other dynamic indicators of resilience	• Negative residuals based on the estimation of an expected curve of performance • Number of days with negative residuals • Variance/natural logarithm transformed variance • Temporal auto-correlation/lag-1 auto-correlation • Skewness • Cross-correlation (between elements of the system)	(Adriaens et al., 2020) (Scheffer et al., 2018) (animals and humans) (Poppe et al., 2020) dairy cows (Berghof et al., 2019b) laying hens

(Taghipoor et al., 2023)

Perturbed Lactation Model (PLM)

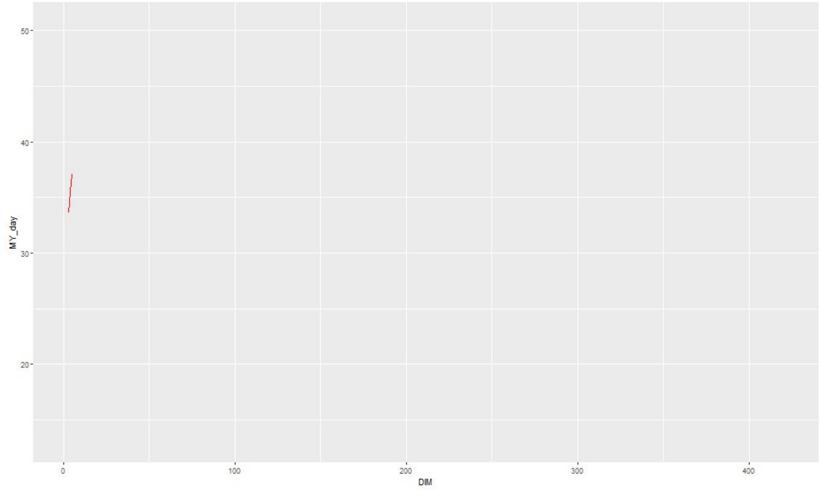
- The model is called a perturbed lactation model (**PLM**) with an explicit representation of perturbations.

- A theoretically undisturbed lactation curve (expected lactation curve) was predicted to enable the characterization of the lactation potential of each cow in the absence of environment perturbations (Ben Abdelkrim et al., 2021a)

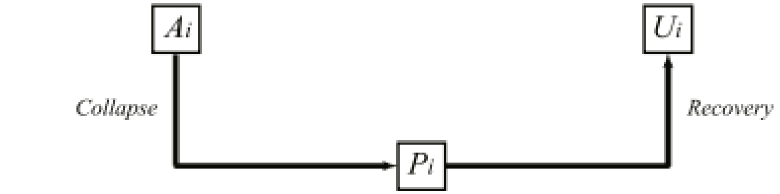
The model combines two components:

i) The **unperturbed lactation model** that describes a theoretical lactation curve (Wood, 1967), is assumed to reflect female production potential.

ii) The **perturbation model** describes all the deviations from the unperturbed lactation model with four parameters: starting date, intensity, and shape (collapse and recovery).

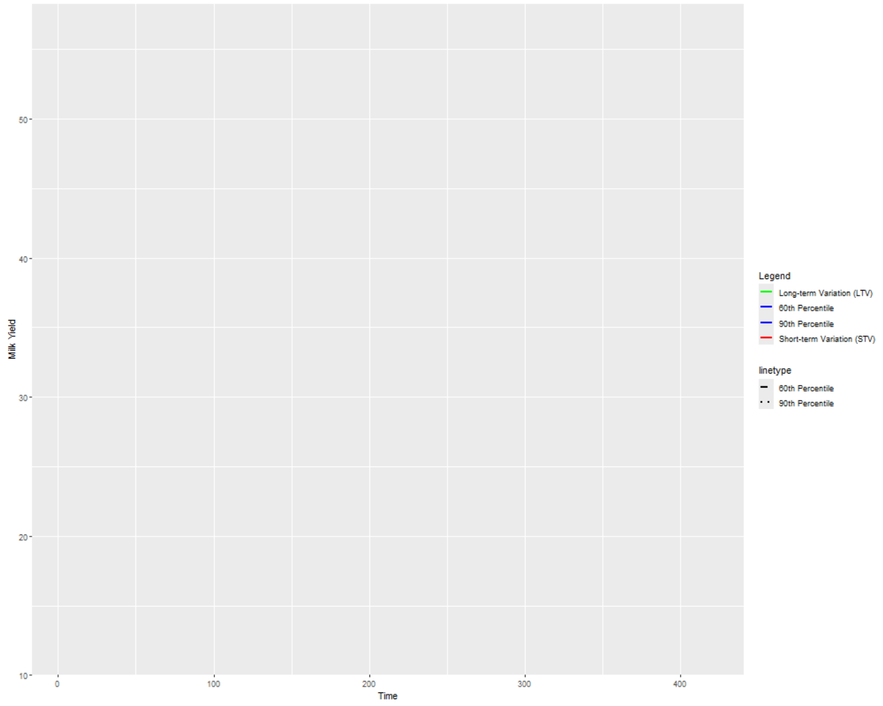


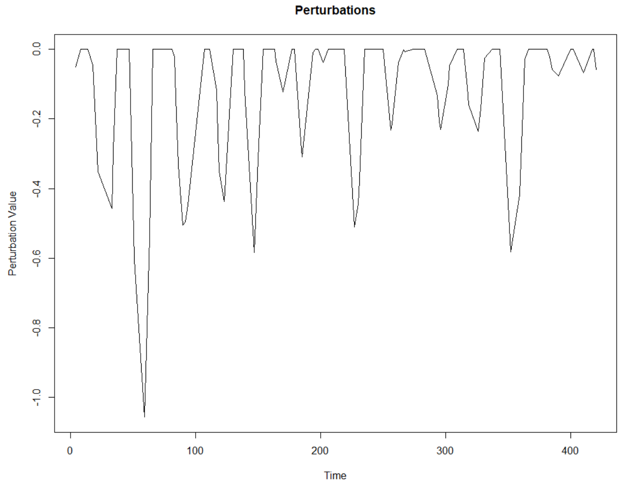
a)



Ben Abdelkrim et al., 2021a

Differential Smoothing (DS)





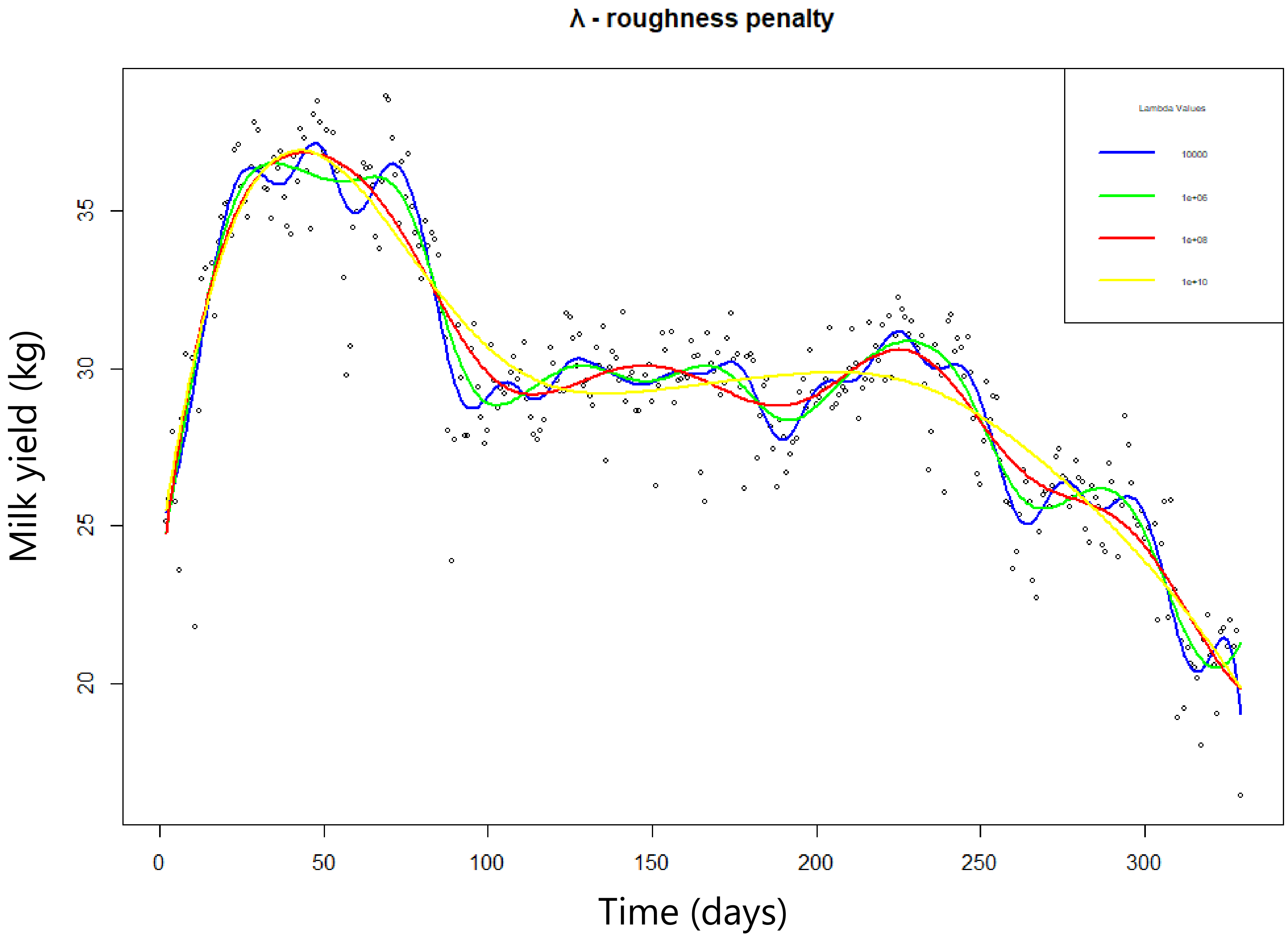
- The data processing and statistical analyses were done by using R and the smoothing approach described by Ramsay and Silverman (2005) was used (package "fda": Ramsay et al., 2018).

- The λ (roughness penalty) parameter controls the relative emphasis given to goodness of fit versus smoothness.

- The study relies on the study of Codrea et al. (2011) and Abdelkrim et al. (2021b).

- The difference between longer-term phenotypic potential performance (LTV) and short-term variations (STV) provides different measures of perturbations.

λ - roughness penalty



Different methods, same concept

Perturbed lactation model (PLM):

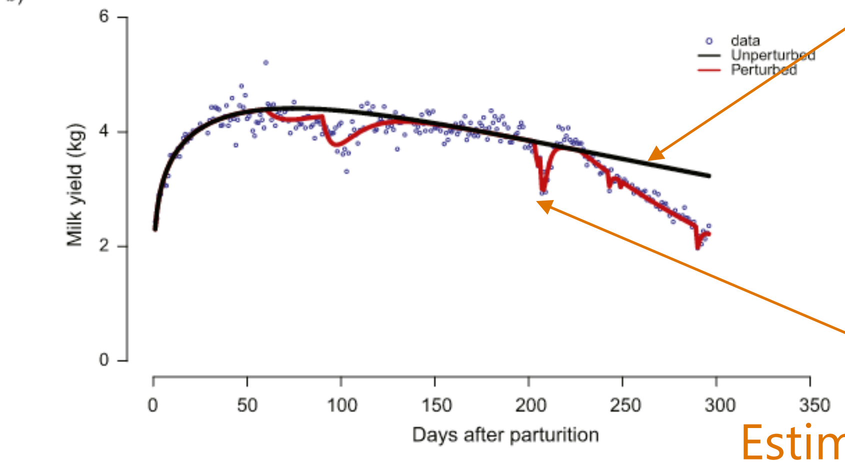
- Theoretical wood curve
- Compartment model for collapses

Differential smoothing (DS):

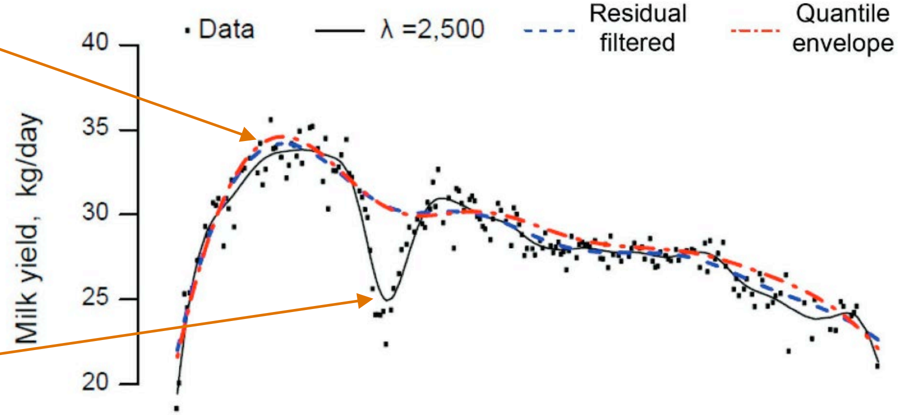
- Difference between long term and short term curve (or heavy and light averaging)

Estimated unperturbed curve

Ben Abdelkrim et al., 2021a



Ben Abdelkrim et al., 2021b



Estimated perturbations

Table Abbreviations and variables selected to define a perturbation

DS	PLM	
STV: Short-term variations curve	**N:** Mean of the total number of perturbations	
LTV: Long-term phenotypic potential performance curve	**tp:** Starting time	**Perturbation parameters**
AUC: Areas under the curve of the difference between the STV and LTV curves	**k_0:** Intensity	**Perturbation parameters**
AUC_{LD}: Estimation of loss per day (AUC/ΔT)	**k_1:** Collapse speed	**Perturbation parameters**
ΔT: Duration of deviation detected	**k_2:** Recovery speed	**Perturbation parameters**
AUC_{LD}: Collapse phase time by deviation	**a**	**Wood parameters**
T_{col}: Recovery phase time by deviation	**b**	**Wood parameters**
T_{rec}: Maximum performance loss during deviation	**c**	**Wood parameters**
V_{min}: Minimum value recorded during the deviation	**Loss:** Milk yield loss.	

Estimated unperturbed curve

Luke
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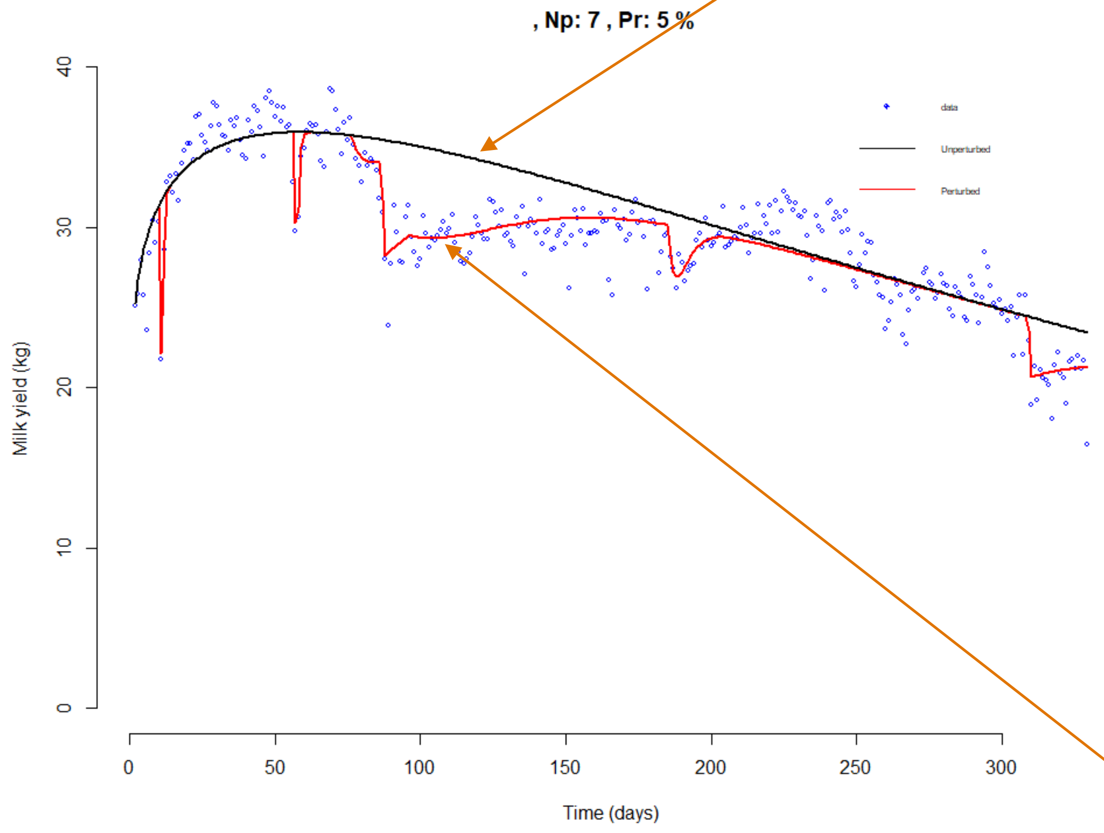

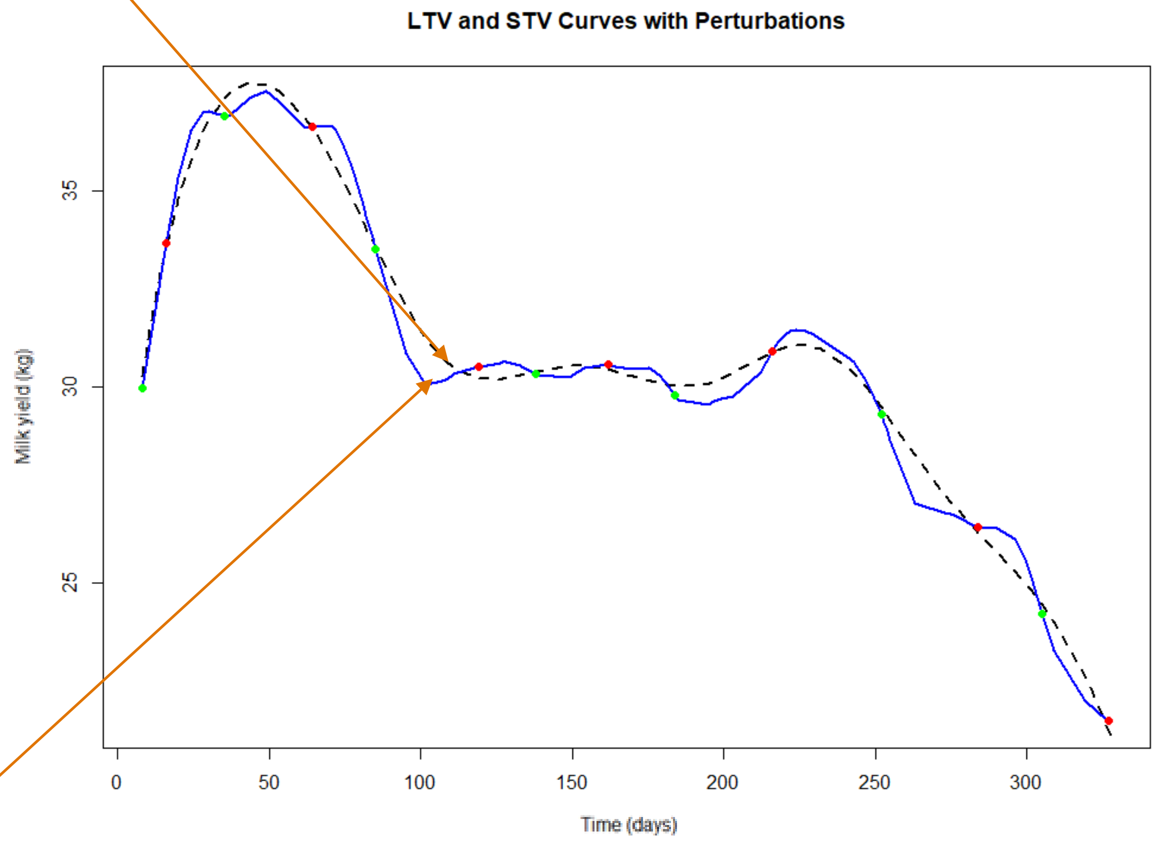

Estimated perturbations

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OVERVIEW

- Extract biological knowledge from perturbations using tailored methods.
- Critical for gaining significant insights.
- Filter out irrelevant noise and optimize data smoothing for clearer results.
- Effectively merge diverse data types.
- Ensure result accuracy.

Thank you for your attention!

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