



Animal Life Cycle Submodule on RuFaS Model:

a Sensitivity Analysis to Evaluate Animal Reproductive Protocols

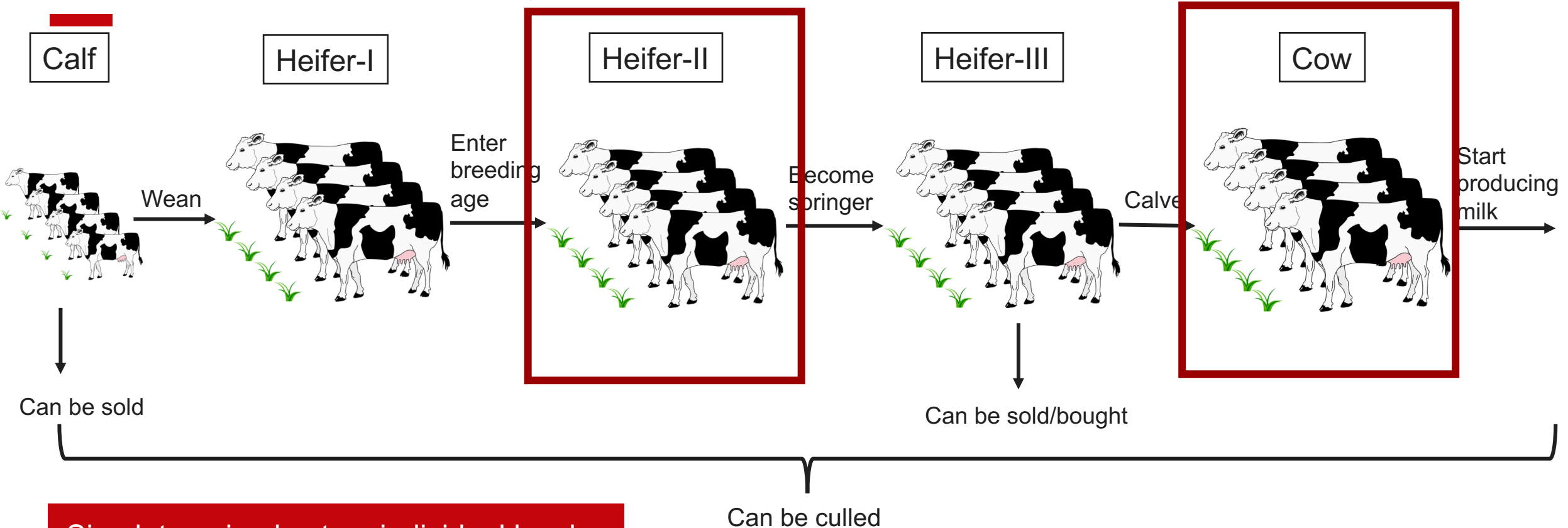


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Animal Life Cycle Submodule



- Simulate animals at an individual level
- Monte Carlo / stochastic methods

Objective

Use global sensitivity analysis to:

- Verify the model correctness and robustness
- Identify the most influential factors affecting heifers' and cows' reproduction performance to provide insights to farmers
- Gain knowledge about significant variables
 - Reduce the burden of inputting for users
 - Help develop new models for future researchers

Sensitivity Analysis

- Can quantify the importance of model input variables





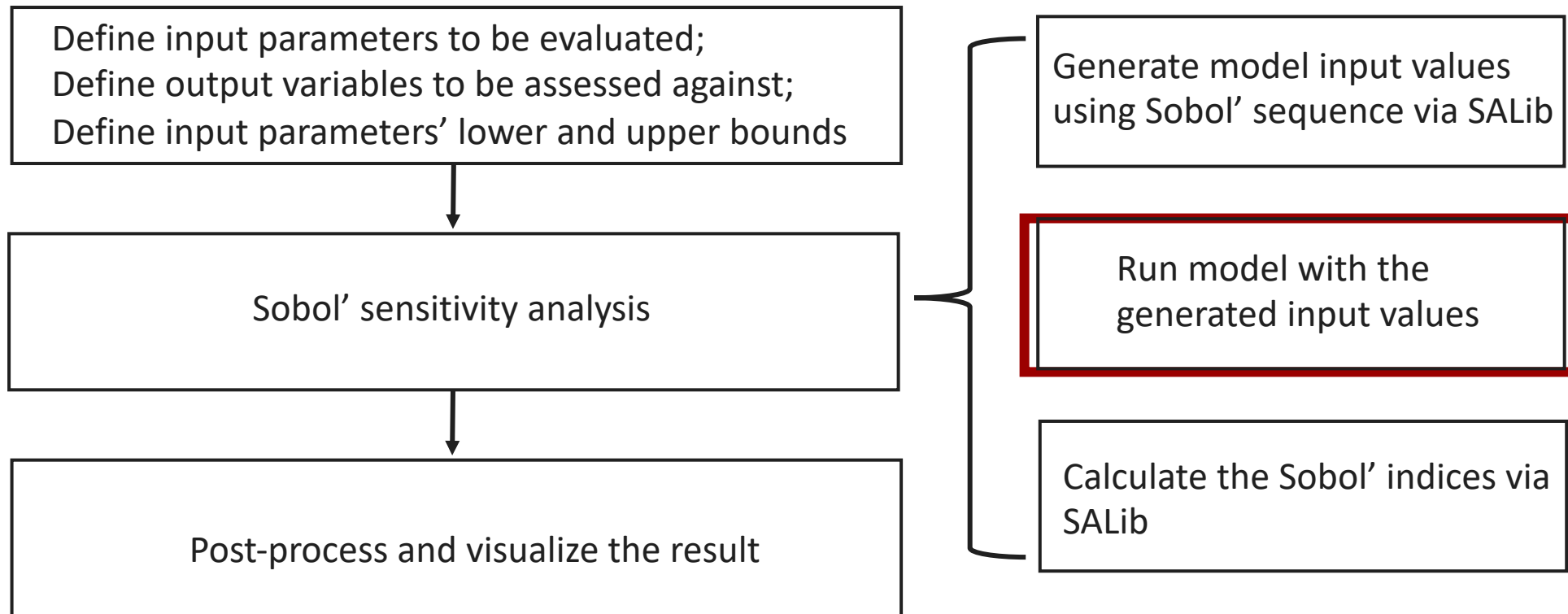
Sobol' Method

- Pros:
 - Global sensitivity analysis
 - Variance-based
 - Allow the effects of interactions between parameters
 - Give both the first-order sensitivity index and total sensitivity index
 - Reliable
- Cons:
 - Computational requirement is high

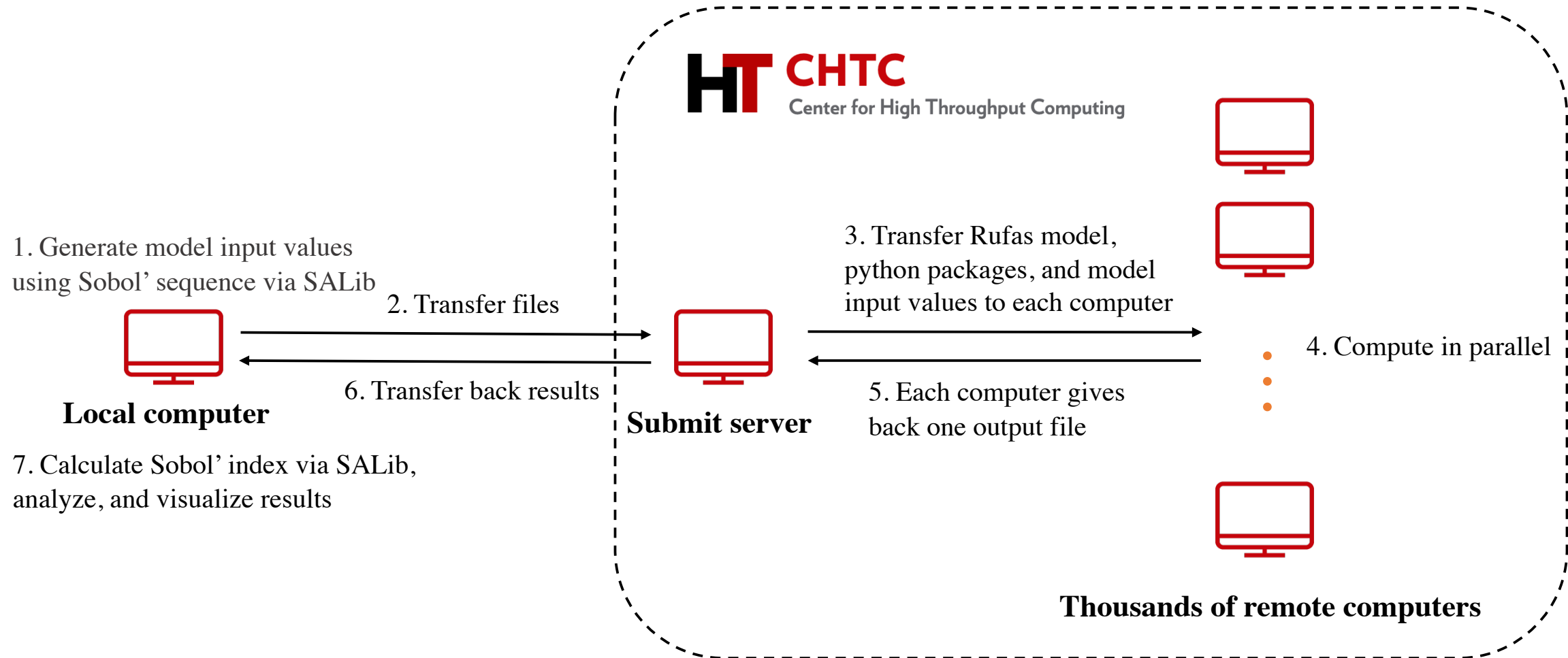
Sobol' sensitivity index

- Impact of an input x (e.g., breeding start day) to a model output y (e.g., 21-d pregnancy rate)
- This impact is measured by the proportion of variance caused by input x relative to the total variance of output y
- **First-order Sobol' sensitivity index (S1)**
 - impact of parameter x alone on the model output y
- **Total Sobol' sensitivity index (ST)**
 - Overall impact of parameter x along with the impact caused by the interaction of this parameter x and other parameters

Sobol' Method



Analytic Framework



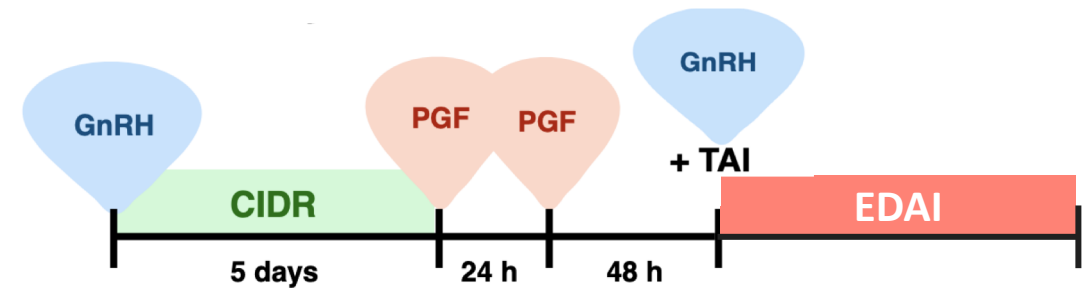
Heifer Reproductive Protocols

- Pure estrus detection (ED)



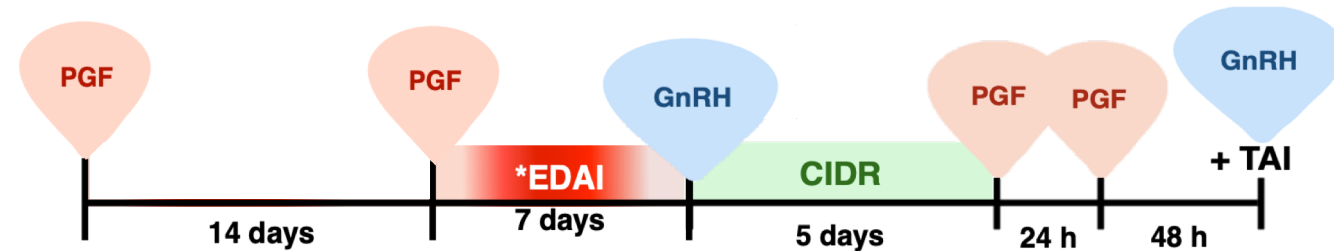
- Timed AI (TAI)

- First breeding:
 - 5-d CIDR-Synch with GnRH and 2 PGF
- Subsequent breedings
 - EDAI



- Synch-ED

- First breeding:
 - Two PGF followed by ED
- Subsequent breedings
 - TAI



(DCRC, 2018)



Input Parameter Interval

Input variables	Abbreviation	ED	TAI	Synch-ED
Breeding start day (d)	BS		(342, 418)	
Breeding period (d)	BP		(126, 154)	
TAI conception rate (%)	TAI CR	NA	(48, 72)	(48, 72)
Estrus detection rate (%)	EDR	(48, 72)	(48, 72)	(56, 84)
Estrus conception rate (%)	ECR		(48, 72)	
Average estrus cycle length (d)	EC		(18, 24)	
Average gestation length (d)	GL		(270, 282)	



Output Variables

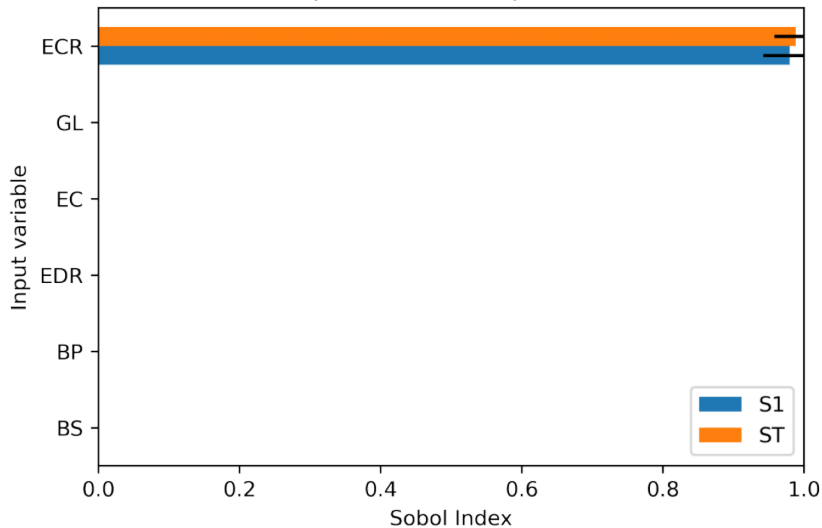
- Related to herd structure:
 - Parity 1 percentage, parity 2 percentage, parity 3 percentage, parity 3+ percentage, young animal to cow ratio, culling rate
- Relate to reproduction:
 - 21-d service rate, 21-d conception rate, 21-d pregnancy rate, sold calves last year, average breeding to pregnancy time, average culling age, average open time, bought heifer number, number of culled heifer, detection for estrus duration, number of AI, number of CIDR injection, number of GnRH injection, number of pregnancy check, number of PGF injection, number of sold heifer
- Relate to economics:
 - Net return, feed cost, reproduction cost



Results for Objective 1: Verify the model correctness and robustness

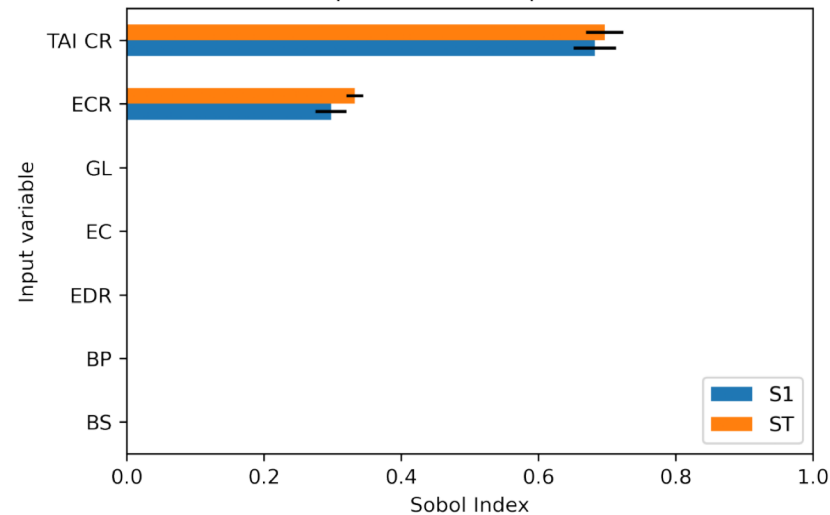
ED

Output: 21-d conception rate



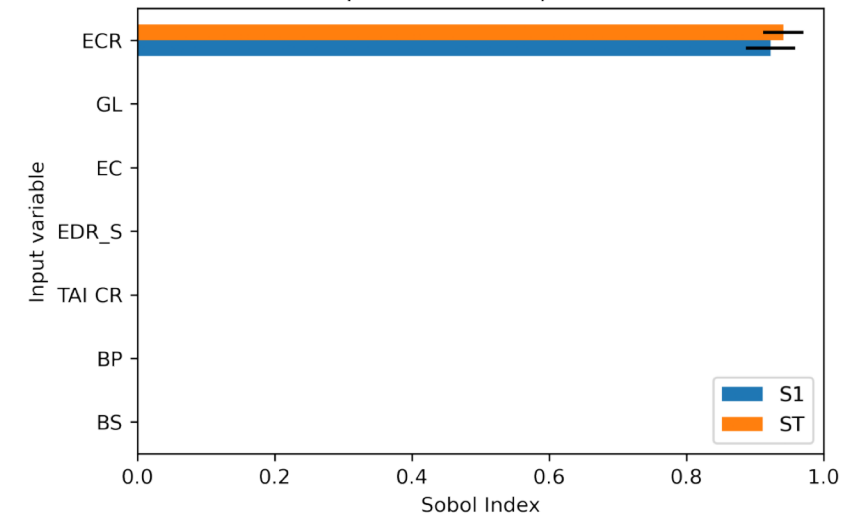
TAI

Output: 21-d conception rate



Synch-ED

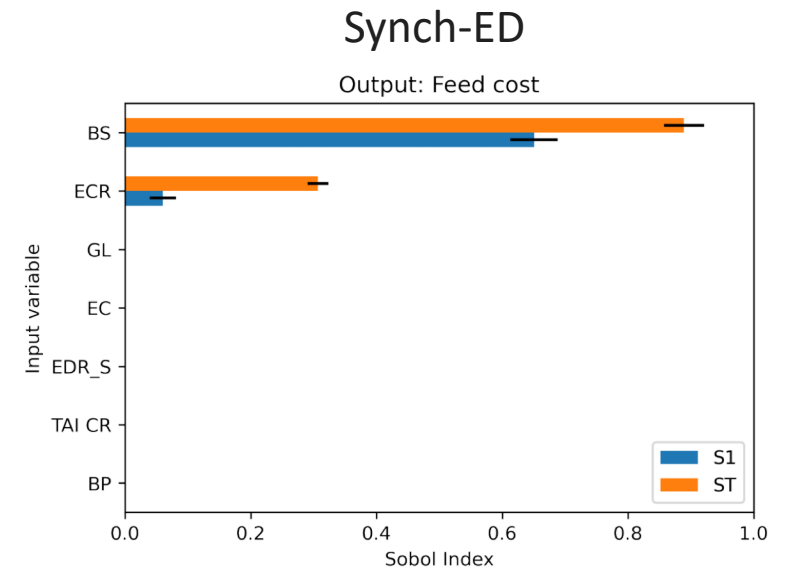
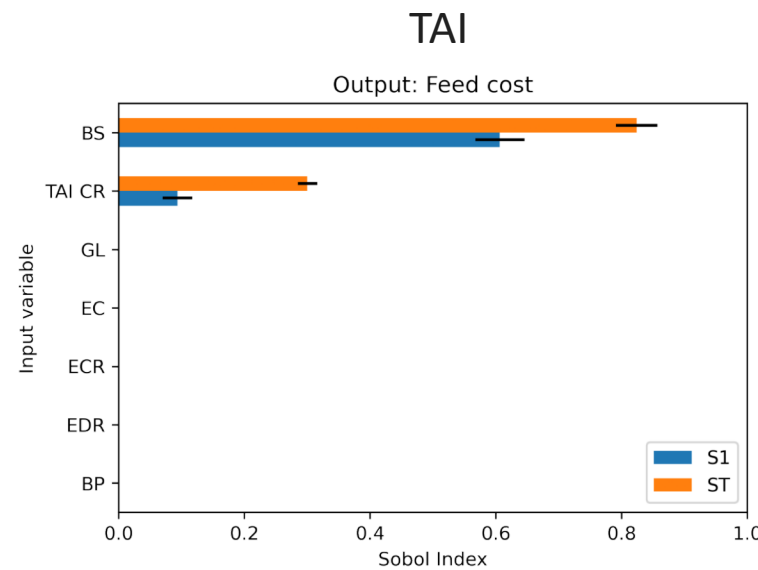
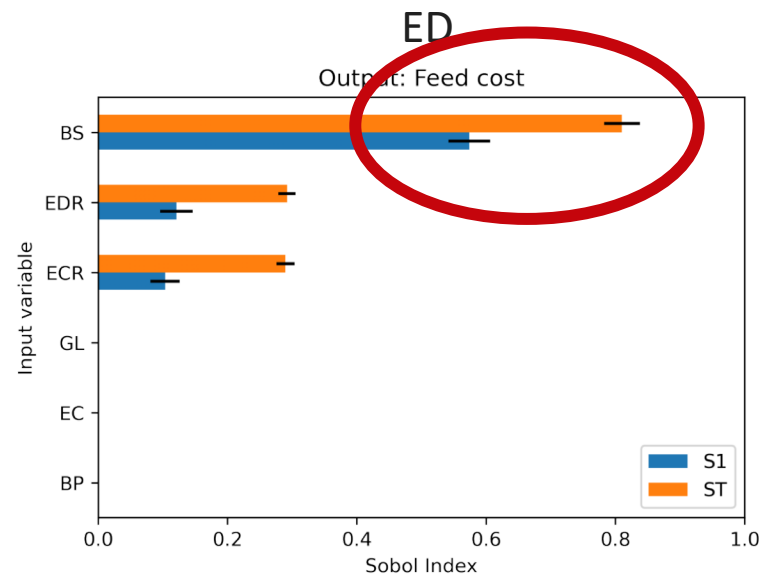
Output: 21-d conception rate



Average estrus cycle length: EC, Average gestation length: GL,
Breeding start day: BS, Breeding period: BP,
Estrus conception rate: ECR, Estrus detection rate: EDR,
TAI conception rate: TAI CR

*Input variables that have first order Sobol' indices less than 0.05 were not shown in the figure

Results for Objective 1 & 2: Verify the model correctness and robustness & Provide Insights to Farmers

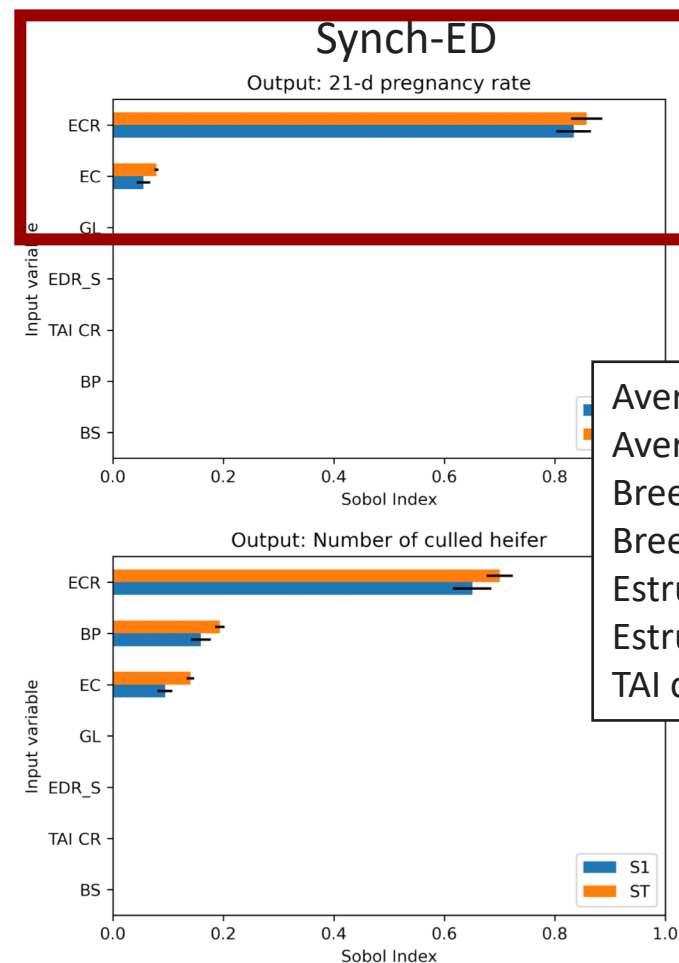
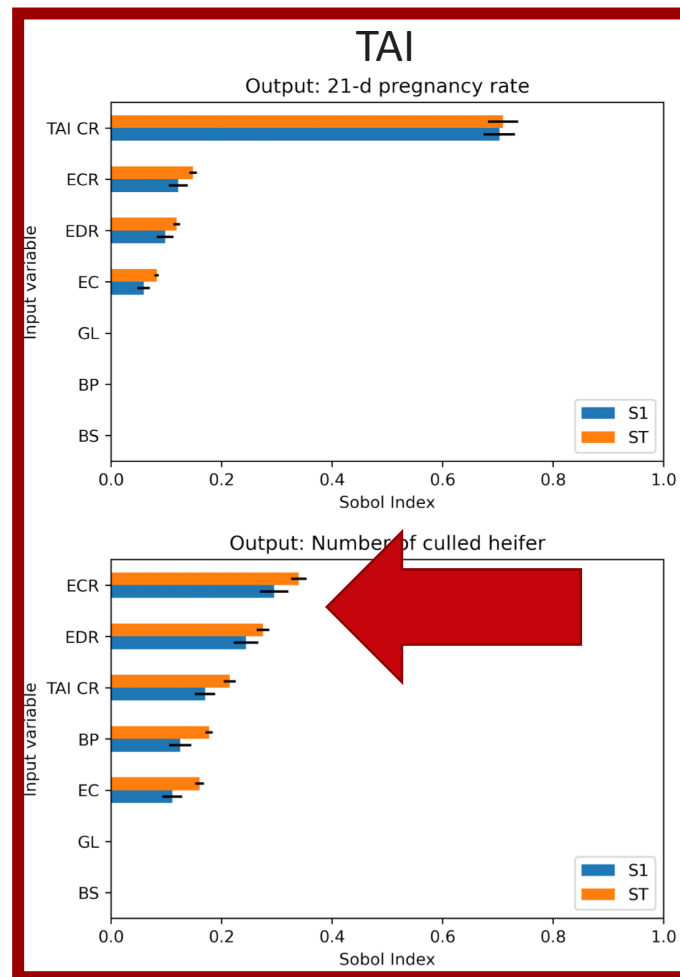
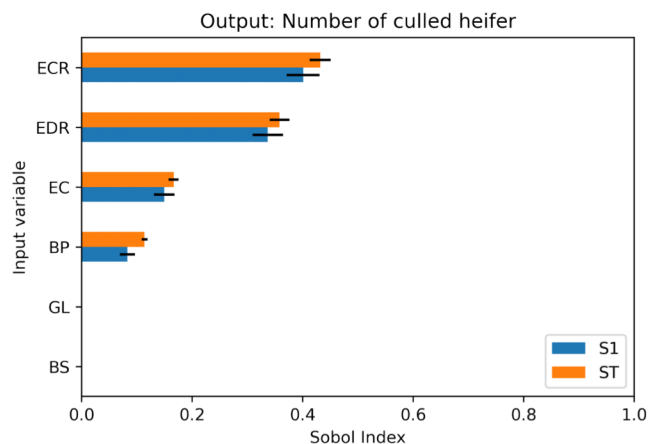
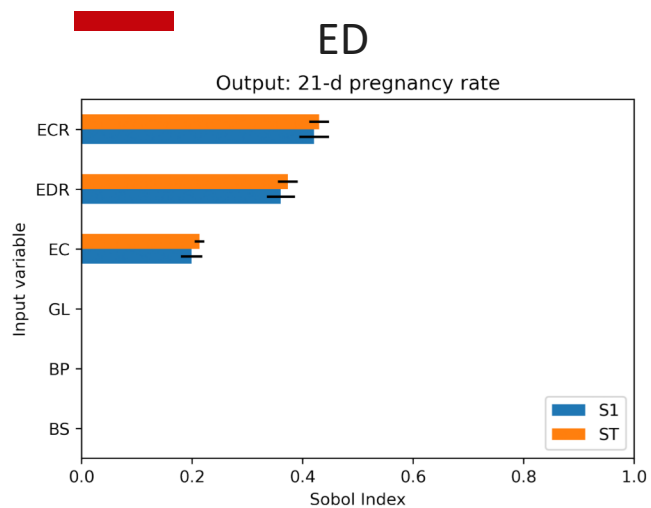


Average estrus cycle length: EC, Average gestation length: GL,
 Breeding start day: BS, Breeding period: BP,
 Estrus conception rate: ECR, Estrus detection rate: EDR,
 TAI conception rate: TAI CR

*Input variables that have first order Sobol' indices less than 0.05 were not shown in the figure



Results for Objective 2 & 3: Provide Insights to Farmers & Gain Knowledge about Significant Variables



Average estrus cycle length: EC,
Average gestation length: GL,
Breeding start day: BS,
Breeding period: BP,
Estrus conception rate: ECR,
Estrus detection rate: EDR,
TAI conception rate: TAI CR



*Input variables that have first order Sobol' indices less than 0.05 were not shown in the figure

Take-home Messages



- Global sensitivity analysis for animal life cycle can:
 1. Verify the model correctness and robustness
 2. Provide insights to dairy farmers
 3. Identify the significant input variables
- Assumptions are critical



Future work

- Submit a manuscript about this work (SA on reproduction)
- Joseph: SA on the rest of Animal module
- Yijing: Build functionality to simulate genetic progress on top of Animal Module



Thank you & Questions