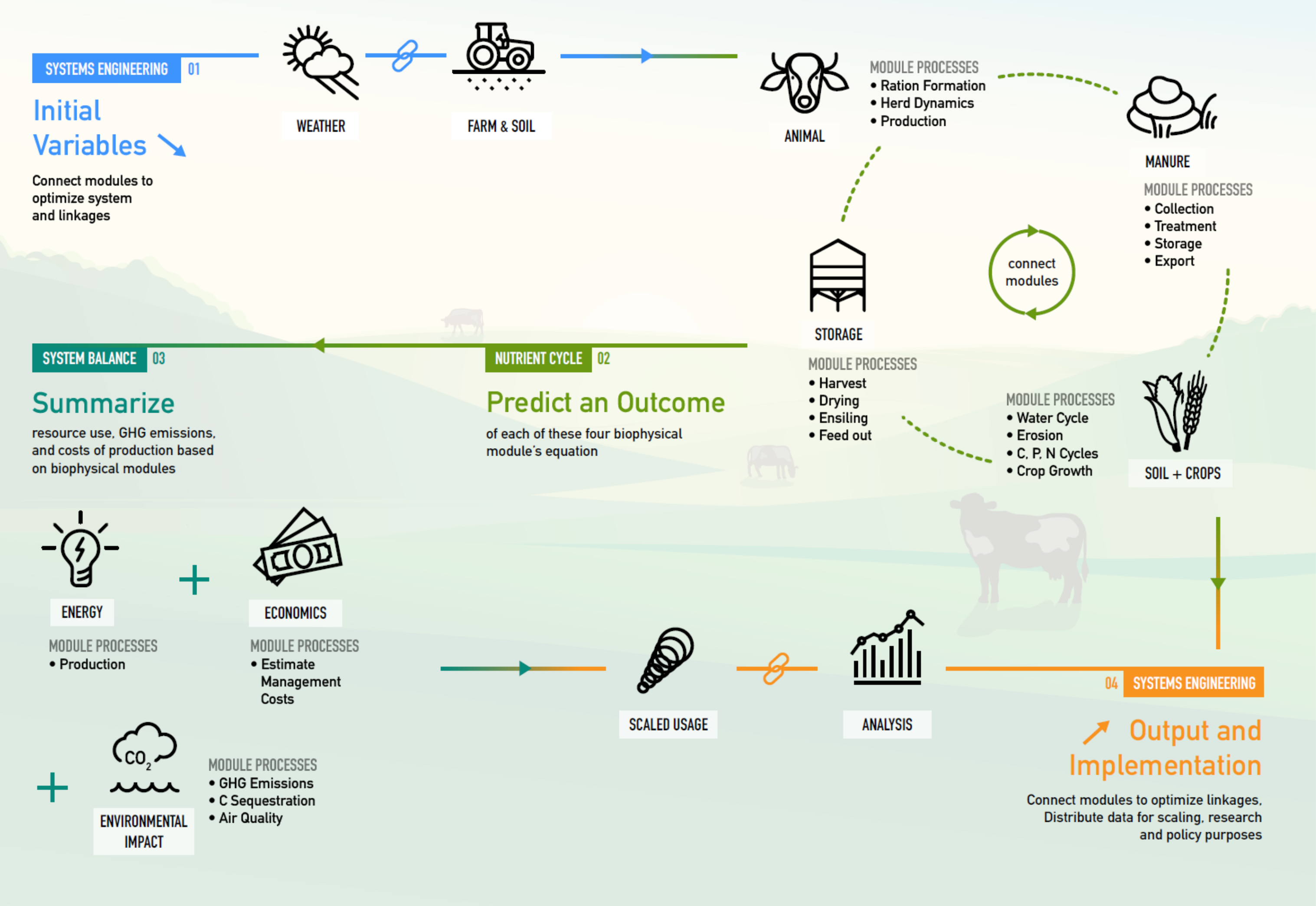
Modeling Sustainable Dairy Systems

RUFAS AND OTHER REED LAB ACTIVITIES

RuFas Team

- 5 scientists
  - Reed (Cornell)
  - Thoma (U of Arkansas)
  - Panke-Buisse (USDFRC)
  - Cabrera (UW Madison)
  - Kebreab (UC Davis)
- 2 Post Docs
  - Hansen (Cornell)
  - Motew (USDFRC)
- 3 PhD Students
  - Li (UW Madison)
  - Li (UC Davis)
  - Barrientos (Cornell)
- 5 Student Programmers
- Many collaborators
  - USDA-ARS – Idaho, Colorado, Wisconsin, Beltsville
  - DMI
  - Newtrient
  - NEAFA, General Mills

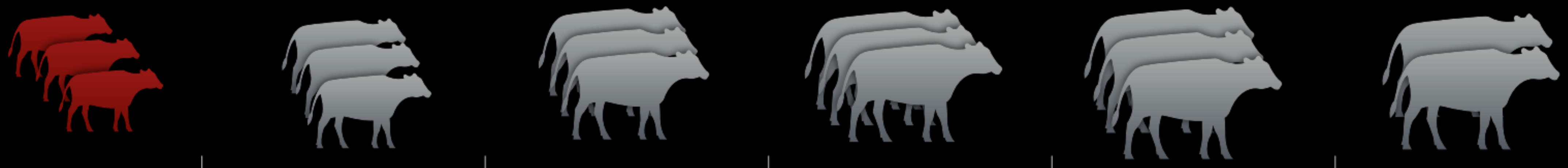


Ruminant Farm Systems (RuFaS) Model

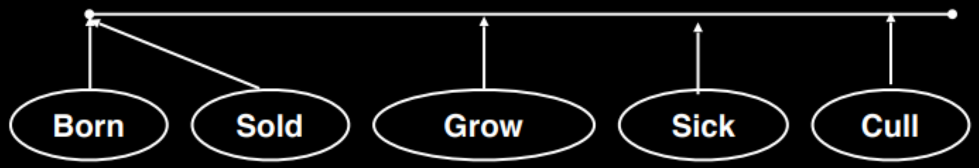
RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓

Animal life cycle model



Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell



- Calves
  - Born, gender assigned according to semen type
  - Sold, as male/ female calf
  - Grow, with initial birth weight and average daily gain
  - Sick, calf specific health issues
  - Cull, leaving the group before wean

Animal life cycle model

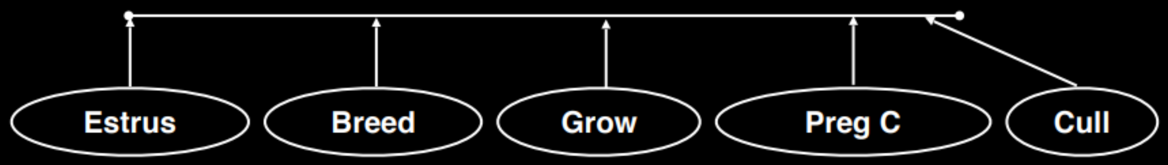
Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell

- Heifers I
  - Wean, feed
  - Grow, with ADG
  - Sick
  - Cull, leaving the group before breeding

Animal life cycle model

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled

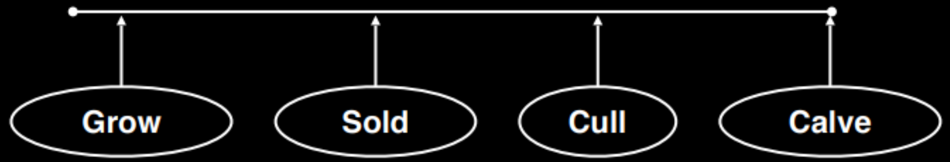
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell



- Heifers II
  - Estrus, if estrus detection involved, estrus ~ N(21,2.5)
  - Breeding, AI after ED and TAI protocols
  - Grow, related to nutrition and pregnancy status
  - Preg checks, three times on day 32, 91, 200 after AI
  - Cull, reproductive failure and health issue

Animal life cycle model

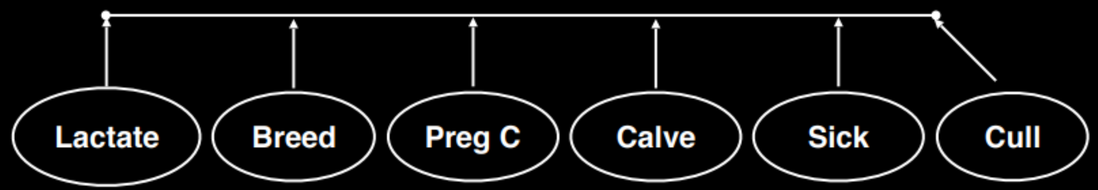
Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell



- ## Heifers III
  - Grow, nutrition needs and supply
  - Sold, as pregnant heifer
  - Cull, leaving the group before enter
  - Calve, at the end of the gestation ~ N(278,6)

Animal life cycle model

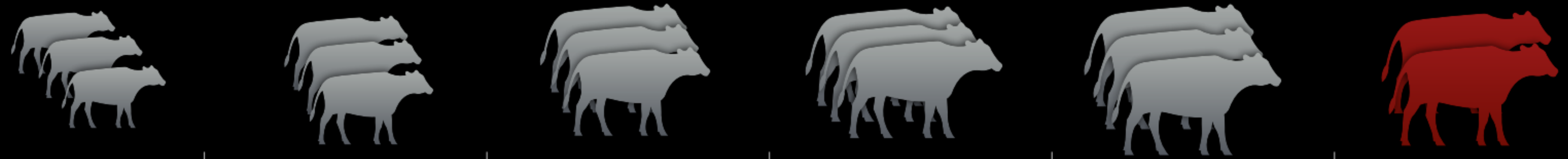
Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell



- Cow
  - Lactate, follow the production level specific curve
  - Breed, AI after ED and TAI protocols
  - Preg checks, three times on day 32, 91, 200
  - Calve, at the end of the gestation ~ N(278,6)
  - Sick, calf sensitive illness
  - Cull, leaving the group before wean

Animal life cycle model

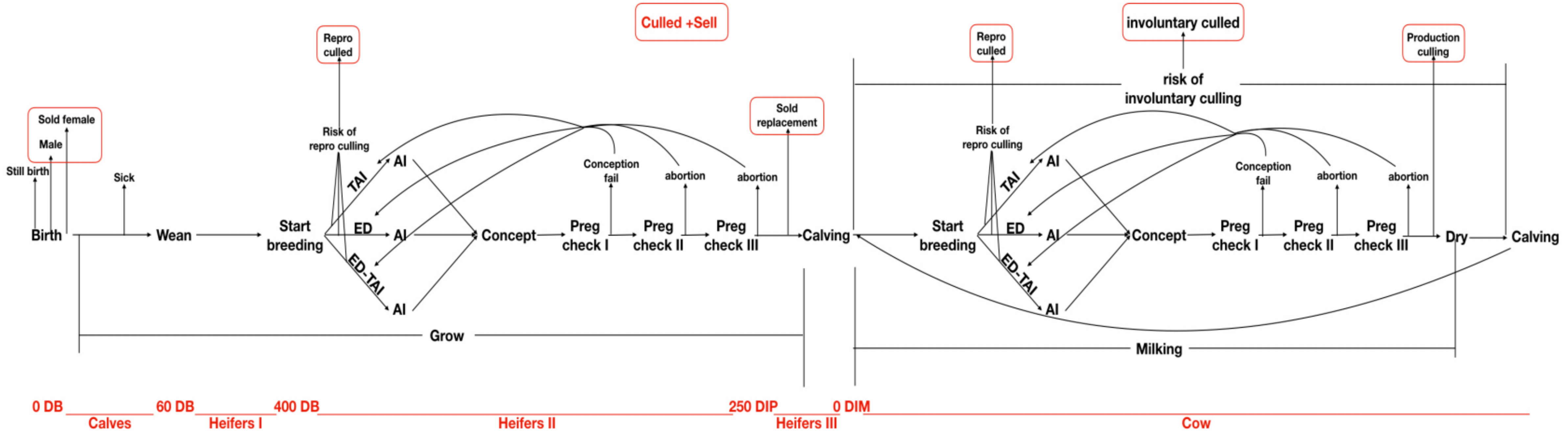
Calves	Heifers I	Heifers II	Heifers III	Cow	Culled



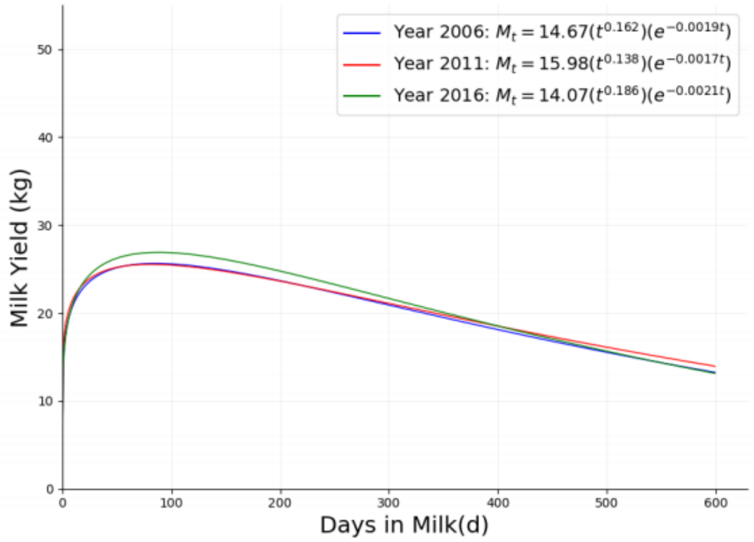
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell

- Culled
  - Maintenance
  - Sold

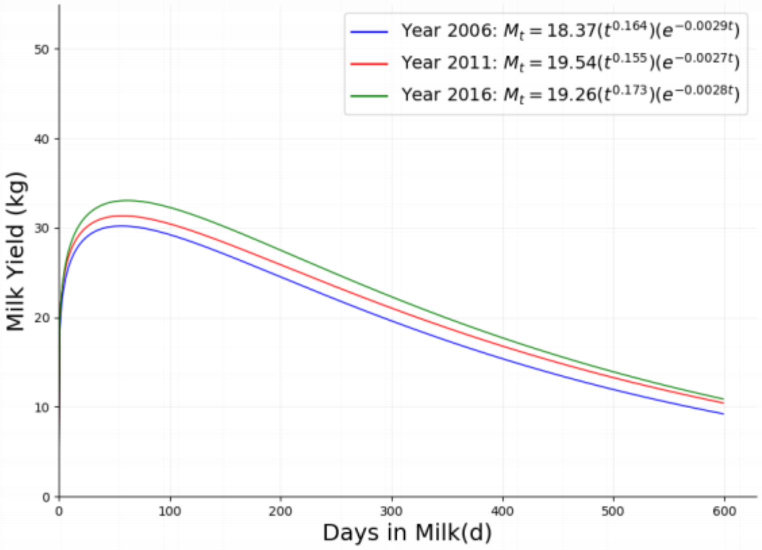
Individual animal life story



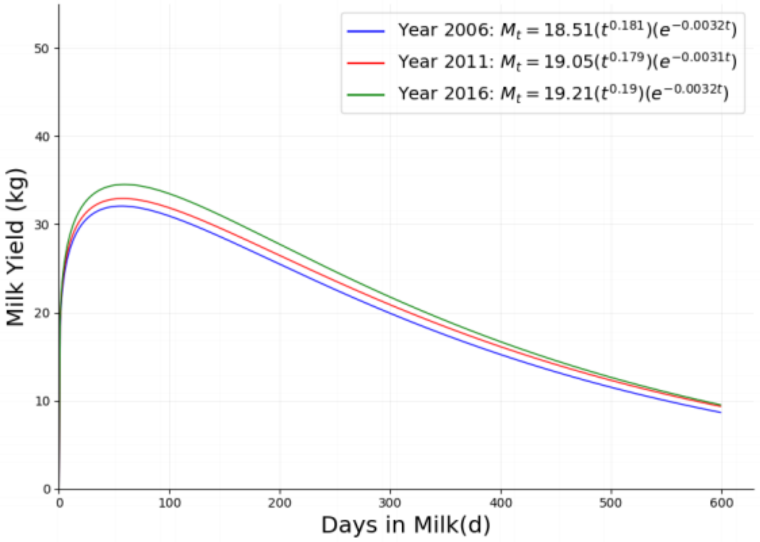
Curves across years



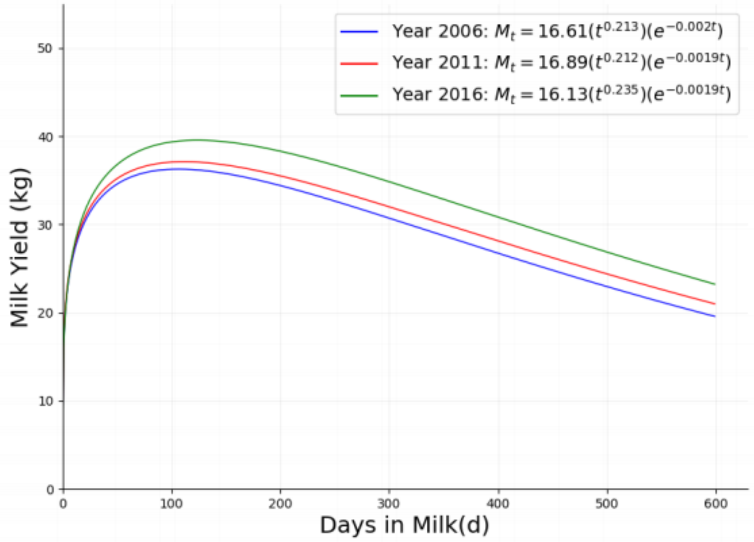
Jersey Lactation 1



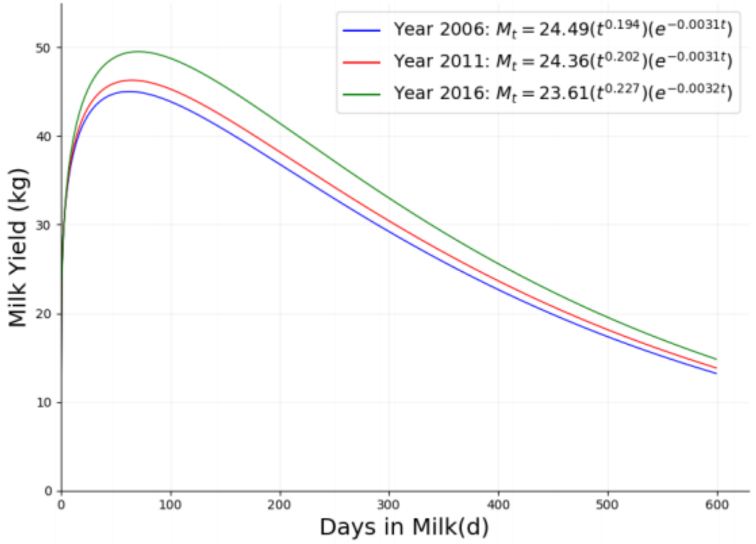
Jersey Lactation 2



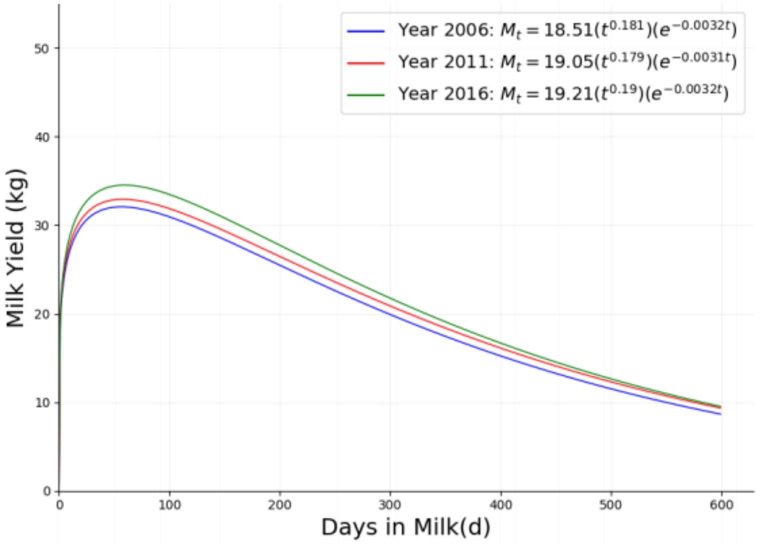
Jersey Lactation >2



Holstein Lactation 1

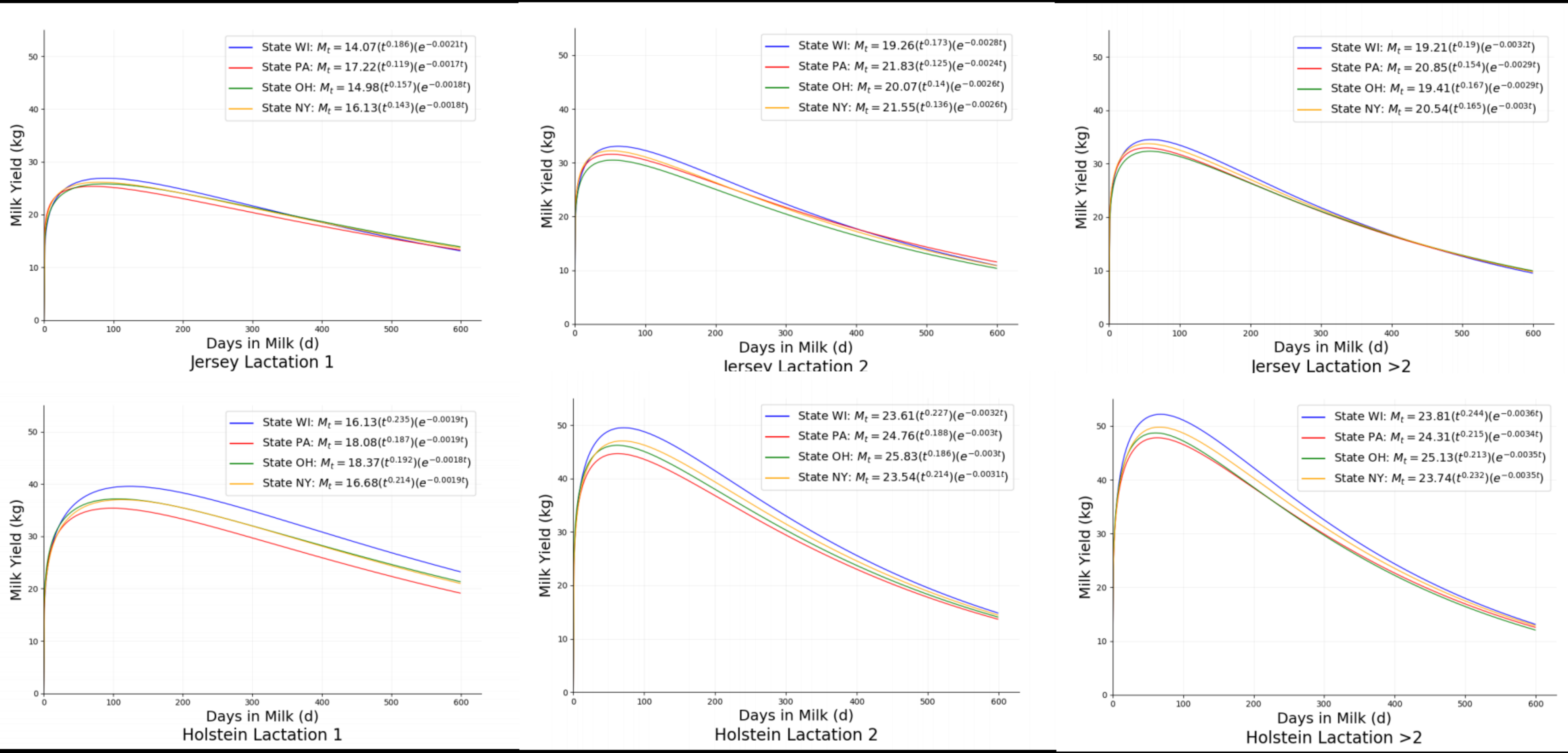


Holstein Lactation 2



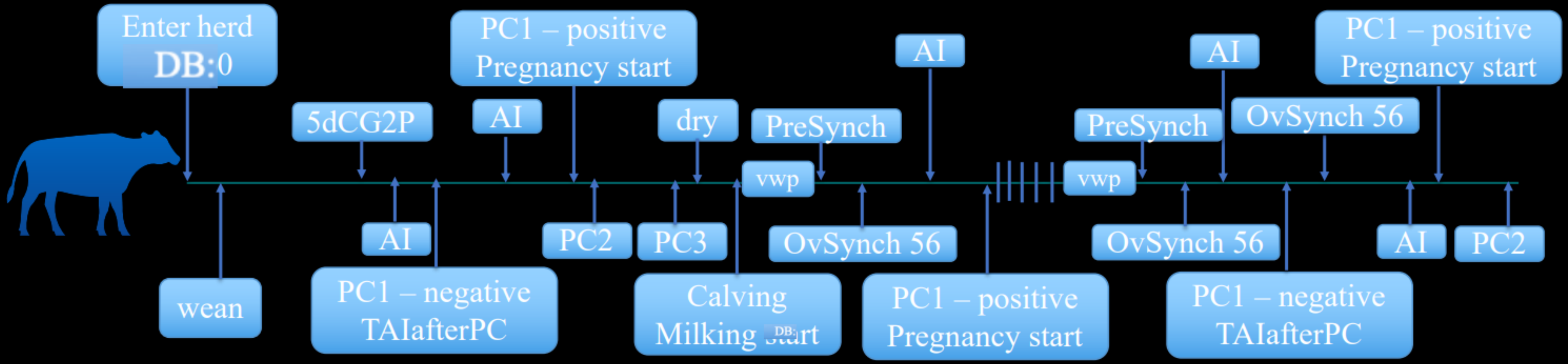
Jersey Lactation >2

Curves across states

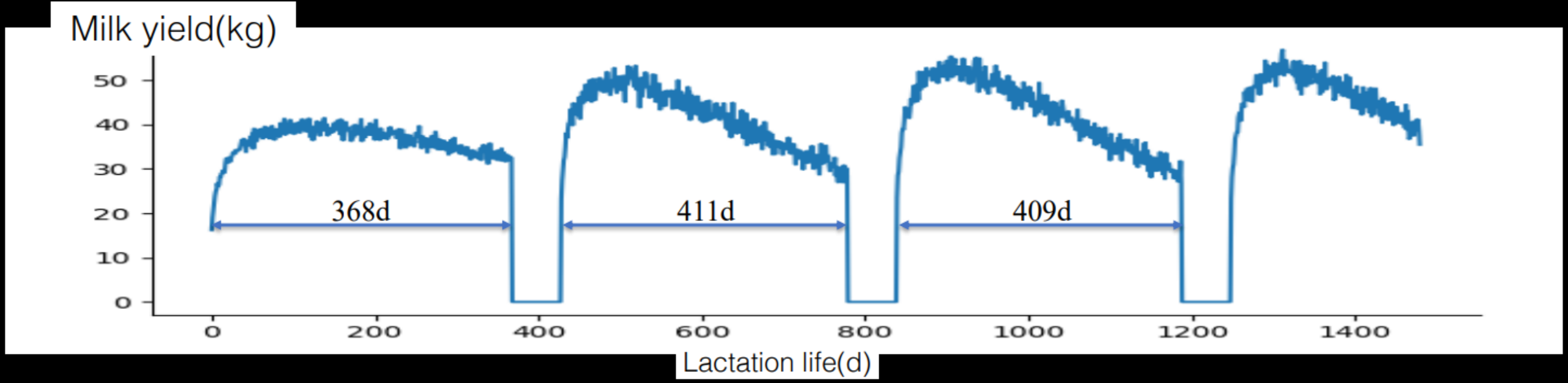


Output sample - animal

1000 targeted herd size, 3000days, 1 individual:

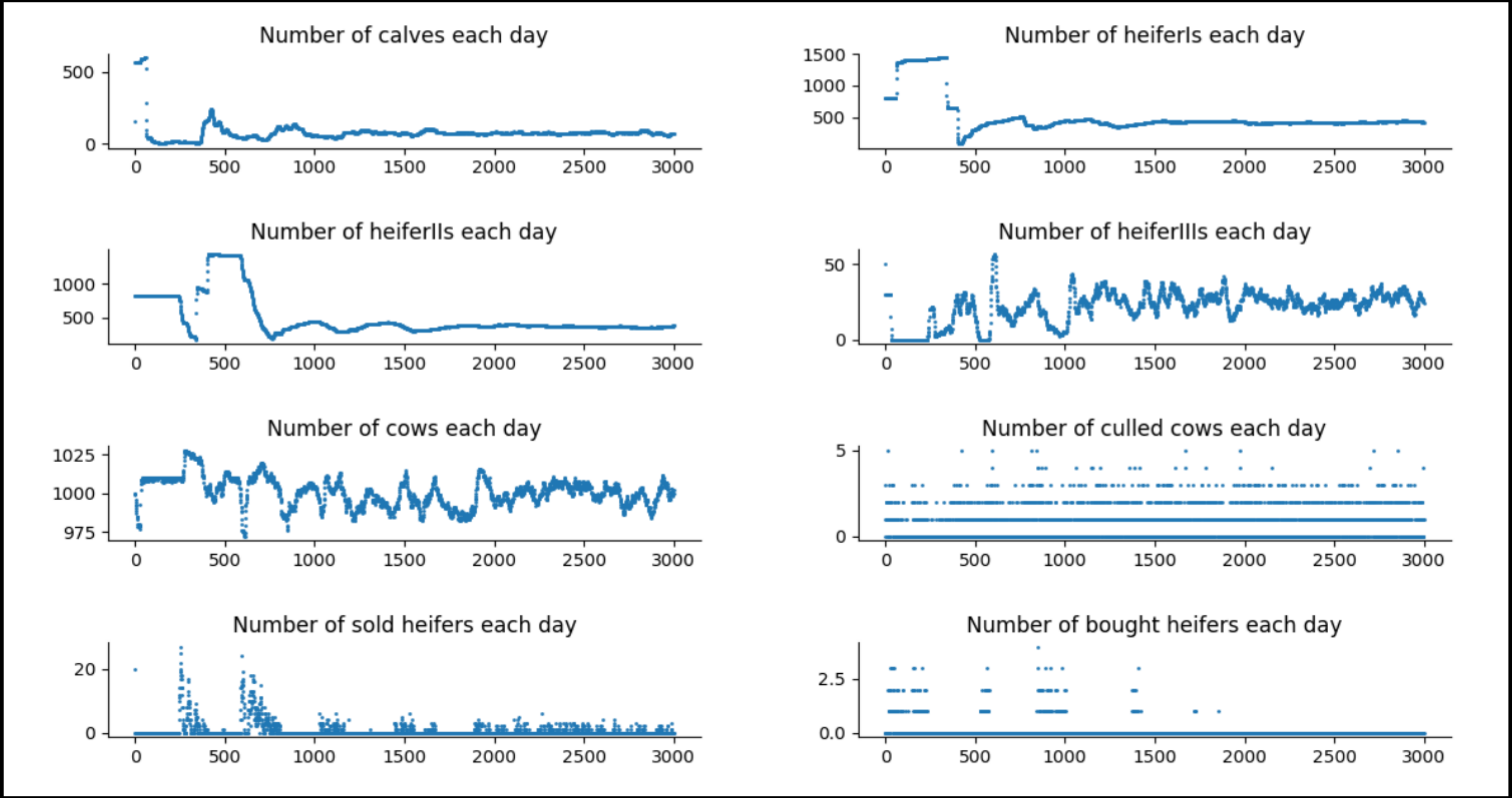


Days Born: 2213; Body Weight: 748.90kg; Repro program: TAI, 5dCG2P+PreSynch+OvSynch56+TAIafterPC
Parity: 4; Curve: Wood's; Days in milk: 232d; Milk produced: 35.44kg; Days in preg: 137d; Gestation Length: 265d.



Output sample - herd

1000 targeted herd size, 3000days, overall:



RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓

Two directions of the model

Undefined diet

Input:
- Animal state
- Feed (On farm)
- Feed (Purchased)

Output:
- Nutrient requirement
- Feed intake
- Feed formula
- Manure production

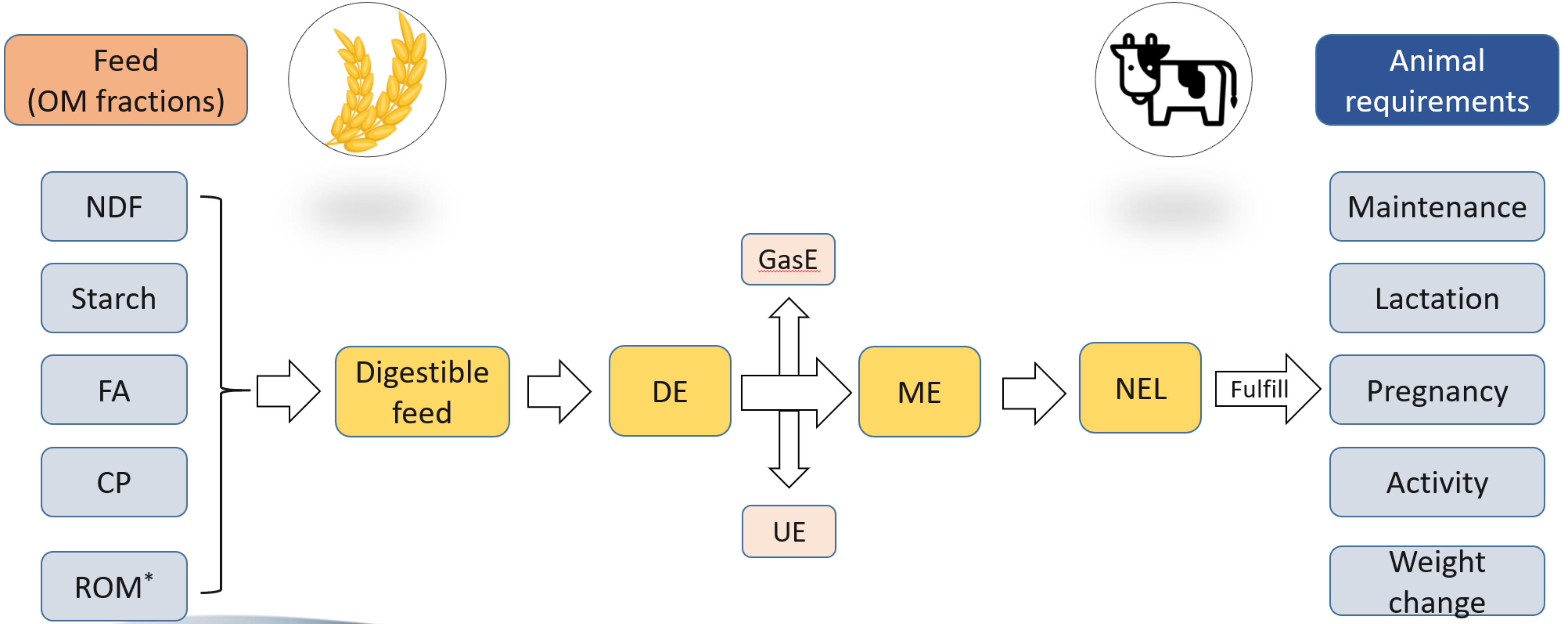
Defined diet

Input:
- Diet
- Animal state

Output:
- Growth
- Milk production
- Manure production

UCDAVIS

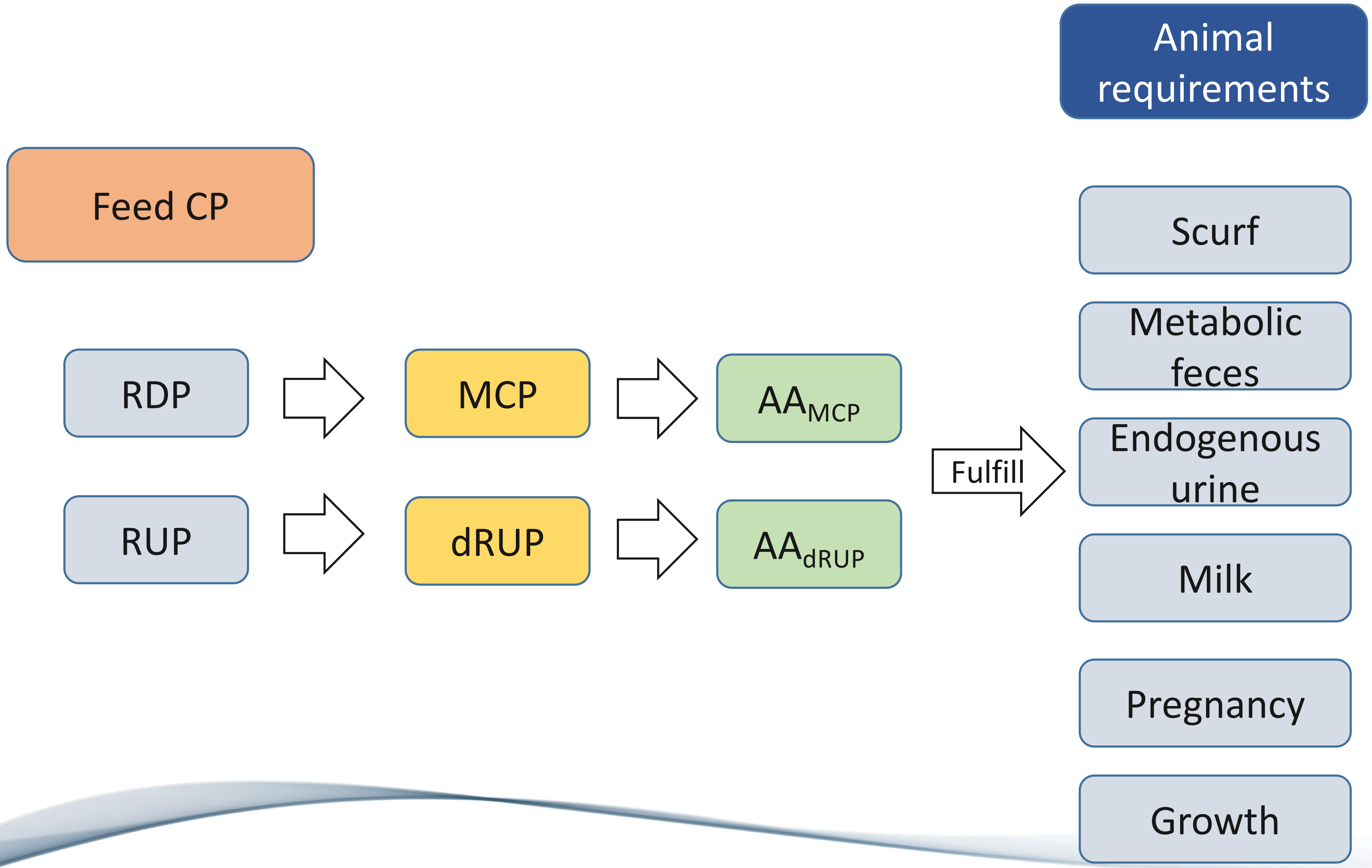
Energy



*** Residue organic matter: ROM = 100 – Ash – NDF – Starch – FA / Fat Factor – CP**

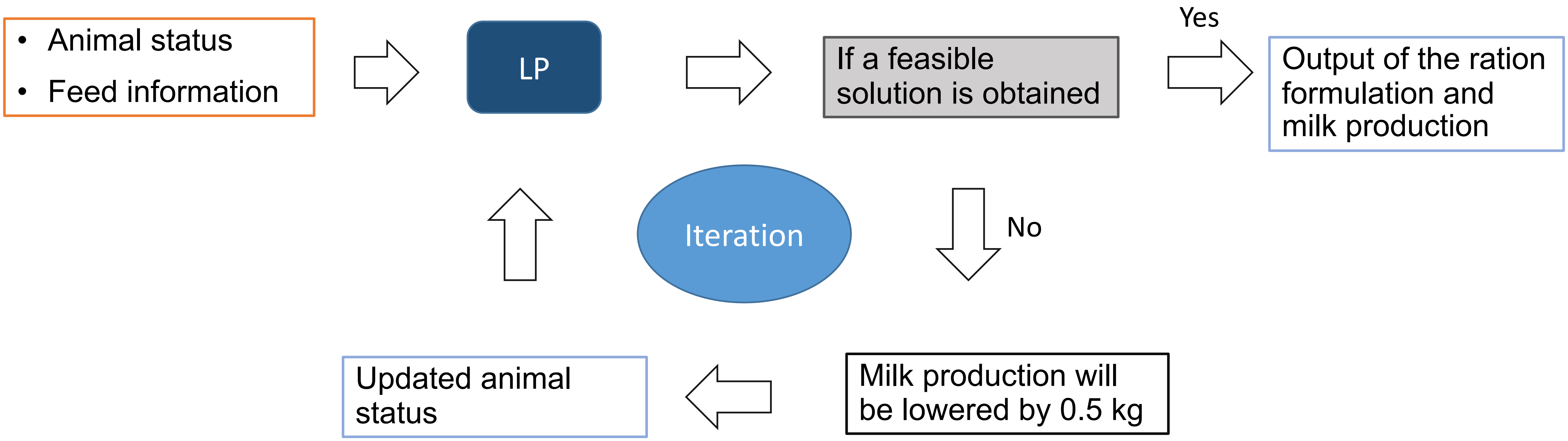
UCDAVIS

Protein



- Amino acids (AA) requirements are used instead of protein requirement
- 9 essential AA requirements are specified: His, Ile, Leu, Lys, Met, Phe, Thr, Trp and Val, with each having 6 components
- The AA profiles of MCP, RUP and the 6 components are also specified by NRC

LP flowchart



UCDAVIS

LP simulation

Animal information:

- Body weight = 600 kg
- Days in milk = 100
- Milk production = 35 kg
- Milk protein = 3.2%
- Milk fat = 3.5%
- Milk lactose = 4.85%

Feed compositions (% of DM) and prices ($/kg of DM)

Feed	DM	CP	FA	NDF	ADF	Starch	Price
Alfalfa hay	90.75	19.00	1.61	42.85	33.88	1.83	0.23
Beet pulp	92.30	9.92	0.63	46.85	28.25	0.64	0.23
Corn gluten	89.16	23.19	3.38	35.68	11.52	15.51	0.19
Corn silage	31.27	7.91	2.32	42.59	25.50	30.18	0.07
DDGS	91.07	38.99	6.56	37.60	17.71	6.20	0.16

UCDAVIS

LP simulation

Objective

$Cost_{min}$

Constraints

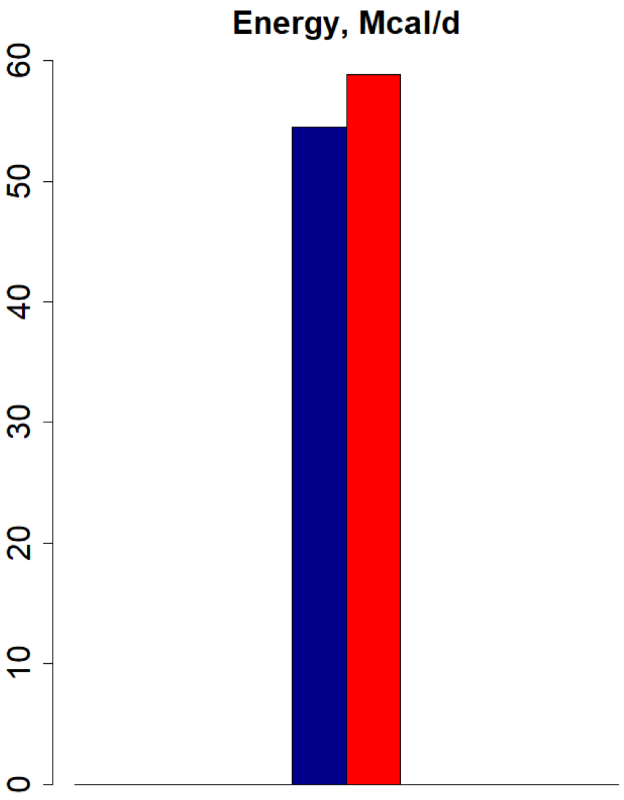
- ME
- Forage NDF
- 9 EAA
- Fat < 7%
- peNDF
- Forage < 70%
- Ca
- DMI
- P

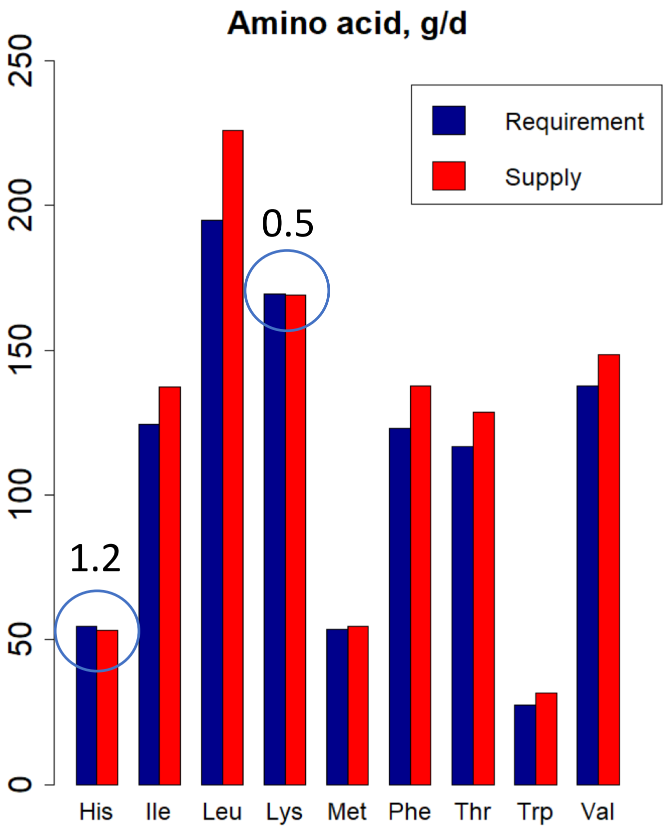
⇨

- $Cost_{min}$ = $3.93/cow
- Alfalfa hay = 8.91 kg
- Beet pulp = 2.45 kg
- Corn gluten = 0
- Corn silage = 7.9 kg
- DDGS = 4.75 kg
- Total = 24.01 kg

UCDAVIS

Ration evaluation





Nutrient compositions of the diet

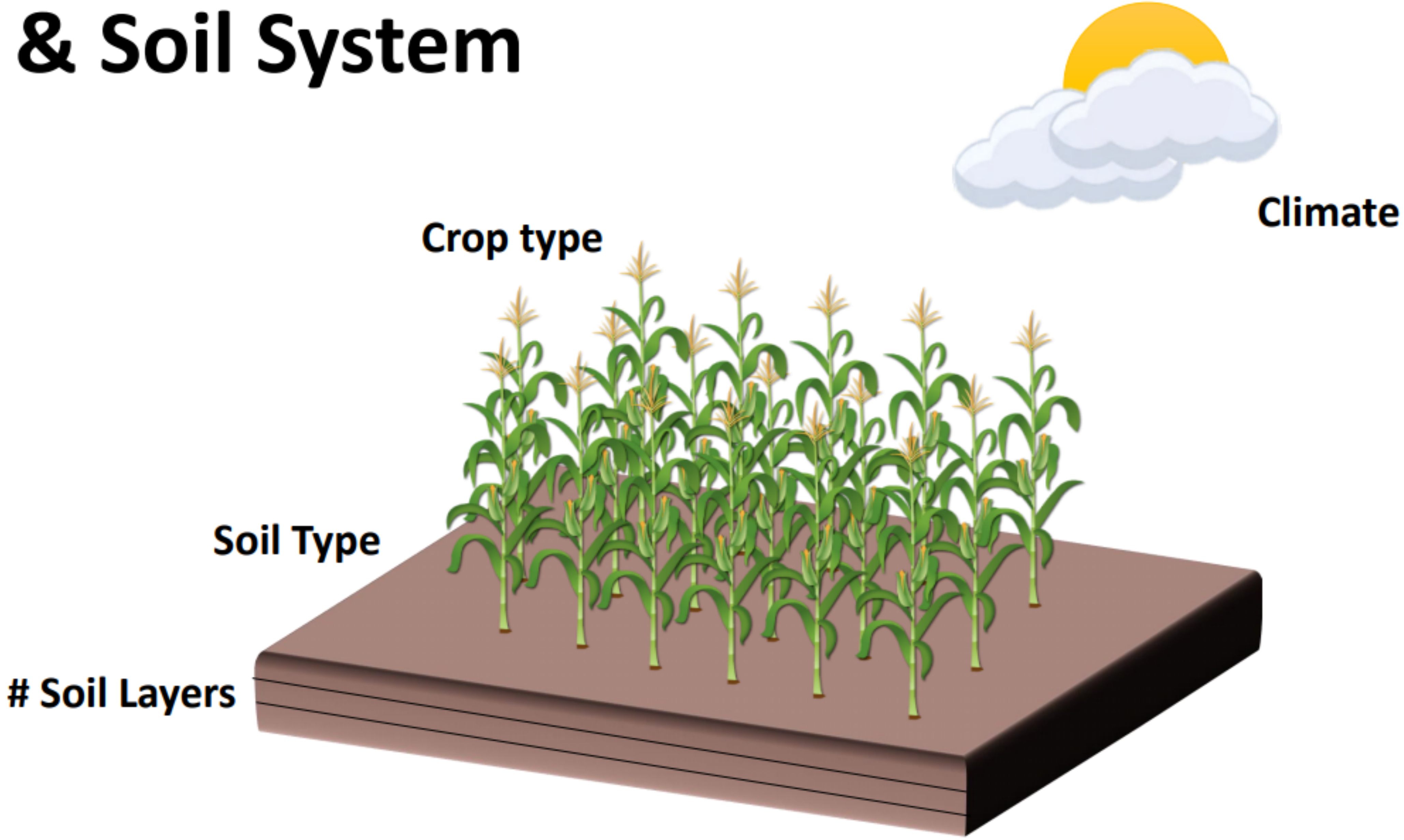
Nutrients	% of DM
CP	18.38
FA	2.72
NDF	42.13
Ca	0.73
P	0.31
Starch	11.90
Forage	70

RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓

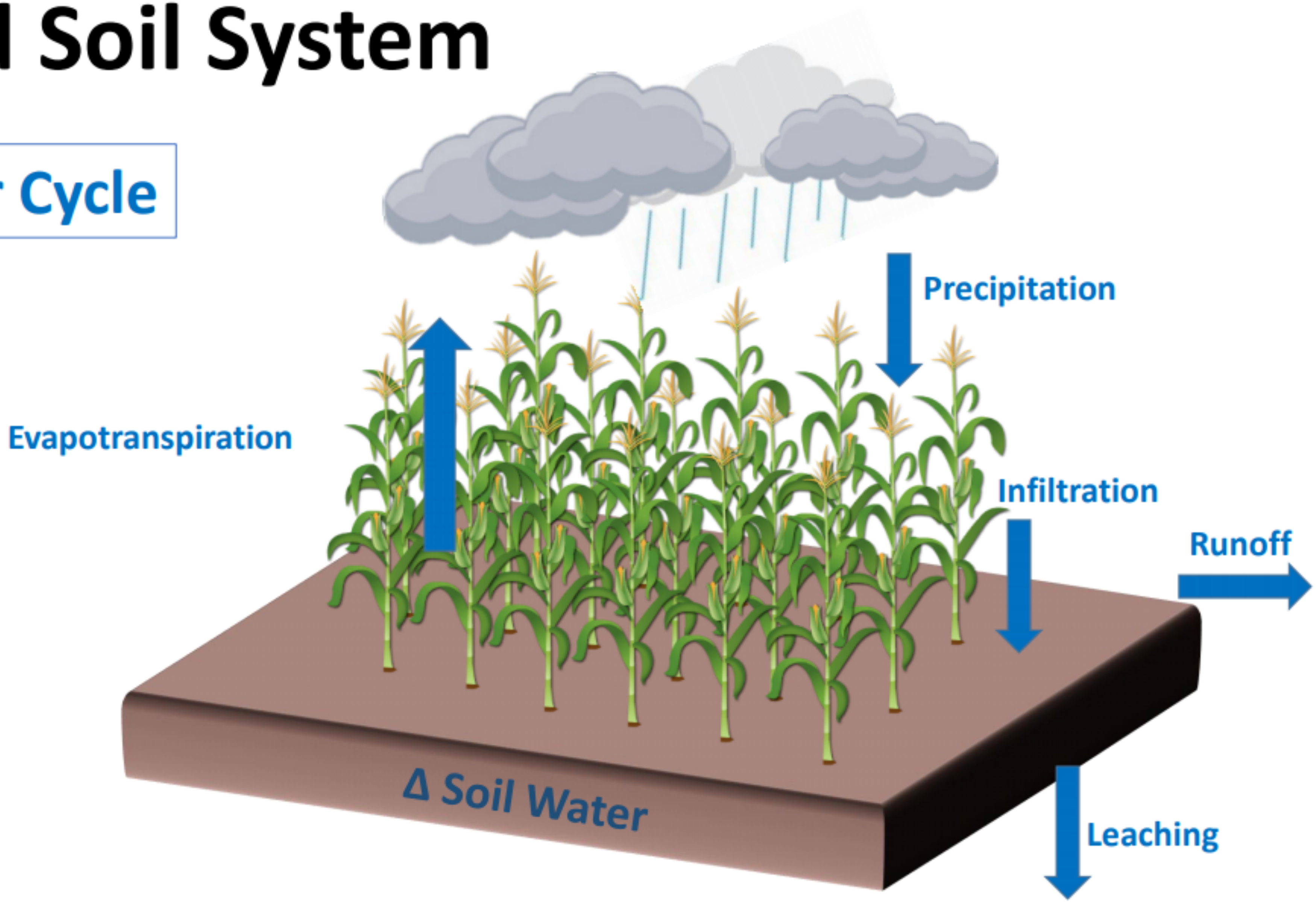
- Crop and Soil Module
  - Water Cycle ✓

Crop & Soil System

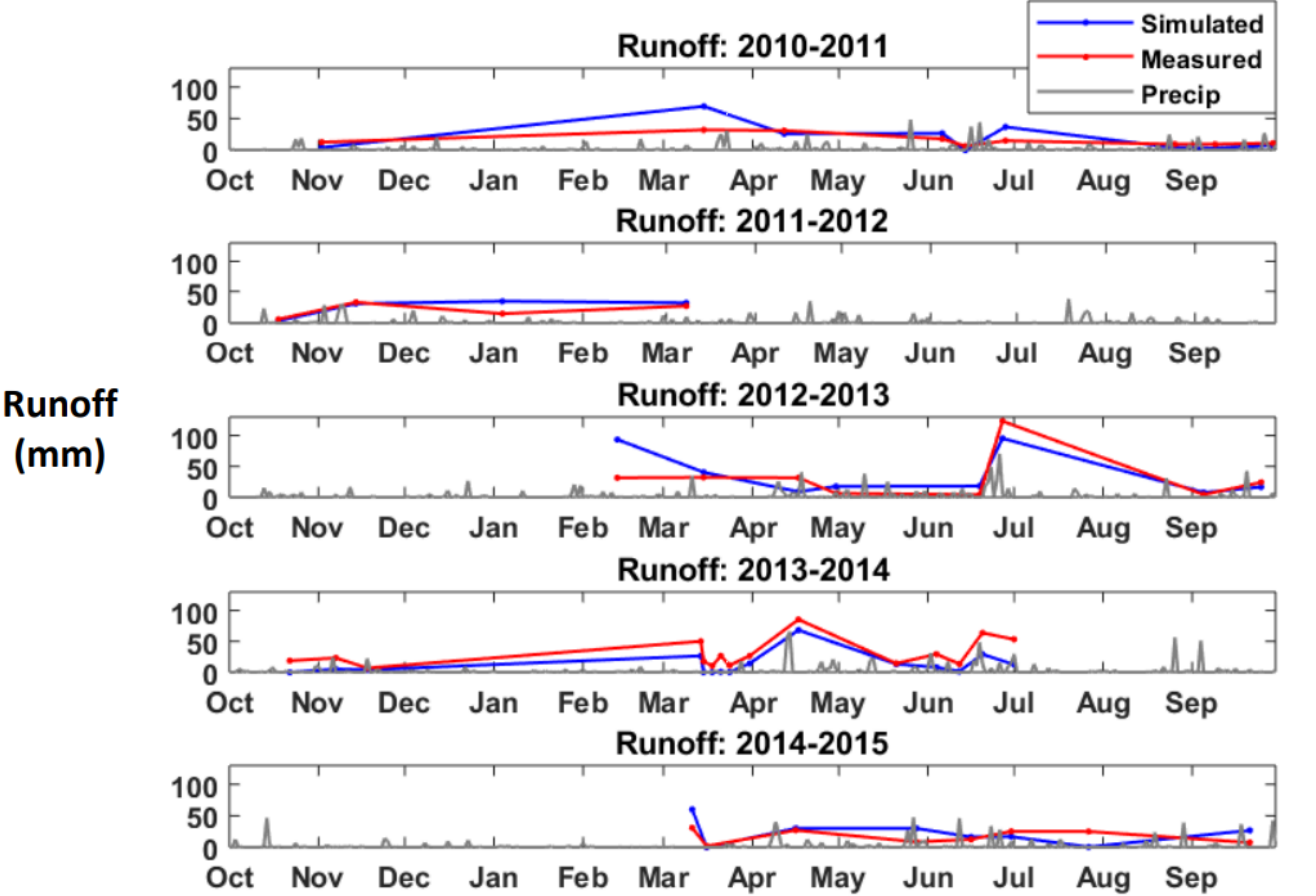


Crop and Soil System

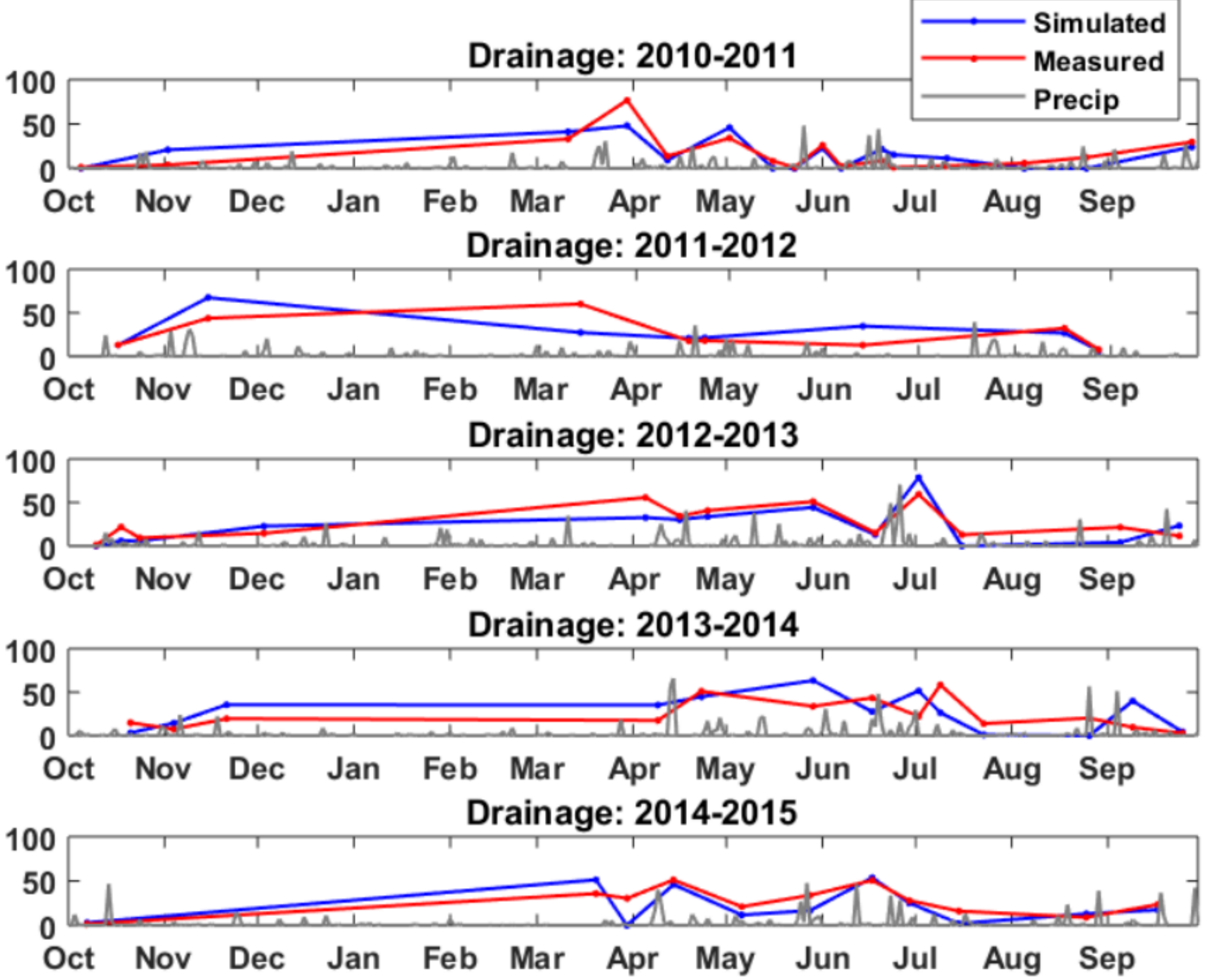
Water Cycle



Runoff Comparison Event-Scale



Drainage Comparison Event-Scale

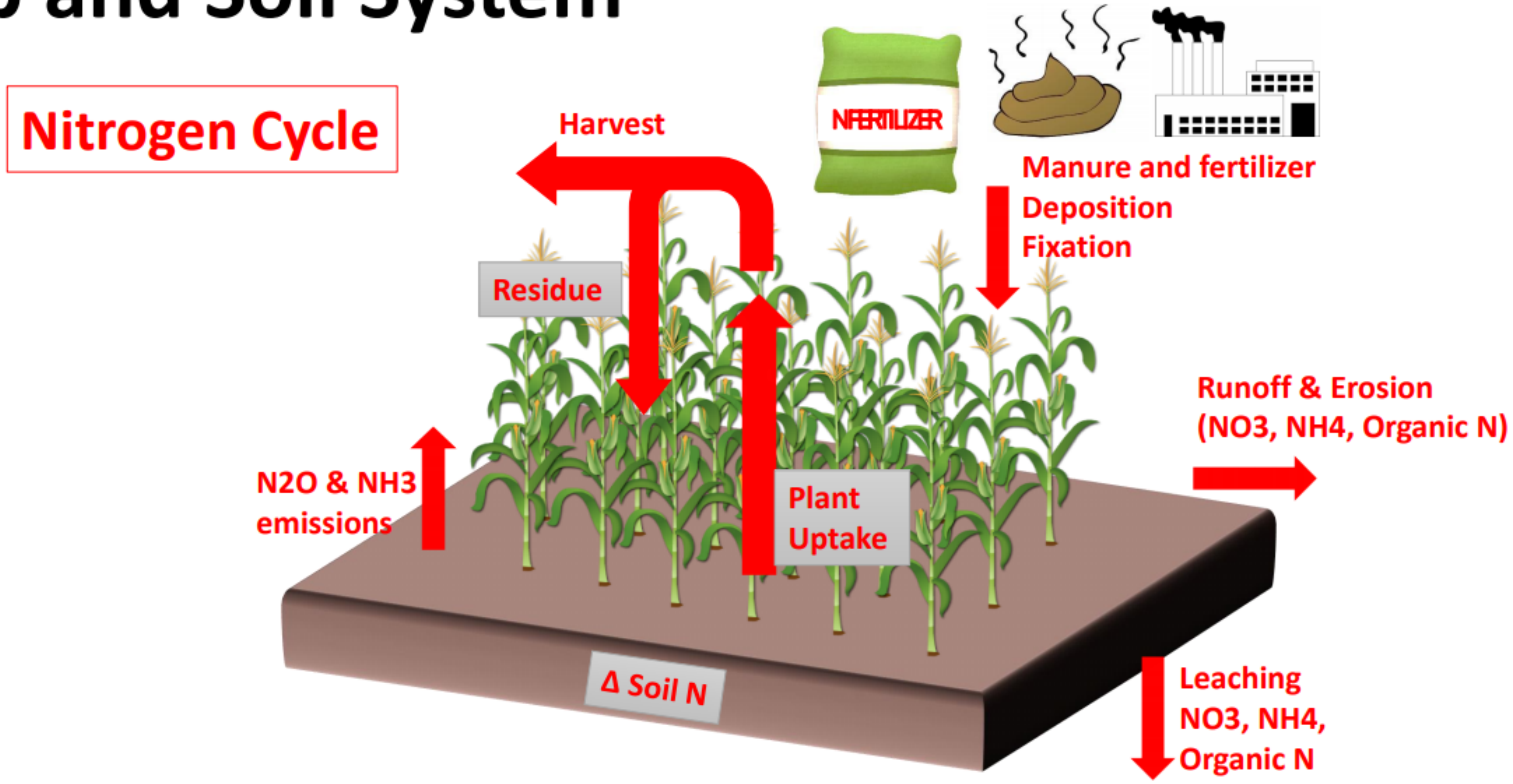


RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓

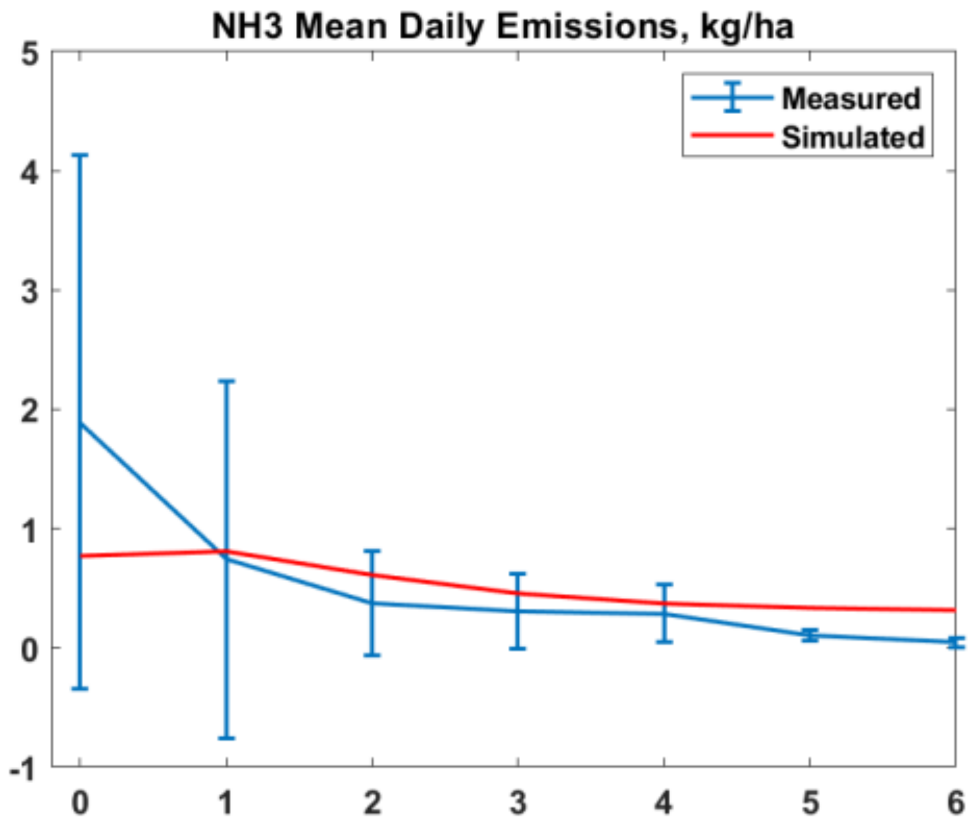
- Crop and Soil Module
  - Water Cycle ✓
  - Nitrogen Cycle ✓

Crop and Soil System



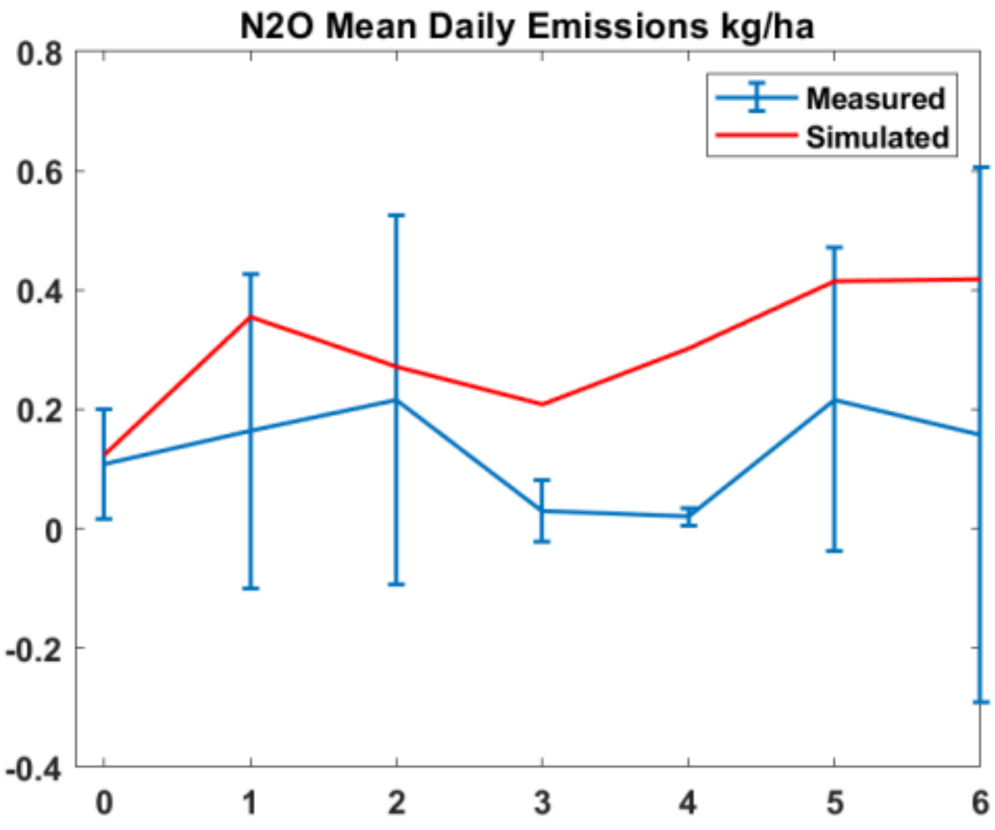
Gas N

NH_3



Days after heifers leave

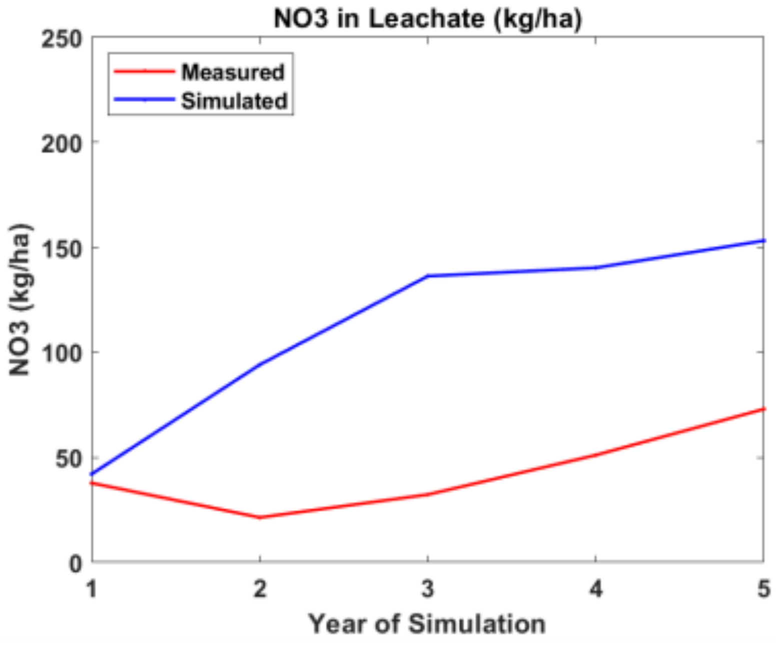
N_2O



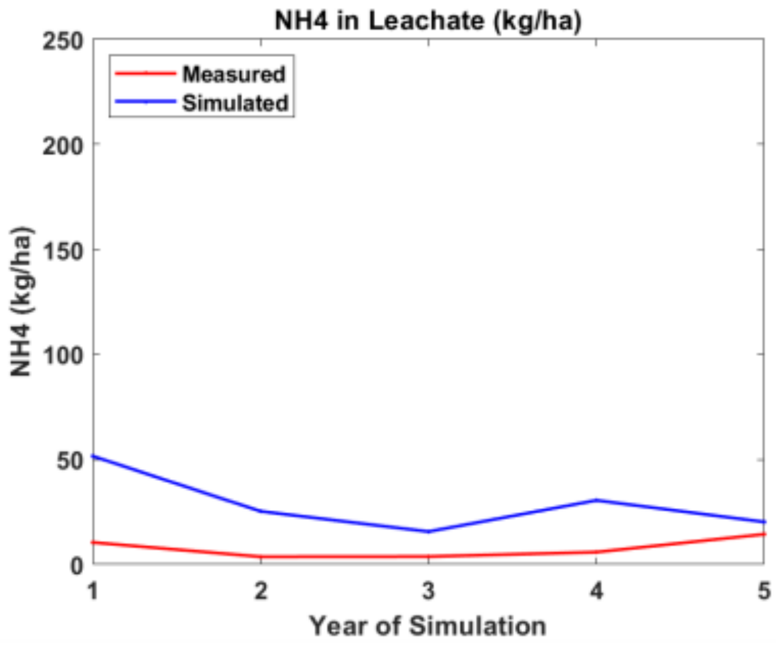
Days after heifers leave

Leachate N

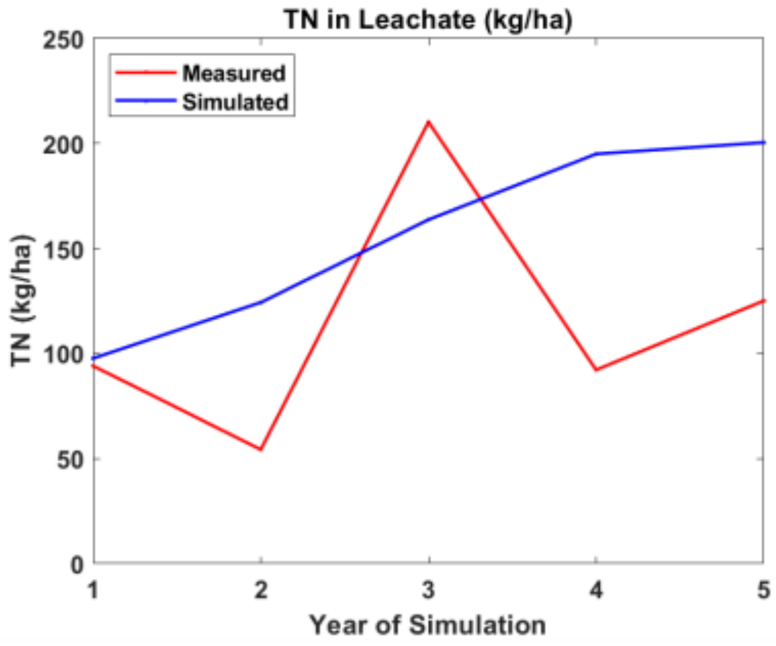
NO_3



NH_4

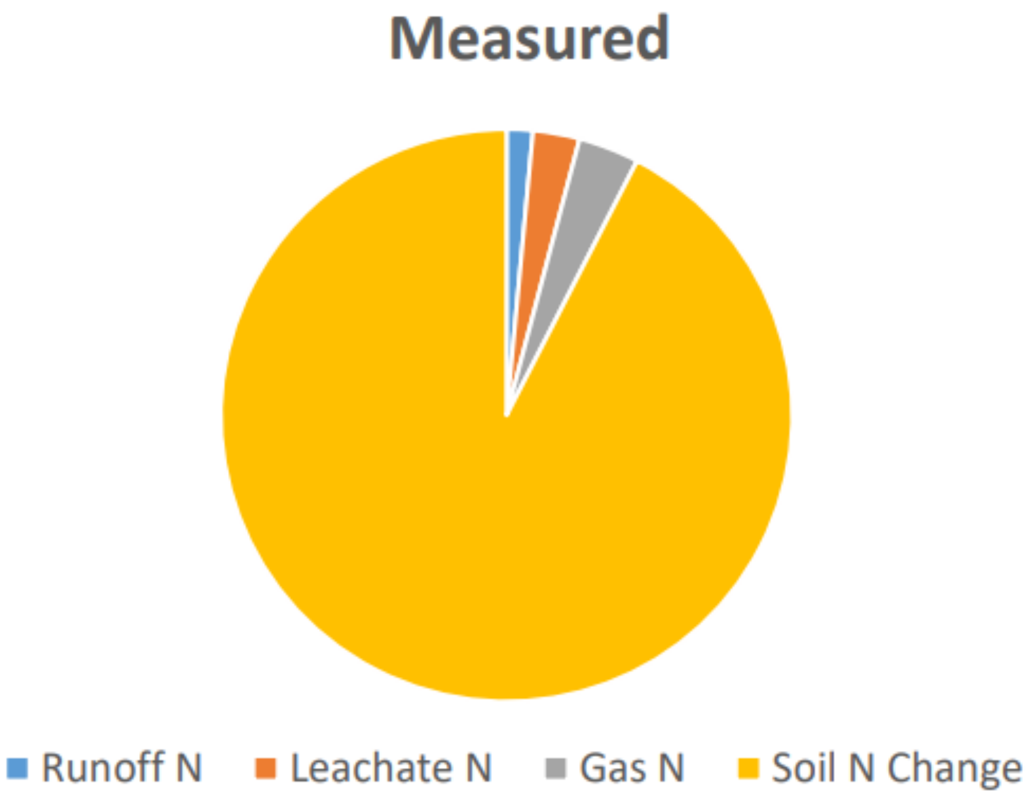


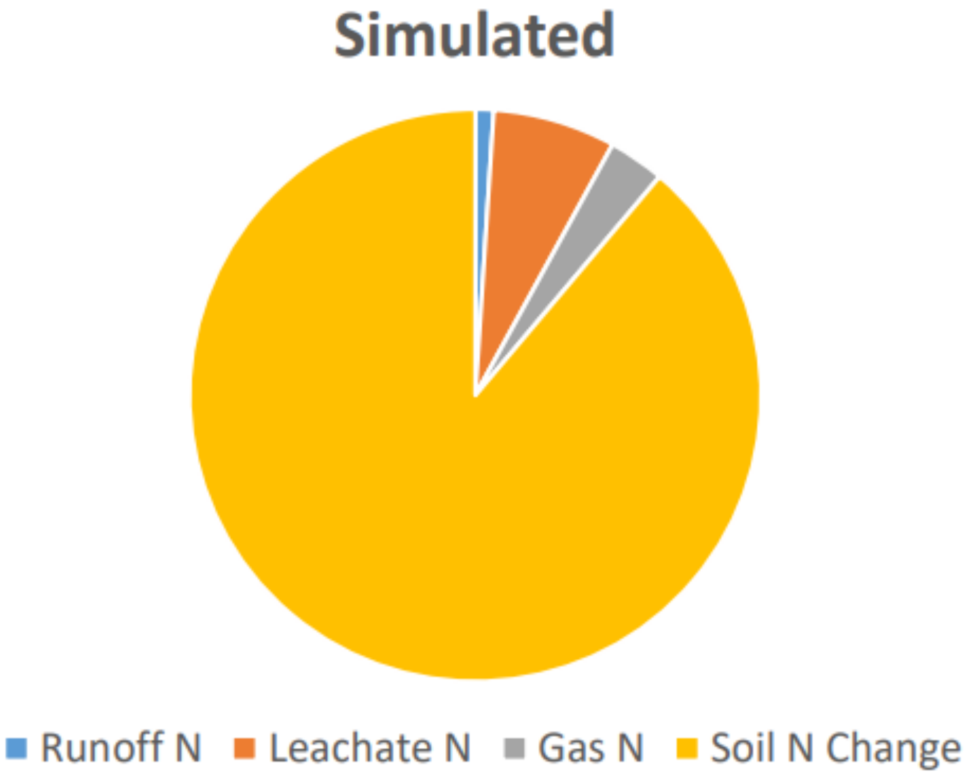
Total N



Year

Total N Budget

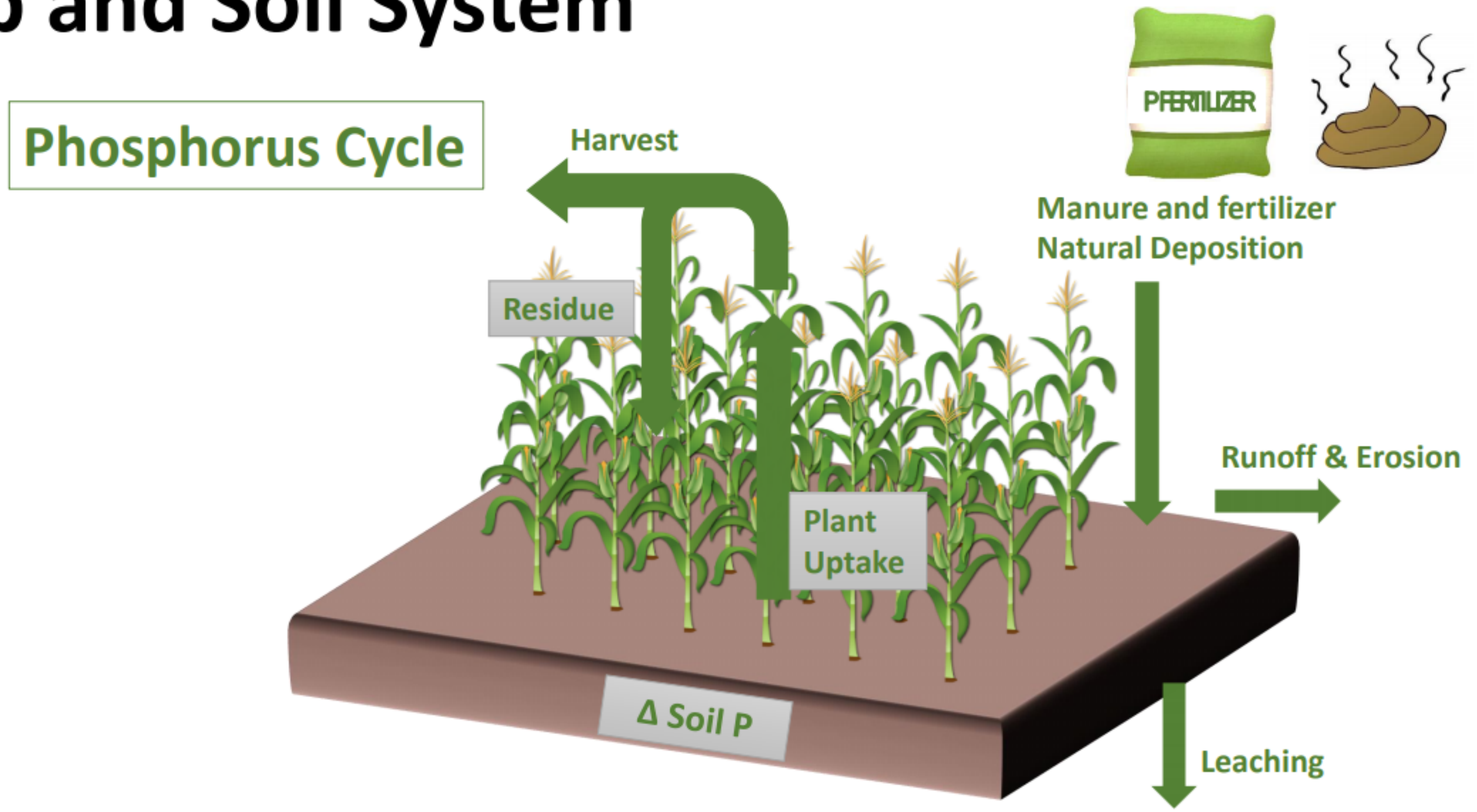




RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓
- Crop and Soil Module
  - Water Cycle ✓
  - Nitrogen Cycle ✓
  - Phosphorus Cycle ✓

Crop and Soil System



Phosphorus

SurPhos
Surface Phosphorus Runoff Model

(Dissolved P)

Modified Universal Soil Loss Equation

(Sediment P)

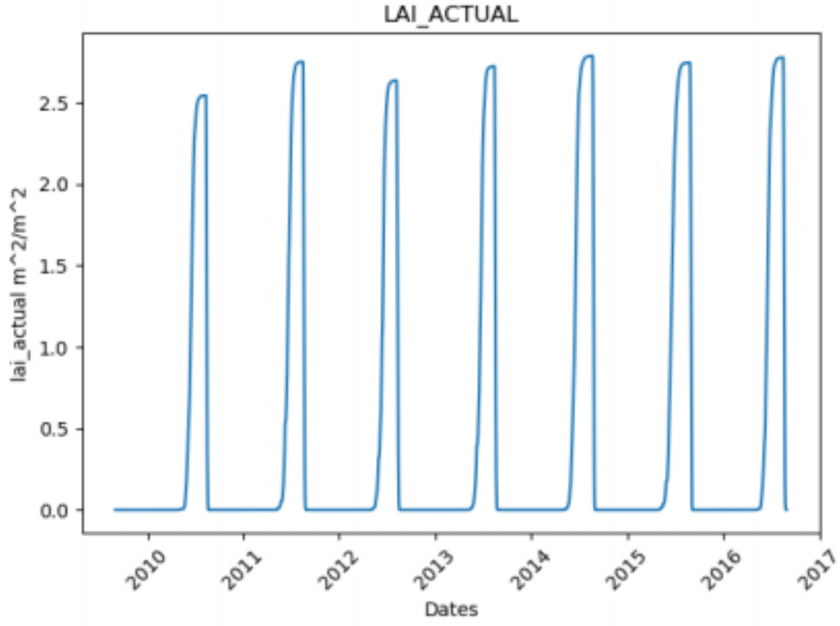
RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓

- Crop and Soil Module
  - Water Cycle ✓
  - Nitrogen Cycle ✓
  - Phosphorus Cycle ✓ (almost)
  - Crop Production ✓

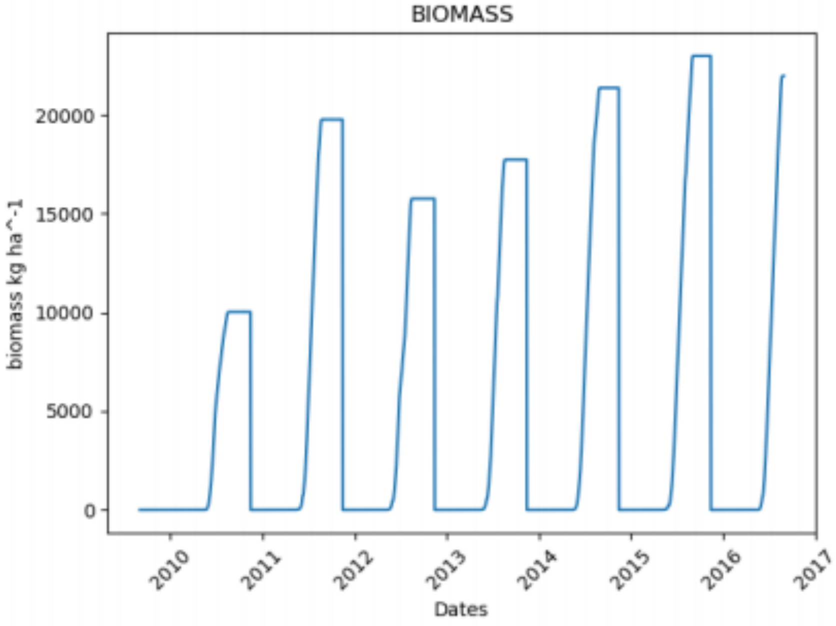
Corn

Leaf Area Index



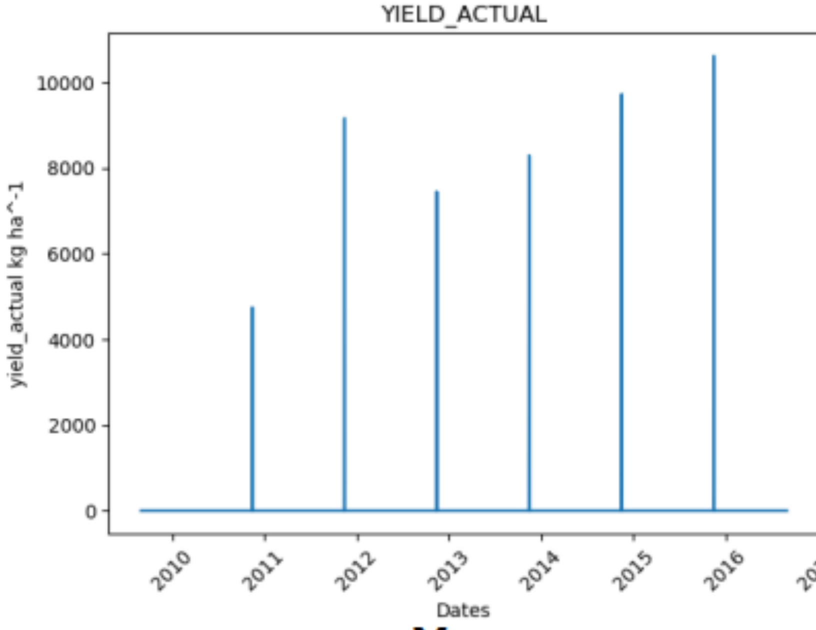
Year

Biomass ($kg\ ha^{-1}$)



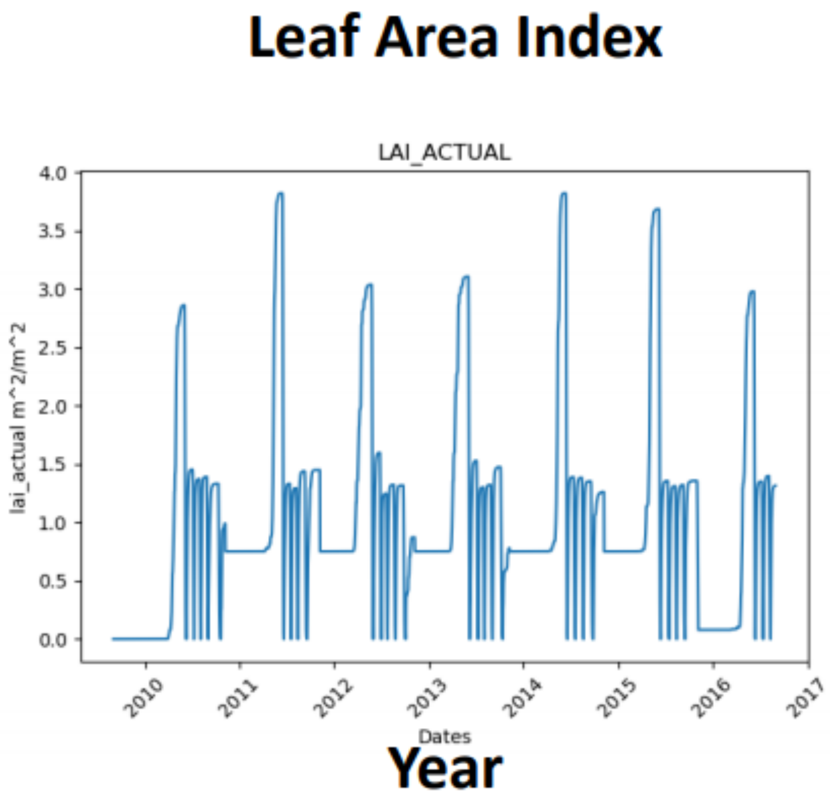
Year

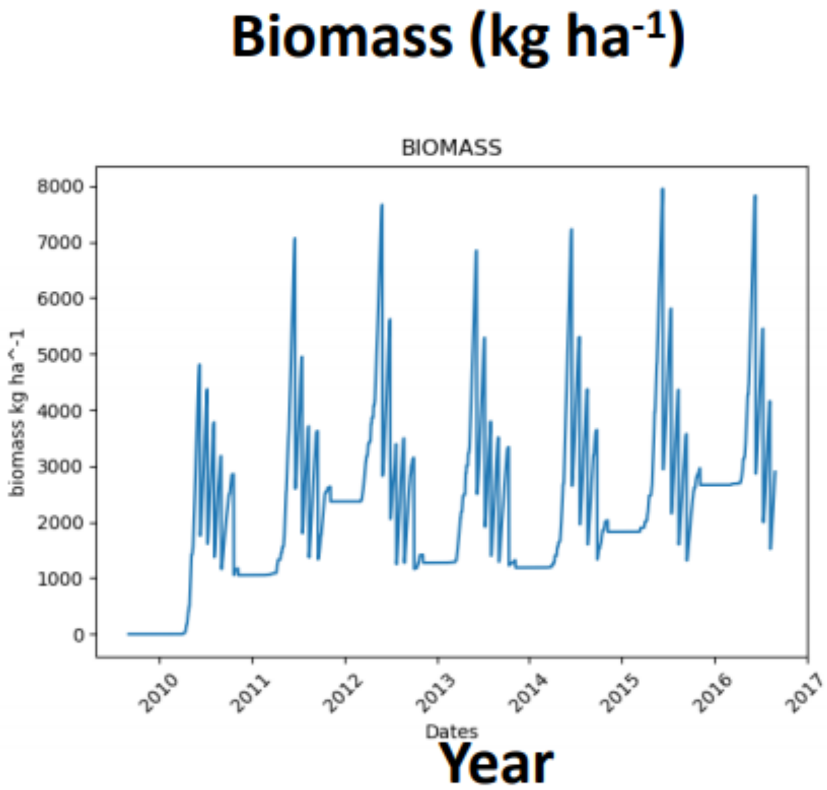
Yield ($kg\ ha^{-1}$)

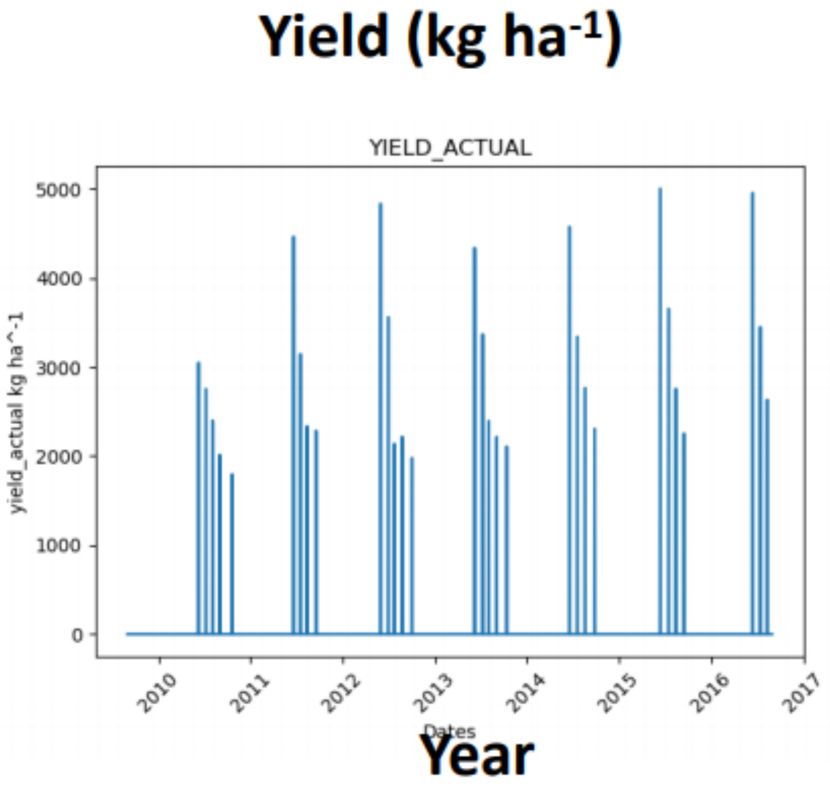


Year

Alfalfa

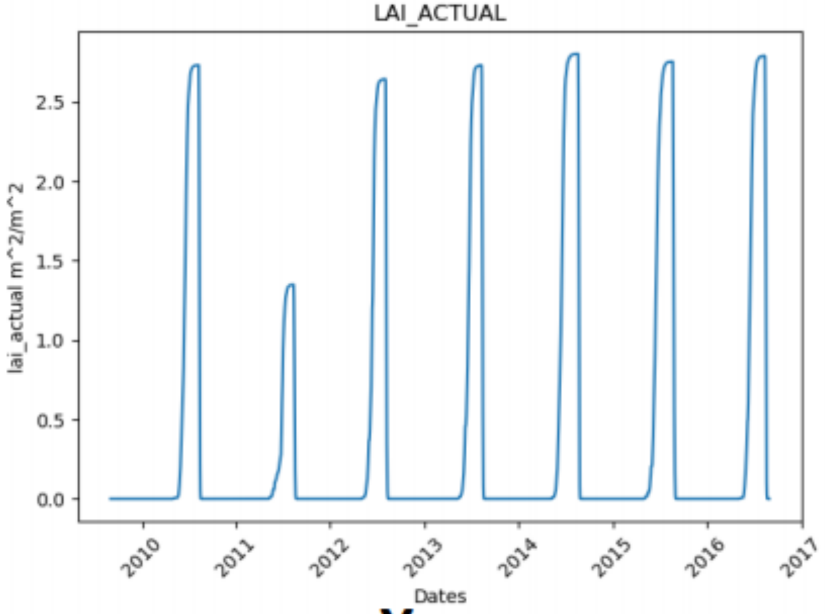

Leaf Area Index
LAI_ACTUAL
lai_actual m^2/m^2
Dates
Year


Biomass (kg ha-1)
BIOMASS
biomass kg ha^-1
Dates
Year


Yield (kg ha-1)
YIELD_ACTUAL
yield_actual kg ha^-1
Dates
Year

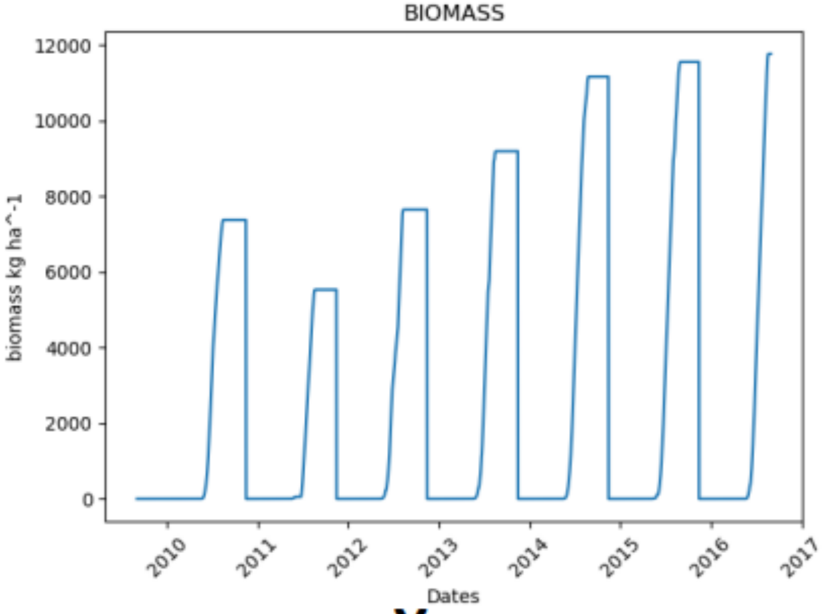
Soybean

Leaf Area Index



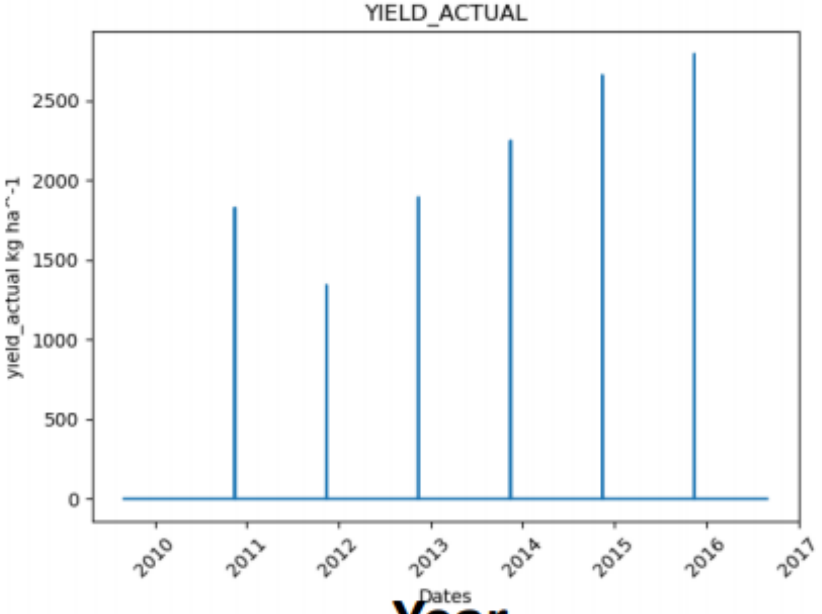
Year

Biomass (kg ha^{-1})



Year

Yield (kg ha^{-1})



Year

RuFaS Progress

- Animal Module
  - Animal life, health, and reproduction events ✓
  - Herd dynamics ✓
  - Linear Least Cost Ration Optimization ✓

- Crop and Soil Module
  - Water Cycle ✓
  - Nitrogen Cycle ✓
  - Phosphorus Cycle ✓ (almost)
  - Crop Production ✓

RuFaS Progress

- Manure Module
  - Simulates NH_3, N_2O, N_2, CO_2, and CH_4 emissions from manure under generic storage conditions ✓
  - Tracks C, N, and DM content of Manure from excretion to application ✓

RuFaS Progress

- Manure Module
  - Simulates NH_3, N_2O, N_2, CO_2, and CH_4 emissions from manure under generic storage conditions ✓
  - Tracks C, N, and DM content of Manure from excretion to application ✓
- Feed Storage Module
  - Predicts nutrient and DM transformations during ensiling ✓
  - Estimates VOC and leachate loss during ensiling ✓

RuFaS Progress – Short-Term Goals

SYSTEMS

- Connect 4 biophysical modules
- Set up shell for pasture module
- Establish model database
- Standardize and refine model output and graphical analysis formats

ANIMAL MODULE

- Preserve mass balance at the animal and barn level
- Formalize feedback between life cycle and ration formulation
- Ration formulation testing and finalization
- Expand feed library
- Expand animal grouping algorithms
- Track time allocation of cows and barn environment (temp and air quality)

RuFaS Progress – Short-Term Goals

CROP AND SOIL MODULE

- Complete Soil P and C modules
- Improve NO_3 leaching functions
- Prioritize and add new crop species
- Acquire new data for testing

MANURE MODULE

- Currently stalled due to lack of personnel

RuFaS Funding

- DMI post-doc function for 1 yr with potential for renewal ($100,000) ✓
  - Received (7/1)
- NIFA- Interdisciplinary Engagement in Animal Systems program ($1,000,000) ✓
  - Submitted (9/5)
- NIFA – Sustainable Agriculture Systems program ($10,000,000; $2,500,000 to Cornell) ✓
  - Submitted (today!)

Other Activities…

MUN Variability and Precision

- **Objectives:**
  1. Determine the accuracy and precision of commercial MUN FTIR analyses
  2. Determine variability in cow MUN between days and across lactation
- **Methods:**
  - Collect cow milk samples for 7 consecutive days at 3 timepoints across lactation
  - Measure MUN with 3 different commercial labs, Barbano FTIR, and Barbano enzymatic assay
- **Expected Outcomes:** Better understanding of ability to use cow MUN for management decisions.

Other Activities…

Feed Variability

- **Objectives:**
  1. Determine the causes and extent of variation in NY farm grown forages
  2. Develop model to optimize management of that variability
- **Methods:**
  1. Survey farm for factors that influence forage quality (soils, varieties, harvest and ensiling methods, feedout methods etc.)
  2. Sample forages at harvest and feedout
  3. Relate extent of variability at feedout to farm management and environmental factors
  4. Develop renewal reward model to predict optimal sampling schedule based on farm management factors
- **Expected Outcomes:** Web or cell-phone application to develop feed nutrient content management plan

Other Activities…

Prediction of Sub-Clinical Mastitis in Milk Robots

- **Objectives:**
  1. Improve accuracy of SCM prediction in automated milking systems (AMS)
  2. Determine if milk from uninfected quarters can safely enter the food chain
- **Methods:**
  1. Collect individual quarter milk samples from pens with AMS 3x/week for 4 months
  2. Assess SCC and culture samples above SCC threshold to determine species present/cause of infection
  3. Use AMS collected parameters (weight, time of milking, milk spectra, conductivity, etc) to predict SCM and mastitis incidence
  4. **Expected Outcomes:** Improved prediction of SCM to identify points of intervention to reverse onset of mastitis.

Thanks for your support!