# Economic Decision Making for Reproduction

2010 Dairy Cattle Reproduction Conference
St. Paul, Minnesota – November 11 – 12, 2010

V. E. Cabrera and J. O. Giordano
University of Wisconsin-Madison

# Introduction

- Direct relationship between reproduction and profitability
- Improving reproductive efficiency should improve profitability
- Economic evaluation of reproductive programs is a frequent question from producers, consultants, and veterinarians
- Answer depends on particular dairy farm and market conditions

# Introduction

- Reproductive economic evaluation is difficult
- Number of factors interacting dynamically
  - Lactation length and magnitude
  - Culling and mortality risk
  - Cost of reproductive program
  - Number of newborn

Very Important Economic Factors

# Introduction

- Several methods could be used to assess the value of reproductive programs
  - Partial cash flow (Meadows et al., 2005)
  - Marginal net revenue (Groenendaal et al., 2004)
  - Markov-chains (none)
  - Dynamic programming (De Vries, 2006)

**Markov-chains could be a solid framework**

**Methodology should be: 1) Inclusive and 2) Practical**

- **Daily** Markov-chains framework
  - Can handle very detailed information
    - Reproductive programs
      - TAI and HD
    - Herd population dynamics
      - Transition matrices
    - Economics
      - Prices and costs
  - Can assess the interactions of all factors in a dynamic way

# How could we use this model?

- Assess the reproductive and economic performance of reproductive programs
- Compare programs using HD, TAI, or both
- Explore the optimal length of the VWP
- Evaluate the interaction between market conditions and reproductive efficiency
- Estimate the impact of adopting new technologies (e.g., ultrasound)

# Objectives

1. Describe the development of a daily dairy herd Markov-chain model

Methodological objective

2. Perform an experiment to evaluate 3 reproductive programs using the developed model

Practical Application objective

Materials and Methods

- A herd follows <u>daily</u> probabilistic Markov-chain of events

| Month in Milk | Month in Pregnancy | | | | | | | | | | | | Revenues & Costs ($) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Cull Cows | | IOFC | Cull | Repro | Calves |
| | Lactation 1 | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | 0.14 | | 453.19 | -66.23 | 0.00 | 0.00 |
| 2 | | | | | | | | | | | 0.09 | | 594.15 | -43.03 | 91.01 | 0.00 |
| 3 | 2 | .56 | | | | | | | | | 0.05 | | 616.65 | -26.48 | 72.57 | 0.00 |
| 4 | 2.0 | 5 | 0.56 | | | | | | | | 0.05 | | 603.35 | -22.81 | 58.31 | 0.00 |
| 5 | 1.67 | | 0.45 | 0.54 | | | | | | | 0.04 | | 577.58 | -19.77 | 47.40 | 0.00 |
| 6 | 1.37 | 0.30 | 0.36 | 0.43 | 0.52 | | | | | | 0.04 | | 548.93 | -18.17 | 38.91 | 0.00 |
| 7 | 1.13 | 0.24 | 0.29 | 0.35 | 0.42 | 0.51 | | | | | 0.04 | | 515.73 | -17.44 | 32.13 | 0.00 |
| 8 | 0.94 | 0.20 | 0.24 | 0.28 | 0.34 | 0.41 | 0.50 | | | | 0.03 | | 480.32 | -16.79 | 26.54 | 0.00 |
| 9 | 0.77 | 0.16 | 0.20 | 0.23 | 0.27 | 0.33 | 0.41 | 0.50 | | | 0.03 | | 444.20 | -16.82 | 21.92 | 0.00 |
| 10 | 0.64 | 0.14 | 0.16 | 0.19 | | | | 0.40 | 0.49 | | 0.04 | | 305.35 | -17.70 | 18.07 | 0.00 |
| 11 | 0.52 | 0.11 | 0.13 | 0.16 | | | | 0.32 | 0.40 | 0.49 | 0.04 | | 196.86 | -19.31 | 14.85 | 97.58 |
| 12 | 0.43 | | 0.11 | 0.13 | 0.15 | 0.18 | 0.22 | 0.26 | 0.32 | 0.39 | 0.04 | | 152.38 | -17.76 | 0.00 | 78.41 |
| 13 | 0.42 | | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.21 | 0.26 | 0.3 | 04 | | 117.16 | -17.53 | 0.00 | 62.99 |
| 14 | 0.41 | | | 0.09 | 0.10 | 0.12 | 0.15 | 0.18 | 0.21 | 0.2 | 04 | | 88.57 | -18.74 | 0.00 | 51.22 |
| 15 | 0.38 | | | | 0.08 | 0.10 | 0.12 | 0.15 | 0.18 | 0.2 | 04 | | 65.09 | -19.10 | 0.00 | 42.02 |
| 16 | 0.35 | | | | | 0.08 | 0.10 | 0.12 | 0.14 | 0.1 | 04 | | 46.03 | -18.82 | 0.00 | 34.63 |
| 17 | 0.32 | | | | | | 0.08 | 0.10 | 0.12 | 0.1 | 04 | | 31.13 | -18.83 | 0.00 | 28.57 |
| 18 | 0.29 | | | | | | | 0.08 | 0.10 | 0.12 | 0.04 | | 19.51 | -18.95 | 0.00 | 23.54 |
| 19 | 0.25 | | | | | | | | 0.08 | 0.10 | 0.26 | | 10.50 | -17.49 | 0.00 | 19.33 |
| 20 | 0.00 | | | | | | | | | 0.08 | 0.00 | | -6.62 | -0.53 | 0.00 | 15.78 |
| 21 | | | | | | | | | | | | | | | 00 | 0.00 |
| 22 | | | | | | | | | | | | | | | 00 | 0.00 |
| 23 | | | | | | | | | | | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| 24 | | | | | | | | | | | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | | | | | | | | | | | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 |

Aging

Aborting

Becoming pregnant

Calving

Culling and Mortality

Starting a next lactation

# Materials and Methods

- The daily Markov-chains matrix
  - 1020 DIM x 282 d gestation x 9 lactations
  - The maximum day for breeding: DIM = 738
  - 1.87 million possible cow **states**

State = parity, DIM, days in gestation

# Materials and Methods

- Value of a reproductive program
  - Daily aggregation for each cow in the herd of:
    1. Milk income over feed cost
    2. Culling cost
    3. Mortality cost
    4. Income from calves
    5. Cost of reproductive program

Very Important Economic Factors

- Final herd structure determined by:
  - Reproductive program
  - Involuntary culling
  - Death
  - Abortion
  - **Reproductive failure** voluntary culling

Cut-off DIM for breeding + Milk production threshold

# Materials and Methods

- Lactation curves determine milk production according to:
  - Lactation number
  - DIM
  - Reproductive status
- Cows leaving the herd are replaced the next day (Meadows et al., 2005; De Vries, 2006; Cabrera, 2010)

Herd population remains constant

# Materials and Methods

- Problem solved by iterations until the herd population reaches **steady state**

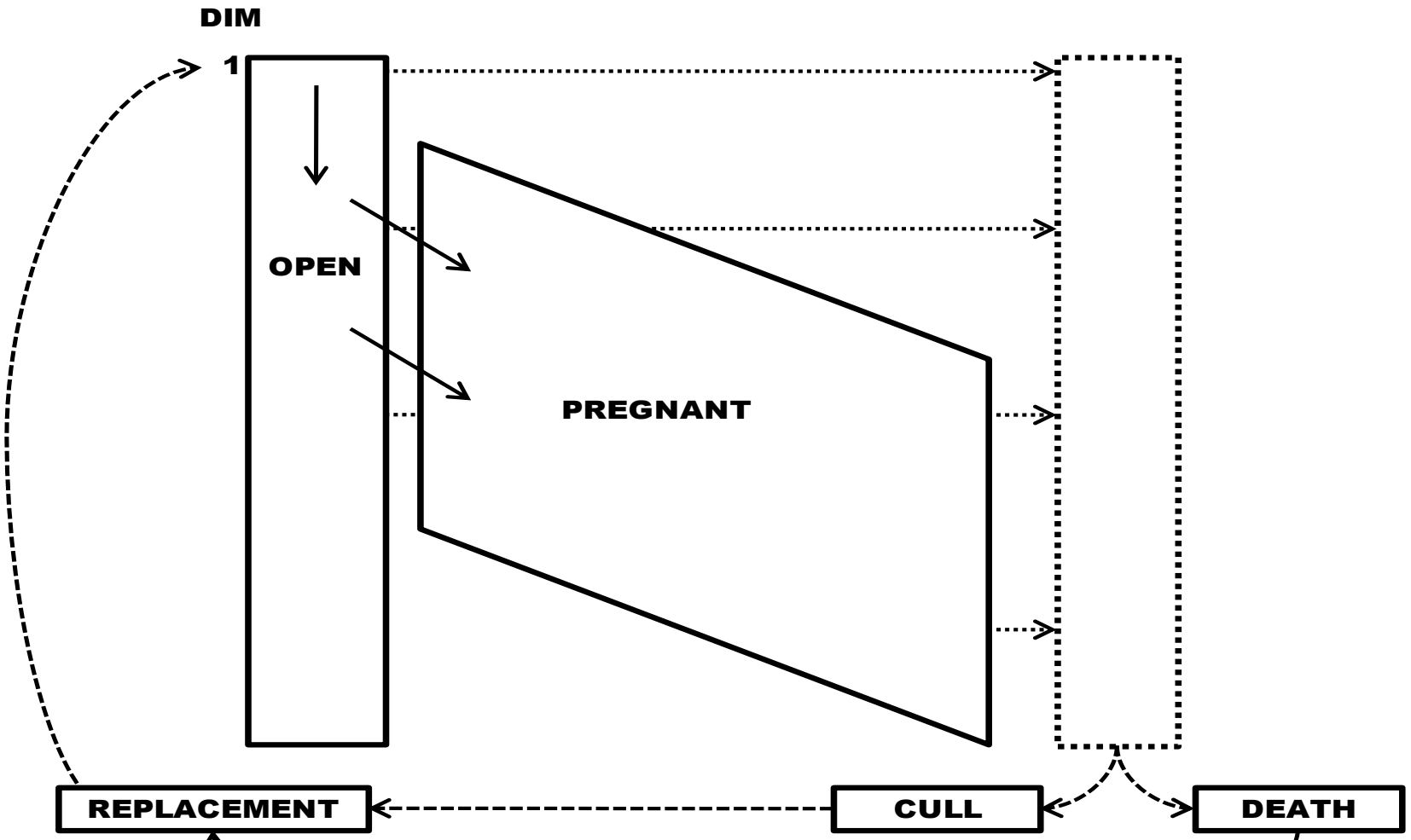
Steady state = number or proportion of cows in a state do not change (any more) from one iteration to the next

2.5 million interacting equations in each iteration

- Daily **transition probabilities** define the probabilities of culling, mortality, pregnancy, and abortion

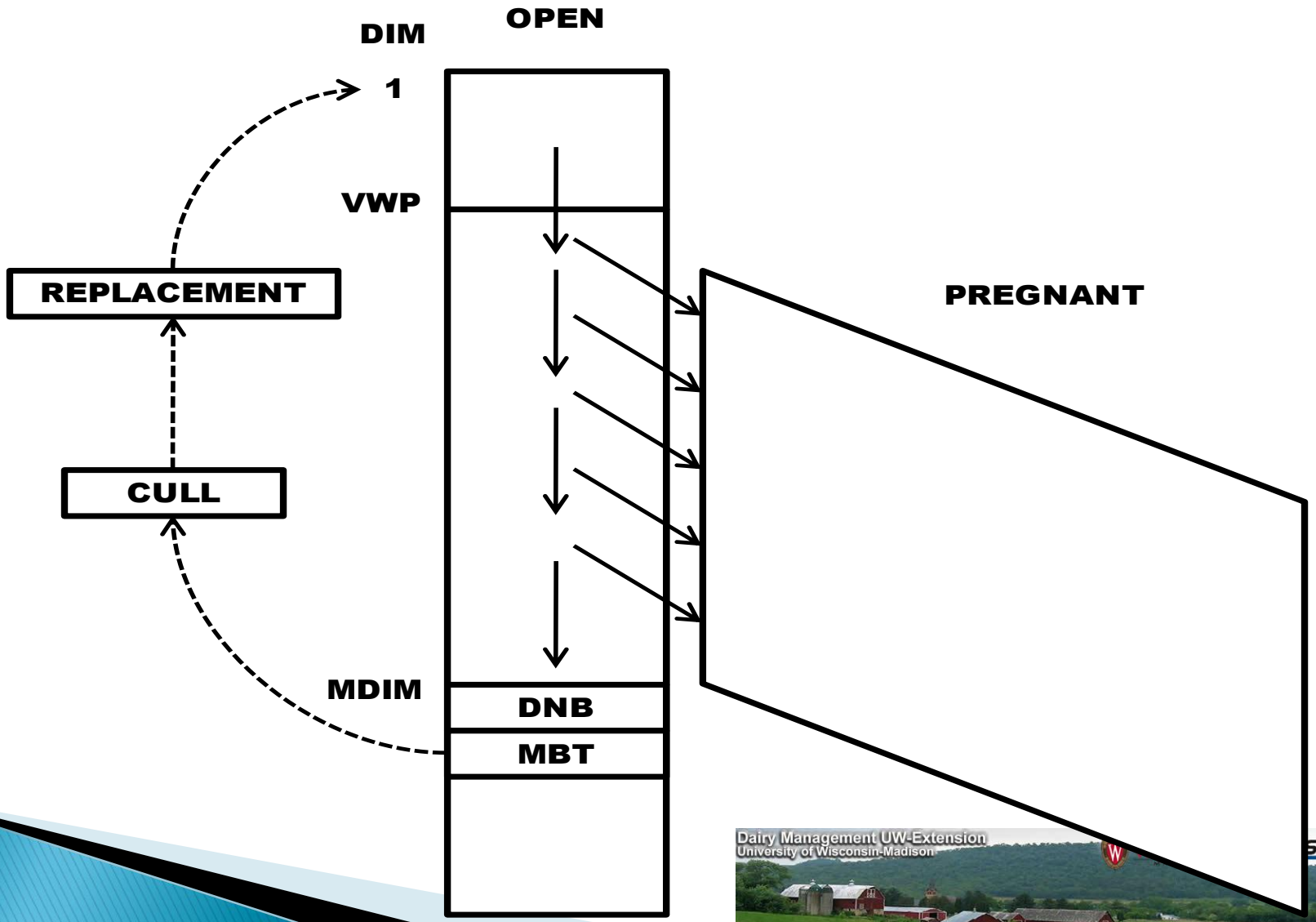
Materials and Methods

# Representation of the involuntary culling and death in the Markov-chain structure for one parity



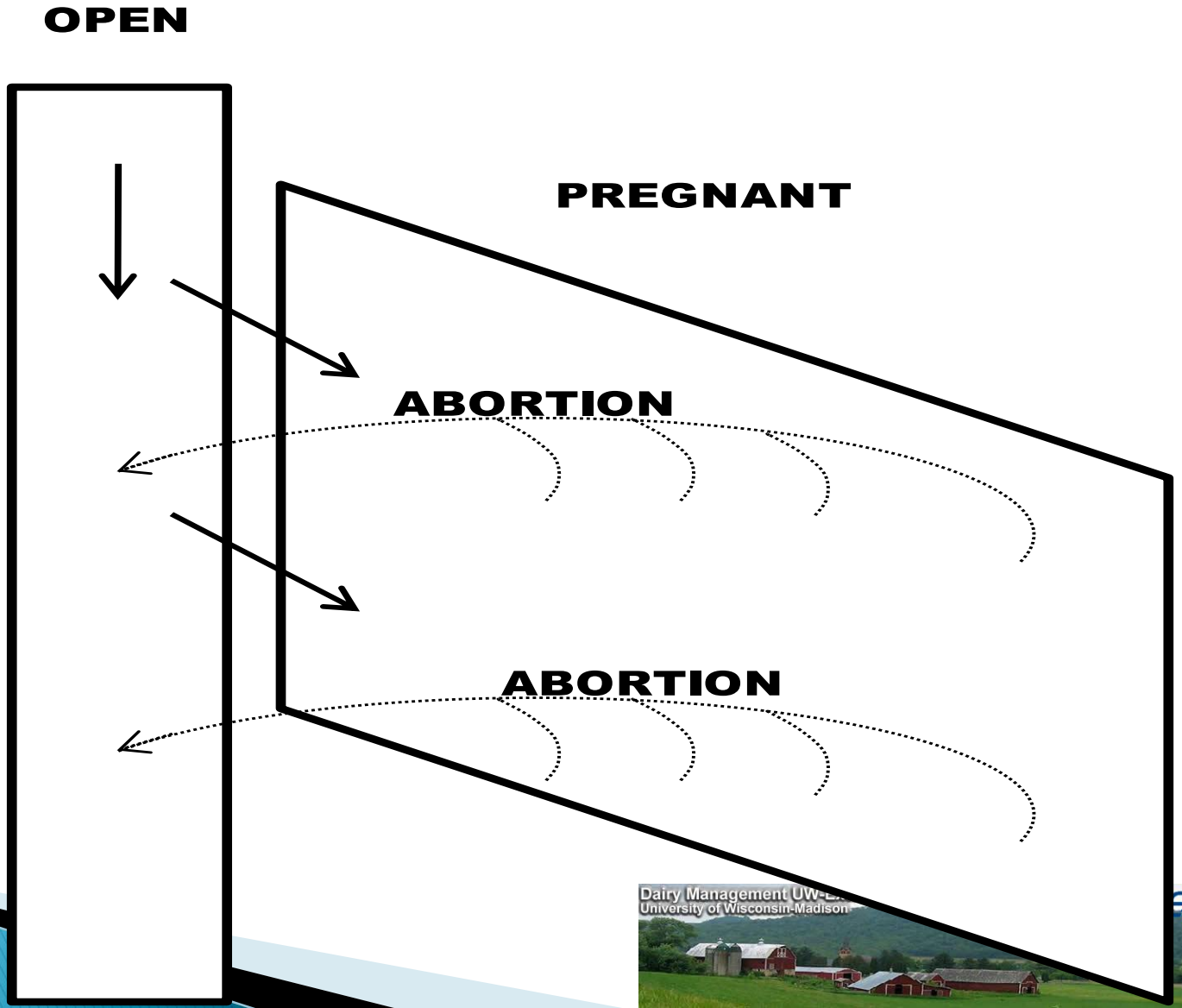
Materials and Methods

# Representation of the breeding process in the Markov-chain structure for one parity



Materials and Methods

# Representation of the abortion process in the Markov-chain structure for one parity



Experiment

## Characteristics of studied reproductive programs

| Type of program | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| 1st Service Program | Estrous Detection | Presynch–Ovsynch | Presynch–Ovsynch |
| 2nd Service Program | Estrous Detection | D32 Resynch | D32 Resynch |
| Voluntary Waiting Period (HD) (d) | 50 | | 50 |
| Voluntary Waiting Period (TAI) (d) | | 72 | 72 |
| Interbreeding Interval (d) | 21 | 42 | 42 |
| Maximum DIM for breeding (d) | 330 | | |
| Milk production to remain in herd (kg) | 27.24 | | |

Experiment

# Characteristics of studied reproductive programs

| Type of program | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| 1st Service Program | Estrous Detection | Presynch-Ovsynch | Presynch-Ovsynch |
| 2nd Service Program | Estrous Detection | D32 Resynch | D32 Resynch |
| Bred at estrus before 1st TAI (%) | | | 60 |
| CR Bred at estrus before 1st TAI (%) | | | 28 |
| Bred at Estrus after1st TAI (%) | | | 60 |
| CR Bred at estrus after1st TAI (%) | | | 28 |

Experiment

# Characteristics of studied reproductive programs

| Type of program | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| 1st Service Program | Estrous Detection | Presynch–Ovsynch | Presynch–Ovsynch |
| 2nd Service Program | Estrous Detection | D32 Resynch | D32 Resynch |
| CR 1st Service TAI (%) | | 42 | 32 |
| CR 2nd + Service TAI (%) | | 30 | 28 |
| HD rate 1st AI (%) | 50 | | |
| CR 1st AI (%) | 30 | | |
| HD rate ≥ 2nd AI (%) | 50 | | |
| CR ≥ 2nd AI (%) | 28 | | |

Same for all lactations

Experiment

## Cost of Reproductive Programs

| Reproductive Program | Hormones | Labor Cost[1] | Total Cost[2] |
|---|---|---|---|
| | ($/cow) | | |
| Presynch-Ovsynch | 10.50 | 3.50 | 30.23 |
| D32 Resynch | 5.50 | 2.00 | 23.73 |
| Breeding at estrus | --- | 0.88 | 17.11 |

[1]Labor cost included hormone administration for Presynch-Ovsynch, D32 Resynch, and estrous detection for breeding at estrus program.

[2]Total cost per AI: **$10** including semen unit and labor. Labor cost to perform pregnancy diagnosis: **$6.23**

Experiment

## Milk Production (MP)

$$MP_{DIM} = a * \left(1 - \frac{e^{\left(\frac{c-DIM}{b}\right)}}{2}\right) * e^{-d*DIM}$$

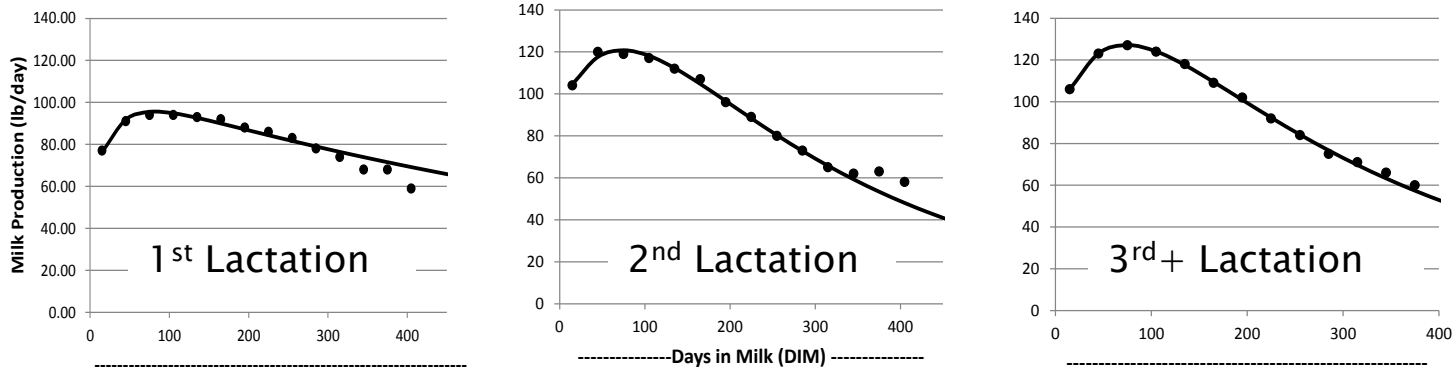
MilkBot Model (Ehrlrich, 2009)

| Notation | Units | Definition |
|---|---|---|
| a | kg/cow/d | Scale |
| b | --- | Ramp |
| c | --- | Offset |
| d | --- | Decay |

Experiment

## Milk Parameters to Define Lactation Curves

| MilkBot Parameter | First Lactation | Second Lactation | ≥Third Lactation |
|---|---|---|---|
| (a) Scale (kg/cow/d) | 49.12 | 94.40 | 89.16 |
| (b) Ramp | 31.16 | 86.06 | 65.06 |
| (c) Offset | −2.67 | 9.26 | 5.71 |
| (d) Decay | 0.0011 | 0.0036 | 0.0033 |




## Observed (dots) vs. Predicted (lines) Lactation Curves

| Month in Pregnancy | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Milk Depression (%) | 0 | 0 | 0 | 0 | 5 | 10 | 15 | --- | --- |

De Vries (2006)

Experiment

## Dry Matter Intake (DMI)

$$DMI_{DIM} = 2\% * BW + 0.3 * FCM$$

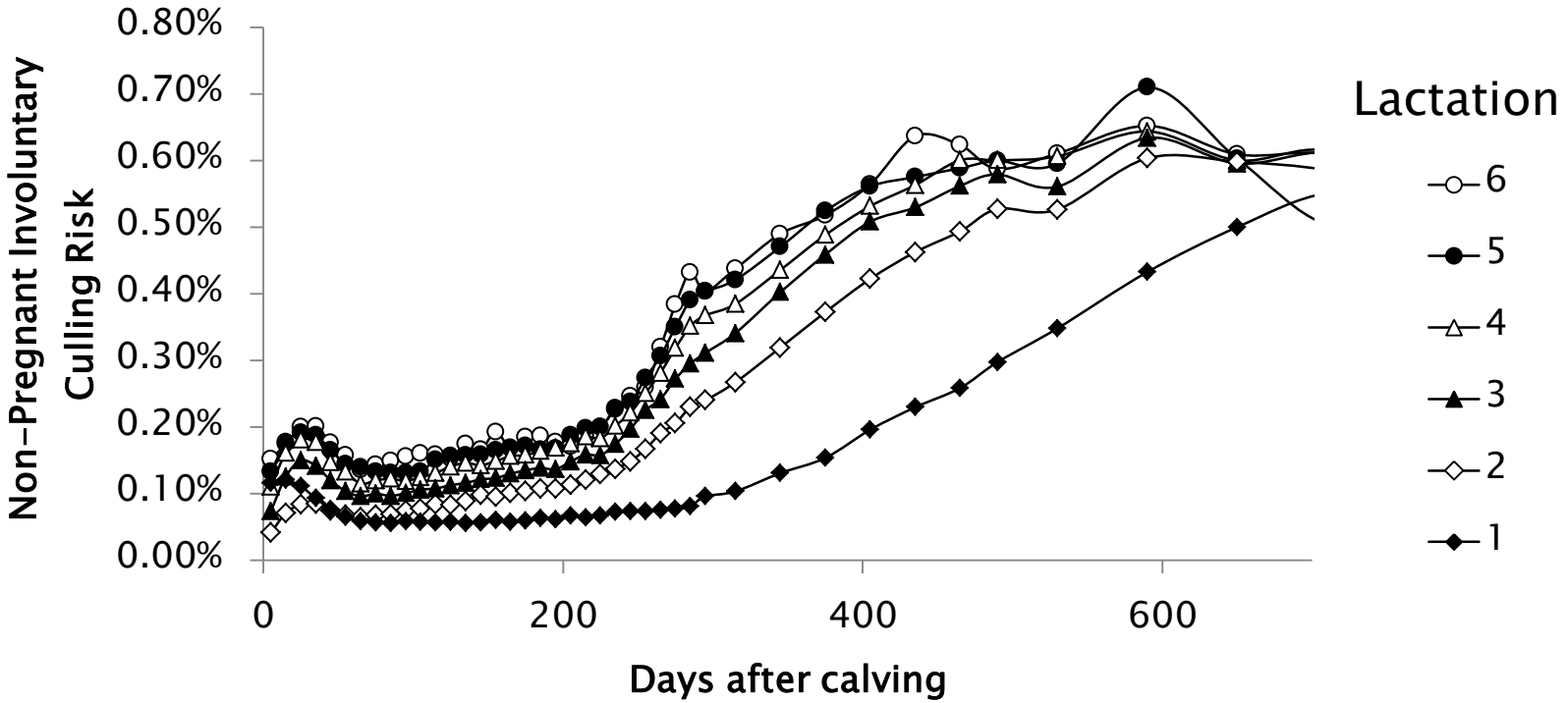
$$\text{FCM} = 4\% * MP_{DMI} + 15 * FAT$$

Van de Haar et al. (1992)

| Notation | Units | Definition |
|---|---|---|
| BW | kg/cow | Body Weight |
| FCM | % | Fat Corrected Milk |
| FAT | % | Milk Butterfat |

Experiment

# Probability of Involuntary Culling and Death




De Vries et al. (2010)

| | | |
|---|---|---|
| Mortality Risk | 17% of Culling Risk | AgSource (2010) |
| Pregnant Culling Risk | 25% of Non-Pregnant | De Vries et al. (2010) |

Experiment

## Probability of Abortion

Month in Pregnancy

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Abortion | 3.5 | 2.5 | 1.5 | 0.5 | 0.25 | 0.1 | 0.1 |

De Vries (2006)

## Economic Variables

| Milk Price | Feed Dry Matter | Heifer Rep. | Salvage Value | New Born Value |
|---|---|---|---|---|
| $/cwt | $/cwt | $/animal | $/animal | $/animal |
| 15 | 10 | 1,400 | 500 | 300 |

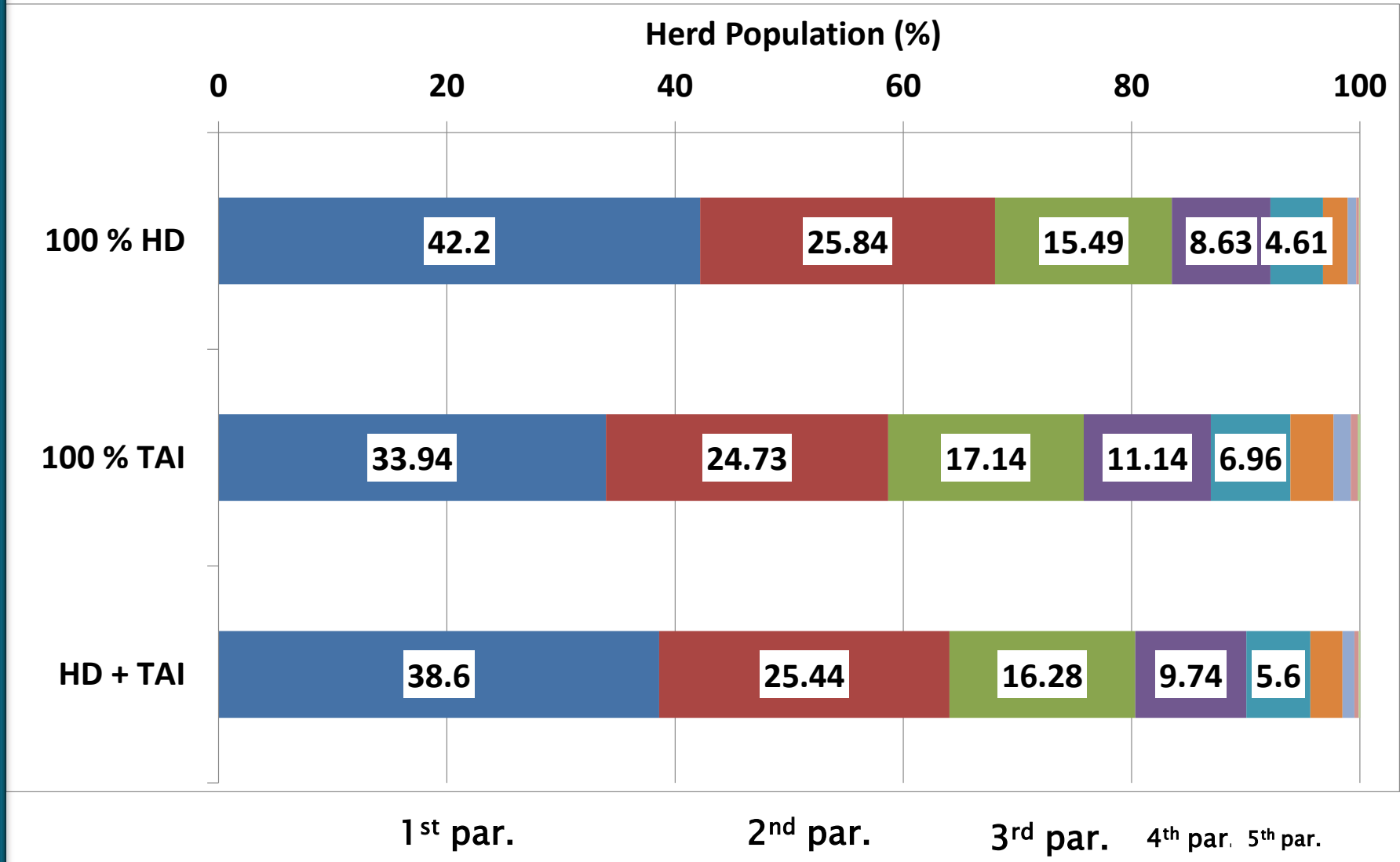
Results

# Steady State Herd Structure

| Type of program | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| 1st parity cows (%) | 42.20 | 33.94 | 38.60 |
| 2nd parity cows (%) | 25.84 | 24.73 | 25.44 |
| 3rd parity cows (%) | 15.49 | 17.14 | 16.28 |
| 4th parity cows (%) | 8.63 | 11.14 | 9.74 |
| 5th parity cows (%) | 4.61 | 6.96 | 5.60 |
| 6th parity cows (%) | 2.17 | 3.78 | 2.82 |
| 7th parity cows (%) | 0.74 | 1.51 | 1.04 |
| 8th parity cows (%) | 0.25 | 0.60 | 0.38 |
| 9th parity cows (%) | 0.09 | 0.24 | 0.14 |

Results

# Steady State Herd Structure



Results

# Herd Reproductive Performance

| | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| 50 d VWP 21-d PR (%) | 12 | 17 | 15 |
| 72 d VWP 21-d PR (%) | --- | 21 | --- |
| Herd pregnant cows[1] (%) | 44.65 | 52.12 | 48.24 |
| Days open[2] (d) | 147 | 130 | 134 |
| Average DIM[3] (d) | 187 | 178 | 182 |
| Lactating population (%) | 90 | 88 | 89 |

[1]Animals that were ≥ 35 d in gestation
[2]Average number of days in milk at which cows became pregnant
[3]Average number of days in milk of all herd

Results

## Economic Value of Reproductive Programs

| | Program 1<br>100 % HD | Program 2<br>100 % TAI | Program 3<br>HD + TAI |
|---|---|---|---|
| | --------$/cow/yr------- | | |
| Value of reproductive program | 2,546.63 | 2,584.29 | 2,571.19 |
| Value over 100% HD | --- | 37.66 | 24.56 |
| Income from newborn | 187.59 | 217.34 | 202.04 |
| Culling and mortality cost | -191.57 | -171.76 | -183.26 |
| Reproductive program cost | -46.47 | -66.56 | -50.07 |
| Milk income over feed cost | 2,597.08 | 2,605.26 | 2,602.48 |

# Discussion

- Feasibility of simulating a dairy herd on a daily basis
  - Better than weekly or monthly models
  - Better than event-driven models
- A daily model overcomes previous models limitations
- Challenge lies in the dimensions and the computational resources needed to solve it

Discussion

- Simpler models could still be useful for practical decision-making

DairyMGT.info

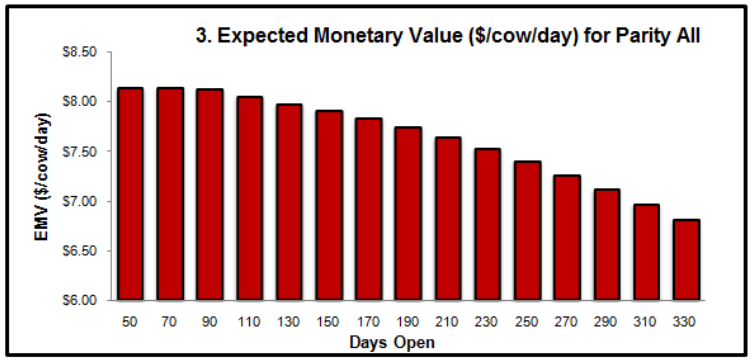
**UW-Dairy Repro$**
Victor E. Cabrera & Julio O. Giordano
**Department of Dairy Science**

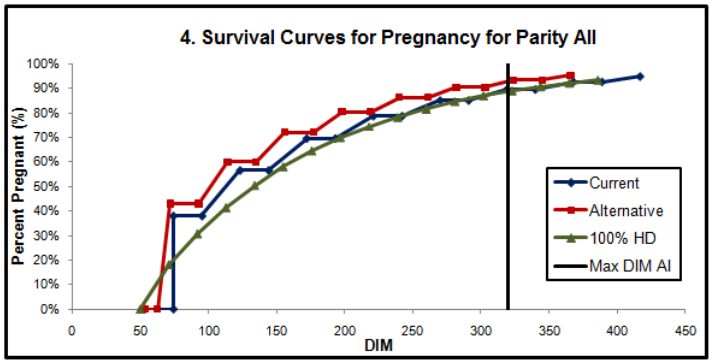
**1. Productive and Economic Parameters Summary**

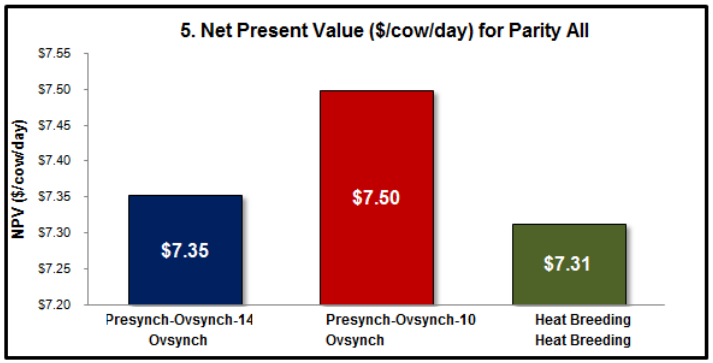
| | | |
|---|---|---|
| Lacating Cows in Parity All | (#) | 1000 |
| Rolling Herd Average (RHA) | (lb/cow/y) | 28000 |
| Milk Price | ($/cwt) | 14.50 |
| Average Value New Born | ($) | 90 |
| Heifer Replacement Value | ($) | 1,000 |
| Salvage Value | ($) | 700 |

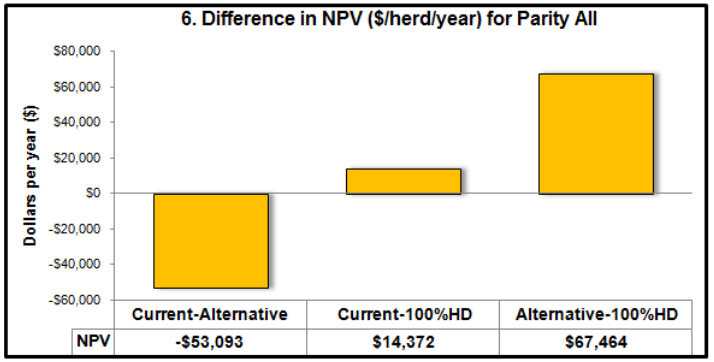
**2. Reproductive Programs Summary**

| | Current | Alternative | Baseline |
|---|---|---|---|
| 1st Service Postpartum | Presynch-Ovsynch-14 | Presynch-Ovsynch-10 | Heat Breeding |
| 2nd and Following Services | Ovsynch | Ovsynch | Heat Breeding |
| Voluntary Waiting Period | 53d | 53d | 50d |
| Maximum DIM for Breeding | | 320d | |
| DIM 1st TAI | 74d | 72d | |
| Interbreeding Interval | 49d | 42d | 21d |
| Heat Bred Before 1st TAI | 0% | 0% | 55% |
| CR Heat Bred Before 1st TAI | 0% | 0% | 33% |
| Heat Bred After 1st TAI | 0% | 0% | 55% |
| CR Heat Bred After 1st TAI | 0% | 0% | 28% |
| CR 1st Service TAI | 38% | 43% | |
| CR 2nd+ Services TAI | 30% | 30% | |
| Cost 1st Service Breeding | $34.00 | $33.89 | |
| Cost Resynch Breedings | $27.33 | $29.33 | |
| Cost Heat Breedings | $16.61 | $18.16 | $17.00 |
| Pregnancy Diagnosis Method | Palpation | Ultrasound | Palpation |
| Pregnancy Diagnosis Cost | $6.56 | $8.16 | $7.00 |



# Conclusions

- Under the bio-economic scenarios included in the experiment: 100 % TAI > TAI+HD > 100 % HD
- Economic evaluation of reproductive programs is complex. Previous models have failed to include the precision needed
- The challenge of translating the daily model to a user-friendly application remains

# Acknowledgement


- This project was supported by Agriculture and Food Research Initiative Competitive Grant No. 2010-85122-20612 from the USDA National Institute of Food and Agriculture

USDA United States Department of Agriculture National Institute of Food and Agriculture

- Thanks to Dr. Paul Fricke and Dr. Milo Wiltbank for their comments and feedback on this study


# Thanks