Economic Decision Making for Reproduction

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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

Introduction

- **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

Introduction

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	2.00	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**

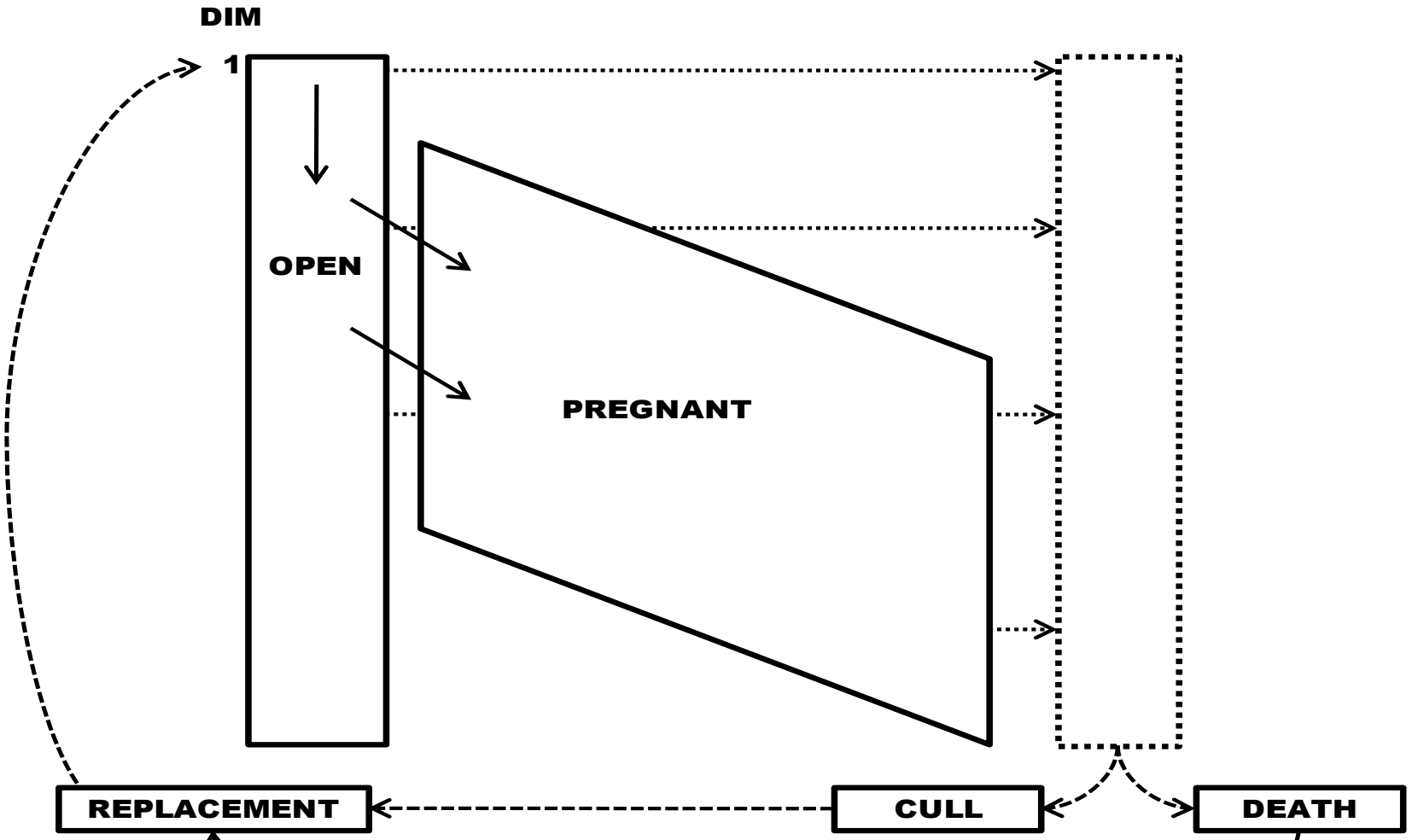
Steady state = number or proportion of cows in a state do not change (any more) from one iteration to the next

2.5 million interacting equations in each iteration

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

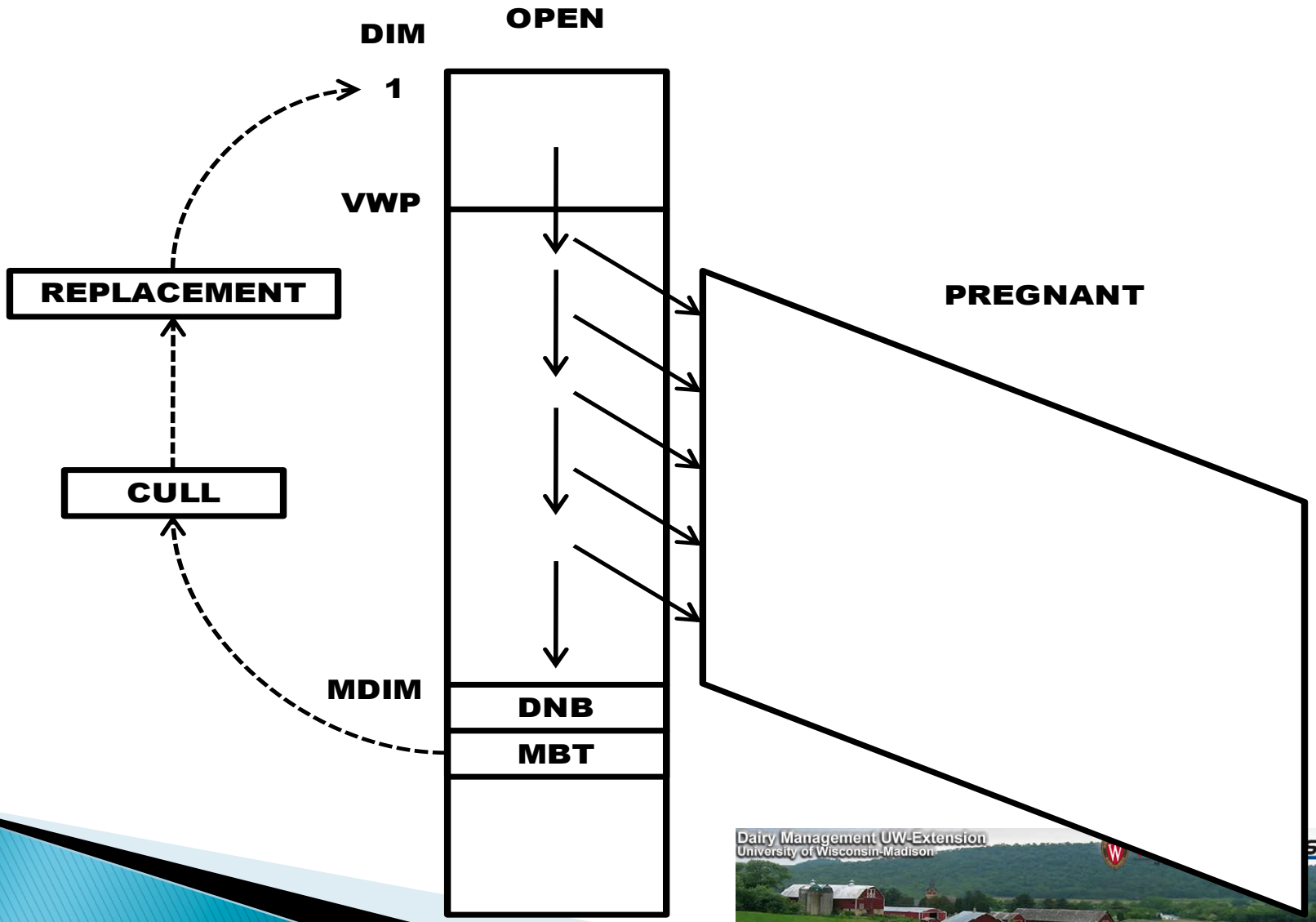
Materials and Methods

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



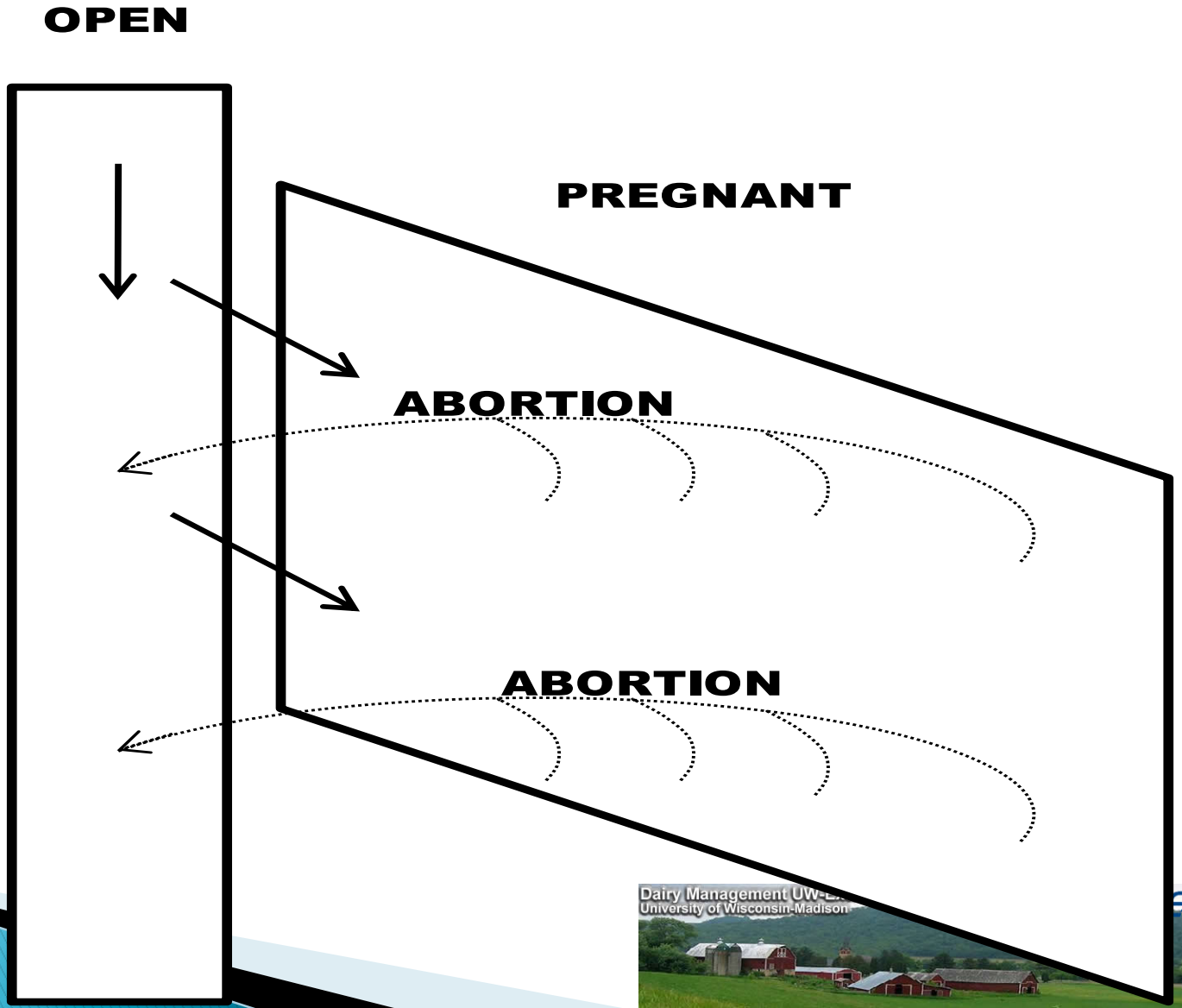
Materials and Methods

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 1 100 % HD	Program 2 100 % TAI	Program 3 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 1 100 % HD	Program 2 100 % TAI	Program 3 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 1 100 % HD	Program 2 100 % TAI	Program 3 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)

$$MP_{DIM} = a * (1 - e^{(c - DIM/b)/2}) * e^{-d * DIM}$$

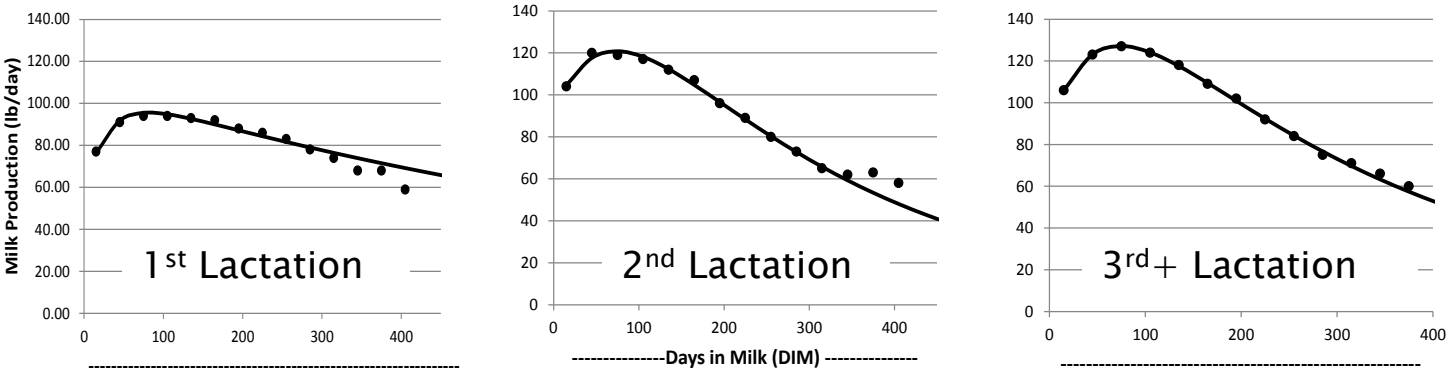
MilkBot Model (Ehrlrich, 2009)

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)

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

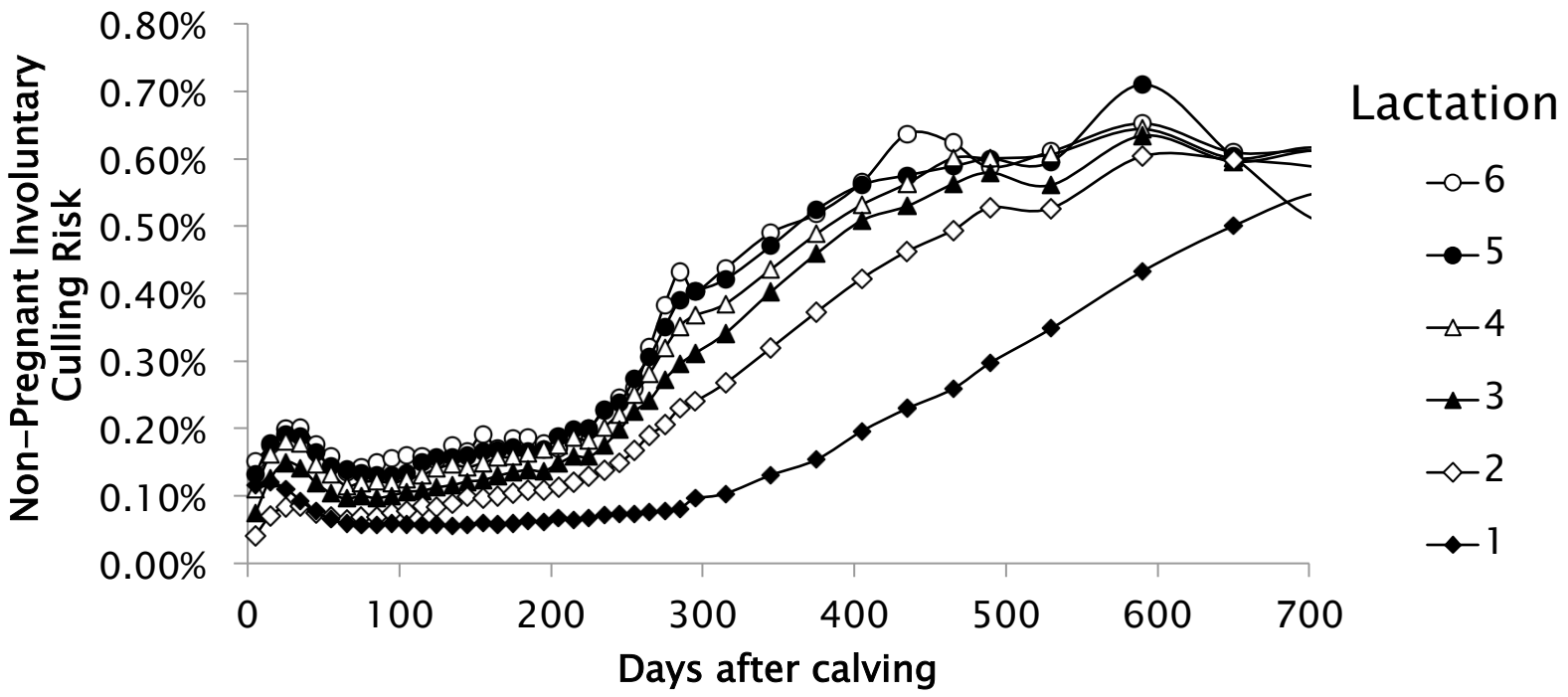
$$FCM = 4\% * MP{\downarrow}DMI + 15 * FAT$$

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

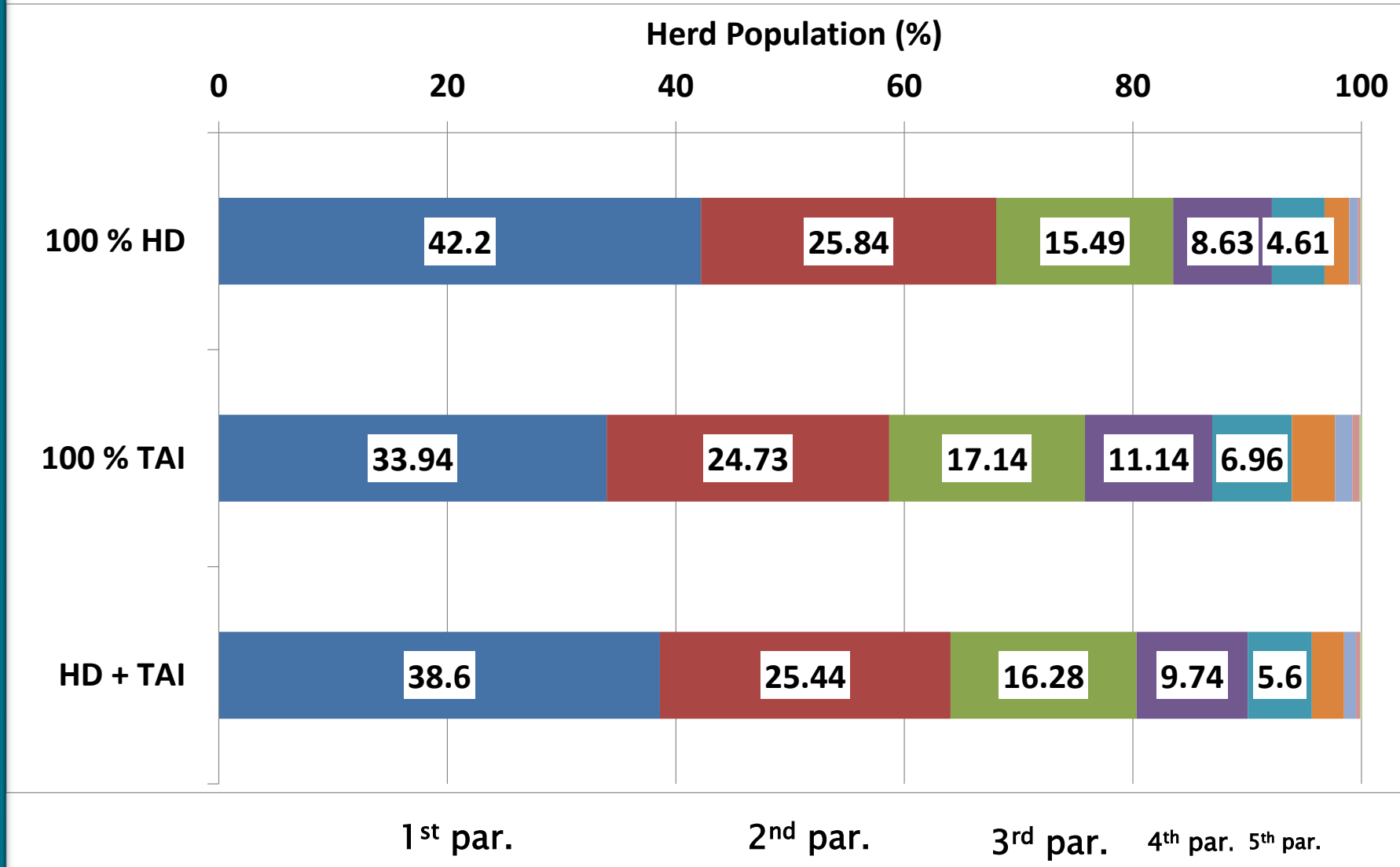
Results

Steady State Herd Structure

Type of program	Program 1 100 % HD	Program 2 100 % TAI	Program 3 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 1 100 % HD	Program 2 100 % TAI	Program 3 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 1 100 % HD	Program 2 100 % TAI	Program 3 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$
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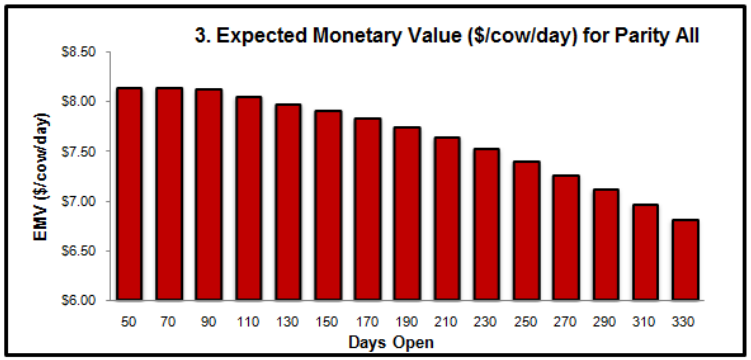
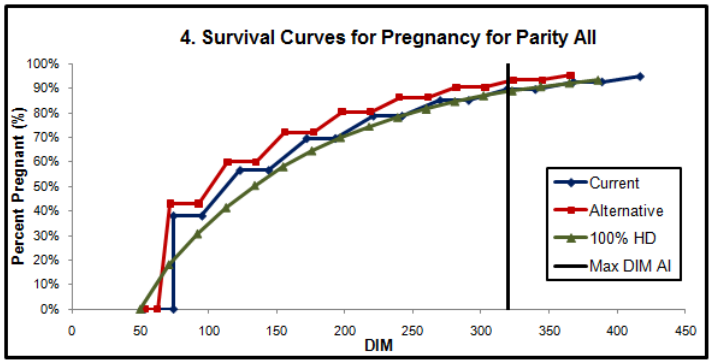
1. Productive and Economic Parameters Summary

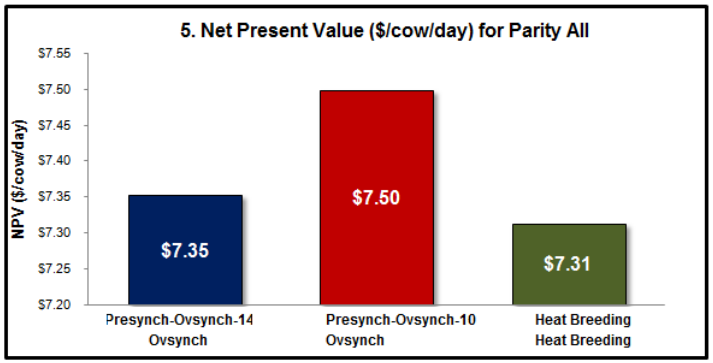
Lacating Cows in Parity All	(#)	1000
Rolling Herd Average (RHA)	(lb/cow/y)	28000
Milk Price	($/cwt)	14.50
Average Value New Born	($)	90
Heifer Replacement Value	($)	1,000
Salvage Value	($)	700

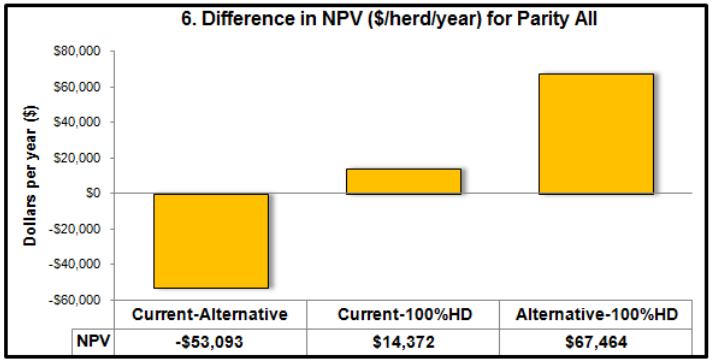
2. Reproductive Programs Summary

	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

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

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