



Economic Decision Making for Reproduction

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- 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



- 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



- 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)



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



- A herd follows daily 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	2.00	0.56									0.05	616.65	-26.48	72.57	0.00
4	2.00	0.56	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	0.39	0.04	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	0.39	0.04	117.16	-17.53	0.00	62.99
14	0.41			0.09	0.10	0.12	0.15	0.18	0.21	0.26	0.04	88.57	-18.74	0.00	51.22
15	0.38				0.08	0.10	0.12	0.15	0.18	0.21	0.04	65.09	-19.10	0.00	42.02
16	0.35					0.08	0.10	0.12	0.14	0.18	0.04	46.03	-18.82	0.00	34.63
17	0.32						0.08	0.10	0.12	0.15	0.04	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	0.04	10.50	-17.49	0.00	19.33
20	0.00									0.08	0.00	-6.62	-0.53	0.00	15.78
21											0.00	0.00	0.00	0.00	0.00
22											0.00	0.00	0.00	0.00	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

- 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



- 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



- 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



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

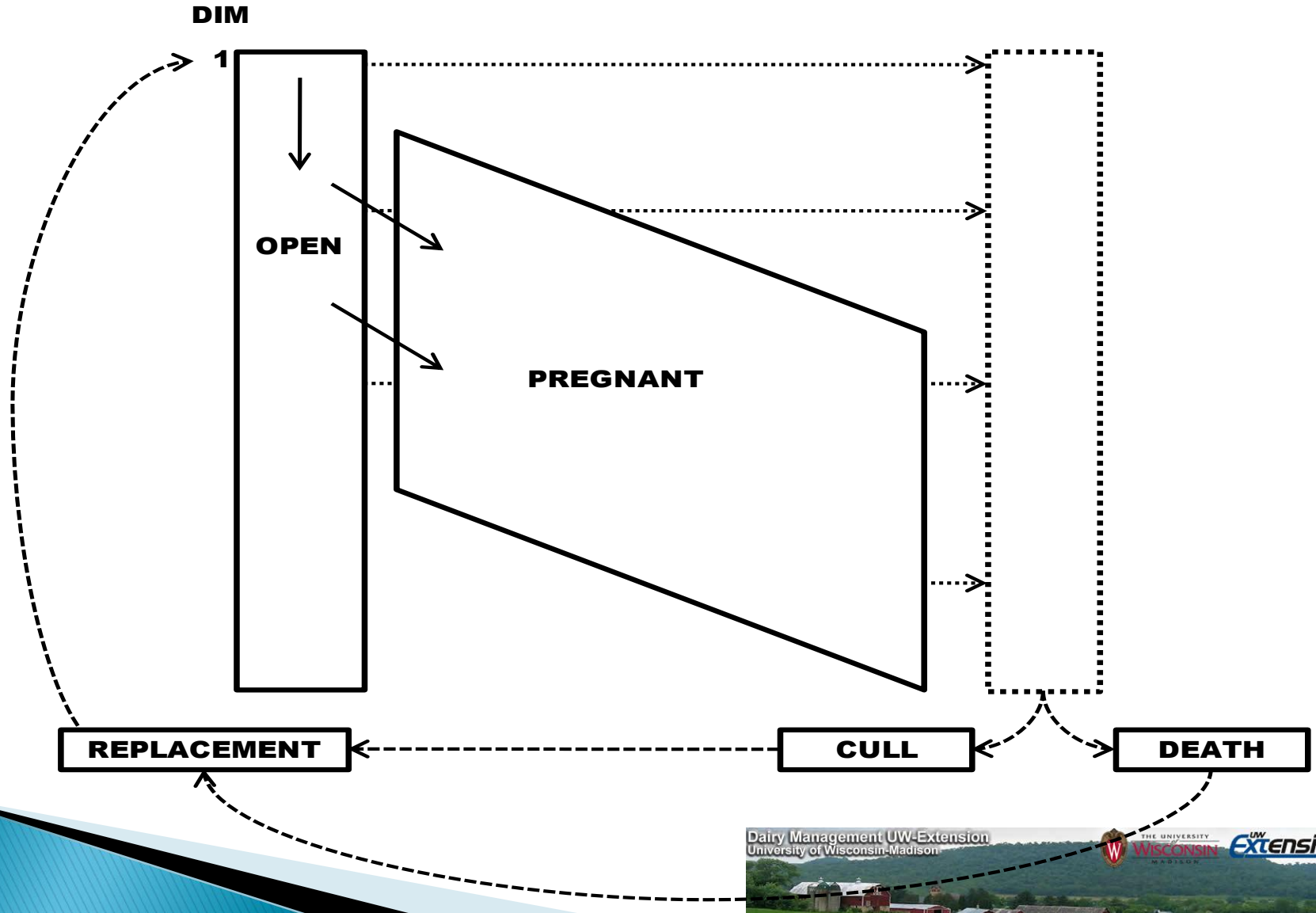
Steady state = number or proportion of cows in a state do not change (any more) from one iteration to the next

2.5 million interacting equations in each iteration

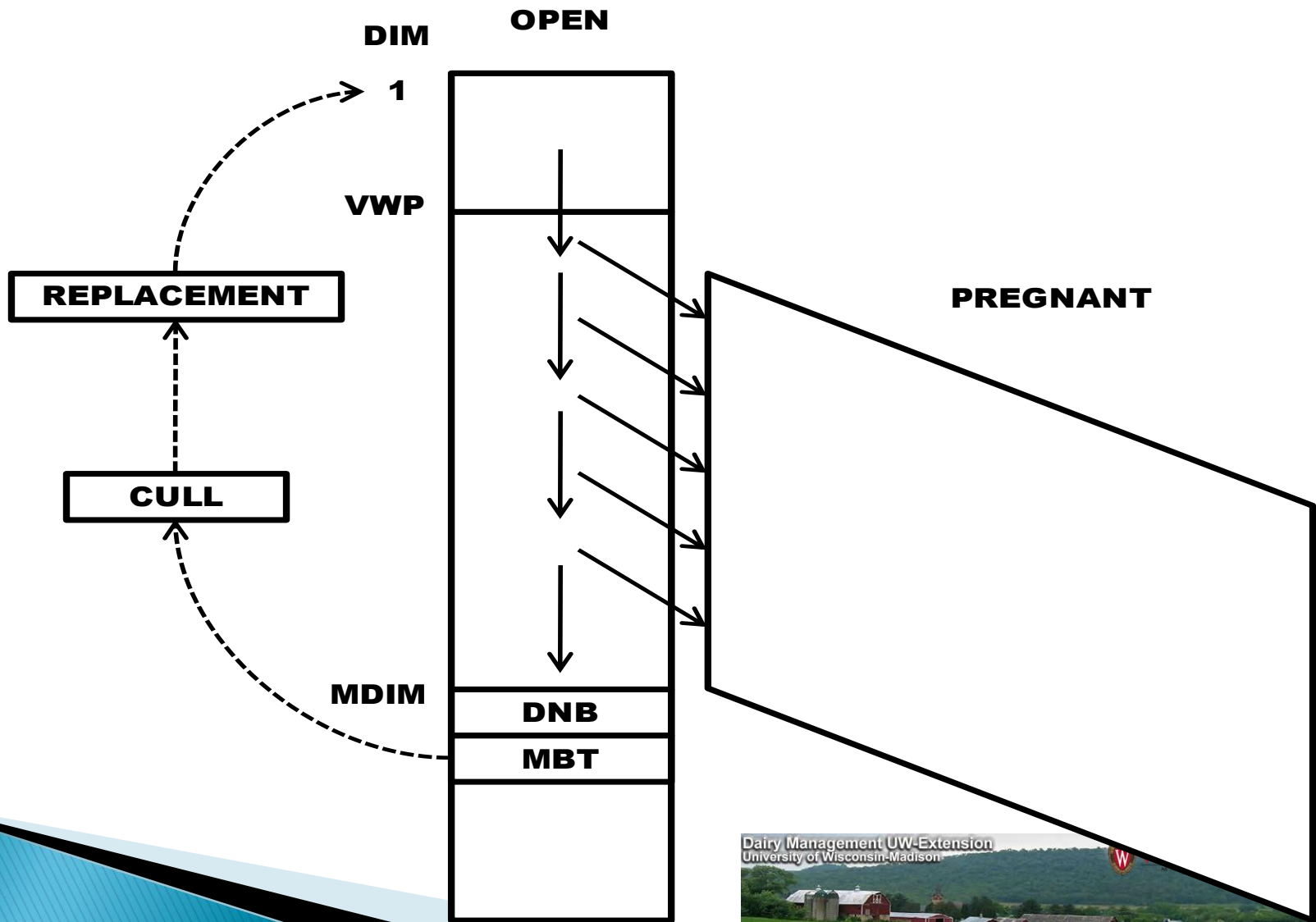
- Daily transition probabilities define the probabilities of culling, mortality, pregnancy, and abortion



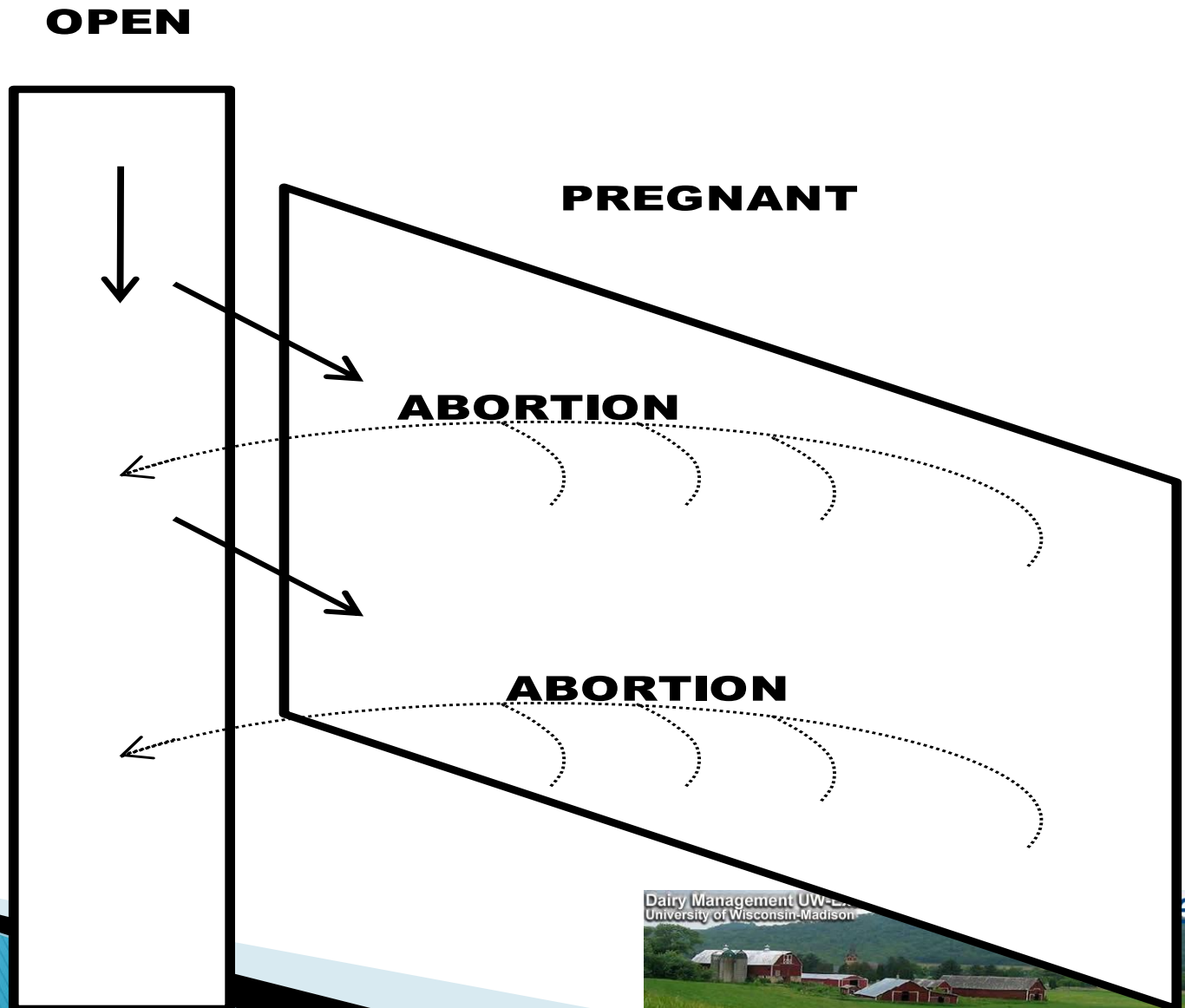
Representation of the involuntary culling and death in the Markov-chain structure for one parity



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



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



Characteristics of studied reproductive programs

	Program 1	Program 2	Program 3
Type of program	100 % HD	100 % TAI	HD + TAI
1 st Service Program	Estrous Detection	Presynch-Ovsynch	Presynch-Ovsynch
2 nd 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		



Characteristics of studied reproductive programs

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



Characteristics of studied reproductive programs

Experiment

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

Same for all lactations



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

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

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



Milk Production (MP)

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

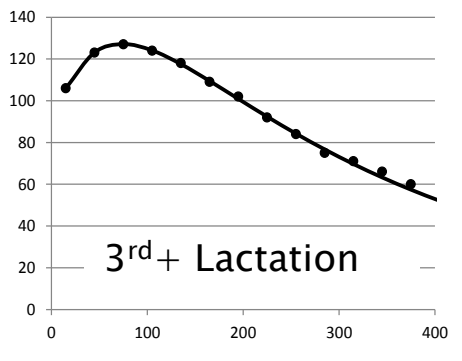
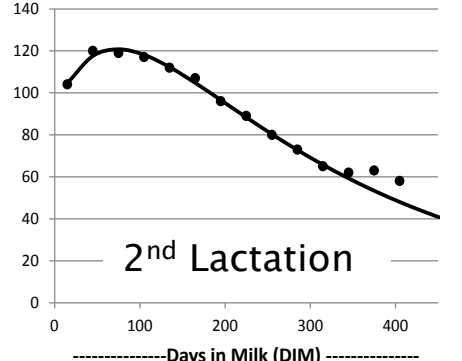
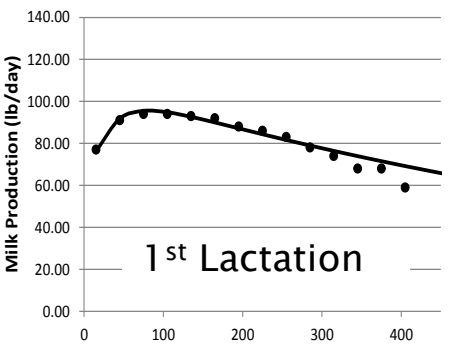
MilkBot Model (Ehrlich, 2009)

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



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)



Dry Matter Intake (DMI)

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

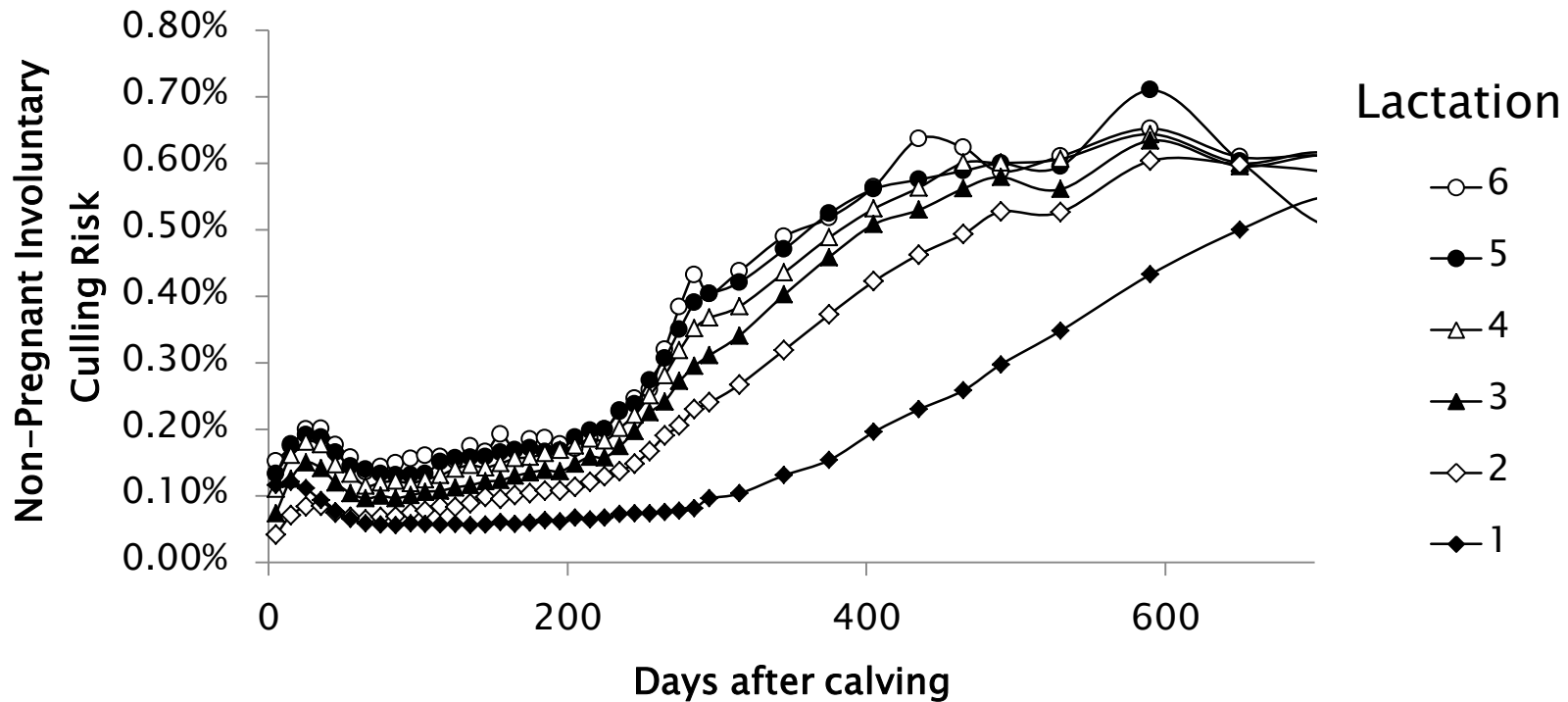
$$FCM = 4\% * MP_{DMI} + 15 * FAT$$

Van de Haar et al. (1992)

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



Probability of Involuntary Culling and Death



De Vries et al. (2010)

Mortality Risk
Pregnant Culling Risk

17% of Culling Risk
25% of Non-Pregnant

AgSource (2010)
De Vries et al. (2010)

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



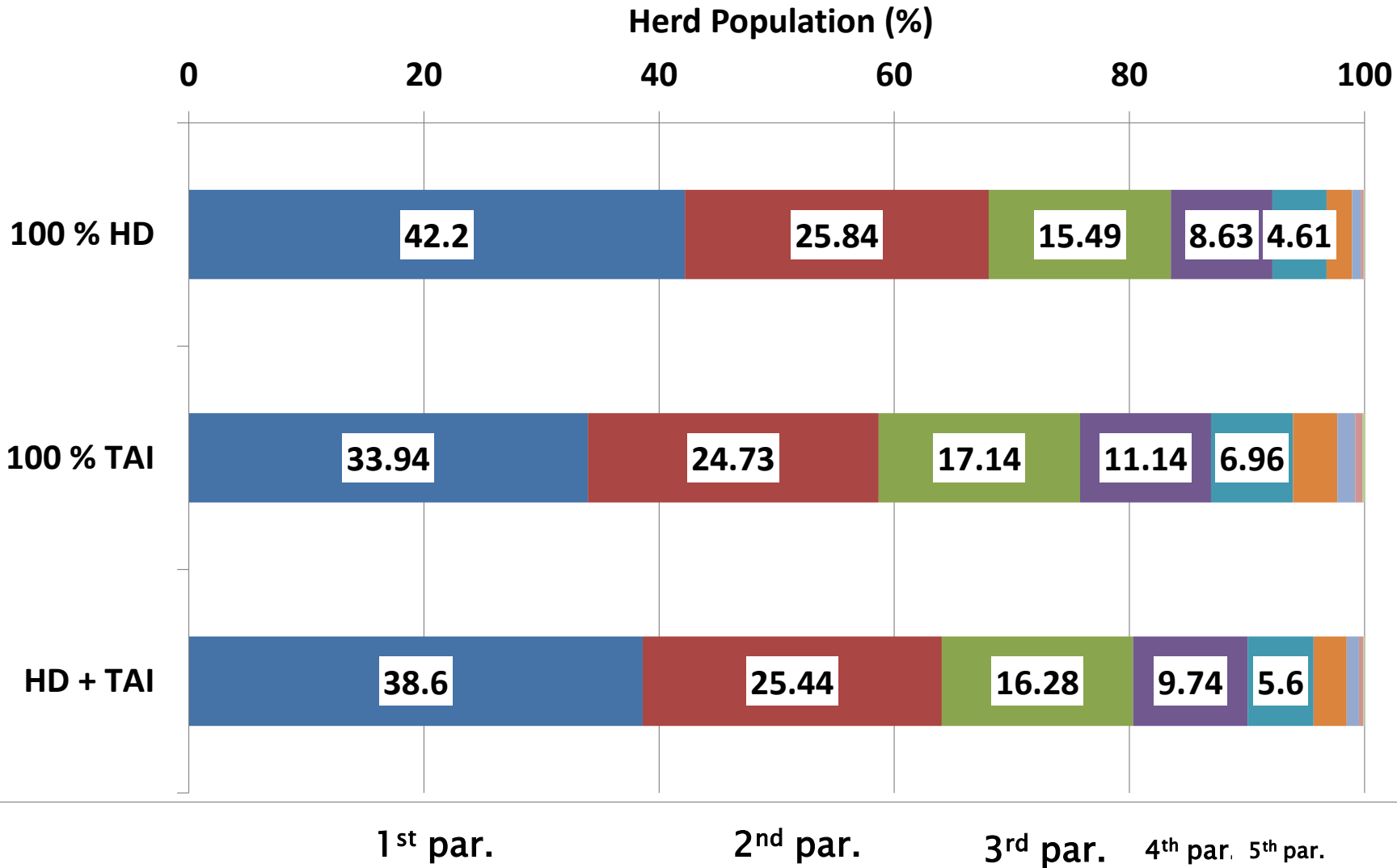
Steady State Herd Structure

Results

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



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

¹Animals that were ≥ 35 d in gestation

²Average number of days in milk at which cows became pregnant

³Average number of days in milk of all herd



Economic Value of Reproductive Programs

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

-----\$/cow/yr-----

Value of reproductive program	2,546.63	<u>2,584.29</u>	2,571.19
Value over 100% HD	---	37.66	24.56
Income from newborn	187.59	<u>217.34</u>	202.04
Culling and mortality cost	-191.57	<u>-171.76</u>	-183.26
Reproductive program cost	<u>-46.47</u>	-66.56	-50.07
Milk income over feed cost	2,597.08	<u>2,605.26</u>	2,602.48

Results



- 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



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

DairyMGT.info



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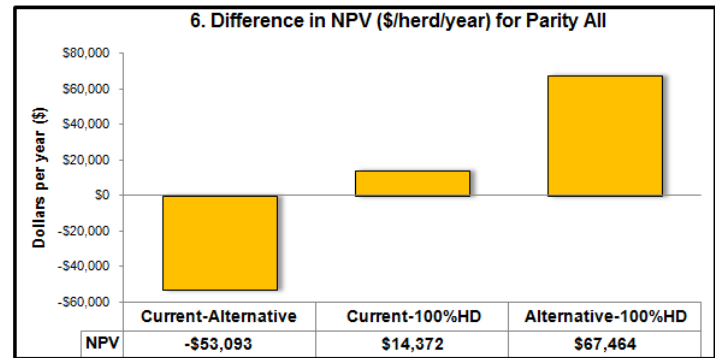
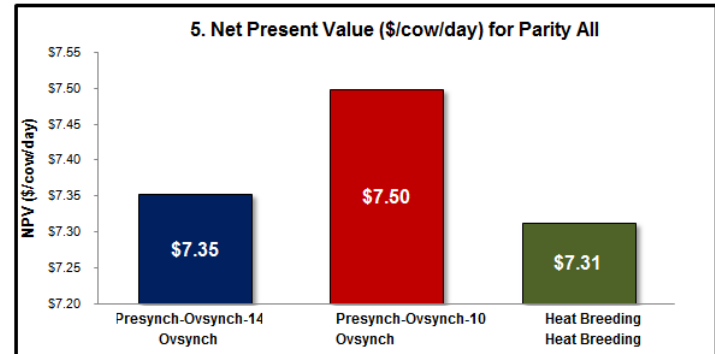
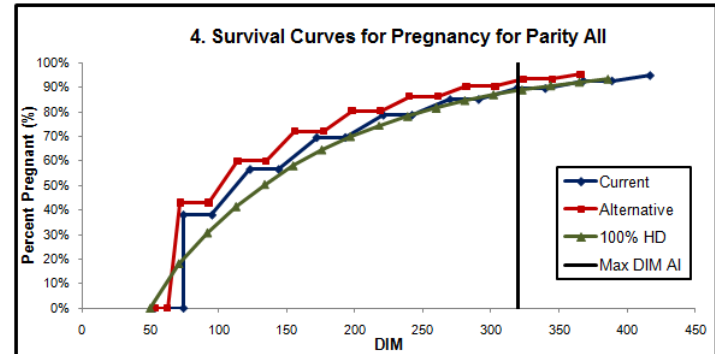
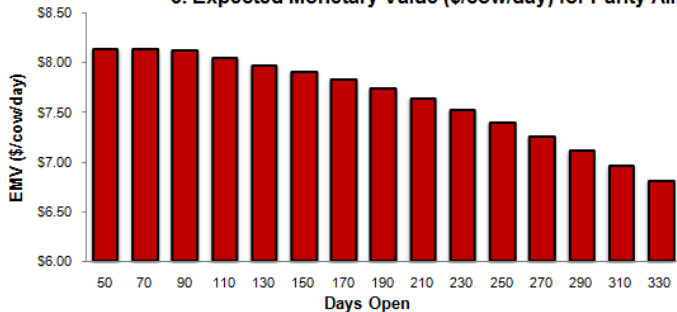
1. Productive and Economic Parameters Summary

Lactating Cows in Parity All	(#)	1000
Rolling Herd Average (RHA)	(lb/cow/yr)	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
1 st Service Postpartum	Presynch-Ovsynch-14	Presynch-Ovsynch-10	Heat Breeding
2 nd 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 1 st TAI	0%	0%	55%
CR Heat Bred Before 1 st TAI	0%	0%	33%
Heat Bred After 1 st TAI	0%	0%	55%
CR Heat Bred After 1 st TAI	0%	0%	28%
CR 1 st Service TAI	38%	43%	
CR 2 nd + 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

3. Expected Monetary Value (\$/cow/day) for Parity All



Discussion

- Under the bio-economic scenarios included in the experiment: $100\% \text{ TAI} > \text{TAI} + \text{HD} > 100\% \text{ HD}$
- 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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Thanks

