MOO: THE MILK OUTPUT OPTIMISER

A management tool for New Zealand dairy farmers

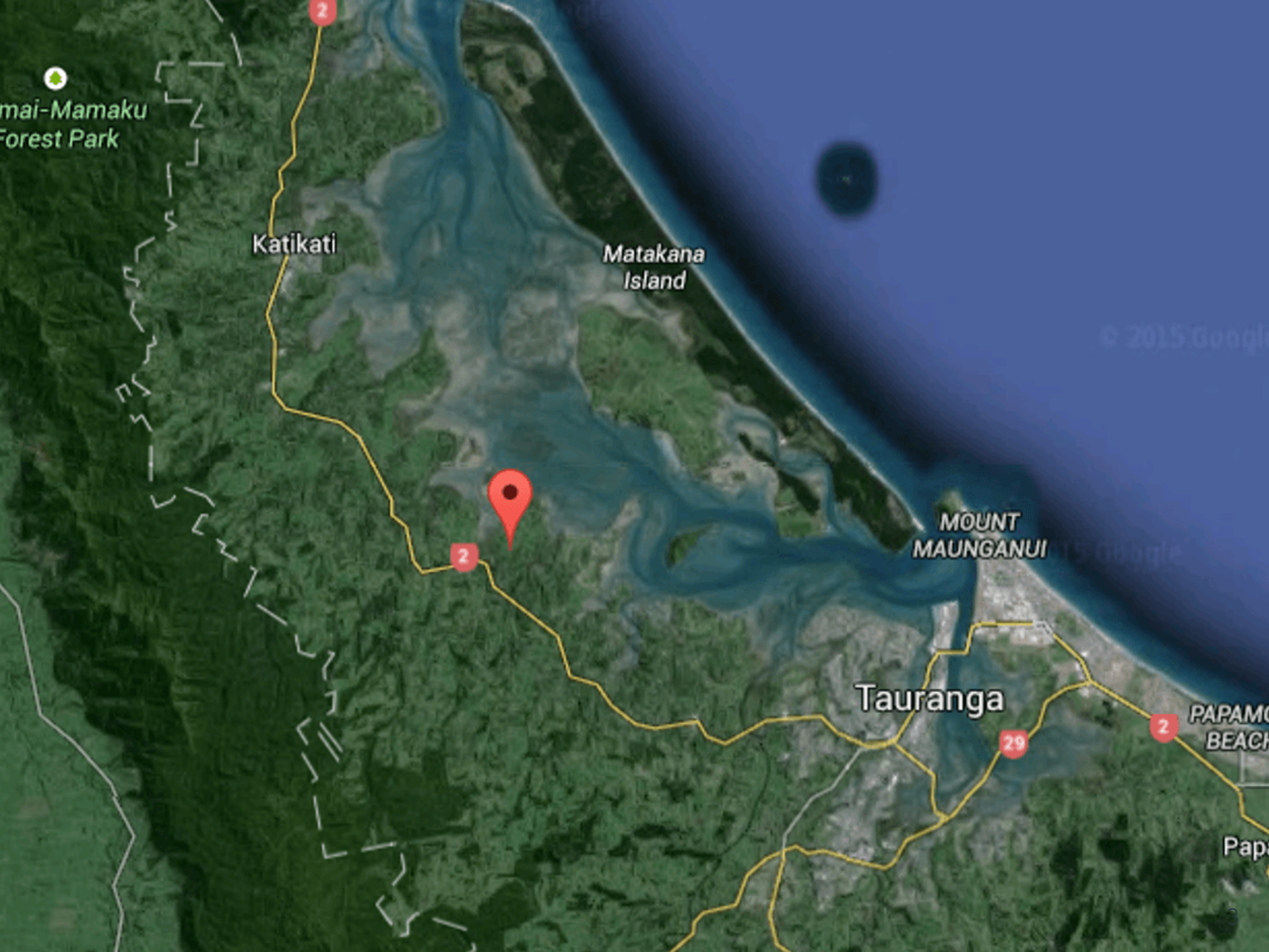
Oscar Dowson

1 June 2015

University of Auckland

WHY DO I CARE?


Tasman Sea
New
Zealand


mai-Mamaku
Forest Park
Katikati
Matakana
Island
MOUNT
MAUNGANUI
Tauranga
2
29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Google earth

WHY SHOULD YOU CARE?

20.5b

litres of milk

20.5b

litres of milk

Enough milk to cover DTU to a depth of 30 metres!

95%

exported

1/4

export goods by value

1/4

export goods by value

Danish Pig exports are only 5%

1/3

of global dairy exports

New Zealand Denmark

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Production (10^9L)	20.5	5

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1 Danish cow produces the same as 2.2 New Zealand cows!

WHY?

Supplementation

More food = more milk

Supplementation

More food = more milk

Genetics

Biological efficiency = more milk

Supplementation
More food = more milk

Genetics
Biological efficiency = more milk

Environment
Better housing = more milk

New Zealand has more land

268k km^2 vs. 43k km^2

New Zealand has more land

268k km^2 vs. 43k km^2

New Zealand has more cows

5 million vs. 0.5 million

SOME RESEARCH QUESTIONS

1. How should supplement be fed?

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2. What is the optimal stocking rate?

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3. Can we minimise the environmental impact of dairying?

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A MATHEMATICAL COW...

E-COW

Evolved over a number of years

SIMCOW (Kristensen et al., 1997), MOOSIM (Bryant, 2006)

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e-Cow

Baudracco et al., 2011

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Sensitive to Genetic and Environmental interactions

A MATHEMATICAL COW

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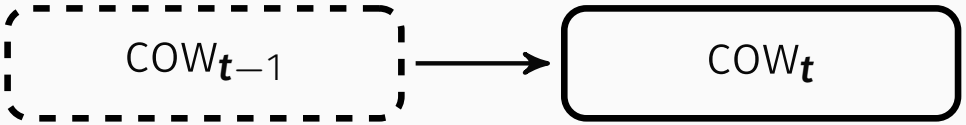

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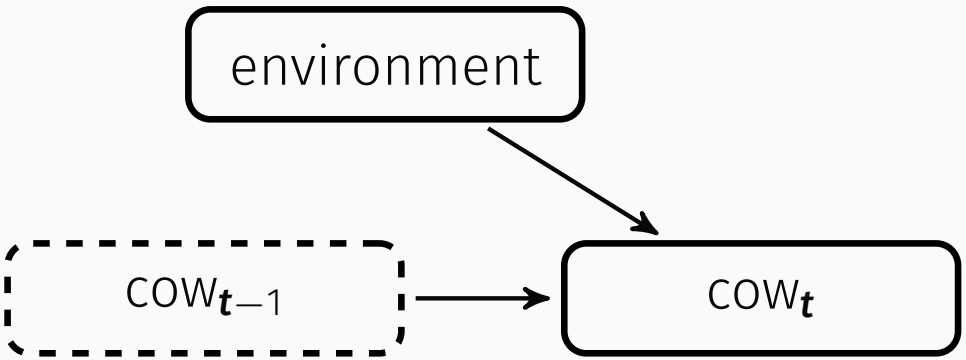

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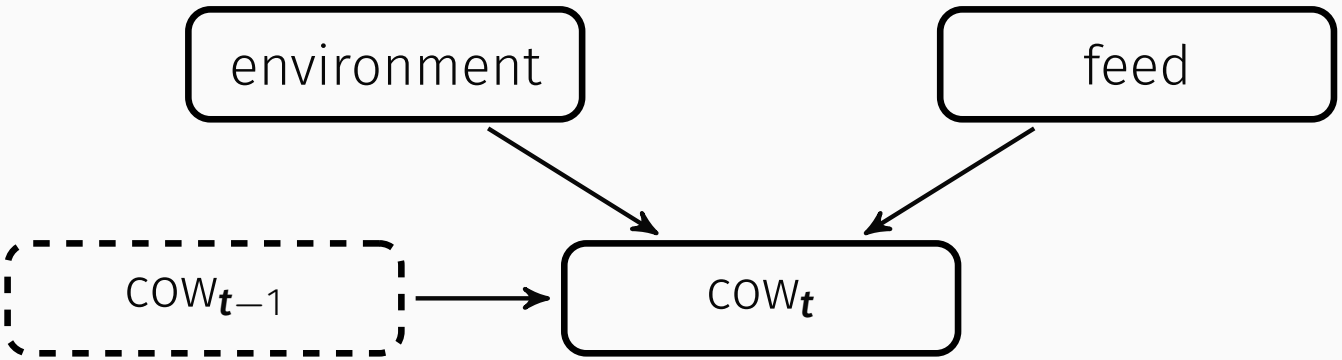

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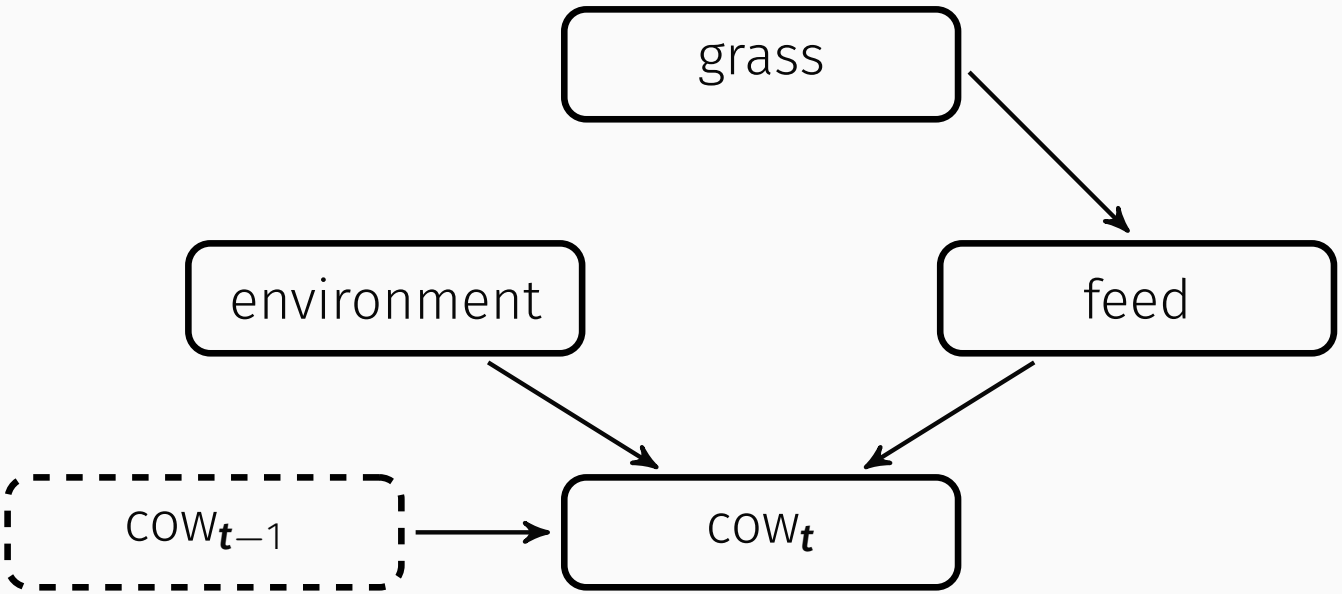

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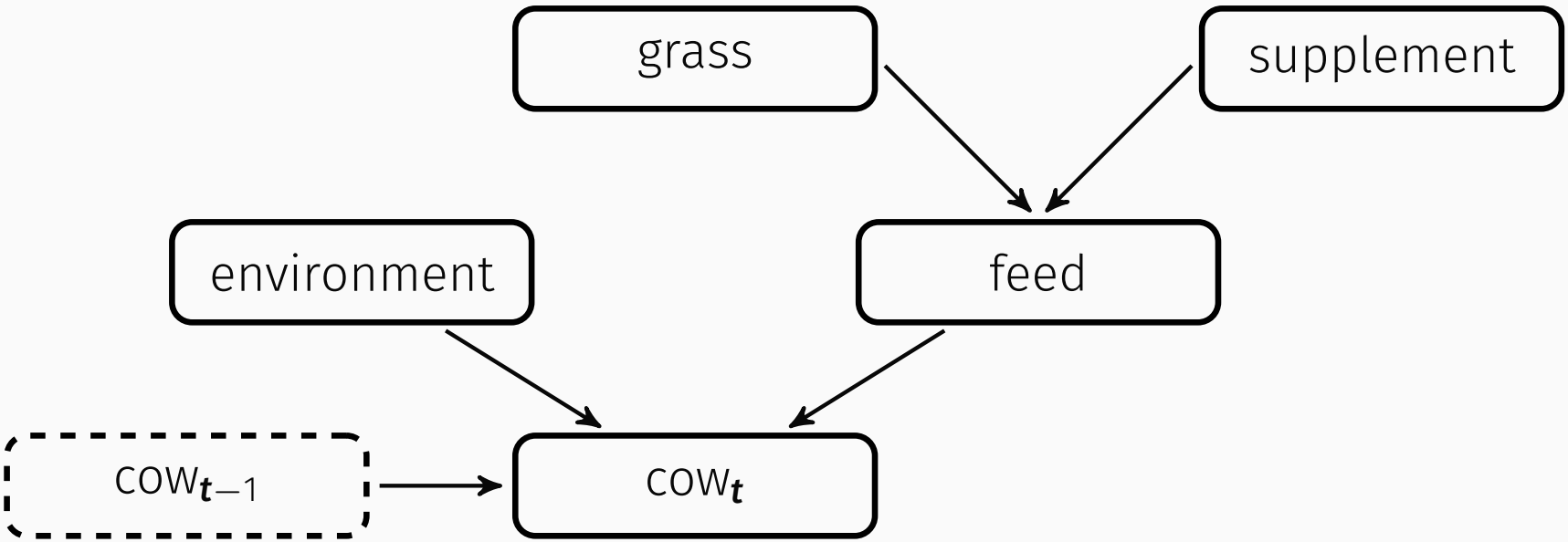

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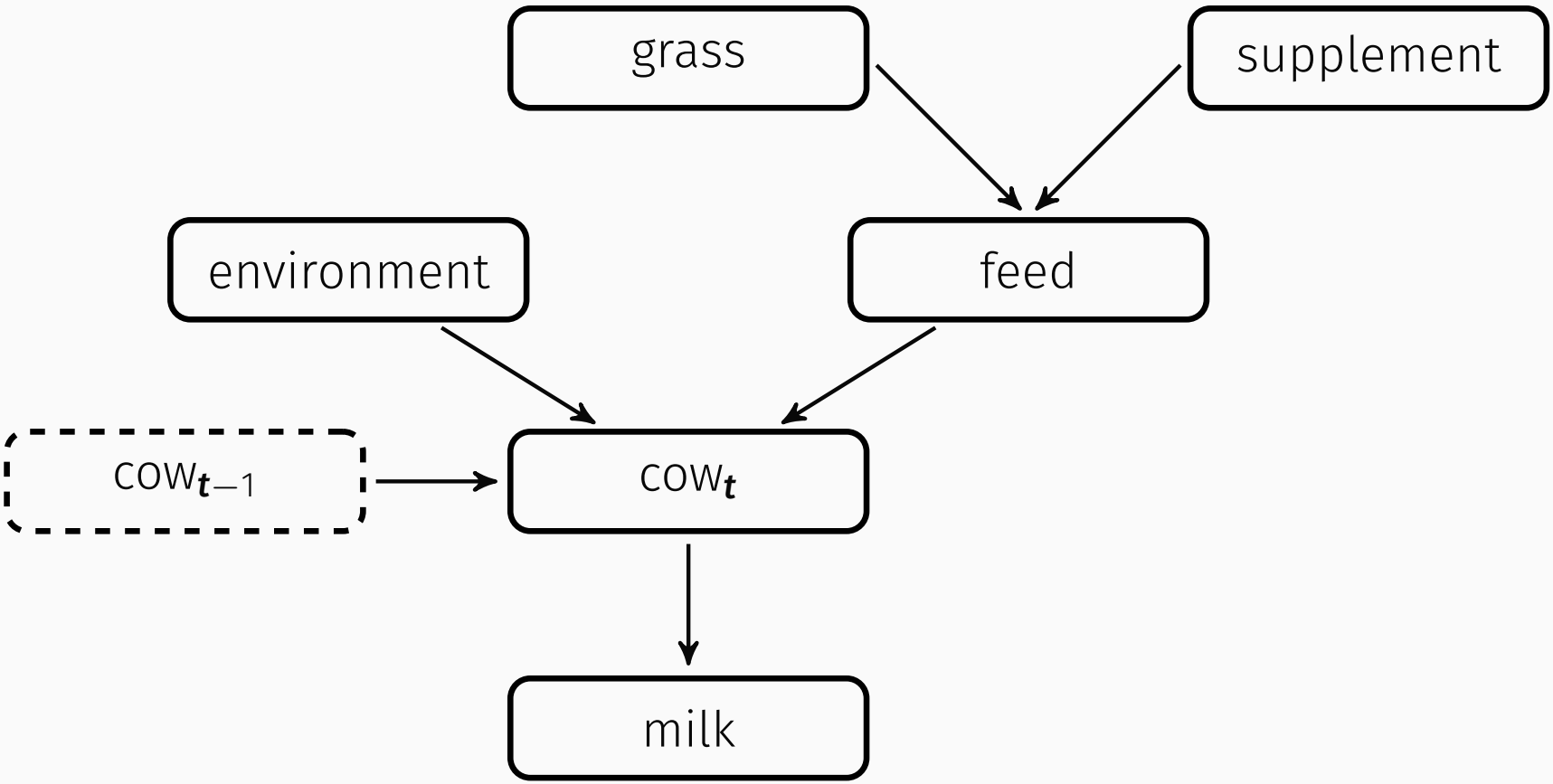

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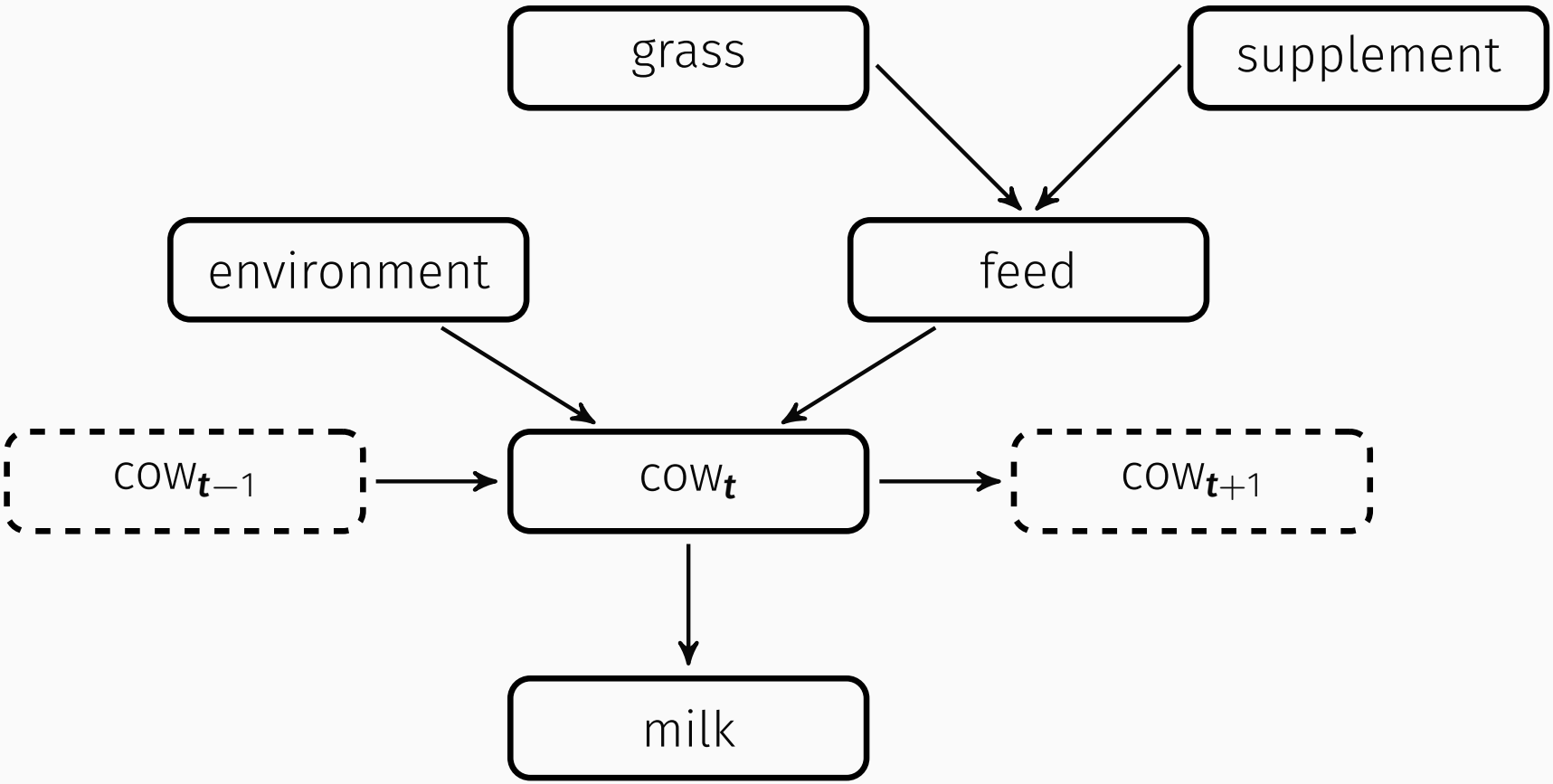

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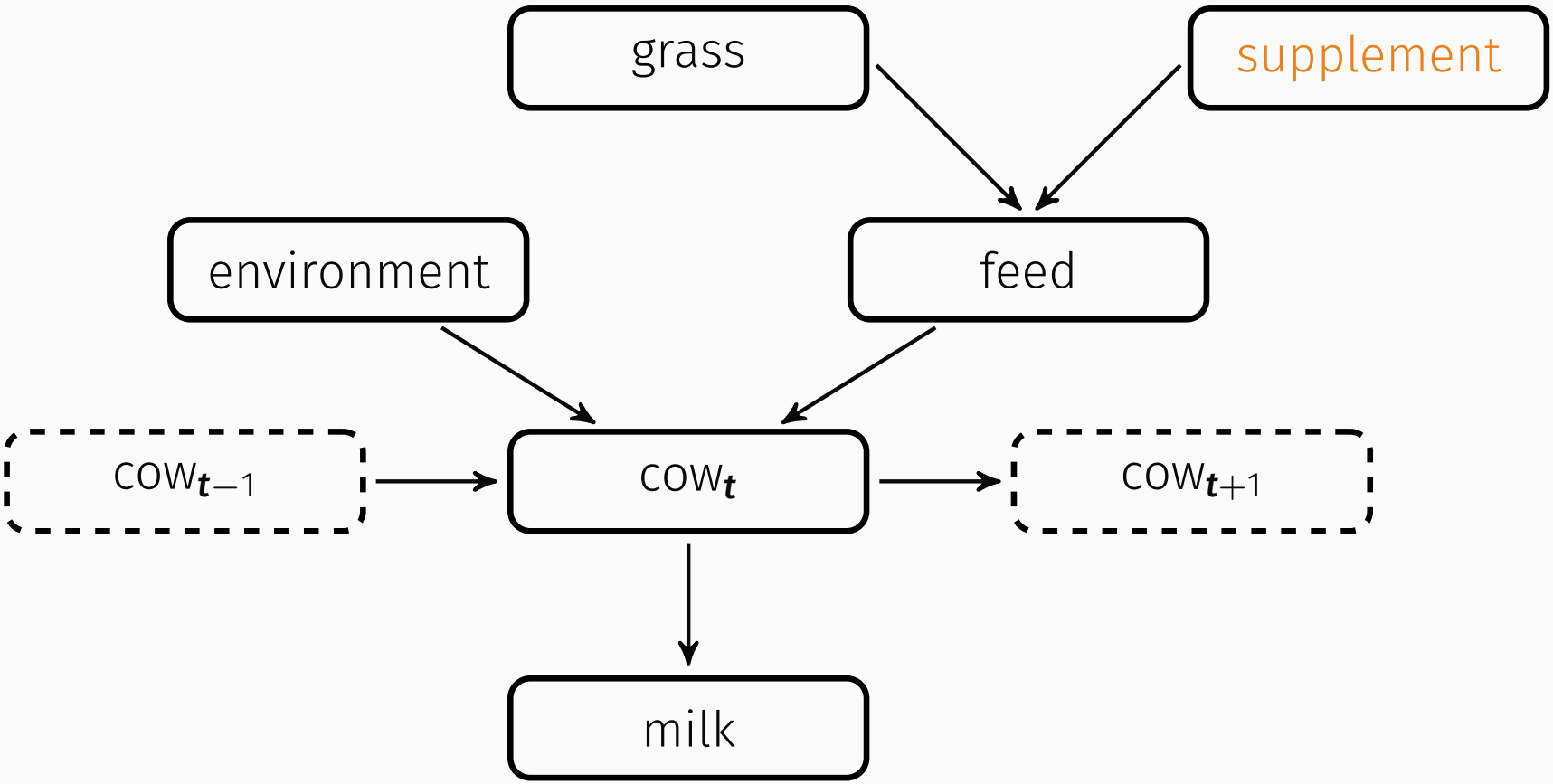

THE BASIC MODEL

General form of the model

Let s_t = kg supplement fed in week t

Let x_t = be the state of the cow at the start of week t

Let m_t = be the quantity of milk produced in week t

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\begin{aligned}
\textbf{max} \quad & \sum_{t=1}^{52} a_t \times m_t - b_t \times s_t & \\
x_{t+1} &= f(x_t, s_t) & \forall t = 1, 2 \ldots 52 \\
m_t &= g(x_t, s_t) & \forall t = 1, 2 \ldots 52 \\
x_1 &= k_1 & \\
x_{53} &\geq k_2 &
\end{aligned}
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1. Mixed Integer Linear Program

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2. Linear Relaxation

SOLUTION METHODS

1. Mixed Integer Linear Program
2. Linear Relaxation
3. Dynamic Program

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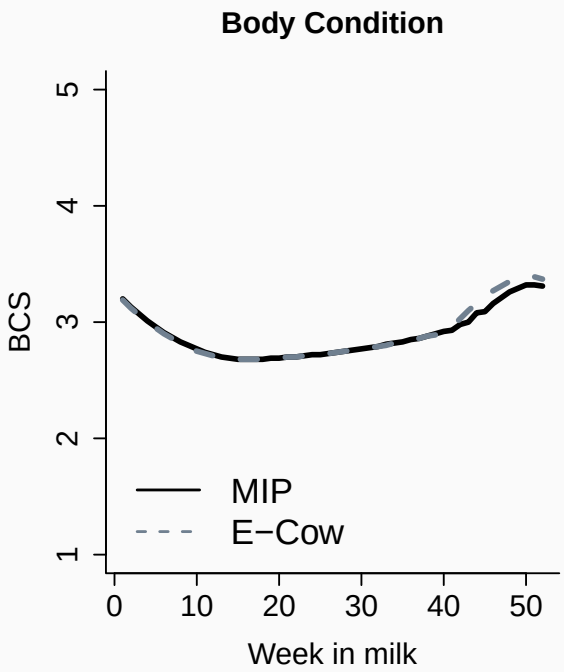
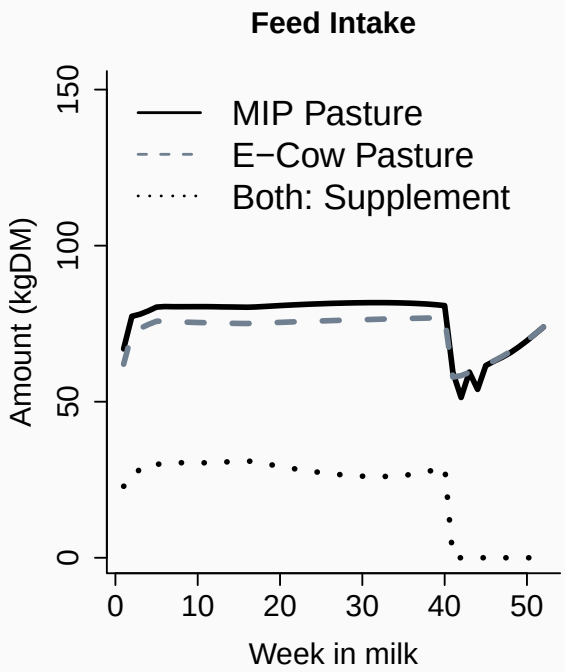
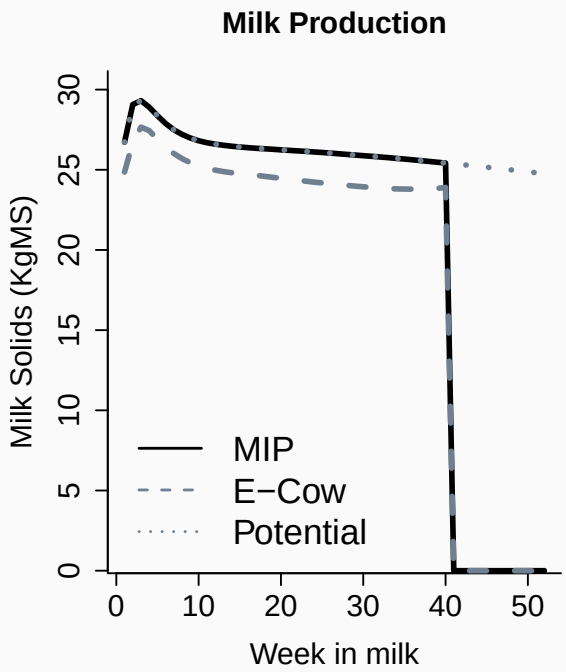
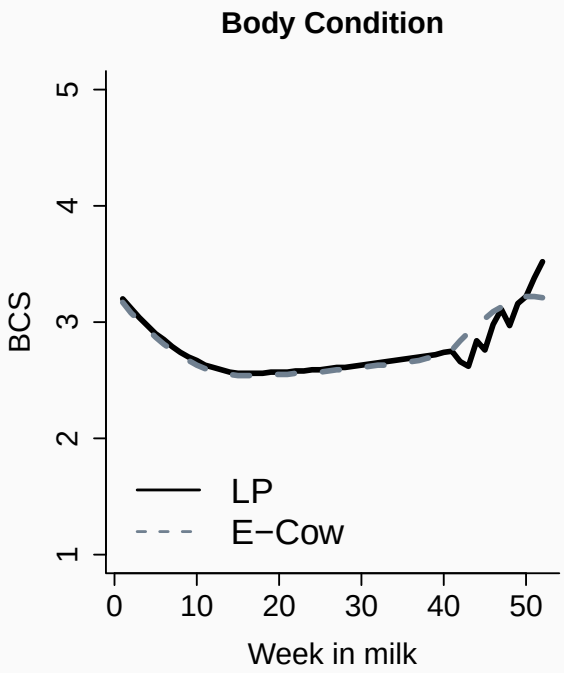
MIP RESULTS

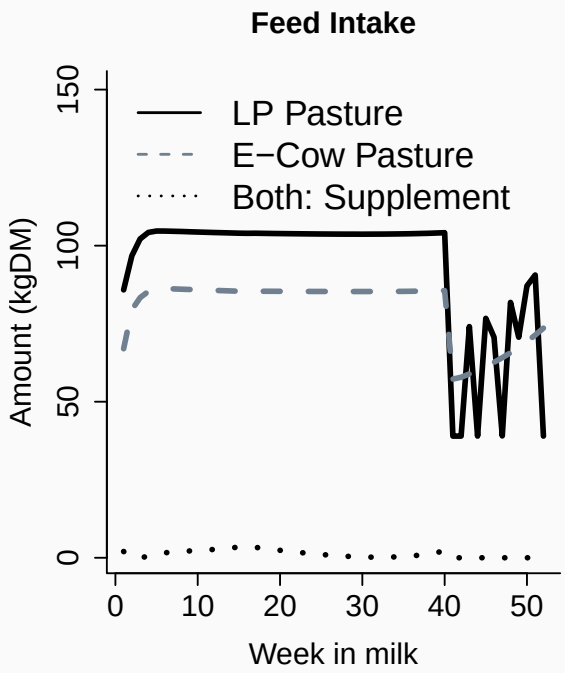

Body Condition
BCS
1
2
3
4
5
0
10
20
30
40
50
Week in milk
MIP
E−Cow

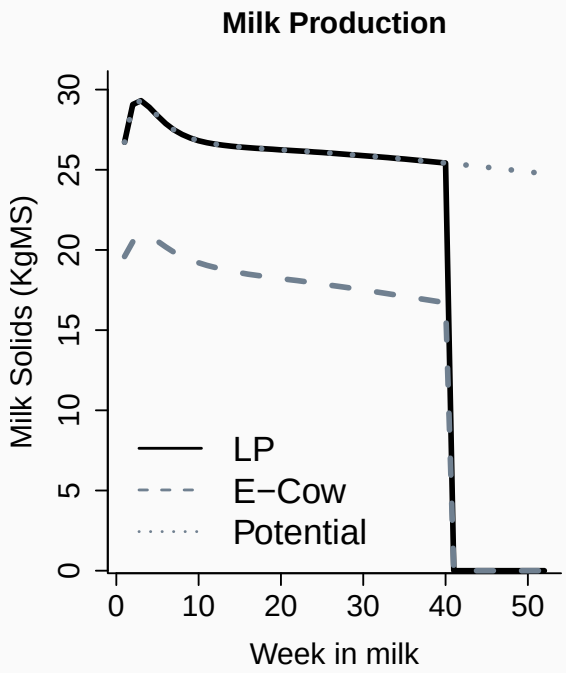

Feed Intake
Amount (kgDM)
0
50
100
150
0
10
20
30
40
50
Week in milk
MIP Pasture
E−Cow Pasture
Both: Supplement


Milk Production
Milk Solids (KgMS)
0
5
10
15
20
25
30
0
10
20
30
40
50
Week in milk
MIP
E−Cow
Potential

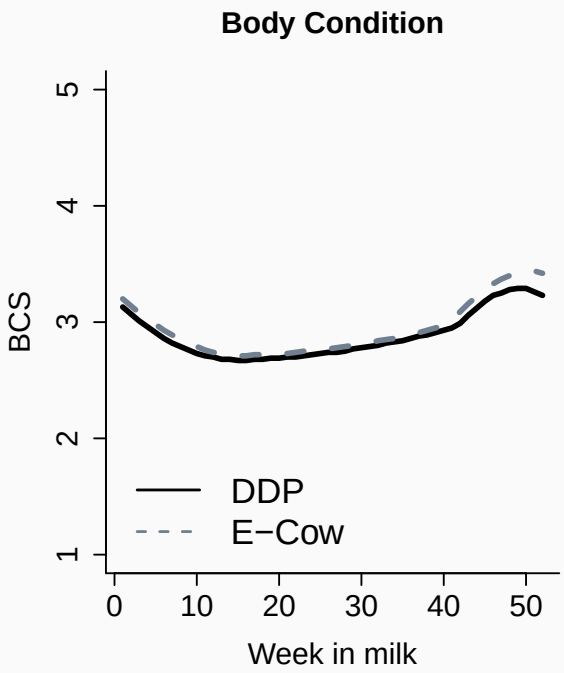
LP RELAXATION RESULTS

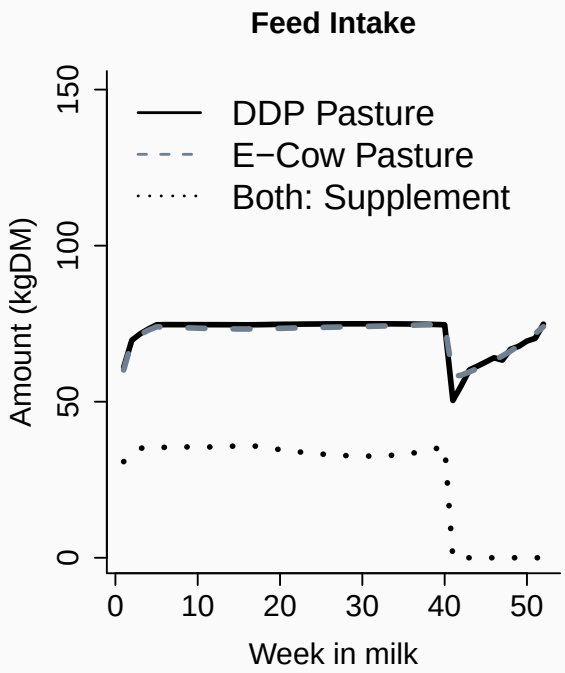


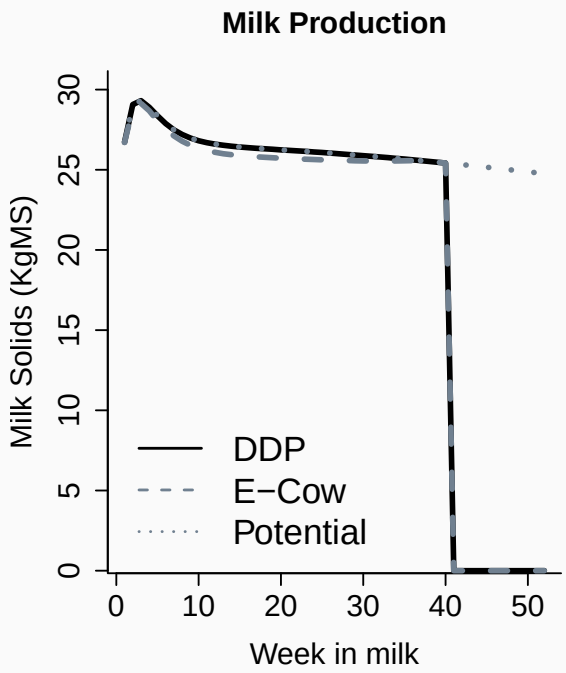




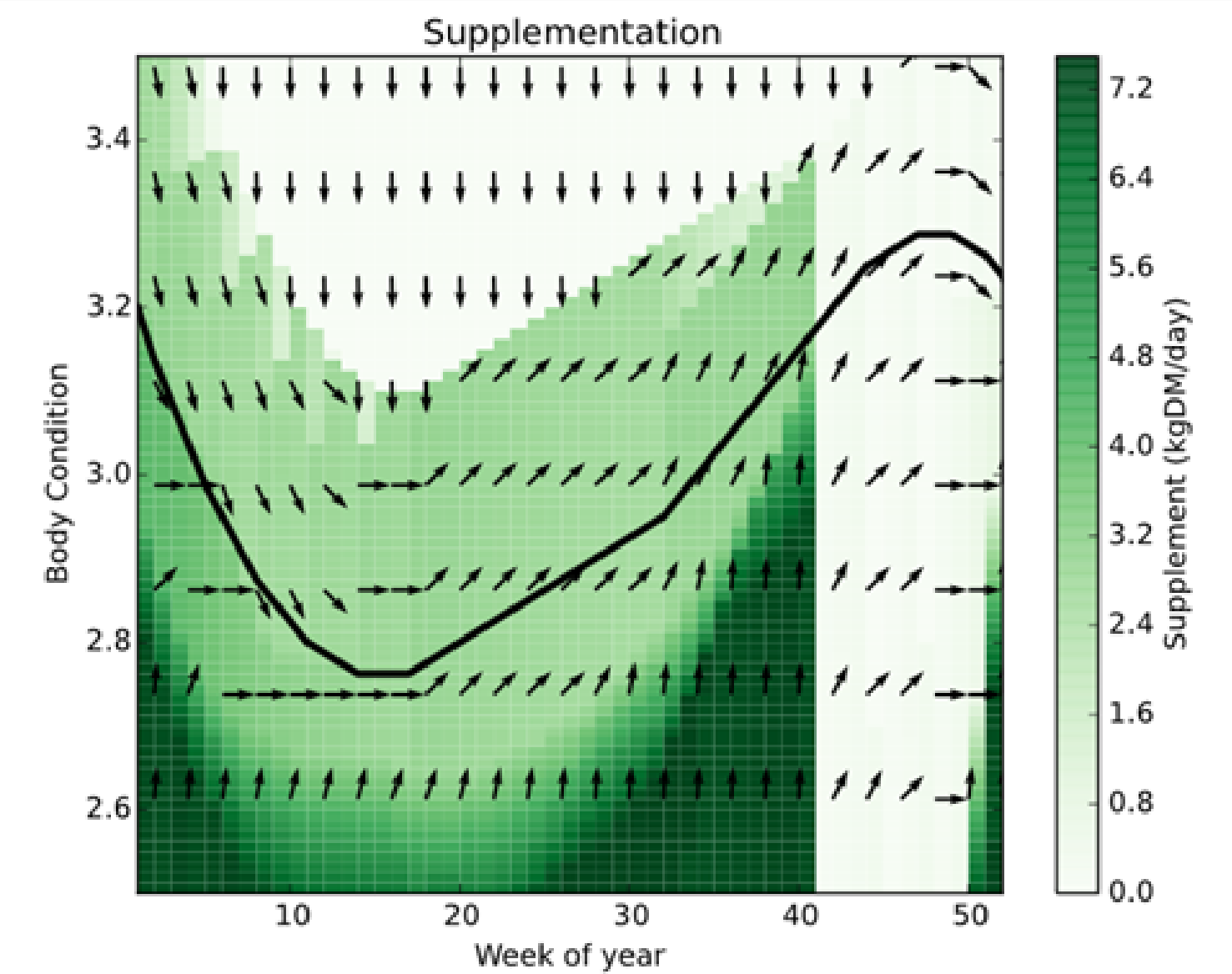
DDP RESULTS


Body Condition
BCS
1
2
3
4
5
0
10
20
30
40
50
Week in milk
DDP
E−Cow


Feed Intake
Amount (kgDM)
0
50
100
150
0
10
20
30
40
50
Week in milk
DDP Pasture
E−Cow Pasture
Both: Supplement


Milk Production
Milk Solids (KgMS)
0
5
10
15
20
25
30
0
10
20
30
40
50
Week in milk
DDP
E−Cow
Potential

DP RESULTS


Supplementation
Body Condition
3.4
3.2
3.0
2.8
2.6
10
20
30
40
50
Week of year
7.2
6.4
5.6
4.8
4.0
3.2
2.4
1.6
0.8
0.0
Supplement (kgDM/day)

A ***BRIEF*** INTRODUCTION TO JULIA

What is Julia?

What is Julia?

A language for technical computing

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High-level, high-performance, dynamic

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Free, and open-source

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High-level, high-performance, dynamic

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Can get within a factor of 2 of pure C

What is JuMP?

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An algebraic modelling language. Think AMPL.

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Lots of supported solvers
Gurobi, CPLEX, Cbc, GLPK, NLopt, Ipopt + more

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http://www.juliaopt.org/
https://github.com/JuliaOpt/

A SIMPLE JUMP MODEL

```
using JuMP, Gurobi

m = Model(solver=GurobiSolver())
# To use CPLEX specify CPLEXSolver() instead

@defVar(m, x>=0, Int)

@setObjective(m, :Min, x)

@addConstraint(m, x>=1)

solve(m)
```

DAIRYANALYTICS.CO.NZ

WHAT IS IT?

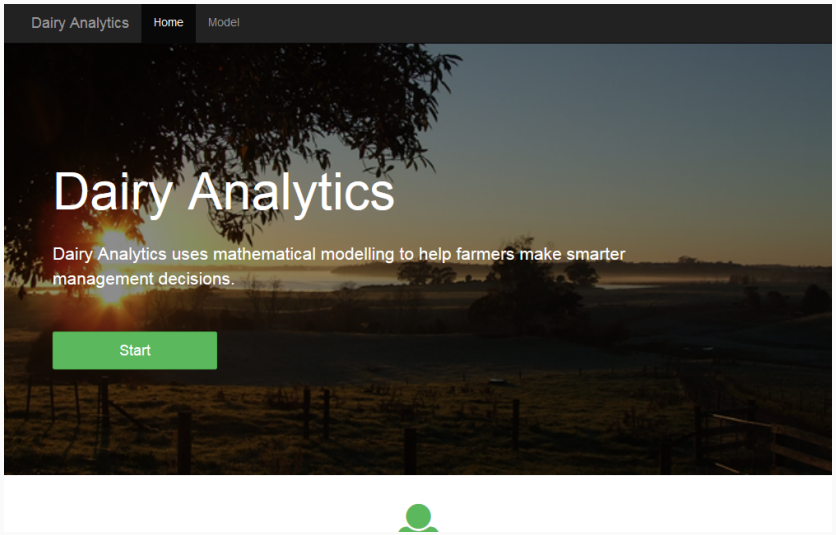
A web-interface for our models.

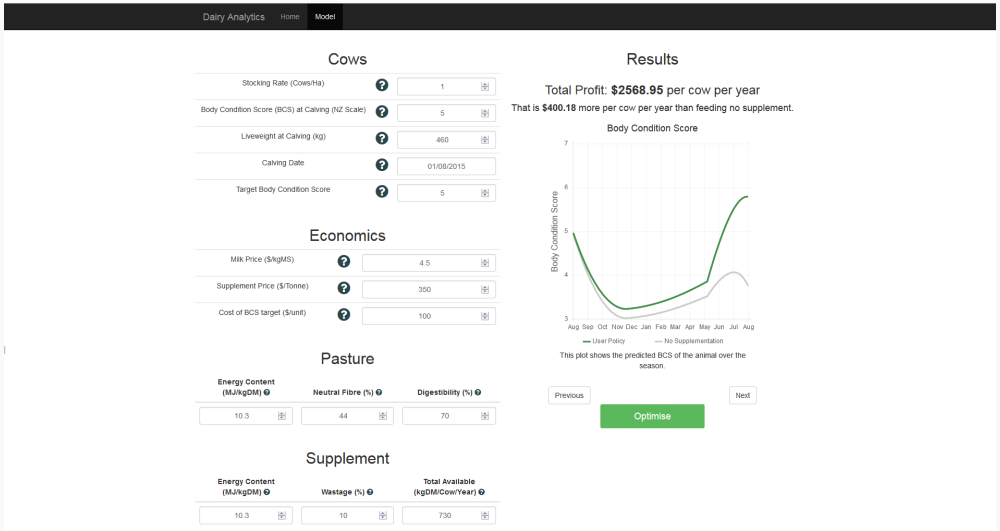
Written in pure Julia

Hosted on AWS

Simple Non-linear optimiser

WHAT IS IT?


Dairy Analytics
Home
Model
Dairy Analytics
Dairy Analytics uses mathematical modelling to help farmers make smarter management decisions.
Start


Dairy Analytics
Home
Model
Cows
Stocking Rate (Cows/Ha)
1
Body Condition Score (BCS) at Calving (NZ Scale)
5
Liveweight at Calving (kg)
460
Calving Date
01/08/2015
Target Body Condition Score
5
Economics
Milk Price ($/kgMS)
4.5
Supplement Price ($/Tonne)
350
Cost of BCS target ($/unit)
100
Pasture
Energy Content (MJ/kgDM)
Neutral Fibre (%)
Digestibility (%)
10.3
44
70
Supplement
Energy Content (MJ/kgDM)
Wastage (%)
Total Available (kgDM/Cow/Year)
10.3
10
730
Results
Total Profit: $2568.95 per cow per year
That is $400.18 more per cow per year than feeding no supplement.
Body Condition Score
Body Condition Score
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
User Policy
No Supplementation
This plot shows the predicted BCS of the animal over the season.
Previous
Next
Optimise

WRAPPING UP

CONCLUSIONS

1. We can optimise existing animal models

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2. We can provide decision support for farmers

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3. We have a web interface to interact with our models

1. We can optimise existing animal models
2. We can provide decision support for farmers
3. We have a web interface to interact with our models
4. There is much work to be done

FUTURE WORK

1. Stochasticity

1. Stochasticity
2. Binary Milking Decisions

1. Stochasticity
2. Binary Milking Decisions
3. Multi-animal

1. Stochasticity
2. Binary Milking Decisions
3. Multi-animal
4. Validation/parameter tuning

THE MOST IMPORTANT THING

THE MOST IMPORTANT THING

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Questions?