MOO: THE MILK OUTPUT OPTIMISER

A management tool for New Zealand dairy farmers

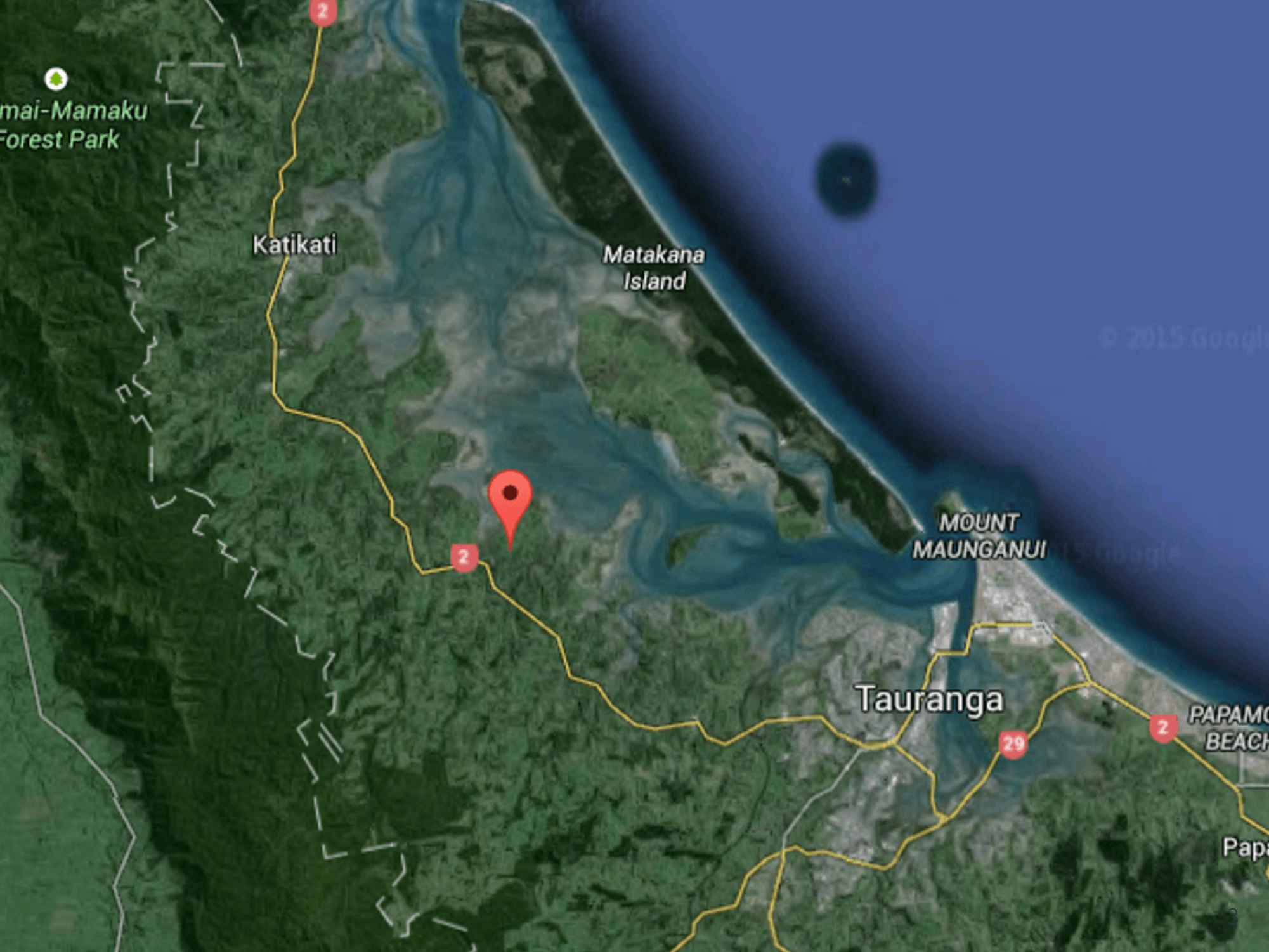
Oscar Dowson

20 August 2015

University of Auckland

WHY DO I CARE?


Tasman Sea
New
Zealand


mai-Mamaku
Forest Park
Katikati
Matakana
Island
MOUNT
MAUNGANUI
Tauranga
2
29
2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© 2015 Google
Google earth

WHY SHOULD YOU CARE?

20.5b

litres of milk

20.5b

litres of milk

Enough milk to cover campus to a depth of 35 metres!

20.5b

litres of milk

Enough milk to cover campus to a depth of 35 metres!

Or fill 8200 swimming pools

95%

exported

1/4

export goods by value

1/45

export goods by value

1/3

of global dairy exports

New Zealand Germany

	New Zealand	Germany
Production (10^9L)	20.5	30

THE GERMAN DAIRY INDUSTRY

	New Zealand	Germany
Production (10^9L)	20.5	30
Cows (10^6)	5	4

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1 German cow produces the same as 1.8 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

“RESEARCH” IN SWITZERLAND


GR 50684

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

Evolved over a number of years

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

e-Cow

Baudracco et al., 2011

Sensitive to Genetic and Environmental interactions

A MATHEMATICAL COW

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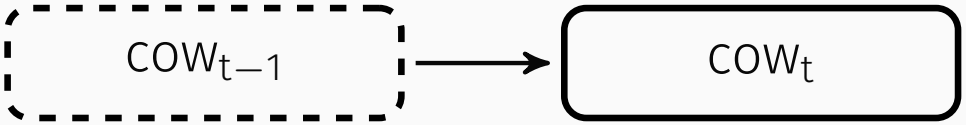

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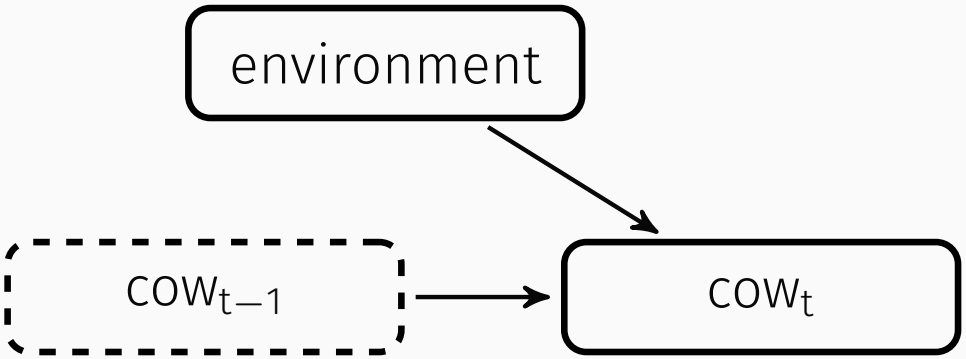

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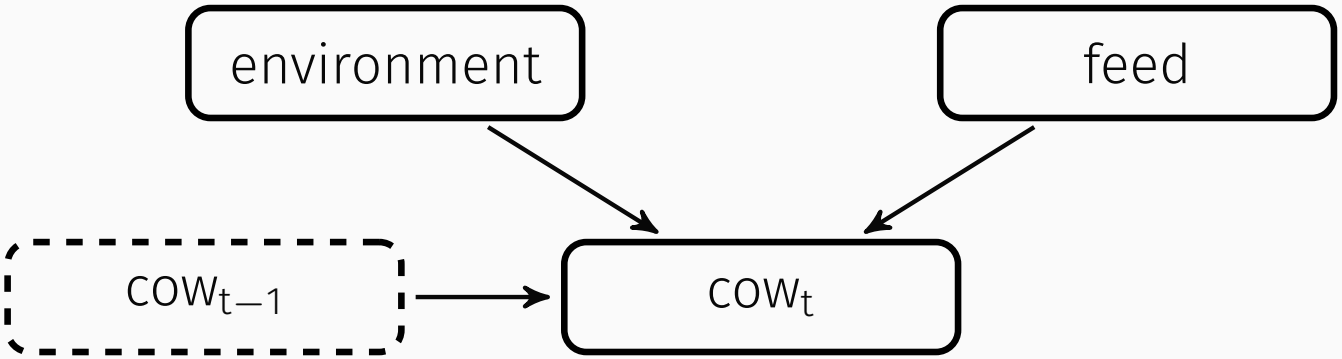

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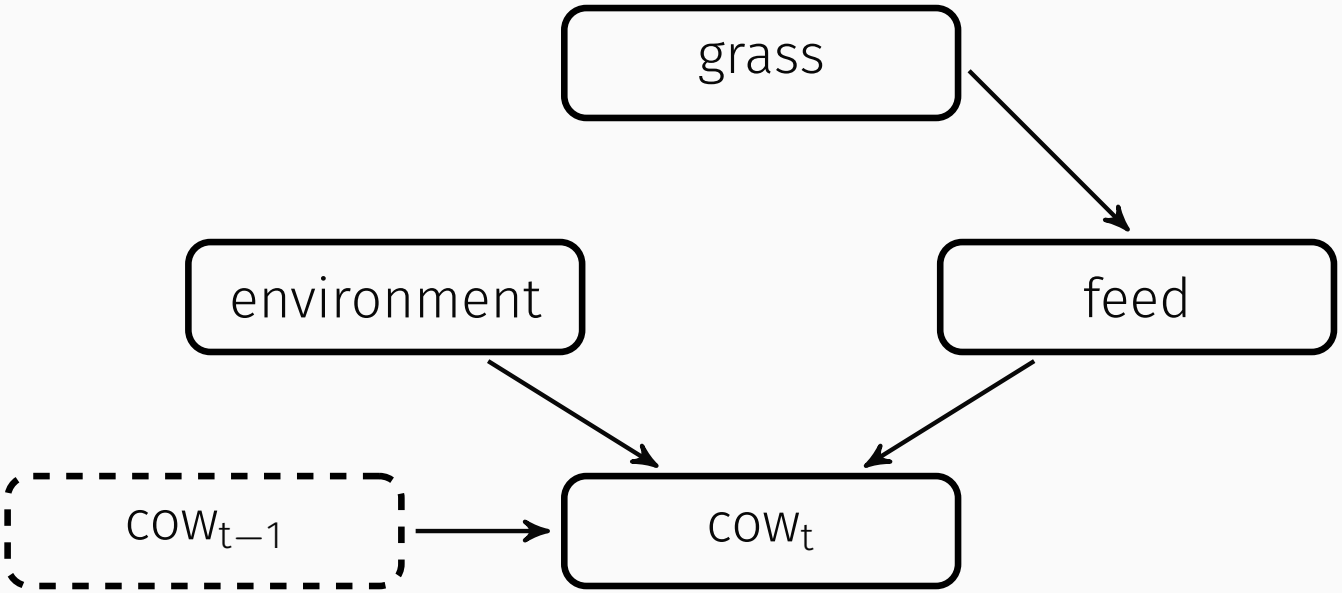

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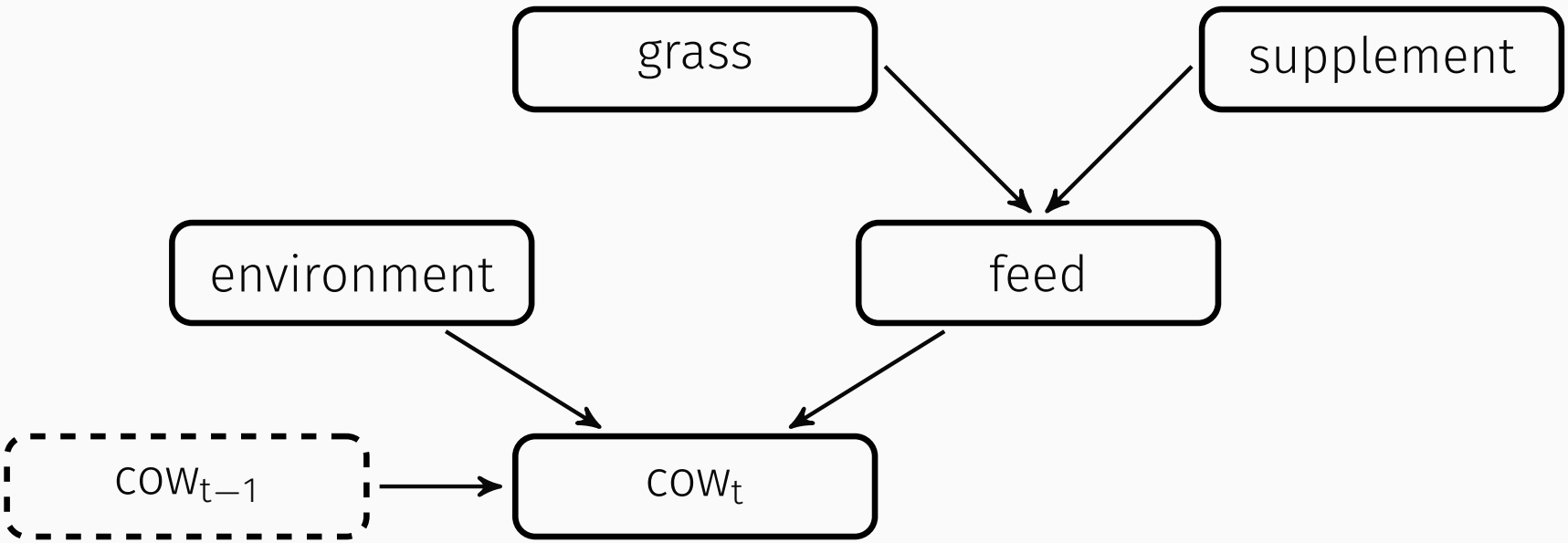

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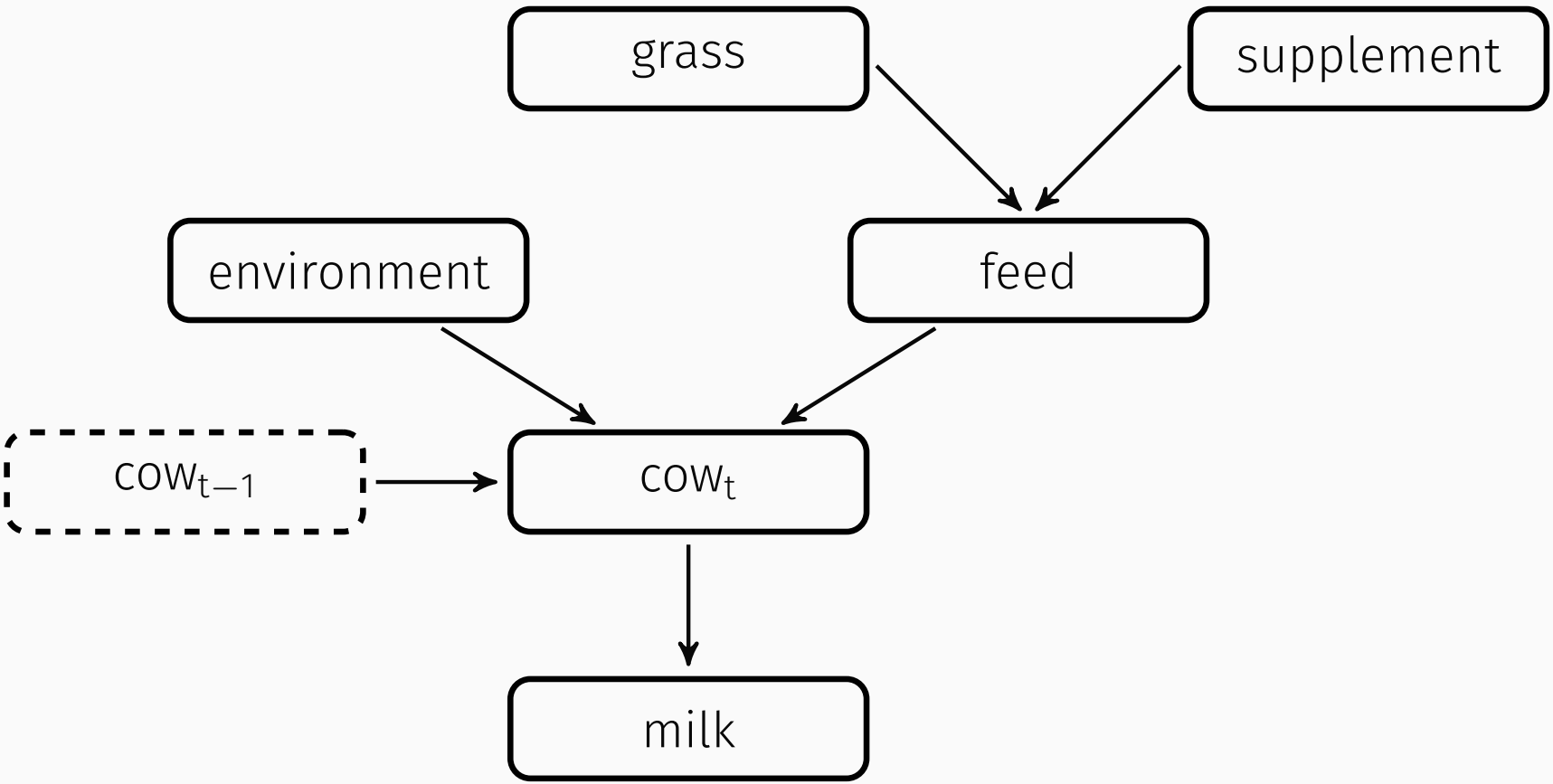

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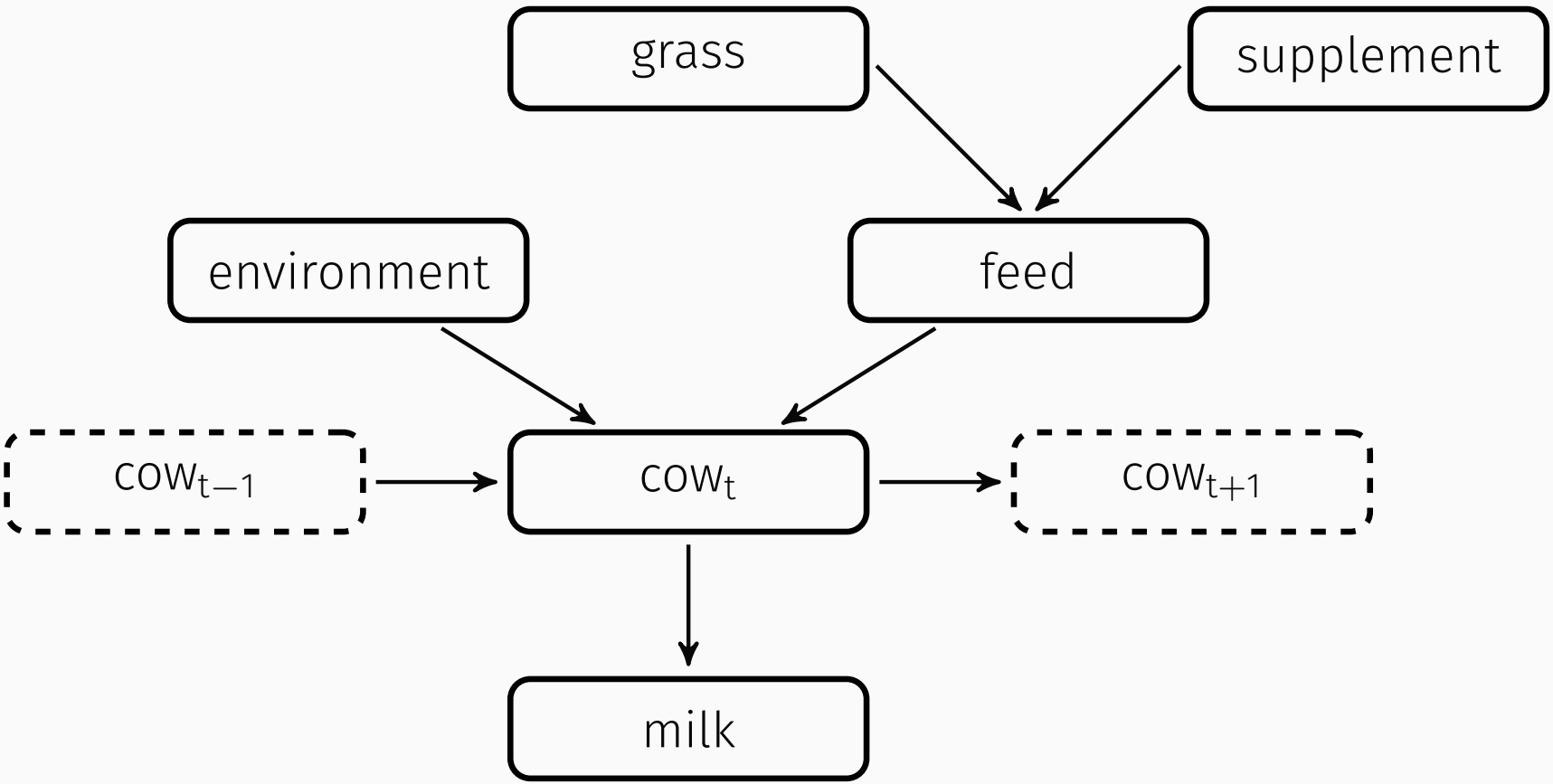

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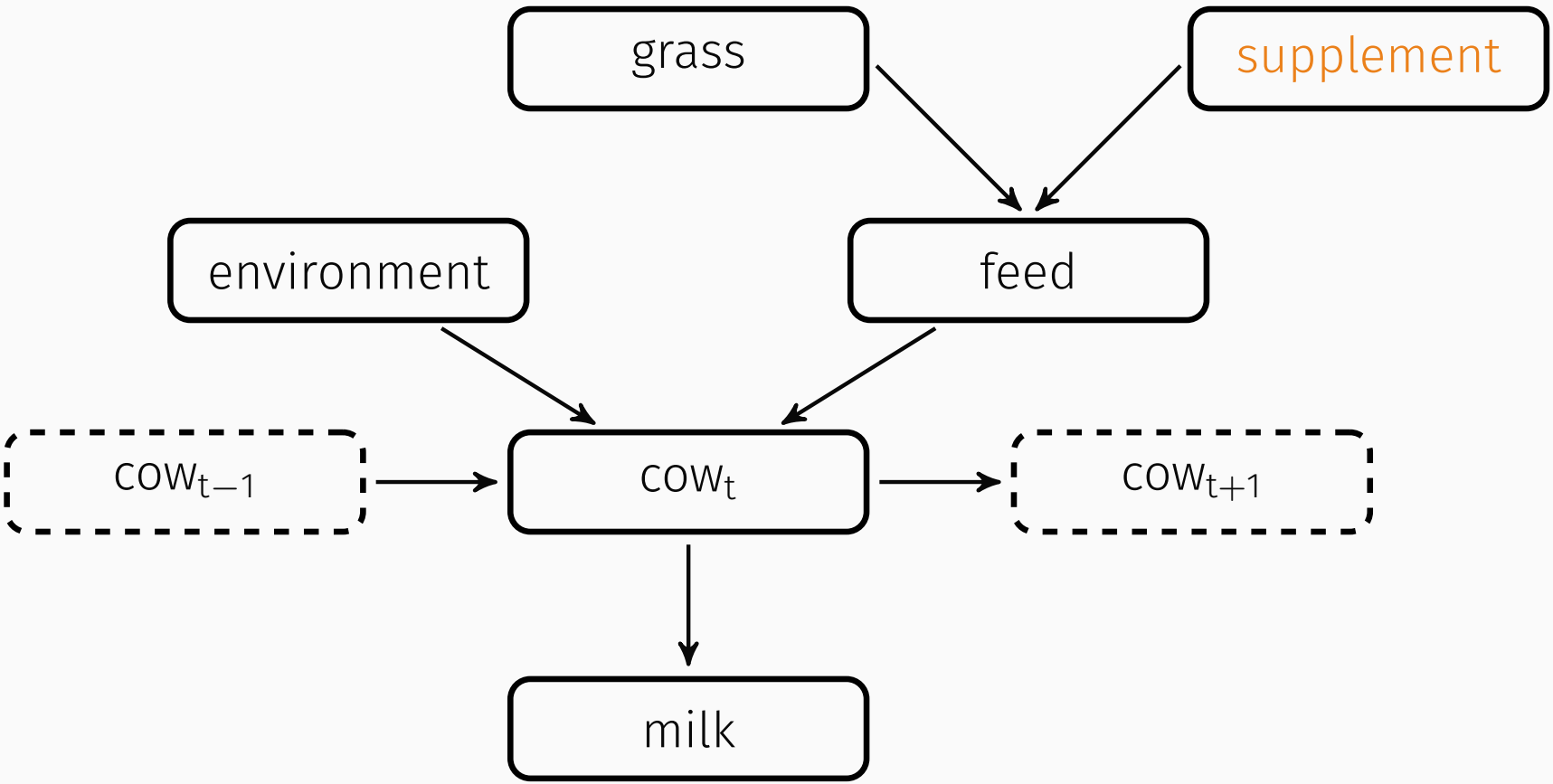

THE BASIC MODEL

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}
\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

SOLUTION METHODS

1. Mixed Integer Linear Program
2. Linear Relaxation

SOLUTION METHODS

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3. Dynamic Program

SOLUTION METHODS

1. Mixed Integer Linear Program
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4. Dual Dynamic Program

SOLUTION METHODS

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5. Non-linear solver

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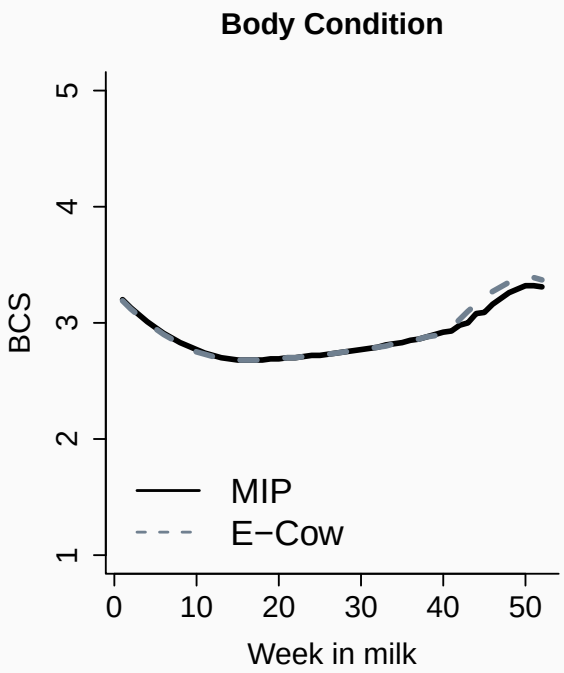
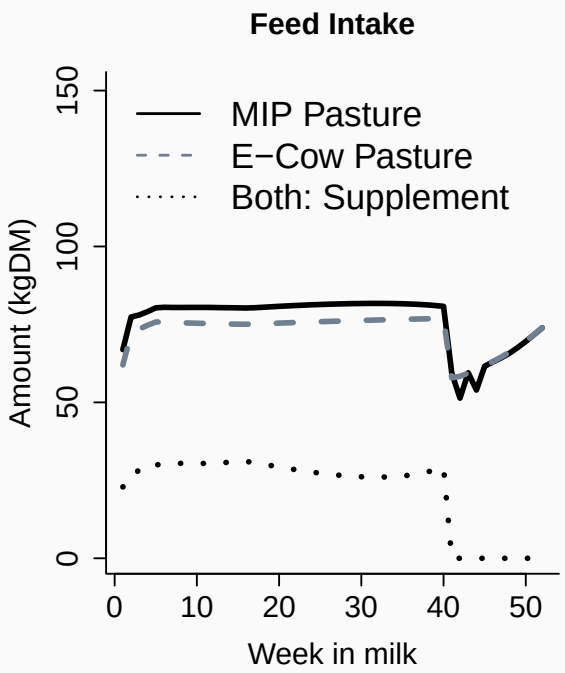
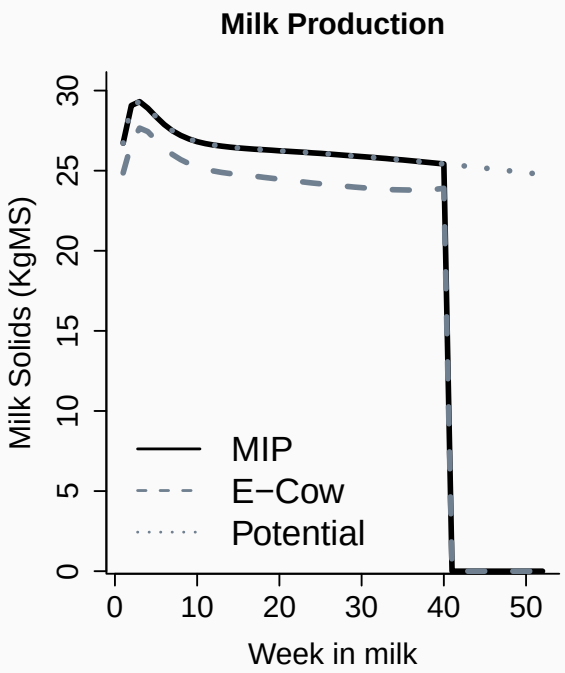
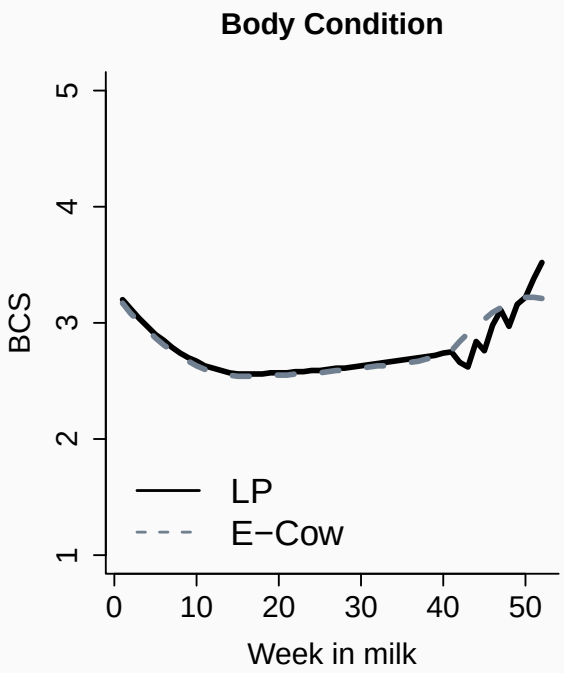
MIP RESULTS

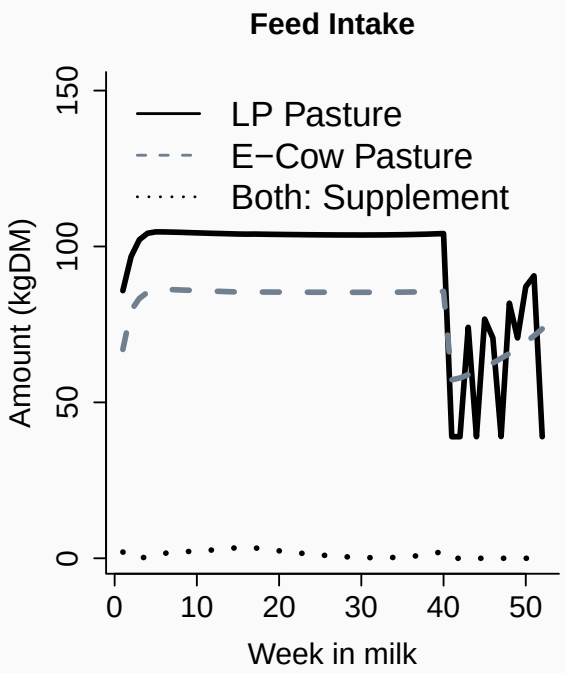

Body Condition
BCS
1
2
3
4
5
0
10
20
30
40
50
Week in milk
MIP
E−Cow

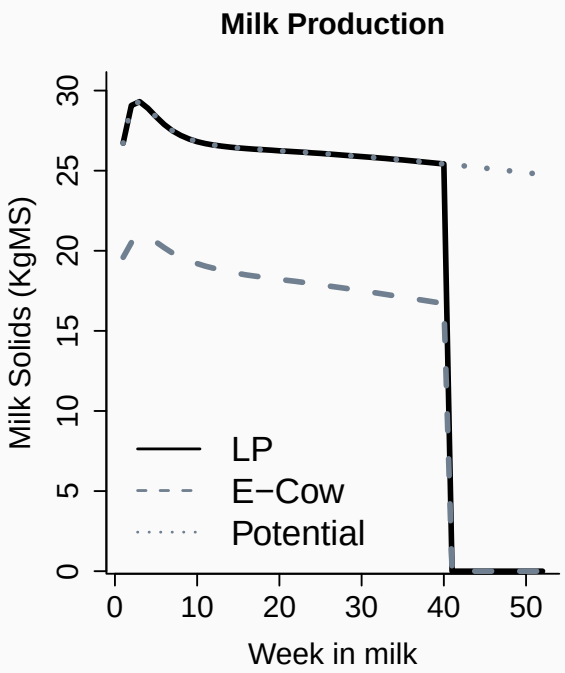

Feed Intake
Amount (kgDM)
0
50
100
150
0
10
20
30
40
50
Week in milk
MIP Pasture
E−Cow Pasture
Both: Supplement


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

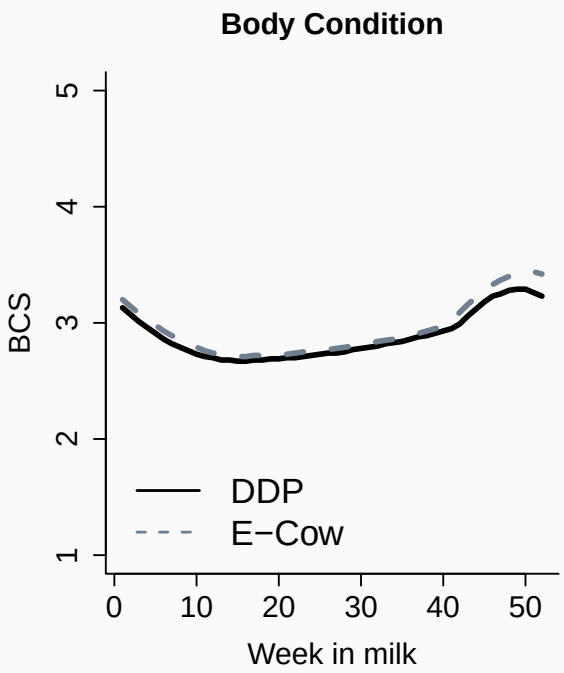
LP RELAXATION RESULTS

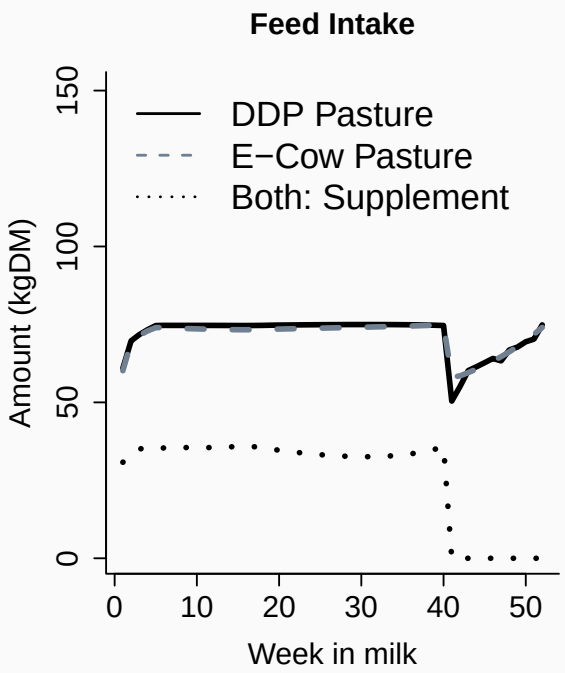


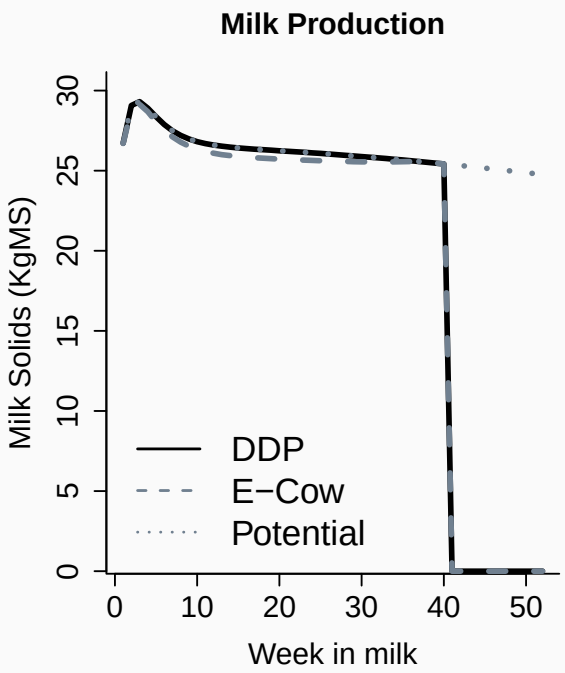




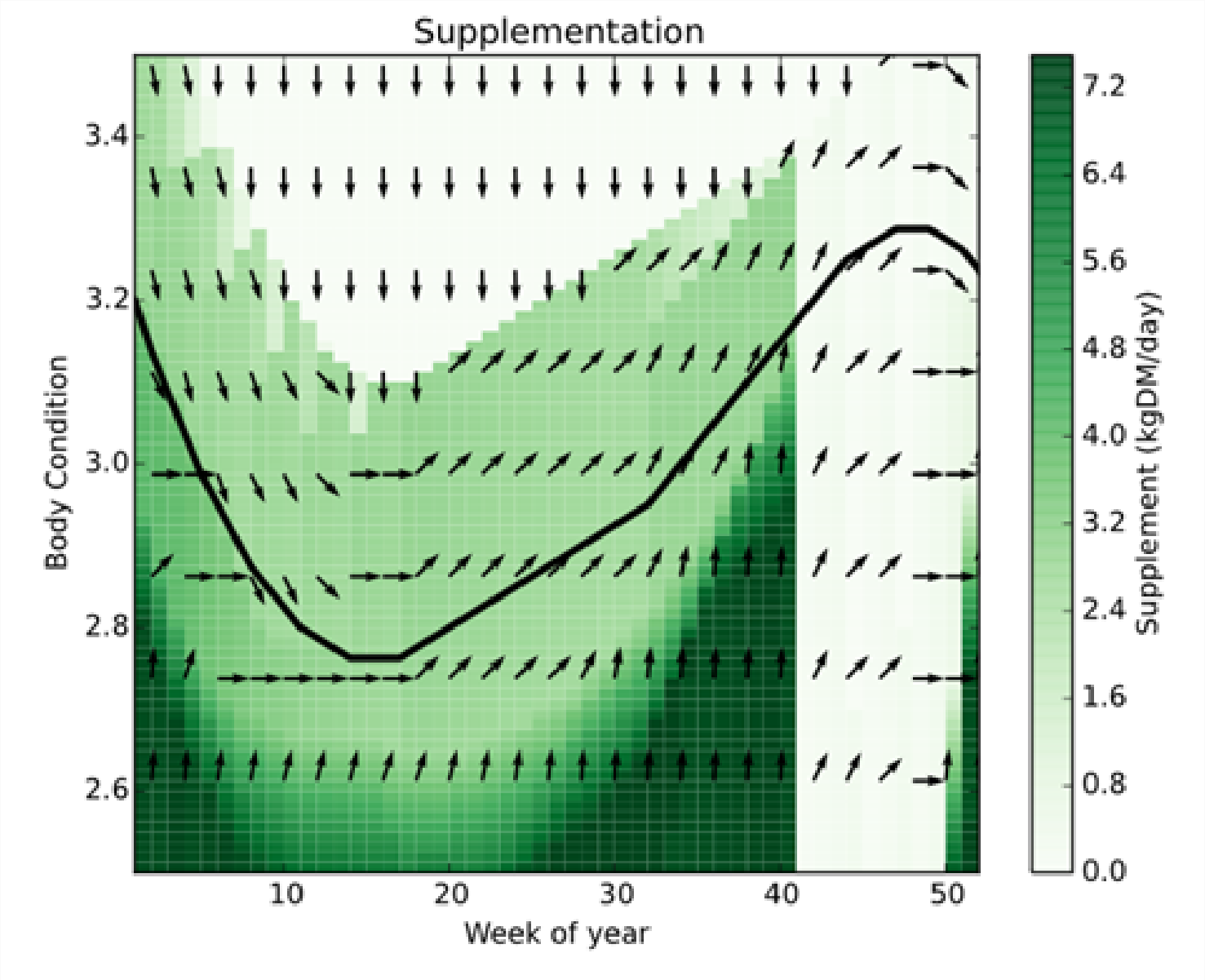
DDP RESULTS


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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A language for technical computing

High-level, high-performance, dynamic

Free, and open-source

What is Julia?

A language for technical computing

High-level, high-performance, dynamic

Free, and open-source

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?

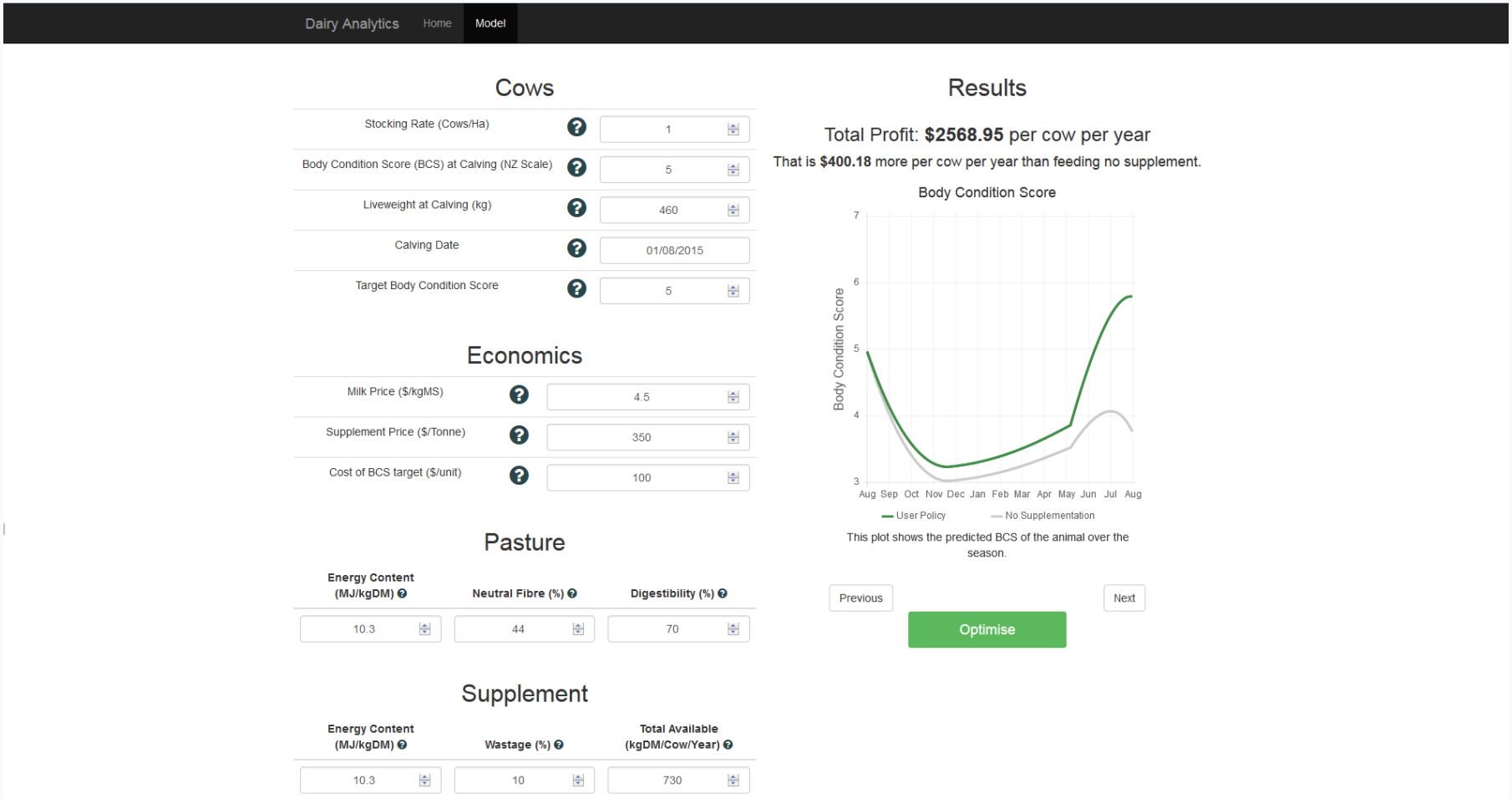
A web-interface for our models.

Written in pure Julia

Hosted on AWS

Simple Non-linear optimiser

WHAT IS IT?


Dairy Analytics
Home
Model
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
7
6
5
4
3
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 (SORT OF)

CONCLUSIONS

1. We can optimise existing animal models

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2. We can provide decision support for farmers

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2. We can provide decision support for farmers
3. We have a web interface to interact with our models

CONCLUSIONS

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

STOCHASTICITY

STOCHASTICITY

The weather isn't deterministic

STOCHASTICITY

The weather isn't deterministic

Neither is the milk price

STOCHASTICITY

The weather isn't deterministic
Neither is the milk price
Or the spot price of feed

STOCHASTICITY

The weather isn't deterministic
Neither is the milk price
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Question

The weather isn't deterministic
Neither is the milk price
Or the spot price of feed

Question

Expectation? Or Risk-Averse

CONTRACTS

A contract market exists for buying supplement

CONTRACTS

A contract market exists for buying supplement
Storage constraints, Capital constraints, Competitors

A contract market exists for buying supplement
Storage constraints, Capital constraints, Competitors

Question

A contract market exists for buying supplement
Storage constraints, Capital constraints, Competitors

Question

How much supplement should I order at the start of the year?

THE “RULE OF THUMB” PROBLEM

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You have a cow

THE “RULE OF THUMB” PROBLEM

You have a cow

It begins in a milking state

THE “RULE OF THUMB” PROBLEM

You have a cow
It begins in a milking state
You can turn it off once

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Usually based on food quantity, cow condition, farmer tiredness

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Question

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It begins in a milking state
You can turn it off once
Usually based on food quantity, cow condition, farmer tiredness

Question

How do you choose a simple “Rule of Thumb”?

THE LAND USE PROBLEM

THE LAND USE PROBLEM

You have a farm (area, location, terrain)

THE LAND USE PROBLEM

You have a farm (area, location, terrain)
It has various paddocks (area, slope, soil type)

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Question

THE LAND USE PROBLEM

You have a farm (area, location, terrain)
It has various paddocks (area, slope, soil type)
You can plant different crops (grass, maize)
Nitrogen leeches into rivers/lakes = BAD

Question

How do you use your land to maximise milking profit whilst minimizing Nitrogen leeching?

THE MOST IMPORTANT THING

THE MOST IMPORTANT THING

THE MOST IMPORTANT THING

Questions?