MOO: THE MILK OUTPUT OPTIMISER

A management tool for New Zealand dairy farmers
or
How to milk your cash cow

Oscar Dowson

October 1, 2015

University of Auckland

WHY DO I CARE?

I never saw a Purple Cow,

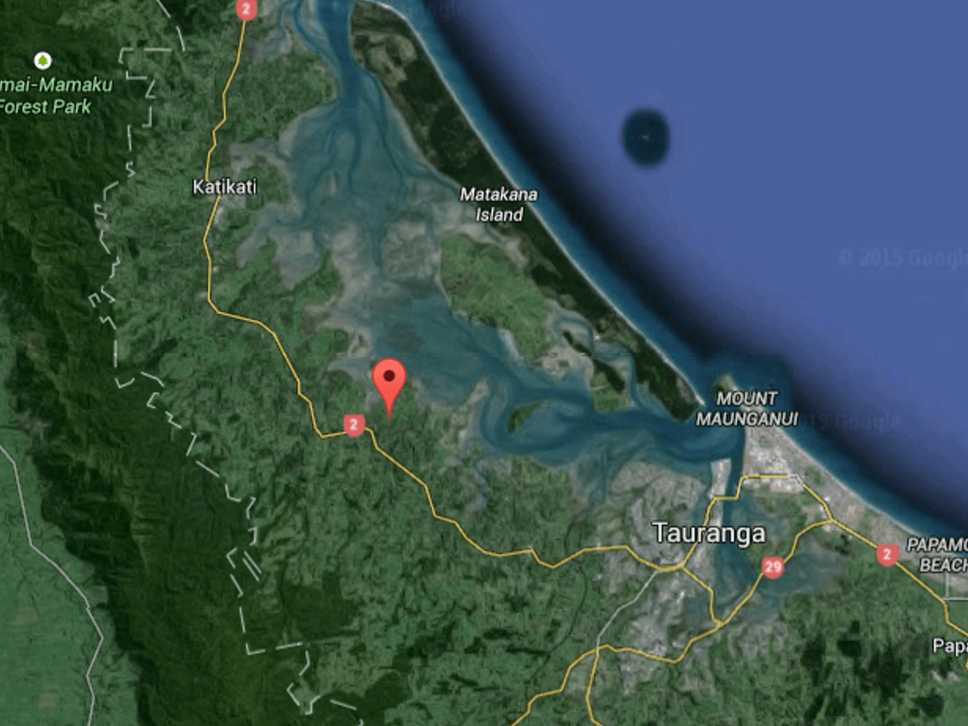
I never hope to see one,

But I can tell you, anyhow,

I'd rather see than be one!

- *Gelett Burgess*


Tasman Sea
New Zealand


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

WHY SHOULD YOU CARE?

20.5b

litres of milk

20.5b

litres of milk

Or fill 8200 swimming pools

95%

exported

1/4

export goods by value

$^{1}/_{4\!\!\!\!-\,5}$

export goods by value

1/3

of global dairy exports

	New Zealand	Germany

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Production (10^9L)	20.5	30

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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 DENMARK

“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

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e-Cow

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Sensitive to Genetic and Environmental interactions

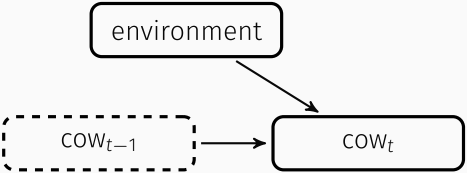
A MATHEMATICAL COW

$\boxed{\mathrm{COW}_t}$

A MATHEMATICAL COW

$$\boxed{\text{COW}_{t-1}} \longrightarrow \boxed{\text{COW}_t}$$

A MATHEMATICAL COW



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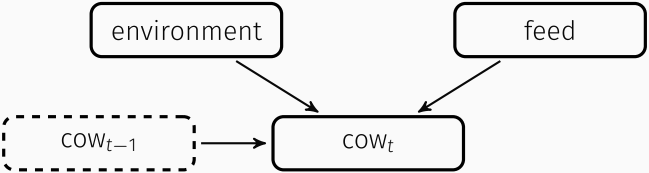

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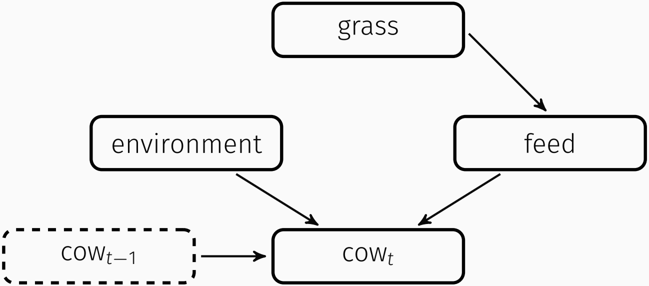

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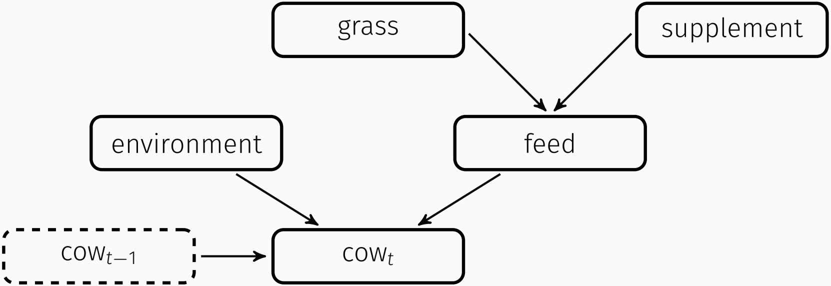

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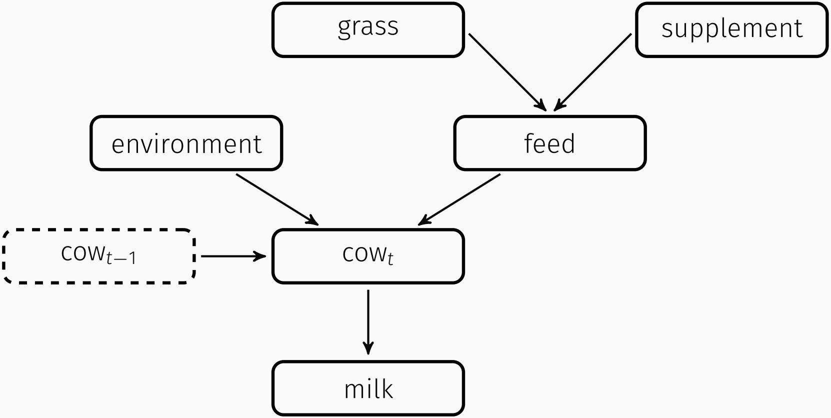

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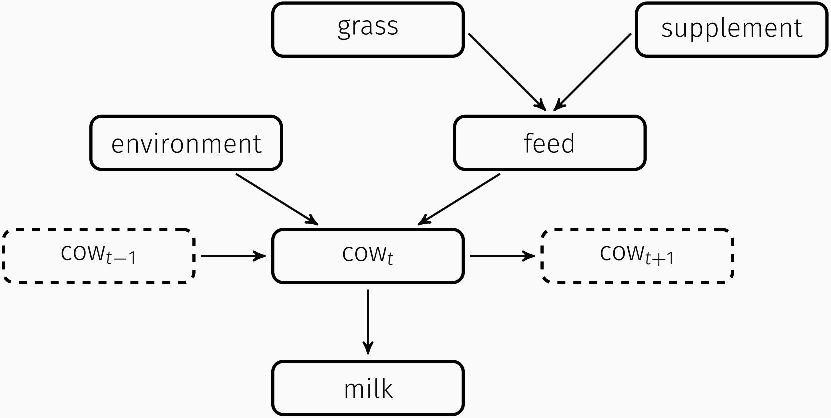

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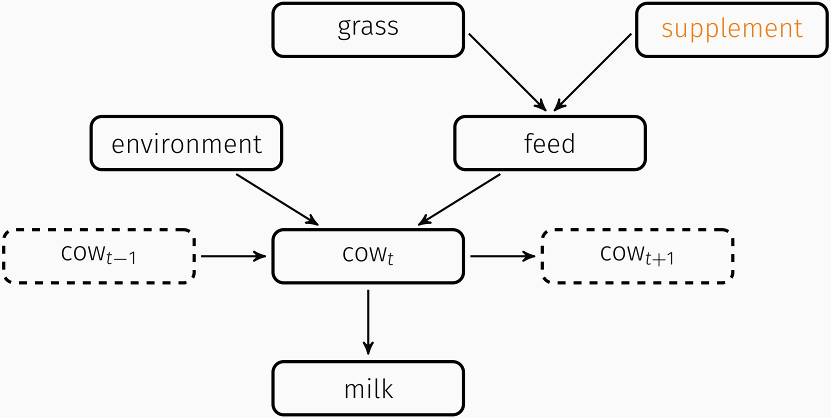

THE BASIC MODEL

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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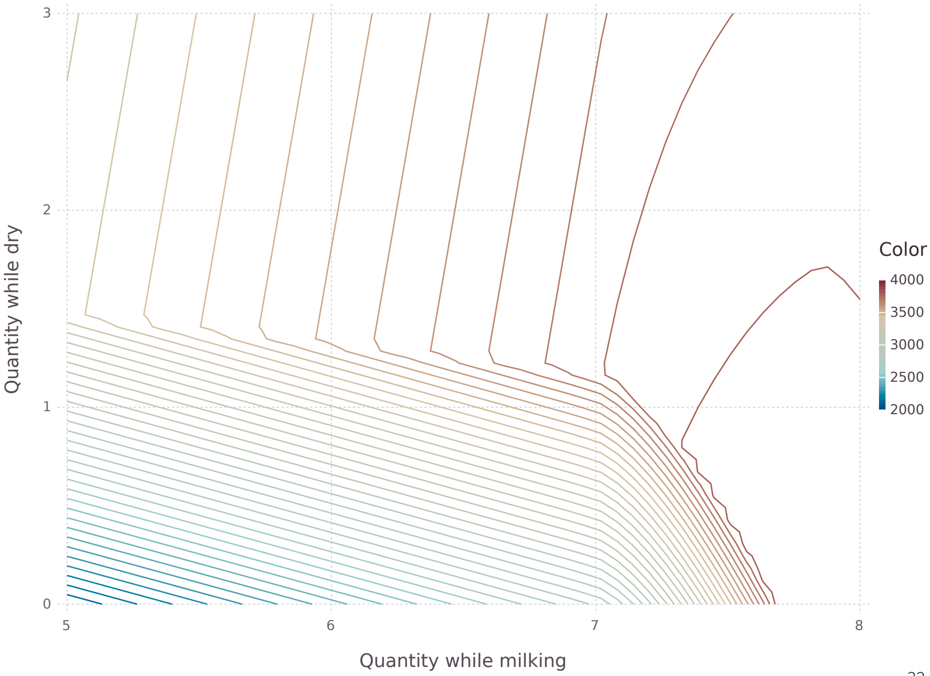
A NON-LINEAR APPROACH


Quantity while dry
Quantity while milking
0
1
2
3
5
6
7
8
Color
4000
3500
3000
2500
2000

A DYNAMIC PROGRAMMING APPROACH

Pros

Pros

1. Every state everywhere

Pros

1. Every state everywhere
2. Global optimum

Pros

1. Every state everywhere
2. Global optimum

Cons

Pros

1. Every state everywhere
2. Global optimum

Cons

1. Slow (maybe)

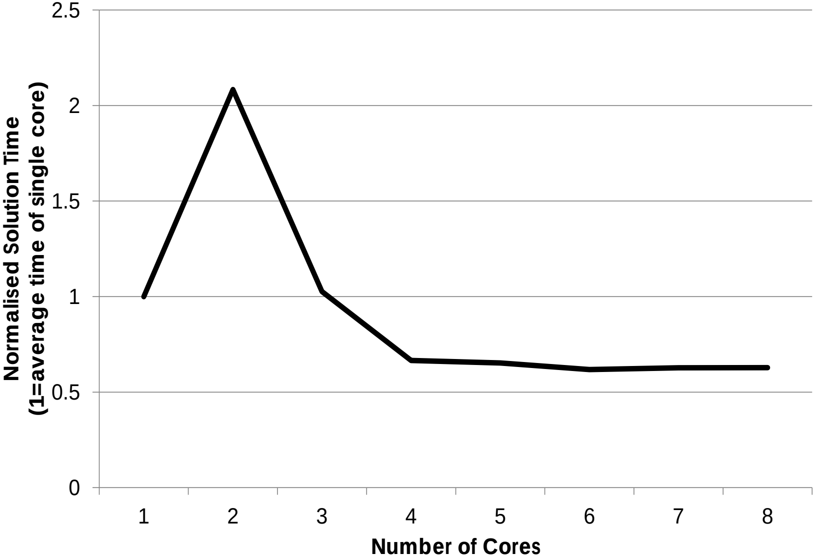
Pros

1. Every state everywhere
2. Global optimum

Cons

1. Slow (maybe)
2. By discretising the state space we introduce interpolation errors

slow (maybe)?



2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
Number of Cores
Normalised Solution Time
(1=average time of single core)

A TWO-PHASE APPROACH

So we have

So we have

1. A fast non-convex NLP

So we have

1. A fast non-convex NLP
2. A DP that solves an approximation

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Proposed Solution Method

So we have

1. A fast non-convex NLP
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Proposed Solution Method

1. Solve the DP with a fine discretisation

So we have

1. A fast non-convex NLP
2. A DP that solves an approximation

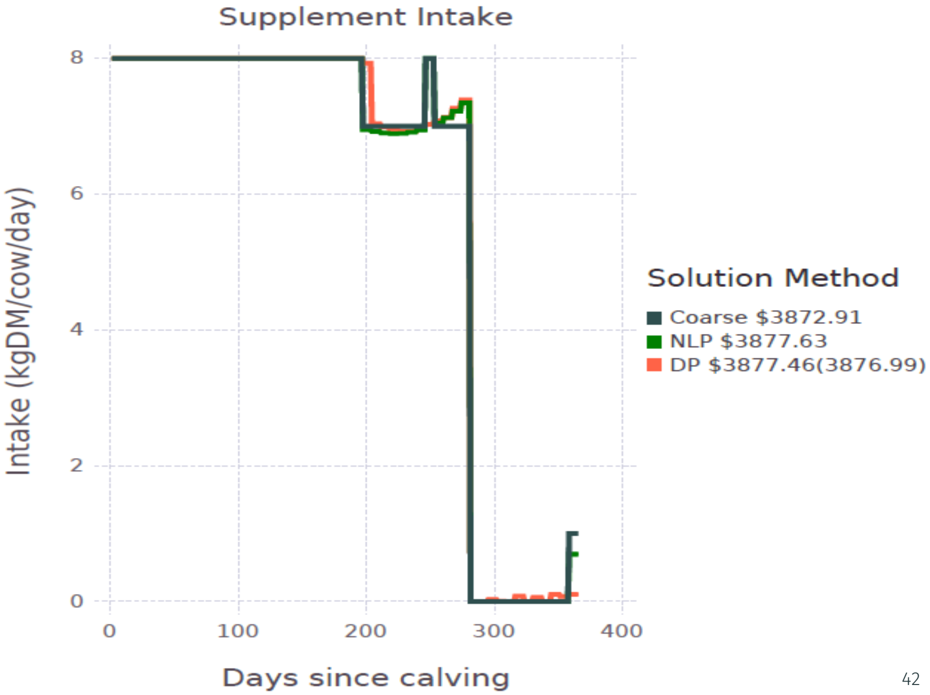
Proposed Solution Method

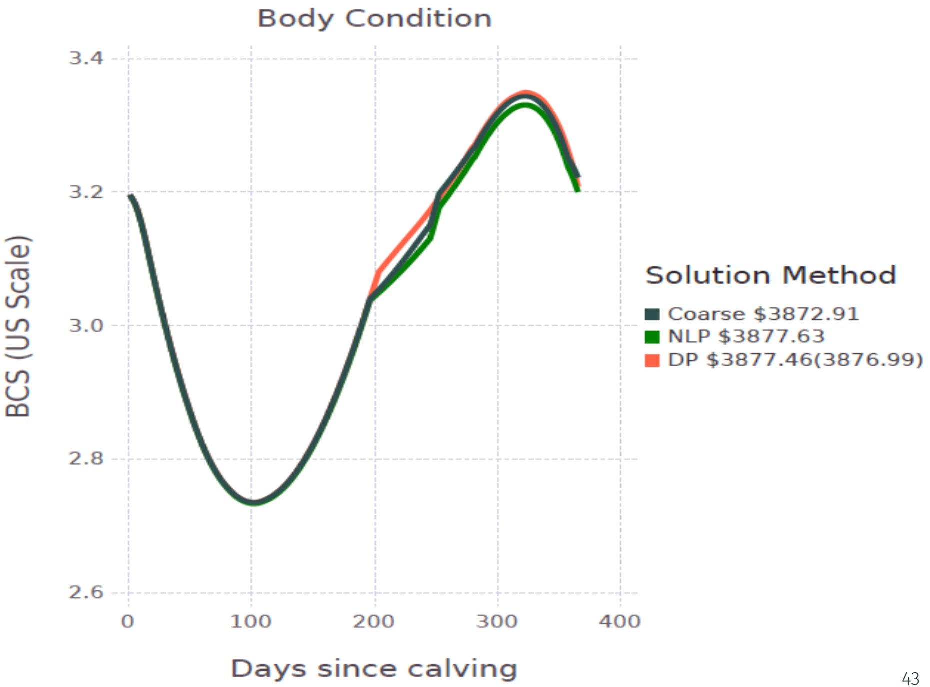
1. Solve the DP with a fine discretisation
2. When you wish to get a policy, use the optimal DP solution as the starting point for the NLP.

BUT WAIT, THERES MORE

Will the policy actually be implemented?

RESULTS


Supplement Intake
Intake (kgDM/cow/day)
8
6
4
2
0
0
100
200
300
400
Days since calving
Solution Method
Coarse $3872.91
NLP $3877.63
DP $3877.46(3876.99)


Body Condition
BCS (US Scale)
3.4
3.2
3.0
2.8
2.6
0
100
200
300
400
Days since calving
Solution Method
Coarse $3872.91
NLP $3877.63
DP $3877.46(3876.99)

IS IT WORTH DOING?

DAIRYANALYTICS.CO.NZ

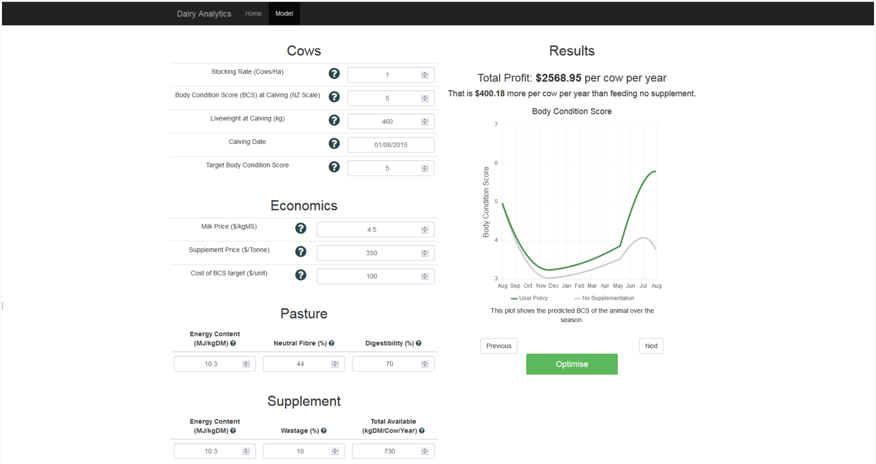
A web-interface for our models.

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
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

WHERE WE ARE HEADED

The weather isn't deterministic

The weather isn’t deterministic
Neither is the milk price

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

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

A contract market exists for buying supplement

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 “DRY OFF” PROBLEM

You have a cow

You have a cow
It begins in a milking state

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

THE “DRY OFF” PROBLEM

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

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It begins in a milking state
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Question

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

Question

When should the farmer dry off his herd?

You have a farm (area, location, terrain)

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

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It has various paddocks (area, slope, soil type)
You can plant different crops (grass, maize)

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Nitrogen leeches into rivers/lakes = BAD

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It has various paddocks (area, slope, soil type)
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Nitrogen leeches into rivers/lakes = BAD

Question

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

Questions?