POWDER

The milk Production Optimizer incorporating Weather Dynamics and Economic Risk

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The dairy farmer problem

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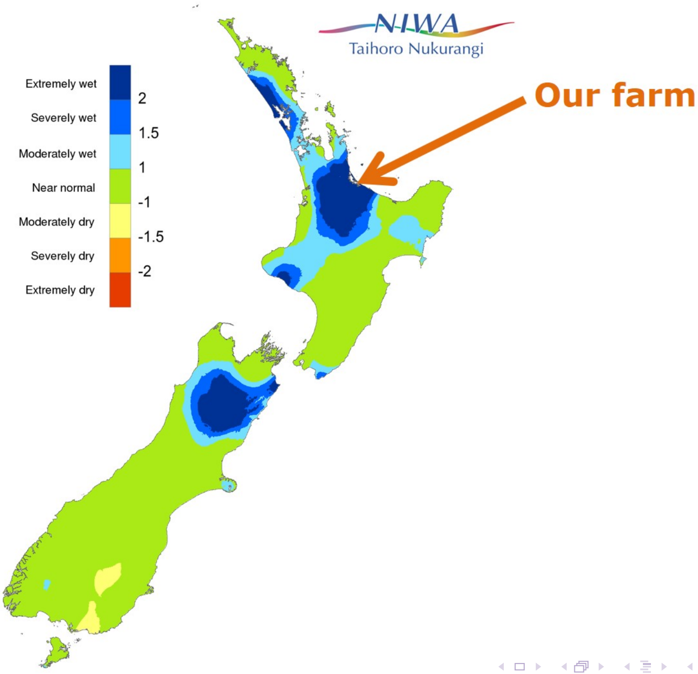
maximise:	revenue from milk production less operating costs
by deciding:	the number of cows to farm
	the quantity of grass to feed
	the quantity of supplement to feed
	when to dry-off the herd
subject to:	obtaining a high Body Condition Score at the end of the season
	uncertainty in grass growth
	uncertainty in the milk price

SPI Drought Index for 9am 27/08/2017 to 9am 26/09/2017




FOR SALE


In my opinion,
all palm oil
should be banned.

What went wrong?

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  - After each year, they are back-paid an *end-of-season* milk price
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- But, a wet year had left paddocks damaged.
- 30 years of experience said: we can't have a bad Summer, Autumn, Winter, AND Spring right?
- Farm consultant's advice: "don't blink"

POWDER - system dynamics

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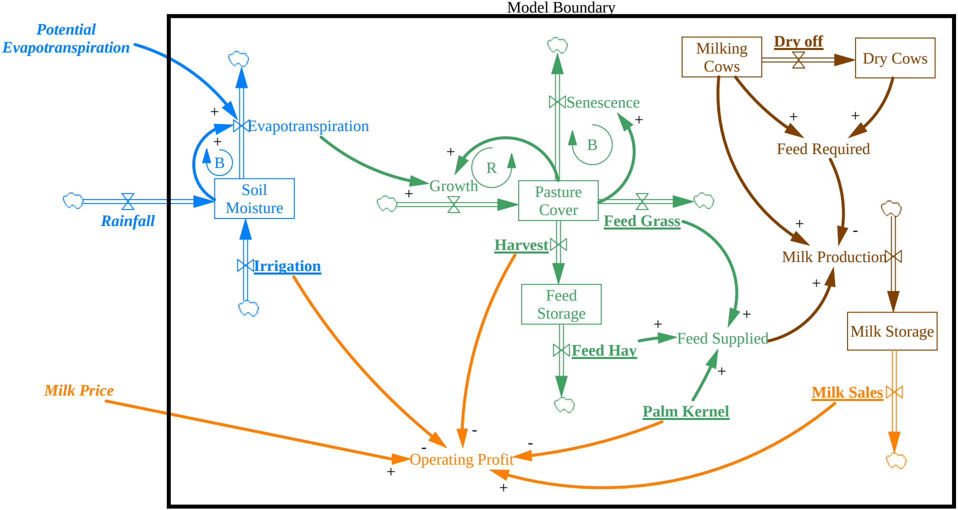
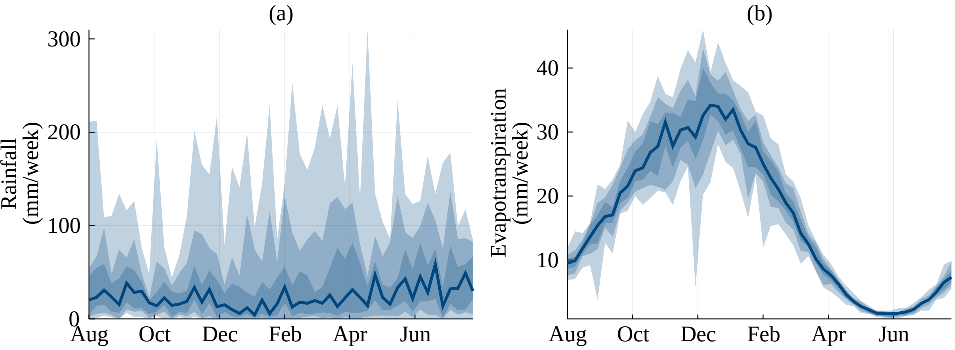


There are four basic sub-models

1. A **weather** model
2. A **crop** model
3. A **production** model
4. A **price** model

Model - weather



Model - crop

Consists of two models:

- Grass growth is proportional to evapotranspiration
- Grass growth is a function of current pasture cover

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Could (should) be improved

Model - production

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- Very basic energy balance
- Energy required for maintenance, pregnancy, and changes in Body Condition Score
- Milk production is proportional to net energy

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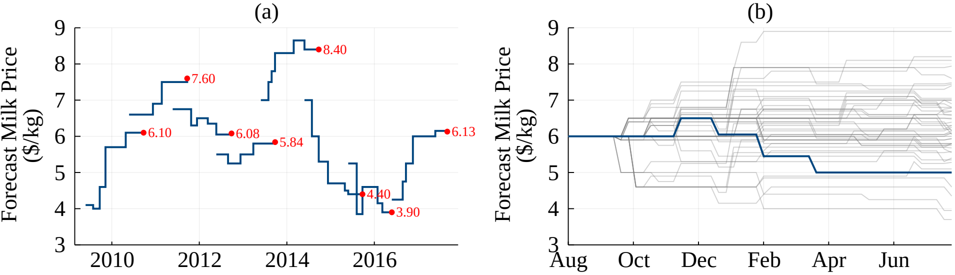
- Farmers get paid the *end-of-season* milk price p_{53}
- During the season, they observe a sequence of *forecast* milk prices $p_1, p_2, \ldots, p_{52}$.
- We model the sequence by an auto-regressive process



Recap

- There are five state variables:
  1. the soil moisture
  2. the pasture cover
  3. the quantity of feed in storage
  4. the number of cows milking
  5. the quantity of milk produced

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- There are three control variables:
  1. the quantity of grass to feed
  2. the quantity of palm kernel to feed
  3. the number of cows to *dry-off*

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- There are three control variables:
  1. the quantity of grass to feed
  2. the quantity of palm kernel to feed
  3. the number of cows to *dry-off*
- There are three random noise terms:
  1. the quantity of rainfall
  2. the quantity of evapotranspiration
  3. a forecast milk price

POWDER - system dynamics

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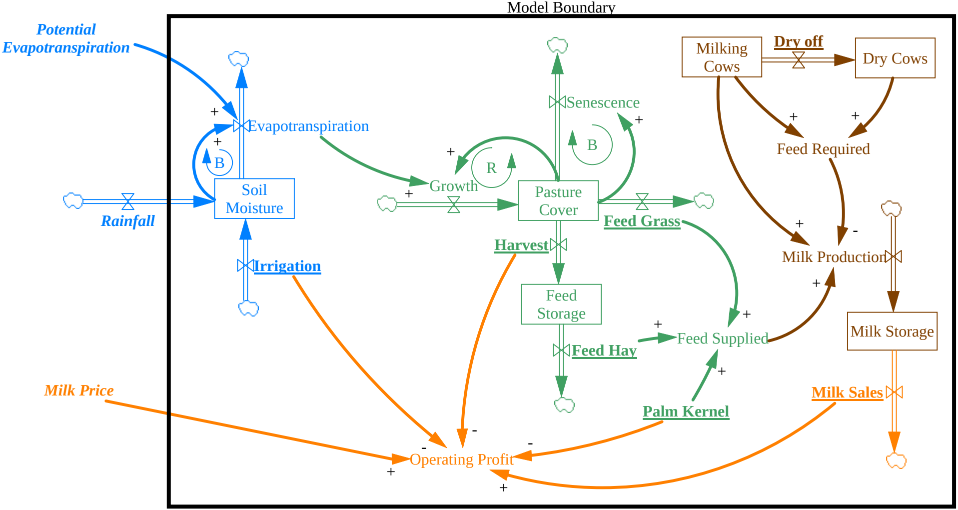

Solution method

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We use stochastic dual dynamic programming

- State-of-the-art for multistage stochastic optimization problems
- A form of approximate dynamic programming
- Uses linear programming duality to calculate the basis functions
- Avoids the "curse-of-dimensionality"

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But is has some serious limitations:

- No discrete decisions
- No nonlinear (non-convex) relationships

Solution method

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The solution is a policy. A policy is a function that takes as input:

- the week
- the value of the state variables at the start of the week
- the realization of the random noise

and produces as output

- the control for the farmer to take

We can simulate this policy using Monte Carlo.

Results

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Now we're going to look at some results.

1. **BLUE** trajectories are **LOW** milk price years
2. **ORANGE** trajectories are **HIGH** milk price years

Results – Low Price Season

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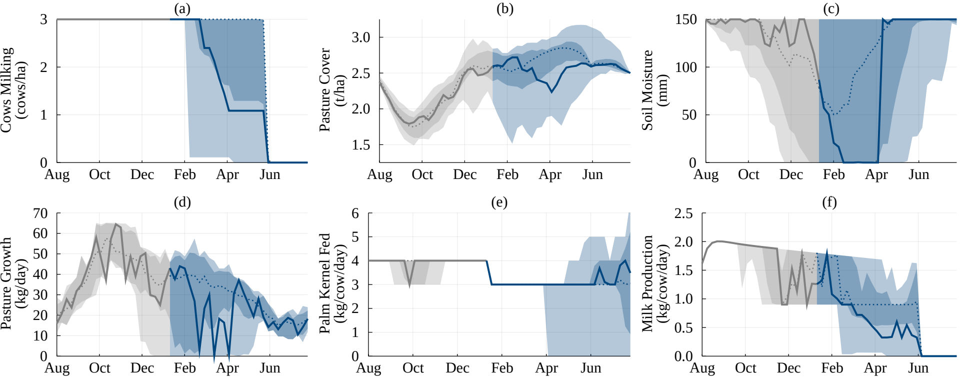

Results – High Price Season

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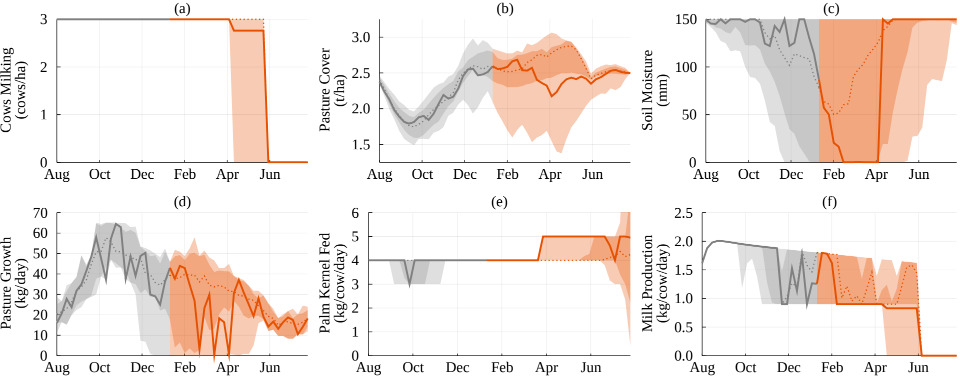

Now lets add in contacting

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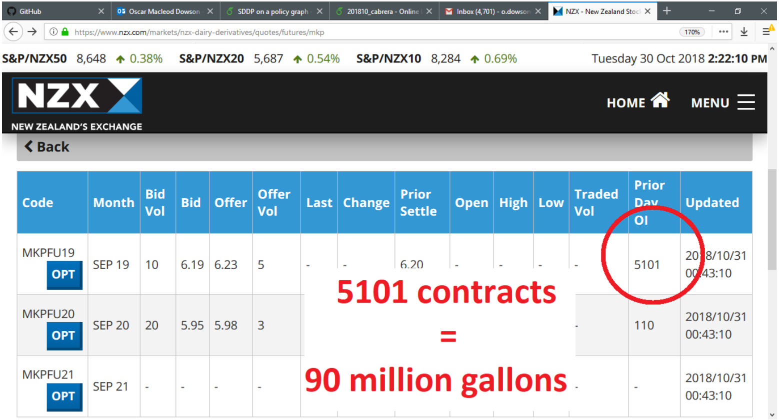
- Recall that farmers get paid the *end-of-season* milk price p_{53}
- But they observe a sequence of *forecasts* p_1, p_2, ..., p_{52}.
- At any point in time, the *forward* milk price trades at the conditional expectation of the *end-of-season* milk price:

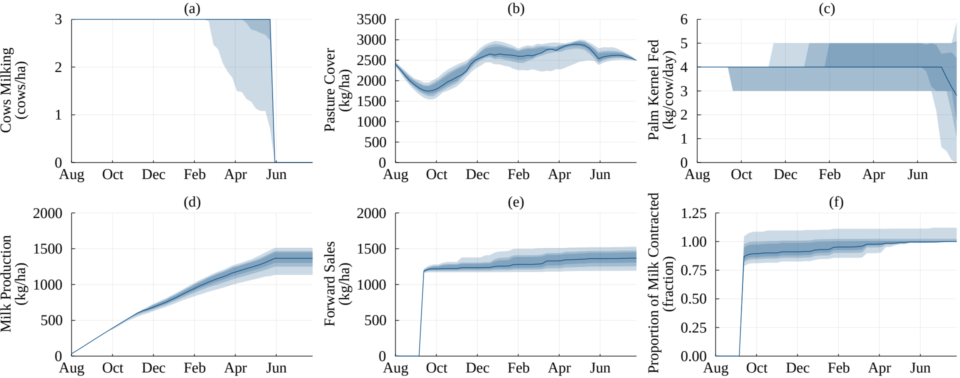
$$p_t^f = \mathbb{E}\left[p_{53} \mid p_t\right]$$

NZX futures

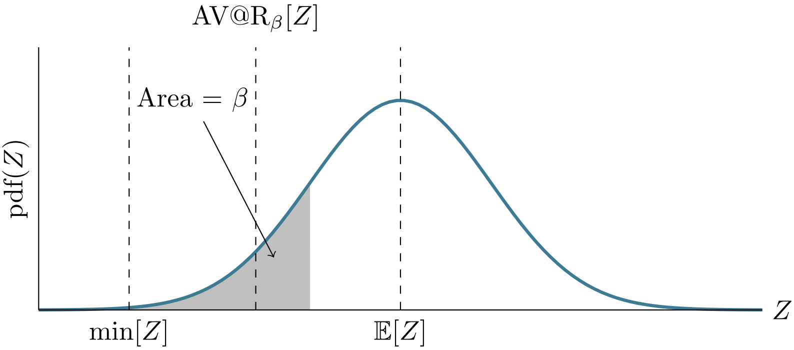


Code	Month	Bid Vol	Bid	Offer	Offer Vol	Last	Change	Prior Settle	Open	High	Low	Traded Vol	Prior Day OI	Updated
MKPFU19 OPT	SEP 19	10	6.19	6.23	5	-	-	6.20	-	-	-	-	5101	2018/10/31 00:43:10
MKPFU20 OPT	SEP 20	20	5.95	5.98	3							-	110	2018/10/31 00:43:10
MKPFU21 OPT	SEP 21	-	-	-	-							-	-	2018/10/31 00:43:10

Results - with contracting



How do we measure risk?



Results - with and without contracting

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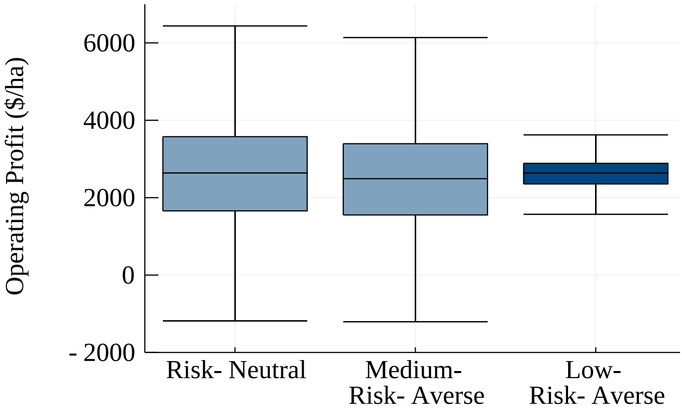
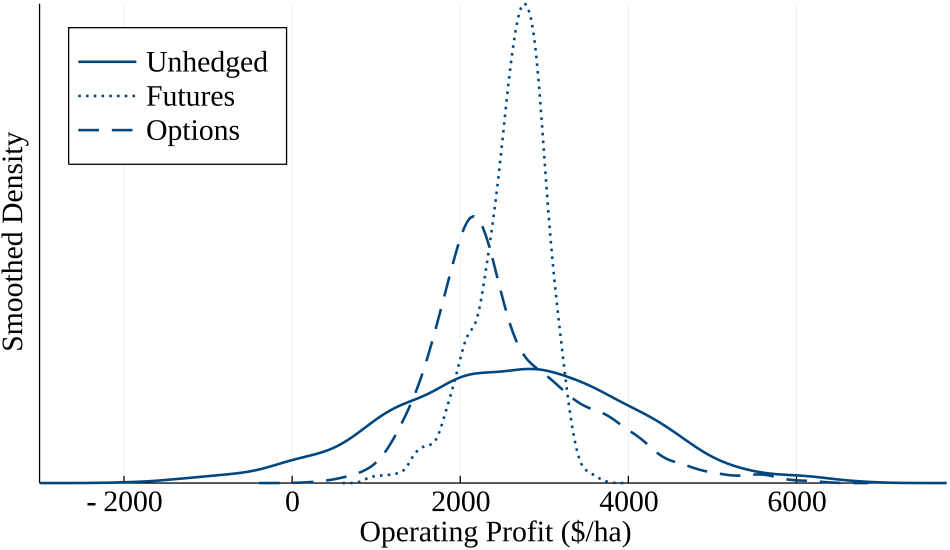


Results - options contracts



Opportunities in agriculture

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[There is] the need for considerable investment in adaptation and mitigation actions to prevent the impacts of climate change from slowing progress in eradicating global hunger and under-nutrition. [....] Building agricultural resilience, or 'climate-smart agriculture,' through improvements in technology and management systems is a key part of this.

Wheeler et al., (2013). Climate Change Impacts on Global Food Security. *Science*, 341:6145

Where to go next

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This talk is not just about pastoral dairy cows in New Zealand.

1. Swap cows for sheep
2. Or grass for corn
3. We can replicate this for many things with weather and price uncertainty

We have the computational tools to solve these problems, but we need help on the modelling side.

Where to go next

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1. Can we come up with a better convex approximation of a cow?
   - We didnt model substitution
   - We didn't model intake limits
   - We assumed BCS followed fixed trajectory
2. Can we improve the grass growth model?
3. Can we introduce nitrogen into the model? Both fertilizer and emissions?
4. Can we introduce stocking rate as a variable? What changes if the farmer can buy/sell stock during the season?
5. How do we farm with a changing climate? Easy to do: just change the probability distribution of weather.
6. POWDER is for one year: but we have (very!) new codes for the infinite horizon case.

Where to go next

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- Thesis: https://researchspace.auckland.ac.nz/handle/2292/37700
- Paper: https://doi.org/10.1016/j.ejor.2018.10.033
- Model(I): https://github.com/odow/MilkPOWDER
- Model(II): https://github.com/odow/MilkPOWDERII
- Library: https://github.com/odow/SDDP.jl
- Tutorials: https://odow.github.io/SDDP.jl/latest/