Whole farm modelling and climate change adaptation research

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Why whole-farm?

- Account for the complexities farmers face when managing complicated farm businesses under risk and uncertainty

- Provide information at the farm business level
  - the level at which farmers think and make decisions

- Increase rate of productivity increase and build adaptive capacity
Achieving impact

Case study farms

Software development

Participatory modelling supporting co-learning
Simplicity (comprehension) - GUI’s vs. Complexity (flexibility) - functions

- Monoculture - Where we all start – “Day 1” of Training Course
Comprehension VS. Flexibility

- Rotations – “Day 2” of Training Course
Simplicity VS. Complexity

Whole-farm. “Day 4” of Training Course – e.g. African small holder

- Proportion of farm allocated to intercropping and solid planting
- Intercropping
- 2 season types
Simplicity = comprehension (GUI’s)
Complexity = flexibility (functions)

Whole (mixed) farm

- Crops
- Pasture
- Forages
- Livestock – dynamic management
- Climate change

- GUI’s too restrictive for all facets
- => Functions and procedures
- Multiple languages (APSIM basic, C#, VB, TCL, R)
- Factorials expose opportunities + weaknesses
RULES and TRANSITIONS

[dayWithin 129 152]
[getEsw $paddock] > 183
[getMSeek2 $paddock] > 0.65
$daysSinceLastHarvest($paddock) > 30
[machineryAvailable tractor1_planter]
[areaPlanted wheat] <= 1
[getEsw $paddock]

Visual format + functions
Some GUI's but........
Crops, forages and pastures

• Initial states
• areas

Functions……
Animals and paddocks

- Numbers => stocking rate
- Liveweight gains for each pasture

More Functions......
MANAGING the STOCK/PADDOCKS

- Bring some animals into the system
- Take some animals out of the system
- Keep track of liveweight and age
- Move stock somewhere.
- Split a mob.
- return the next heaviest mob on the farm
- IsFeedExhausted {paddock}
- IsFeedAvailable {paddock}
- look for another paddock that has lighter animals that can be moved
- look for another paddock (of lesser rank) that is under-occupied (feed > minimum)
- return the amount of feed and type of feed in a paddock

Many Functions......
Adaptation scenarios
Whole-farm + climate change

- A1FI H, A2 L emissions
- Echam5, GCM232, GFDL2.0, GFDL2.1 GCMs
- 2030, 2050
- Climatology + Phase 1 + M-quantile met files
- + Averaged climate models (4 models distilled from 17 models)

Queensland case studies:
- Enterprise change (crop + pasture + livestock mix)
- Moisture seeking planting capability (increasing intensity)
- Fallow length (reducing? intensity)
- Soil water threshold, area planted (the ‘best’ intensity)
- Irrigation allocation (high intensity)
A1FI 2050 Roma enterprise comparison, two future scenarios

Net profit/ha (50yrs)

Existing farm SILO
Extra crop SILO
Extra crop ECham5
Extra crop GDL2.1
A1FI 2050 Roma enterprise comparison, two future scenarios

![Graph showing net profit/ha (50yrs) for different scenarios and enterprises.](image)

- **Existing farm SILO**
- **Extra crop SILO**
- **Extra stock SILO**
- **Low pasture utilisation SILO**
- **Climate**

Net profit/ha (50yrs)

- $400
- $300
- $200
- $100
- $0
- $-100
- $-200
- $-300
- $-400
A1FI 2050 Roma enterprise comparison, two future scenarios

Net profit/ha (50yrs)

Existing farm SILO

Extra stock
Low pasture utilisation
SILO Climate

Extra stock
Low pasture utilisation
GDL 2.1
A1Fl 2050 Roma enterprise comparison, two future scenarios

Net profit/ha (50yrs)

Existing farm SILO

Extra stock Low pasture utilisation SILO Climate

Extra stock Low pasture utilisation GDL 2.1

Extra stock High pasture utilisation GDL 2.1
A1FI 2050 Roma enterprise comparison, two future scenarios

Net profit/ha (60 yrs)

- $400
- $300
- $200
- $100
- $0
- $100
- $200
- $300
- $400

- Existing farm SILO
- Extra crop SILO
- Extra crop ECham5
- Extra crop GDL2.1
- Extra stock Low pasture utilisation SILO
- Extra stock Low pasture utilisation ECham5
- Extra stock Low pasture utilisation GDL 2.1
- Extra stock High pasture utilisation SILO
- Extra stock High pasture utilisation ECham5
- Extra stock High pasture utilisation GDL 2.1
Long-fallowing – a snapshot

Would an extra long fallow between wheat crops, help?

Not whole farm
Long-fallowing – a snapshot

Would an extra long fallow help?
Moisture-seeking planting – how valuable is it?

Difference between GCM scenarios and years

Emerald A1FI, GFDL2.0 (mild)

Emerald A1FI, GFDL2.1 (worst case)

Not whole farm
Can an agronomist use Whole-Farm modelling? ........

Yes, with a whole lot of help.

Thanks
Effect if do nothing

No change in median at 2030, 30% decrease at 2050 and variability increases

A1F1/GFDL 2.0 – Wheat/chickpea crops + backgrounding steers
Worse case scenario - Roma

Net profit/ha (20yrs)

Climate scenario

A1FI GFDL 2.1
High utilisation + climate change

BuffelPaddock SDM 2050

- Current Practise
- HighPU
### Key impacts

- **Rainfall change**
  - Less rainfall
  - More variable rainfall
  - Changed seasonality

- **Temperature change**
  - Fewer frosts
  - Heat stress on crops

### Some adaptations

- Buy more land
- Geographic diversification
- Abandon enterprises e.g. cropping
- Change overheads e.g. leasing
  - Change enterprise mix e.g. crop/pasture

- Change rotations, crop intensity
- Change input use (fert N, legumes)
- Change crop type, crop mix
- Change varieties
- Soil water issues
  - planting water thresholds/area planted
  - moisture seeking
  - long fallows

### Major change

- Incremental change
Adaptation potential

• “we are used to adapting to rainfall variability“
• “… and we will continue adapting... “

Northern growers have a high potential to adapt.....

......... because........

• Experienced with highly variable climate
• Opportunity to switch winter to summer crops
• Many farms are mixed grain and graze
  – Legumes potential to reduce N fertiliser inputs
  – Perennial pastures can increase soil OM
Adapting in Roma

Some learnings

- It seems that whole farm impacts are usually more buffered compared to impact assessments at the single enterprise level
- Cropping still fundamentally the most profitable farming enterprise
- Increasing cropping area by 500 ha (45%) increased farm profit by 21% (current climate)
- Integrating lablab reduced farm profit by 10% if stocking rate left at 0.9 beasts/ha (current climate)

  - BUT

- Integrating Lablab reduced nitrogen fertiliser costs by 25%
- Doubling the stocking rate on the forages from 0.9 to 1.8 beasts per ha can almost match the effect of 500 ha more crop (wheat at $220/t beef at $0.85/kg)
- Increased summer legume utilisation to 37% (previously was 10%)
Initial results (QLD)

- Very different levels of impact cf. southern states – potential to lead the way in farming under a highly variable climate.
- Opportunity to switch winter to summer
- Increased trend to summer cropping
- Reduced frost risk enabling earlier planting
- Cropping still largely more profitable than grazing (mod N fert prices)
- Legumes potential to reduce N fert inputs
Adaptation

- We mainly analyse whole-farm effects (multi-paddock, multi-input).
- Questions revolve around farm business design – how resources (land, water, nutrients, time) are allocated across the whole farm enterprise.

- Queensland case studies:
  - Mixed grain and graze – Roma
  - Dryland Grain – Goondiwindi
  - Mixed grain and graze - CQ
  - Irrigated Cotton/Grain – Dalby
Climate change adaptation studies

- We mainly analyse whole-farm effects (multi-paddock, multi-input).

- Questions revolve around farm business design – how resources (land, water, nutrients, time) are allocated across the whole farm enterprise.

- Queensland case studies:
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General approach

Alternative farming systems

- Practices
  - Tillage & ground cover
  - Moisture seeking

- Tactics
  - Planting rules
  - Soil water thresholds
  - Crop sequences & intensity
  - Long fallowing
  - Forage conservation

- Strategies
  - Crop selection (winter / summer)
  - Water allocations
  - Land allocations
  - Cropping / grazing mix

- Farmers’ preference
  - Risk preference & its trade offs
  - Plastic vs rigid
Case studies: Dalby

Irrigated cropping

- 800 ha cropping area
- 3 storages with combined capacity 1350ML
- 500 ML annual bore allocation
- Overland flow ~ triangular distribution (0,700,1450 ML/year)
- Crop rotation: summer grain (sorghum or maize), cotton, cotton (dependent on stored water).
Case studies: Dalby

Irrigated cropping

[Box plot diagram showing yield (tha or bale/ha) for different crops: Cotton, Maize, Sorghum, Soybean, Mungbean, Wheat.]

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Case studies: Dalby

- Cotton 3 ML/ha
- Maize 4 ML/ha
- Sorghum rainfed
- Wheat 1ML/ha
- Soybean 5ML/ha

- Cotton 4 ML/ha
- Maize 4 ML/ha
- Sorghum rainfed
- Wheat rainfed
- Soybean 3ML/ha
Case studies: Dalby

No CO$_2$ fertilisation effects
Case studies: Roma

Mixed grain and grazing

- Area allocation – proportions of farm area to either
  - Opportunistic crop & grazing paddocks

- 4000ha farm at Roma
- 1100ha of cropping
- 2000ha of Buffel grass
- 400ha of Leucaena / grass
- 400ha of Oats
- 100ha of forage sorghum
Case studies: Roma

Mixed grain and grazing

“Work in progress”
Case studies: Emerald

Rainfed cropping

- 2000 ha no-till cropping system
- Three major soil types: 120, 150 and 180mm
- 1/3 of the area is dedicated to winter crops
- Highly opportunistic in his tactical and strategic management
- Cropping intensity 80-100%
Case studies: Emerald

Rainfed cropping

![Scatter plot showing risk and return (in $,000) relationship.](scatter_plot.png)
Case studies: Goondiwindi

Rainfed cropping

• 3000ha no-till cropping farm subdivided into 10 fields
• Three major soil types: 140, 160 and 180mm
• 2/3 of the area is dedicated to winter crops
• Follows a relatively more fixed rotation
• Cropping intensity 80%
Enterprise mix – a snapshot

Enterprise mix

![Graph showing annual net profit with baseline years 2030 and 2050]
Case studies: Goondiwindi

Rainfed cropping

Still to come
Case studies
Case studies: Roma

Mixed grain and grazing

- Area allocation – proportions of farm area to either
- Opportunistic crop & grazing paddocks

- 4000ha farm at Roma
- 1100ha of cropping
- 2000ha of Buffel grass
- 400ha of Leucaena / grass
- 400ha of Oats
- 100ha of forage sorghum
Adapting in Roma

Impact assessment (A1F1 – dry model)

<table>
<thead>
<tr>
<th>Factor</th>
<th>2030</th>
<th>2050</th>
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<tbody>
<tr>
<td>Crop Income</td>
<td>-5%</td>
<td>-14%</td>
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<tr>
<td>Livestock Income</td>
<td>-1%</td>
<td>-2%</td>
</tr>
<tr>
<td>Overheads</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Farm Profit</td>
<td>-5%</td>
<td>-16%</td>
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<tr>
<td>Livestock Sold</td>
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<td>-1%</td>
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<tr>
<td>Wheat Freq</td>
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<td>Avg Wheat Yield</td>
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<td>-3%</td>
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<tr>
<td>Chickpea Freq</td>
<td>-1%</td>
<td>-2%</td>
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<tr>
<td>Avg Chickpea Yield</td>
<td>-6%</td>
<td>+6%</td>
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</table>
Adapting in Roma

Scenario analysis setup

- 4000ha farm at Roma
- 1100ha of cropping
- 2000ha of Buffel grass
- 400ha of Leucaena / grass
- 400ha of Oats
- 100ha of forage sorghum

- When integrating legume use one of the 220 ha crop paddocks

Options examined

- Changes in proportion of crop and pasture
- Replacing forage sorghum with Lablab
- Integrating Lablab into cropping area
- Integrating winter legume into cropping area
Adapting in Roma

Integrating Lablab into the cropping area

• Baseline farm except
  Lablab integrated (rotated) through the cropping paddocks (1 out of 5 fields)

  • 5 paddocks each 220ha
  • Buffel paddock = 2000ha
  • Leucaena/grass = 400ha
  • Oats = 400ha
  • Forage sorghum = 100ha

• Increased stock numbers

• CC scenario A1F1 (high emission) and ‘dry’ model
Adapting in Roma

Alternative scenarios for current climate

<table>
<thead>
<tr>
<th>Scenario and Year</th>
<th>Base</th>
<th>Extra cropping</th>
<th>Extra pasture</th>
<th>Lablab hi SR</th>
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<tbody>
<tr>
<td>Current</td>
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Adapting in Roma

Alternative scenarios for current climate

![Box plot showing annual net profit ($/ha) for different scenarios: Baseline, Extra crop current, More pasture current, and LabLab current.](image)
Adapting in Roma

Alternative scenarios for CC scenarios

[Graph showing box plots for different scenarios]
Modelling change

Two CO$_2$ emission scenarios

A1FI scenario – high CO$_2$
A1FI = fossil fuel reliance
High temp increase
It’s where we are tracking
2.4 to 6.4 °C (4.0 best est.)

A2 scenario – mid to high CO$_2$
A2 = Mod to high temp increase
Slower development
2 to 5.4 °C (3.4)
‘A drying’ model

Annual rainfall pattern of change PDGW

Annual temperature pattern of change PDGW

Annual-average decreases over most of Australia, but increases in the tropics. Widespread decreases in autumn winter and spring, with widespread increases in summer and spring increases in the north-west.

Increases across Australia, greatest inland.
Some strategies – a case farm

1. Examining proportion of crop and livestock (historical + new climate)

- 4000ha farm at Roma
- 1100 ha cropping
- 2000ha Buffel
- 400ha Leucaena/grass
- 400ha Oats
- 100ha Forage sorghum
- When integrating legume use one of the 220 ha crop paddocks
- 1100 steers 250kg in > 450 kg out
Benefits of moisture seeking - wheat

- Earlier planting possible
- 20% greater cropping frequency

**Moisture seeking Rainfall trigger**

**Planting strategy**

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<td>2-May 27-May 12-May 17-May 22-May 27-May 1-Jun 6-Jun</td>
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<tr>
<td><strong>Rainfall trigger</strong></td>
<td>6-Jun 1-Jun 27-May 12-May 17-May 22-May 27-May 1-Jun 6-Jun</td>
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</table>

**Scenario**

- Mean annual cropping frequency (%)

| Scenario   | % Planting Suasion of %  
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<tbody>
<tr>
<td><strong>Moisture seek</strong></td>
<td>Current 2030 2050</td>
</tr>
<tr>
<td><strong>Rainfall trigger</strong></td>
<td>Current 2030 2050</td>
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</tbody>
</table>
Conclusion

- Whole farm modelling capability well developed (crop and stock)
- Input from stakeholders has set direction
- Relevant scenarios presented
- Melded well with soil C and mitigation activities
- Scenarios to be refined for group benefit