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Climate change and agriculture:
Climate impacts modelling

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23rd November, 2005, Scottish Executive, Edinburgh, UK

Climate change and agriculture

- Crops
- Land use rotations
- Crops and Livestock
- Whole farms
- Farming systems
- Farming and climate change amelioration

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Rationale

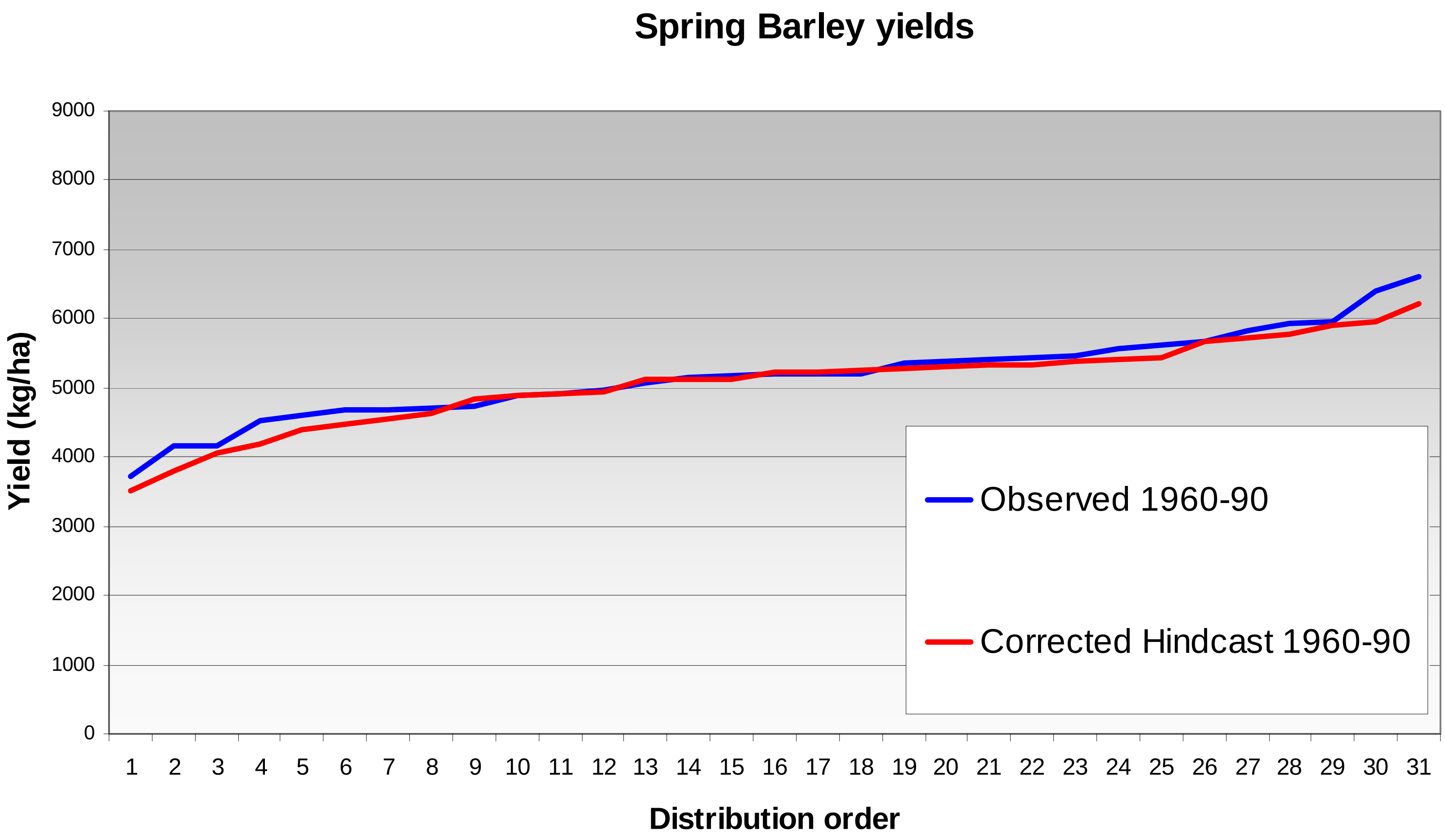
✓ Climate is key determinant of the productivity of crops grown in many regions of the world

✓ Our understanding of the effects of climate on the growth and yield of crops continues to improve through the efforts of crops scientists and agro-climatologists

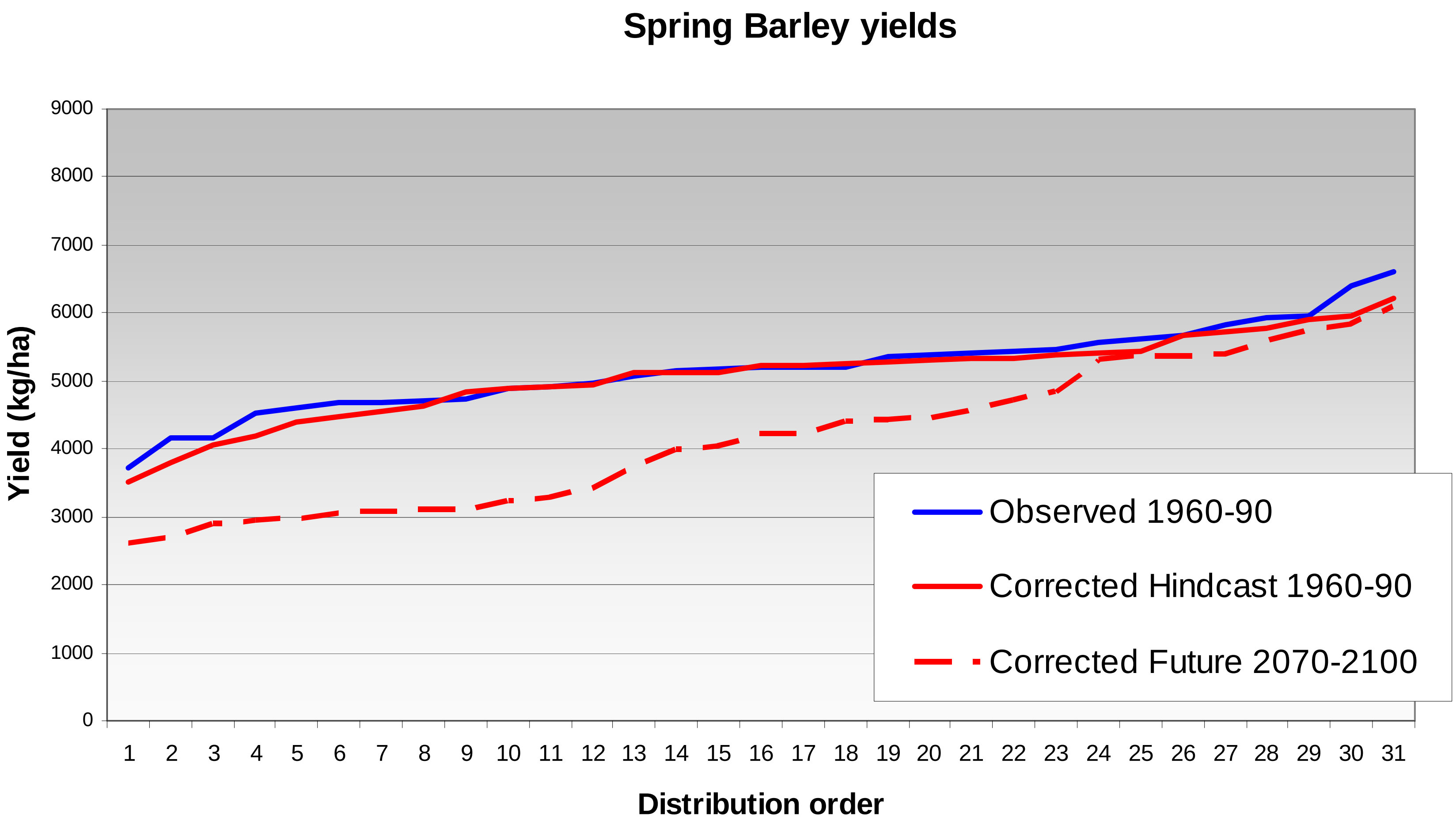
✓ Continuing development of crop simulation models, weather generators and global circulation models presents an opportunity to combine these tools into crop and climate change systems

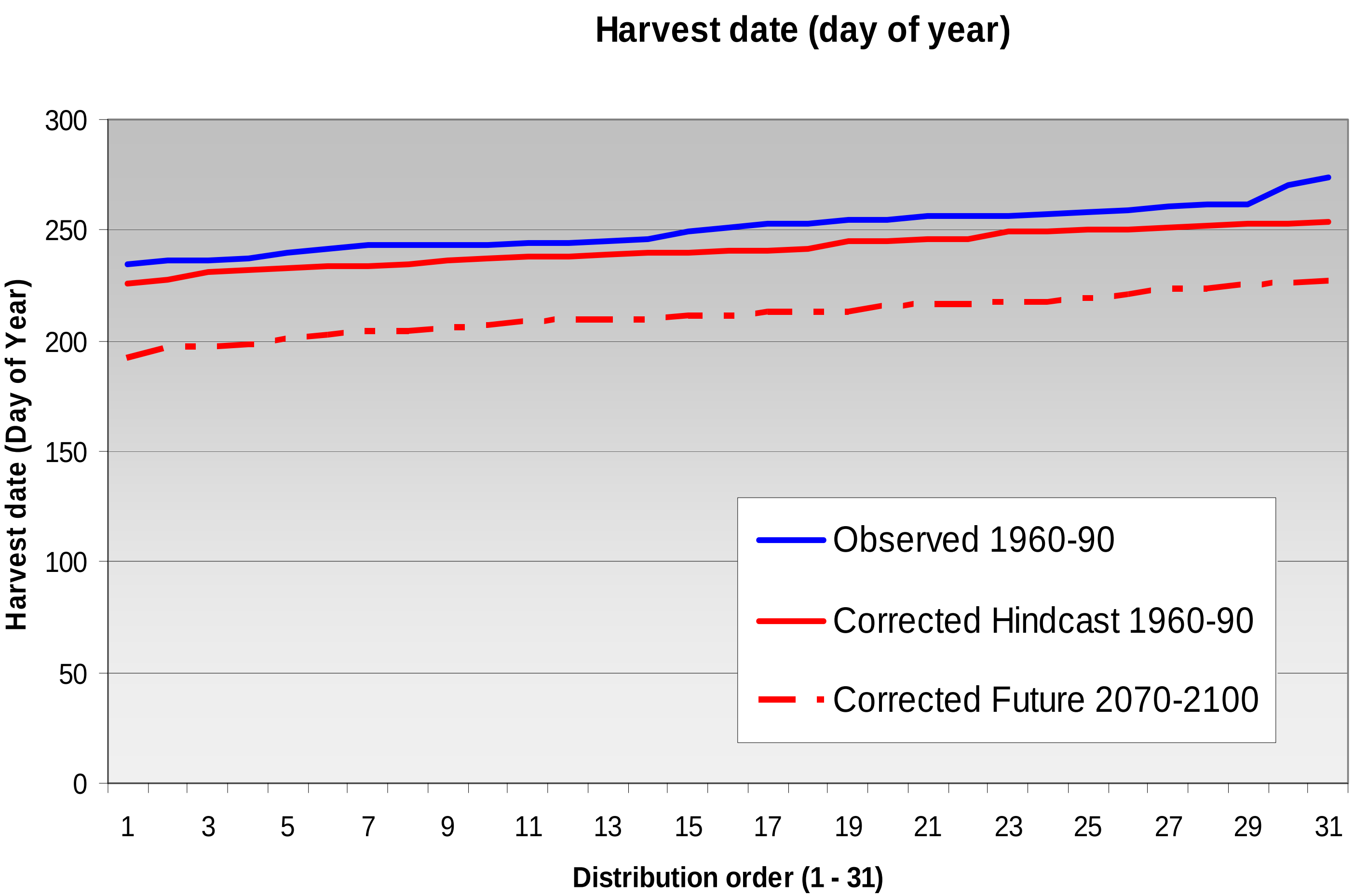
✓ Crop models using daily climatic data allow us to simulate the influence of climate scenarios and CO_2 concentration on either crop development, growth and productivity in the long term

Assessing the impacts of climate data quality on crop model estimates:



Potential future yields?





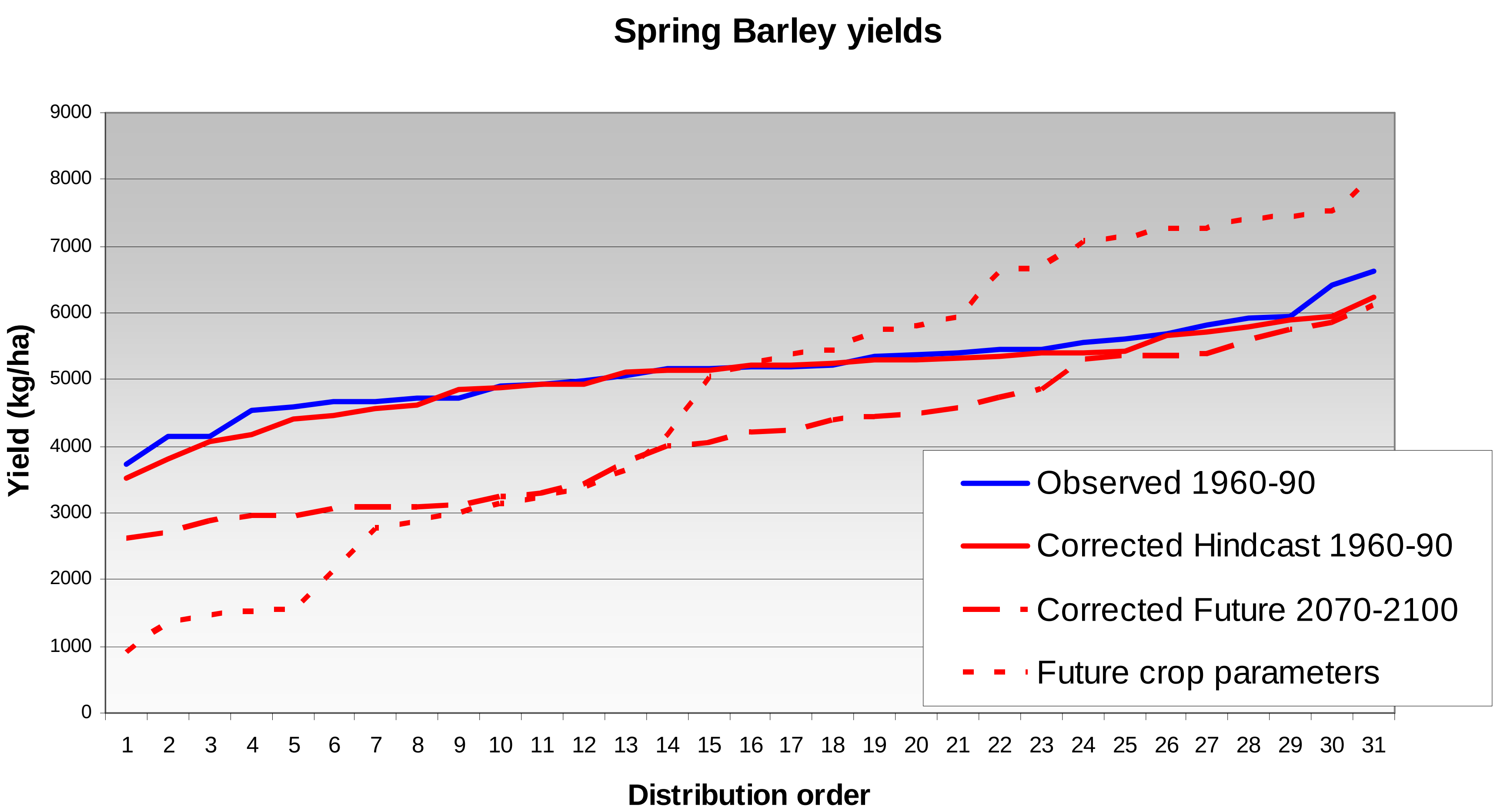
Differences in Mean harvest date:
Observed = 250
Hindcast = 242
Future = 211

Therefore harvest date is c. 40 days Earlier

This is due to the relationships between thermal time accumulation and phenology

However, this does not take into consideration plant breeding for slower phenological development….

Spring Barley yields



30 year mean yield (kg/ha):
Hindcast = 5706
Observed = 5172
Phenology adjusted future = 4708

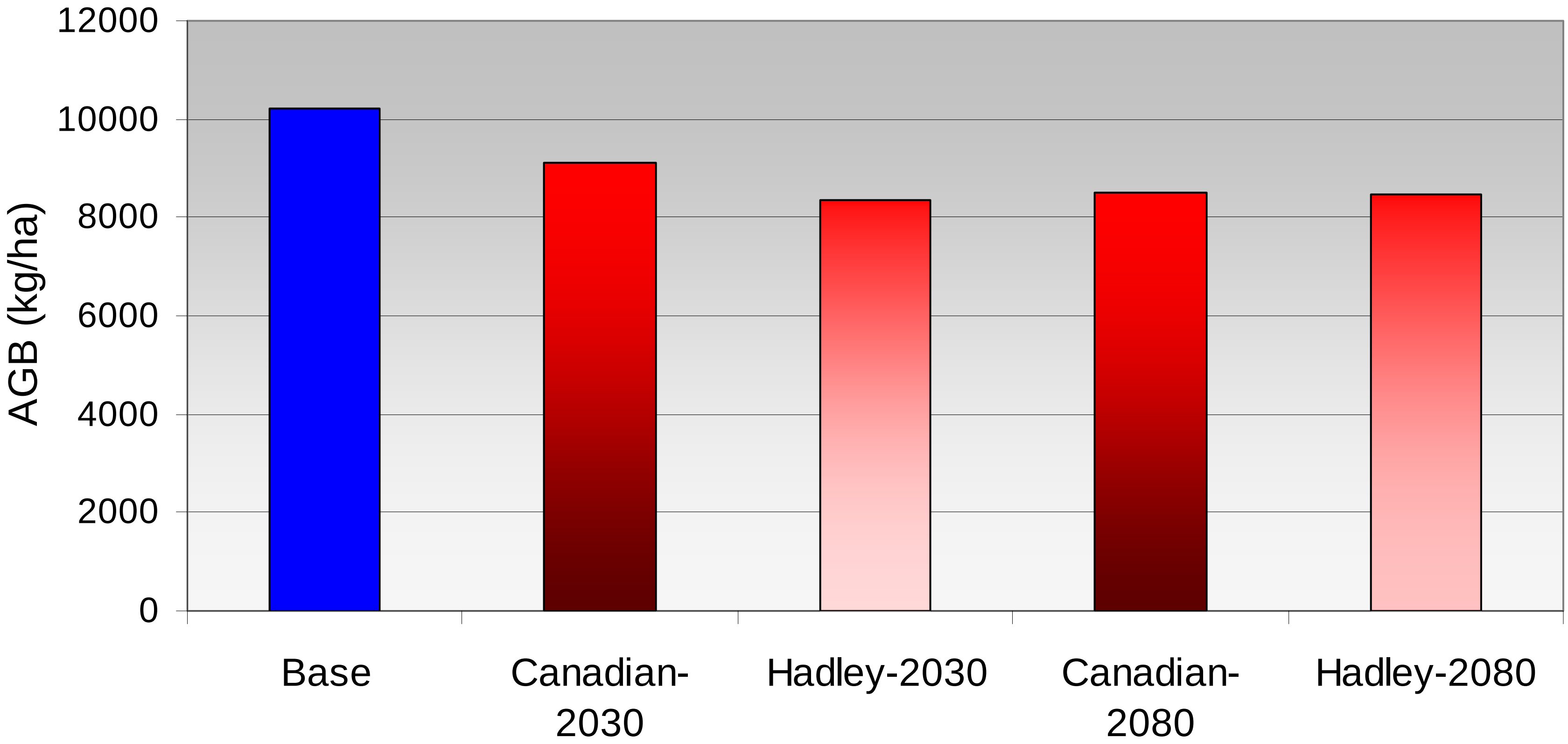
Observed – estimated:
5172 – 4708 = 464 kg/ha decrease
BUT much greater variability

Some issues:

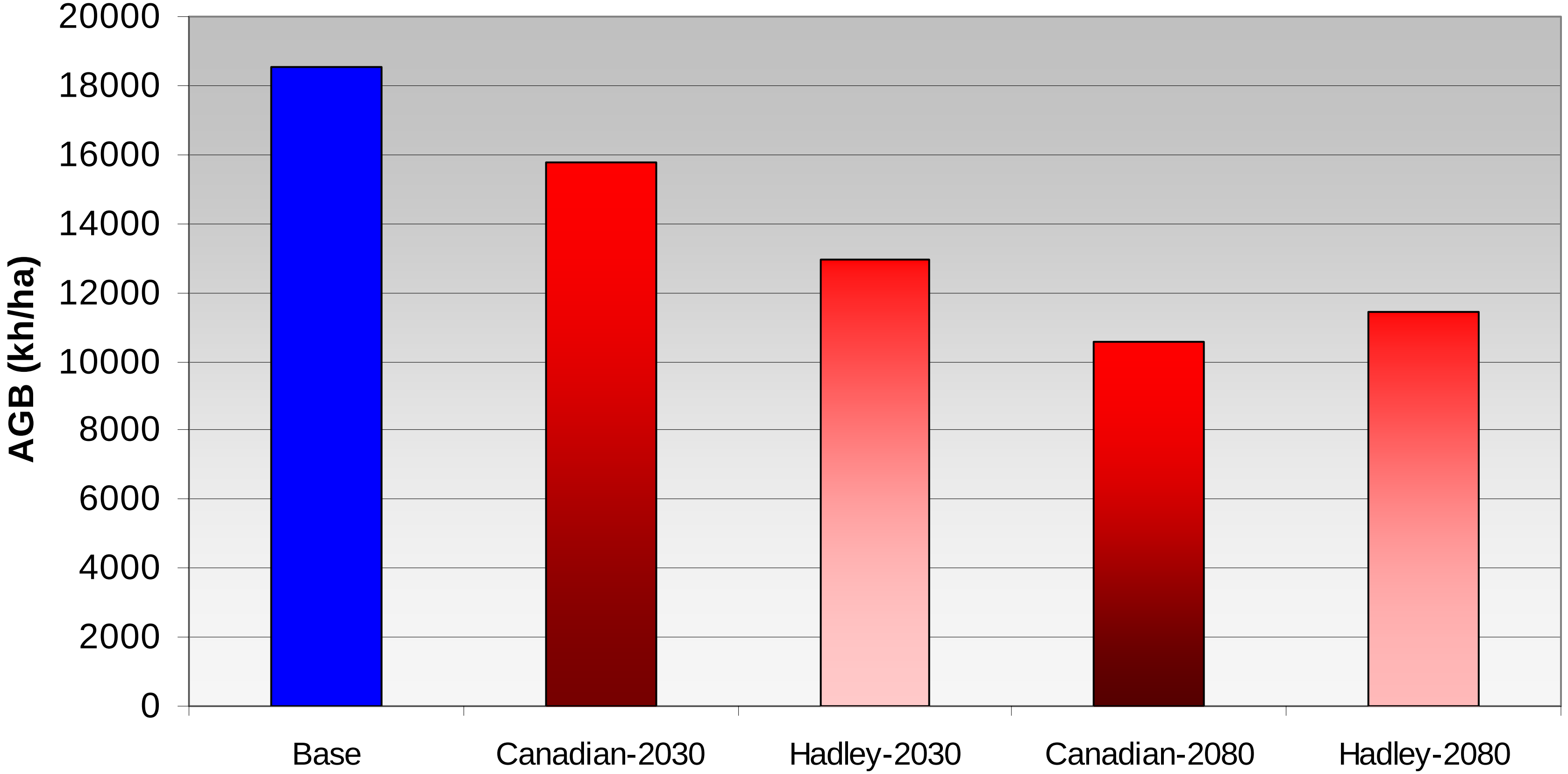
- Timing of higher temperature events and crop growth stages
  - Heat stress in winter wheat: c.40% reduction in biomass if event occurs at anthesis
  - Harvest Index reduces from 0.53 to 0.33

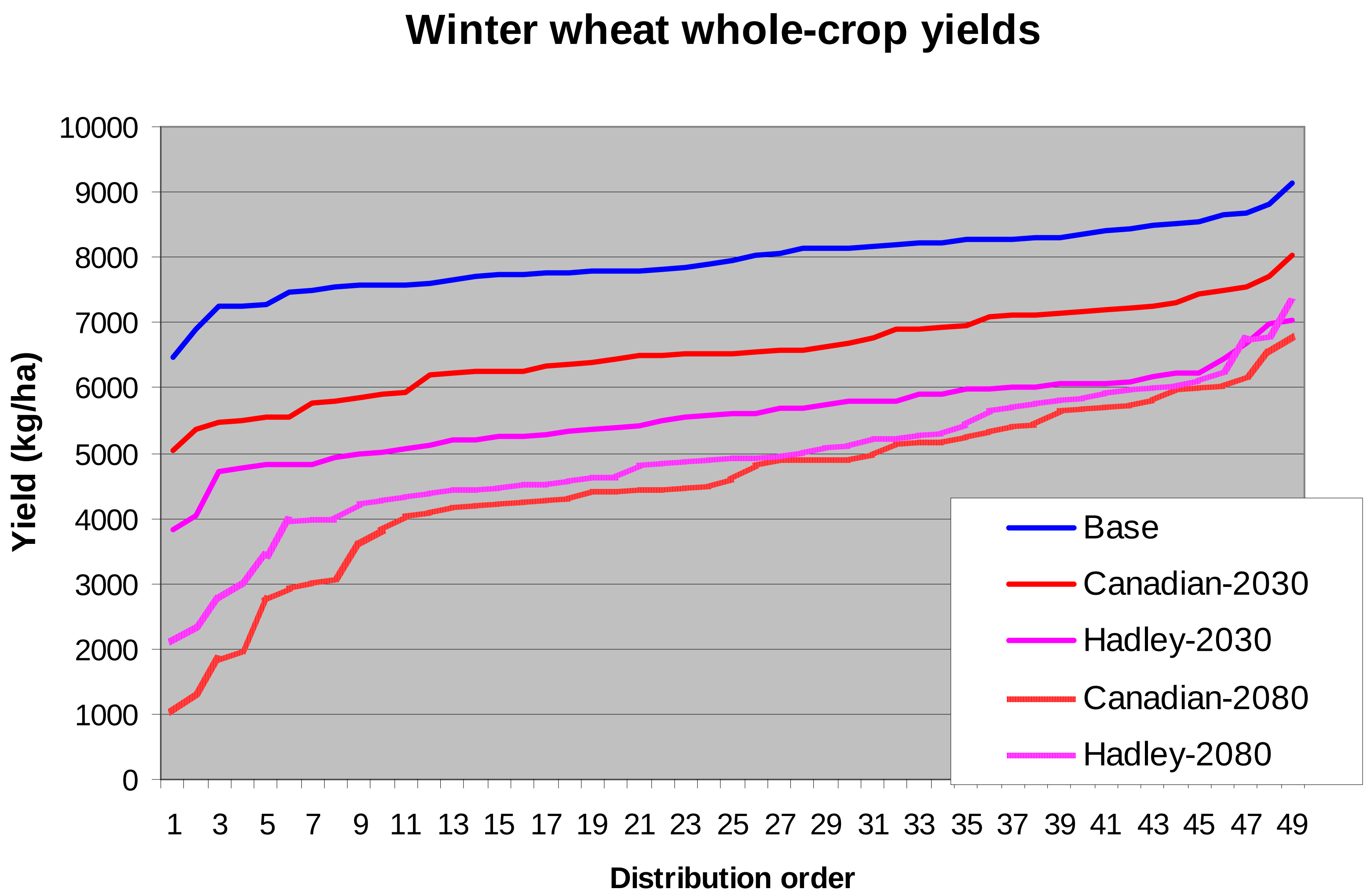
  (Wollenweber et al. 2003. J. Agronomy & Crop Science)

Above Ground Biomass for Spring barley whole-crop harvest



Above Ground Biomass for Winter Wheat Whole Crop Harvest




Winter wheat whole-crop yields
Yield (kg/ha)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
Distribution order
Base
Canadian-2030
Hadley-2030
Canadian-2080
Hadley-2080

Rotations: an example from Montepulciano

- ✓ 9-year rotation:sugarbeet-durum wheat-capsicum-4 year alfalfa-durum wheat-tobacco
- ✓ Two climate scenarios: baseline and Canadian 2030

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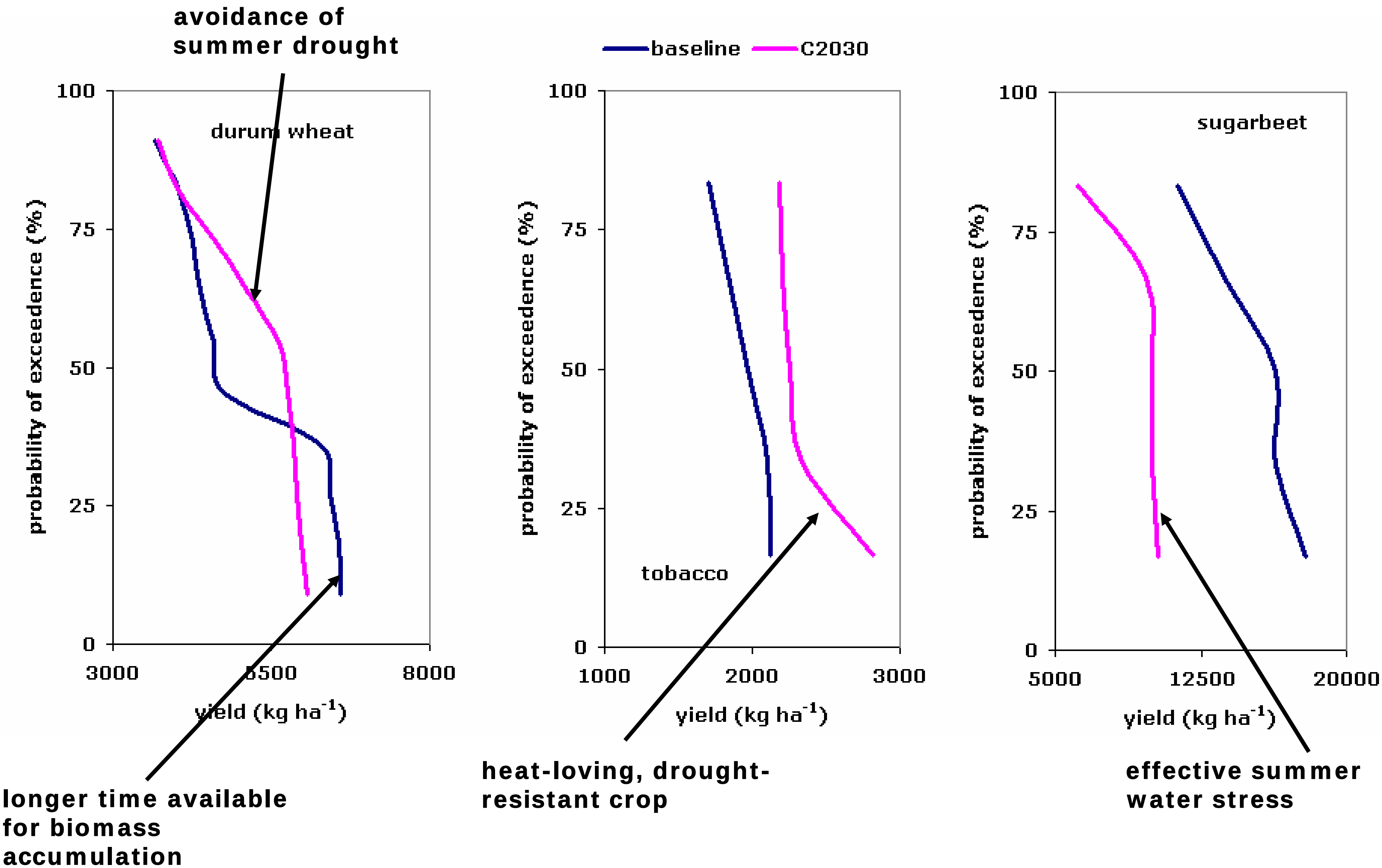
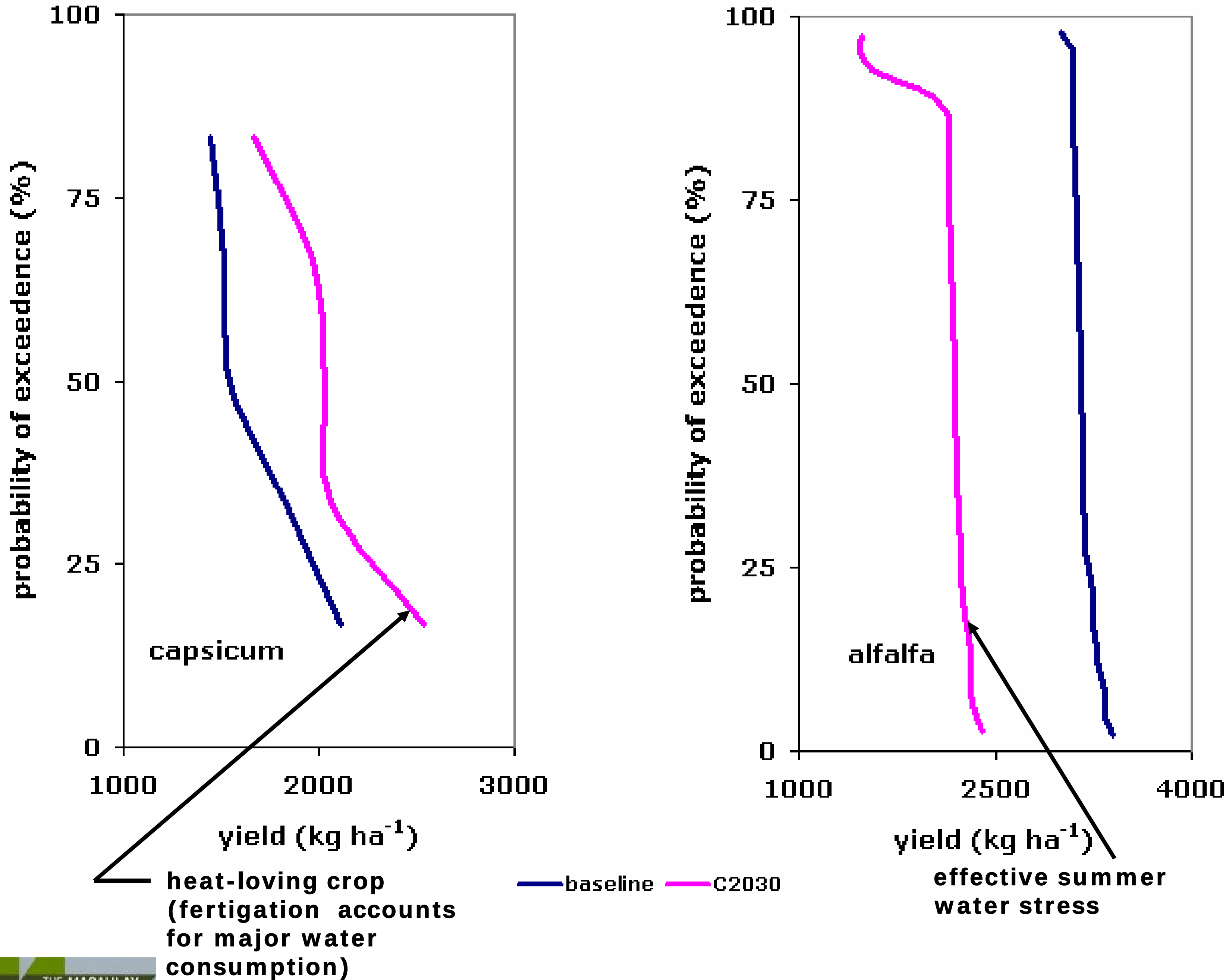

avoidance of
summer drought
baseline
C2030
durum wheat
tobacco
sugarbeet
probability of exceedence (%)
100
75
50
25
0
3000
5500
8000
1000
2000
3000
5000
12500
20000
yield (kg ha-1)
longer time available
for biomass
accumulation
heat-loving, drought-
resistant crop
effective summer
water stress


100
75
50
25
0
probability of exceedence (%)
capsicum
1000
2000
3000
yield (kg ha-1)
heat-loving crop
(fertigation accounts
for major water
consumption)
baseline
C2030
100
75
50
25
0
probability of exceedence (%)
alfalfa
1000
2500
4000
yield (kg ha-1)
effective summer
water stress

Biophysical risks – extra considerations:

- Extreme event frequency increase
  - Wind, rain, drought, storms
- Pests / diseases / weeds
  - Fungal pathogens
  - Liver fluke, pole barber worm etc
  - Pneumonia (housing)
  - Adverse weed competition
- Physical damage
  - Lodging in cereals
  - Windthrow in trees
  - Erosion

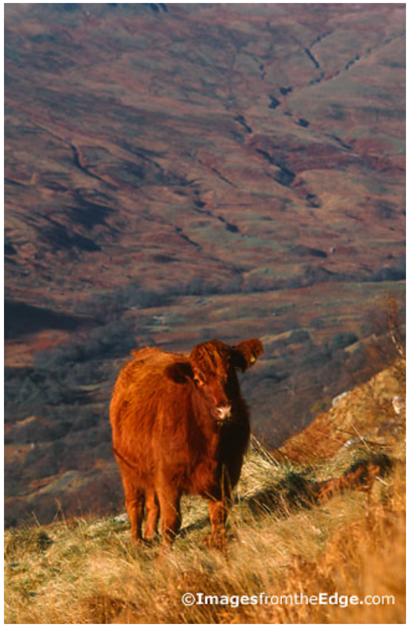
Crops and Livestock

- Need to know how the relationships between primary and secondary production may change
- Possibilities:
  - Increases in primary production
    - Higher stocking rates?
    - Shifts in management / systems (silage cuts / autumn to spring calving etc..)
  - Decreases in primary production
    - Same stocking rates – more bought-in supplements
    - Lower stocking rates

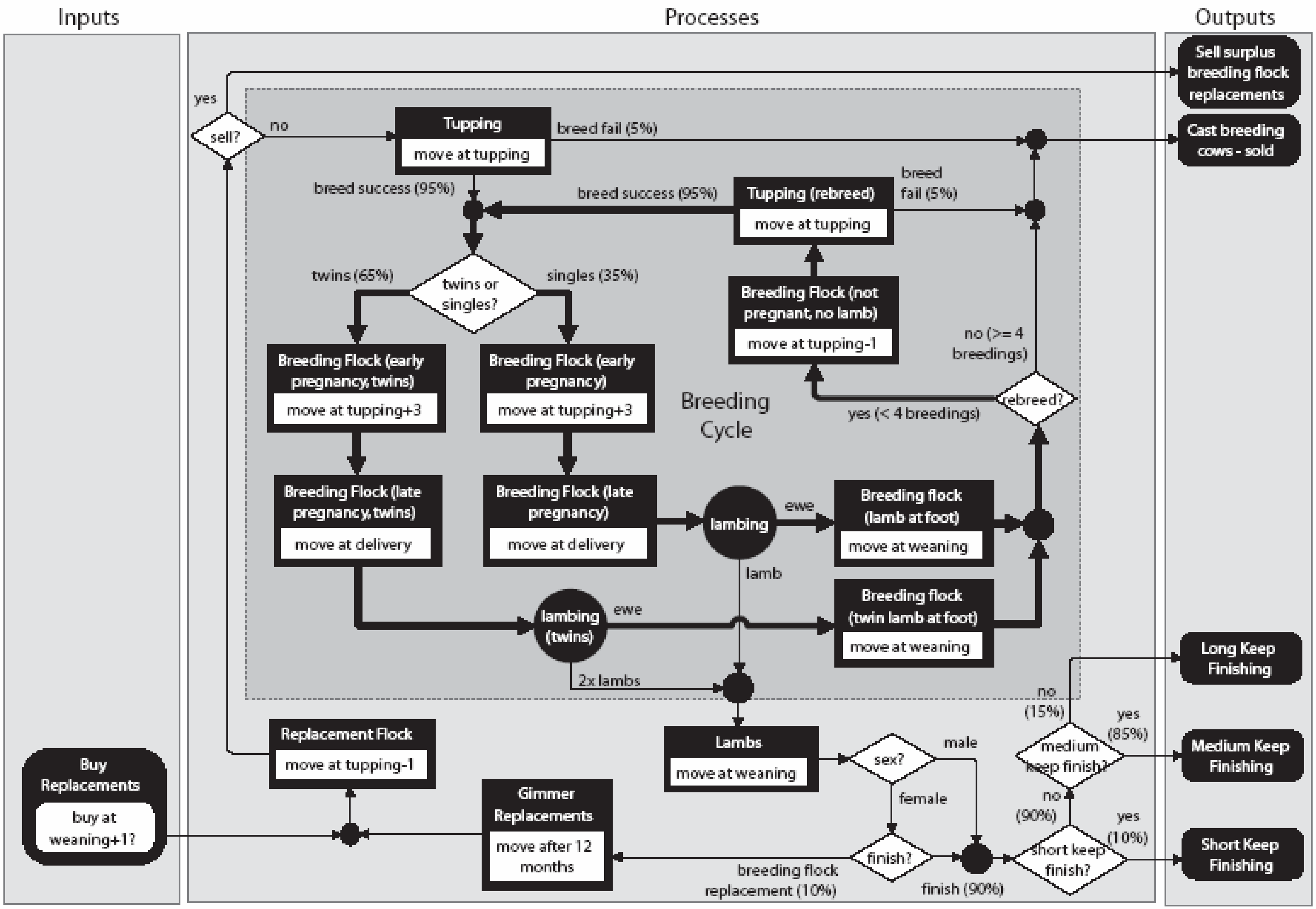
Implications for livestock

- Potential for more silage cuts
  - Lower individual yields
  - Changes fertiliser regime
- Silage quality may be affected
  - Lower quality = more supplements
- Potentially more / less biomass for grazing
- Off-site finishing – grazing still available?
- Poaching – housing relationships

- Stochastic events
  - Foot and mouth



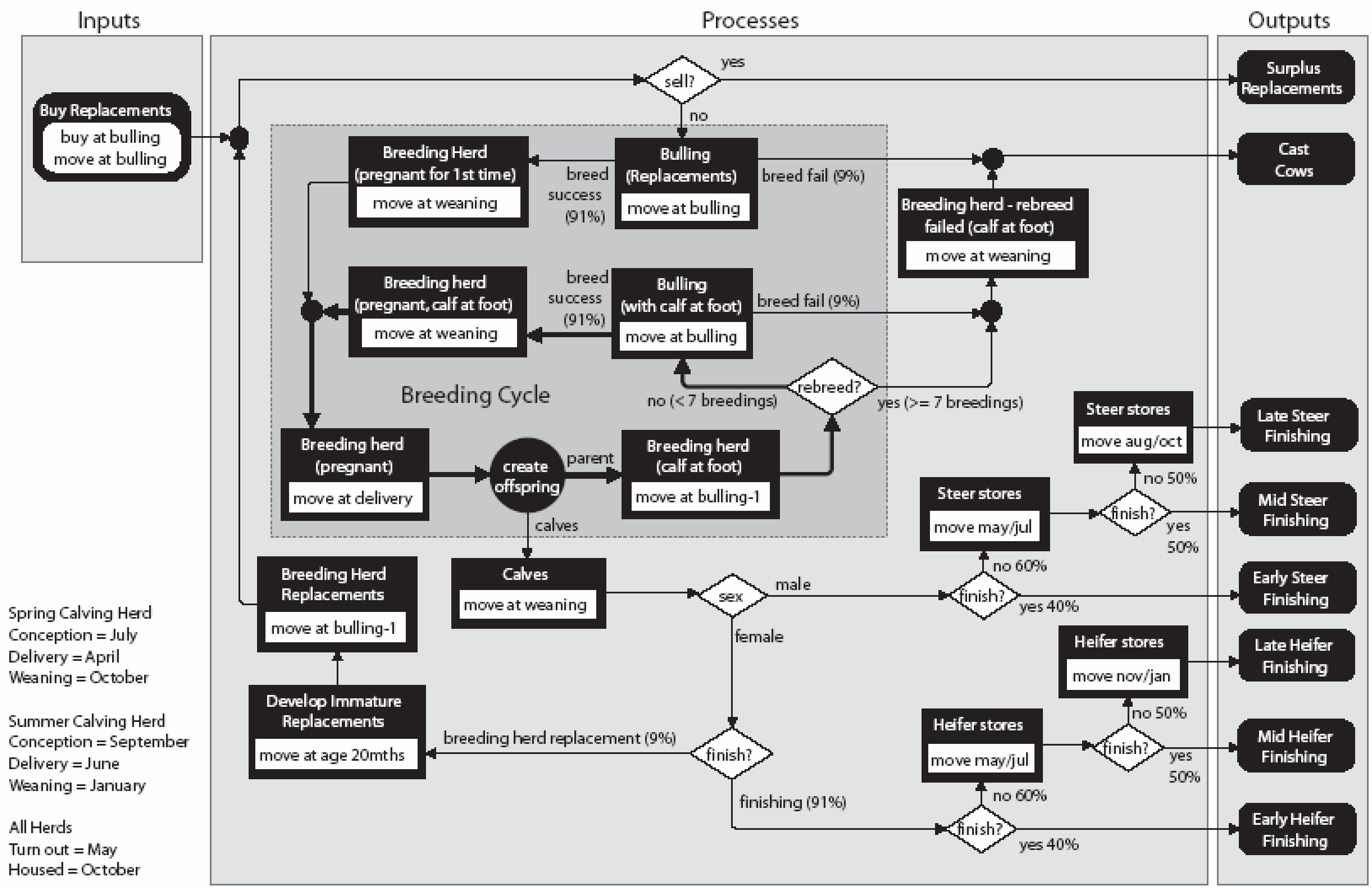
Herd network diagram – Hartwood Sheep



March Lambing Flock
Conception = october
Delivery = march
Weaning = july
Turn out = march
Housed = December

May Lambing Flock
Conception = december
Delivery = may
Weaning = august
Not Housed.

Herd network diagram – Hartwood Sucklers



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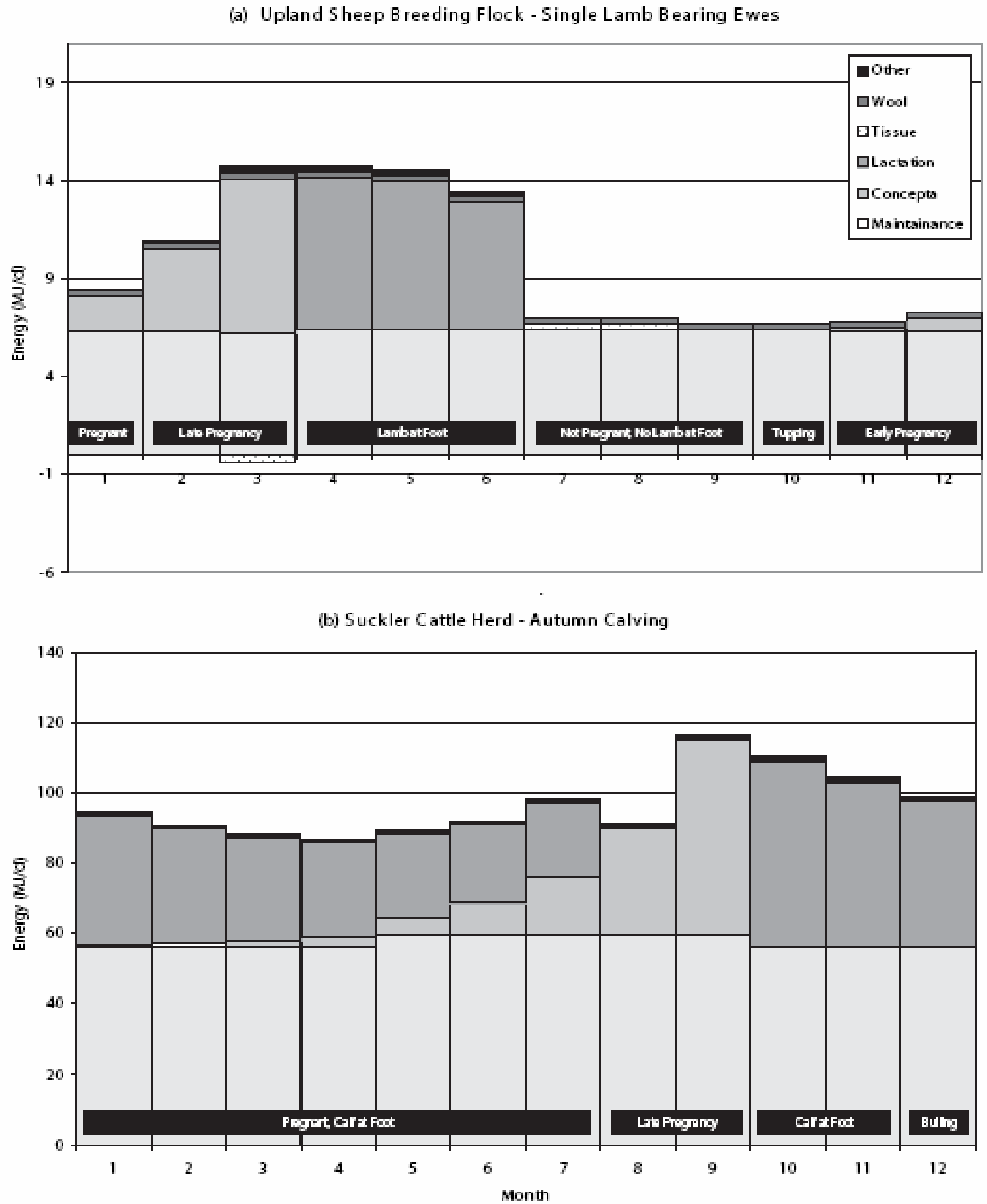
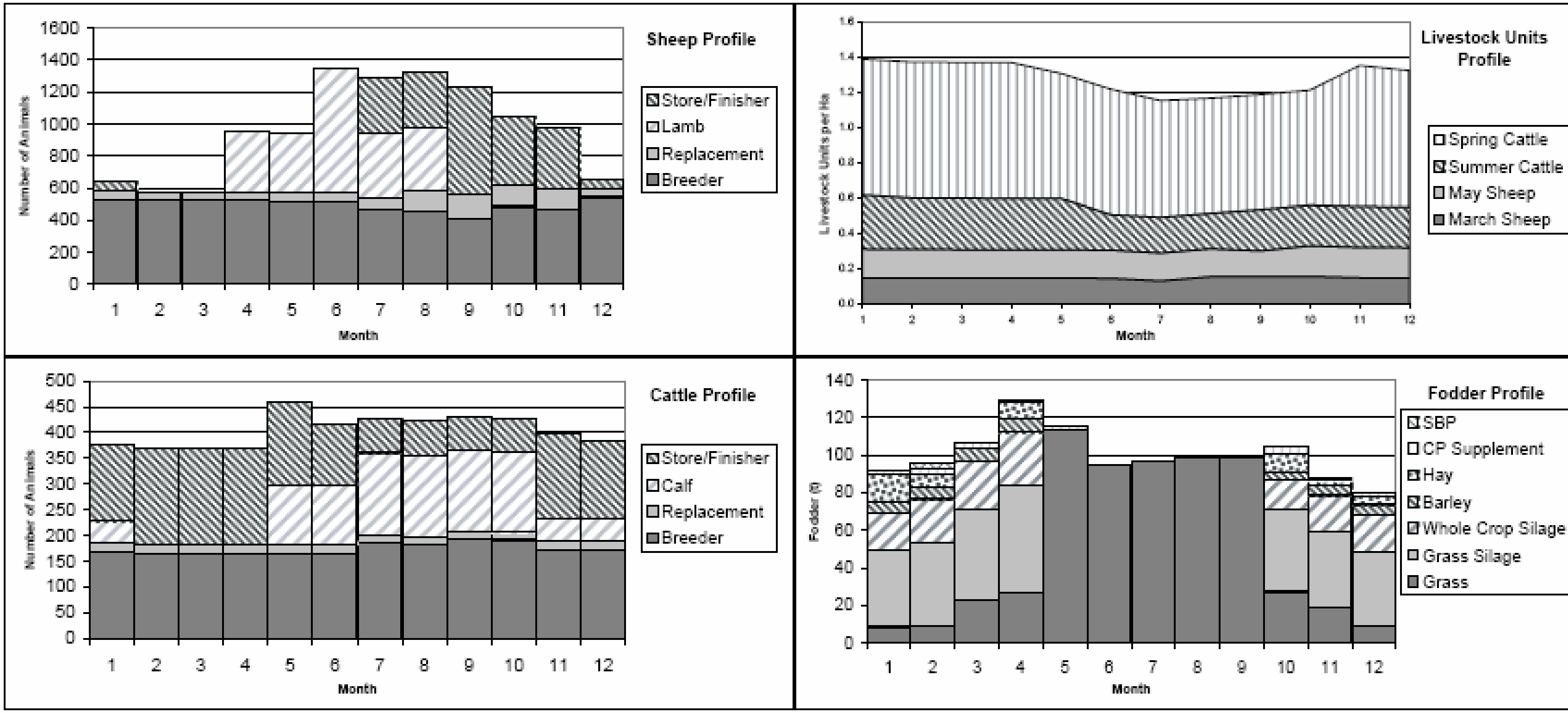


If we know what the energy requirements are for each stage / month in the year, we can determine what the feed budget will be – how much needs to be produced on the farm and how much needs to be bought in.

Livestock and Fodder Profiles Hartwood - Current Management



Areas	(Ha)
Cattle Grazing	73
Sheep Grazing	79
Silage	50
Wholecrop	28
Re-seed	20
Forestry	68
Rough Grazing	28
Total	345

Production	(t/ha)	Total (t)
Cattle Pasture	8.1	589
Sheep Pasture	6.4	505
Silage	10.2	482 *
Aftermath	2.5	127
Cereal Wholecrop	12.7	320 *

* total tonnage includes losses incurred between field and silage pit.

On-farm Produced Fodder	Prod (t)	Req (t)	Util (%)
Cattle Pasture	589	200	34%
Sheep Pasture **	632	264	42%
Grass Silage	482	315	65%
Wholecrop Silage	320	151	47%

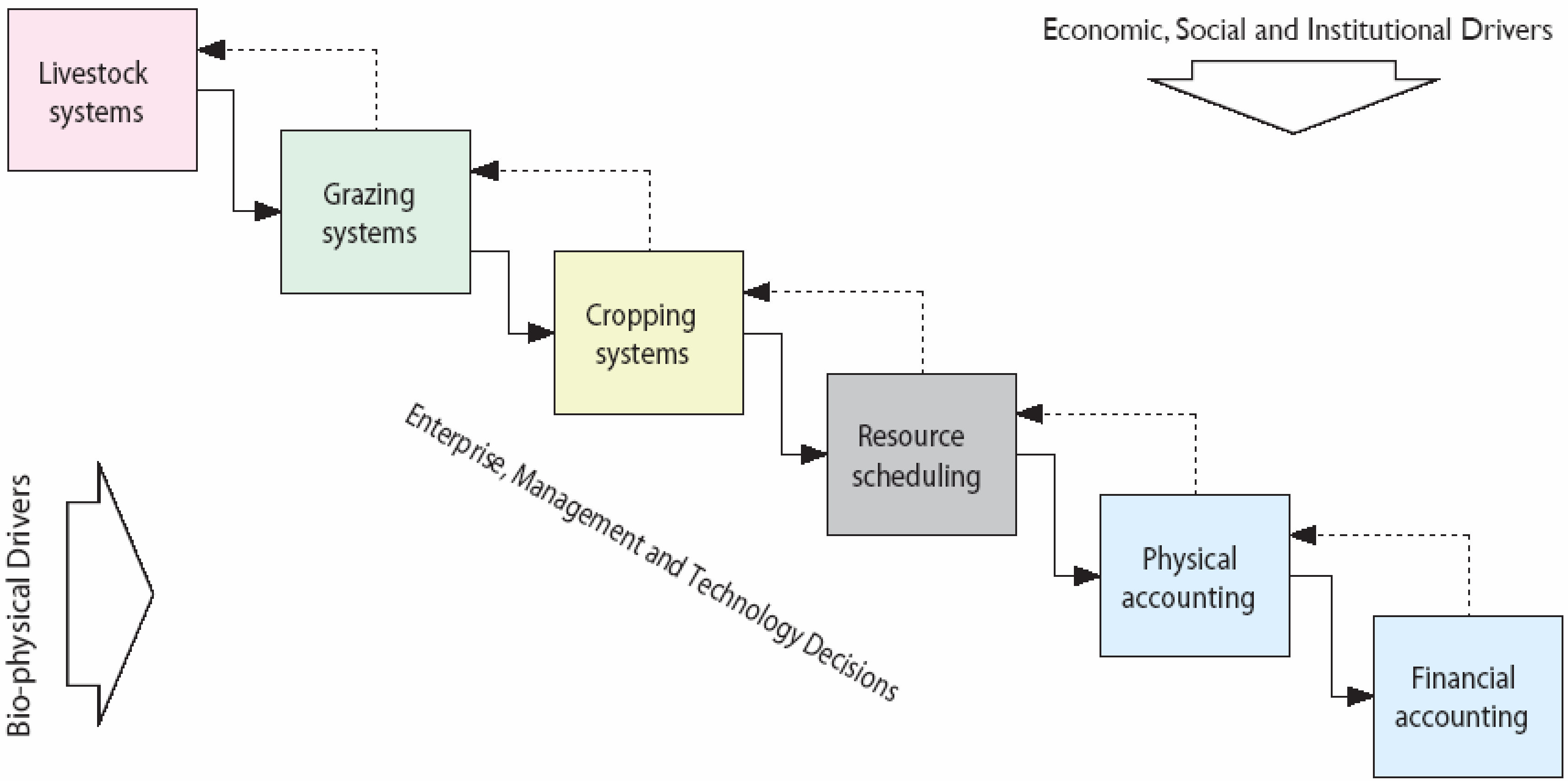
** includes 127t aftermath

Bought-in Fodder	Total (t)
Barley	41.8
Hay	46.8
CP Supplement	19.5
Sugar Beet Pulp	3.3

Whole farm systems

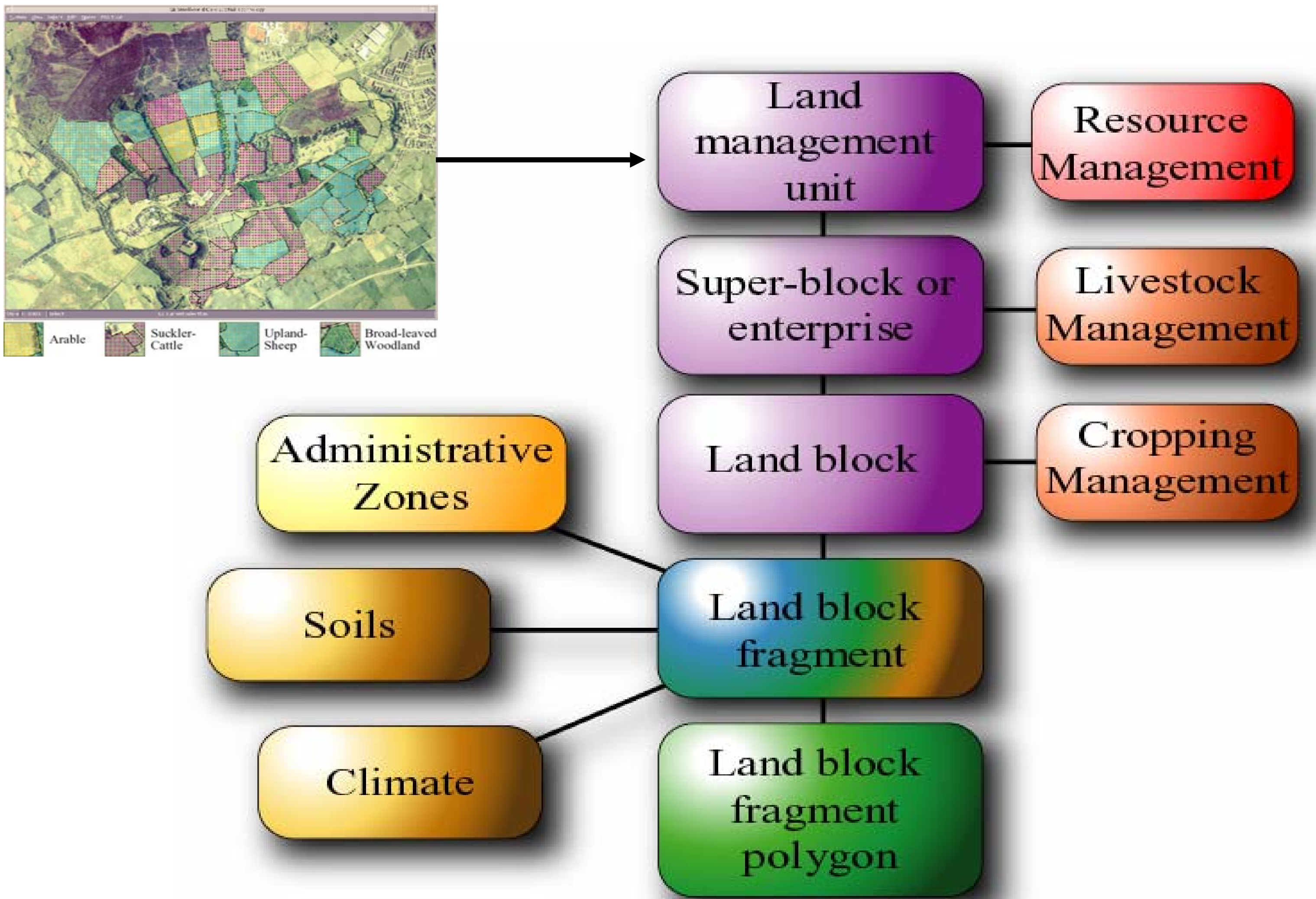
- Cumulative effects of individual land uses
  - Labour and resource scheduling
- Beyond the farm system
  - Effects of internal changes
- Uncertainty in modelling the whole system under climate change
  - Why estimates become unreliable

Farm-systems Modelling Framework

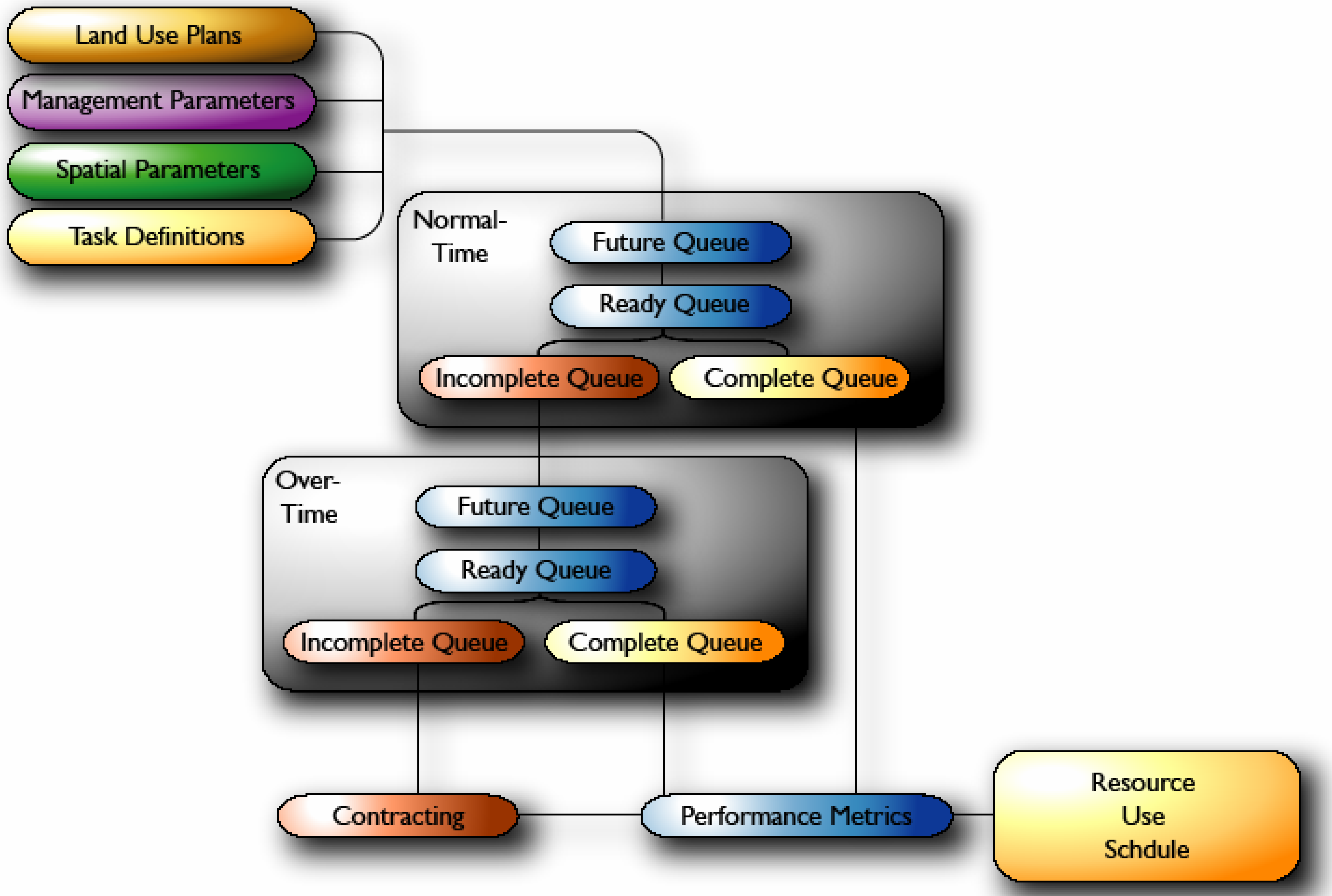


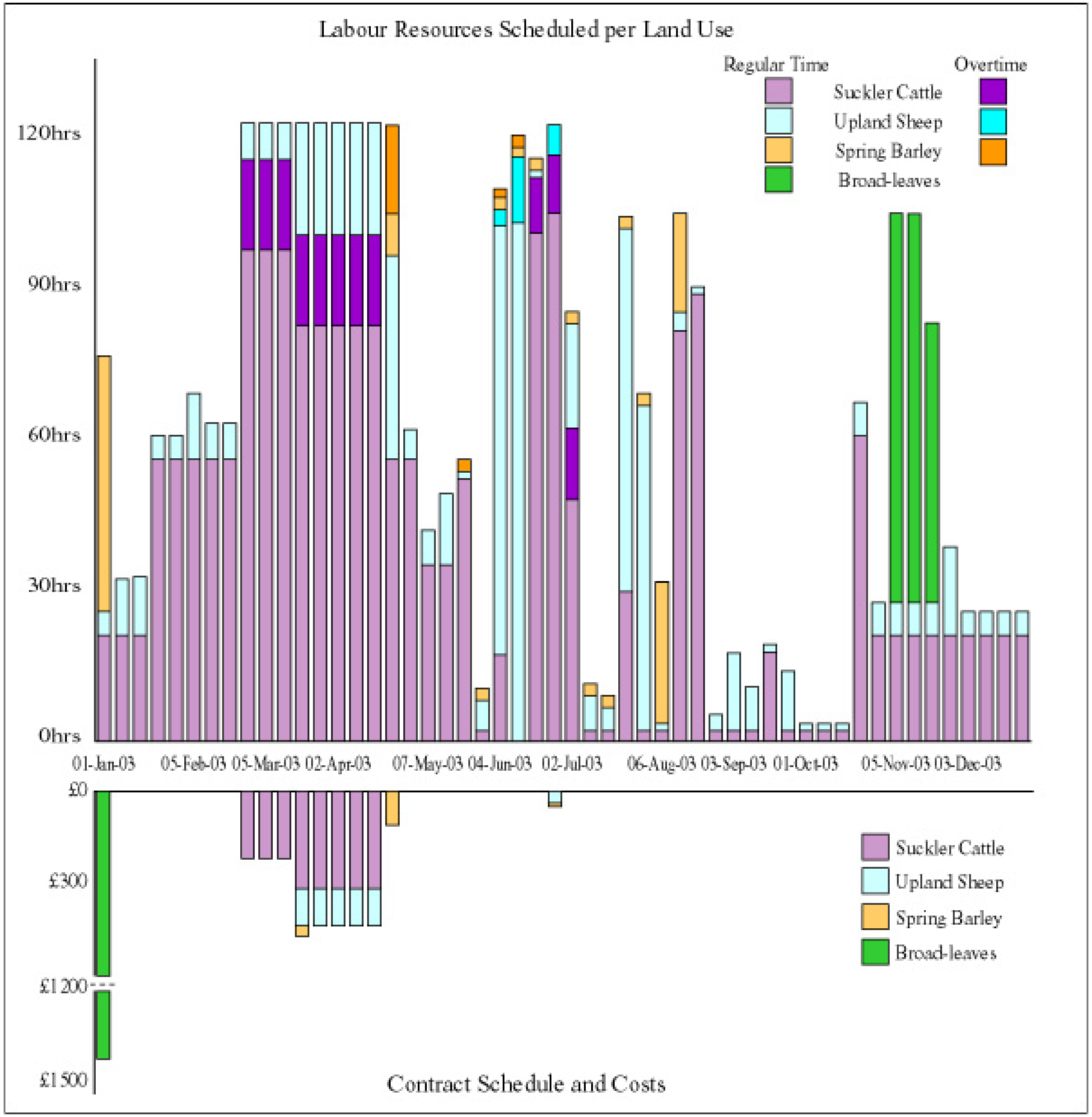
Whole farm systems:

Hierarchy of geo-spatial classes and management regimen



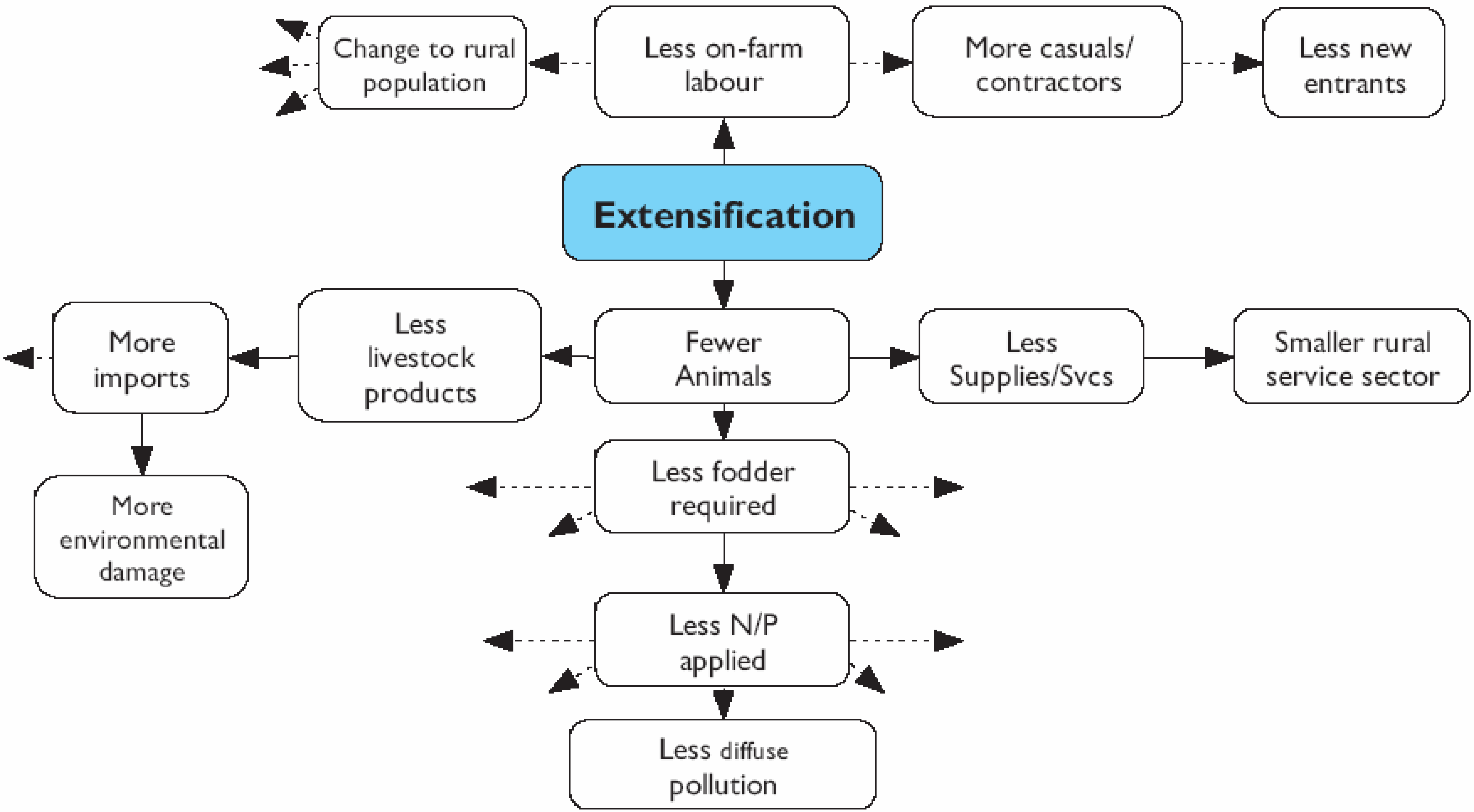
Resources Scheduling Tool Architecture




Labour Resources Scheduled per Land Use
Regular Time
Overtime
Suckler Cattle
Upland Sheep
Spring Barley
Broad-leaves
120hrs
90hrs
60hrs
30hrs
0hrs
01-Jan-03
05-Feb-03
05-Mar-03
02-Apr-03
07-May-03
04-Jun-03
02-Jul-03
06-Aug-03
03-Sep-03
01-Oct-03
05-Nov-03
03-Dec-03
£0
£300
£1200
£1500
Suckler Cattle
Upland Sheep
Spring Barley
Broad-leaves
Contract Schedule and Costs

HARTWOOD CASE STUDY Item	2004/5 Whole-Farm Amount (£)	2005/6 Reformed Whole-Farm Amount (£)	2005/6 Extensified Whole-Farm Amount (£)
Sales	£109,505	£101,740	£48,758
Compensation (OTMS)	£7,880	£7,880	£1,576
Pillar I	£56,488	£52,075	£48,825
Pillar II	£10,517	£10,517	£10,517
Pillar I and II	£67,006	£62,592	£59,342
Sales, Comp and Support	£184,391	£172,213	£109,677
Replacement Costs	-£16,922	-£16,922	-£7,482
Operations Costs	-£39,836	-£39,836	-£16,496
Fodder Costs	-£22,850	-£22,850	-£9,650
FARM GROSS MARGINS	£104,783	£92,605	£76,048
FTE	2.5	2.5	1.0
Salary Costs	-£43,450	-£43,450	-£17,380
Overtime	-£2,000	-£2,000	-£2,000
Buildings and Machinery	-£12,390	-£12,390	-£3,995
Contractor Costs	-£4,500	-£4,500	-£5,566
Fixed Costs	-£62,340	-£62,340	-£28,940
FARM NET MARGIN	£42,443	£30,265	£47,108
Per person break even	£34,357	£29,486	£64,488

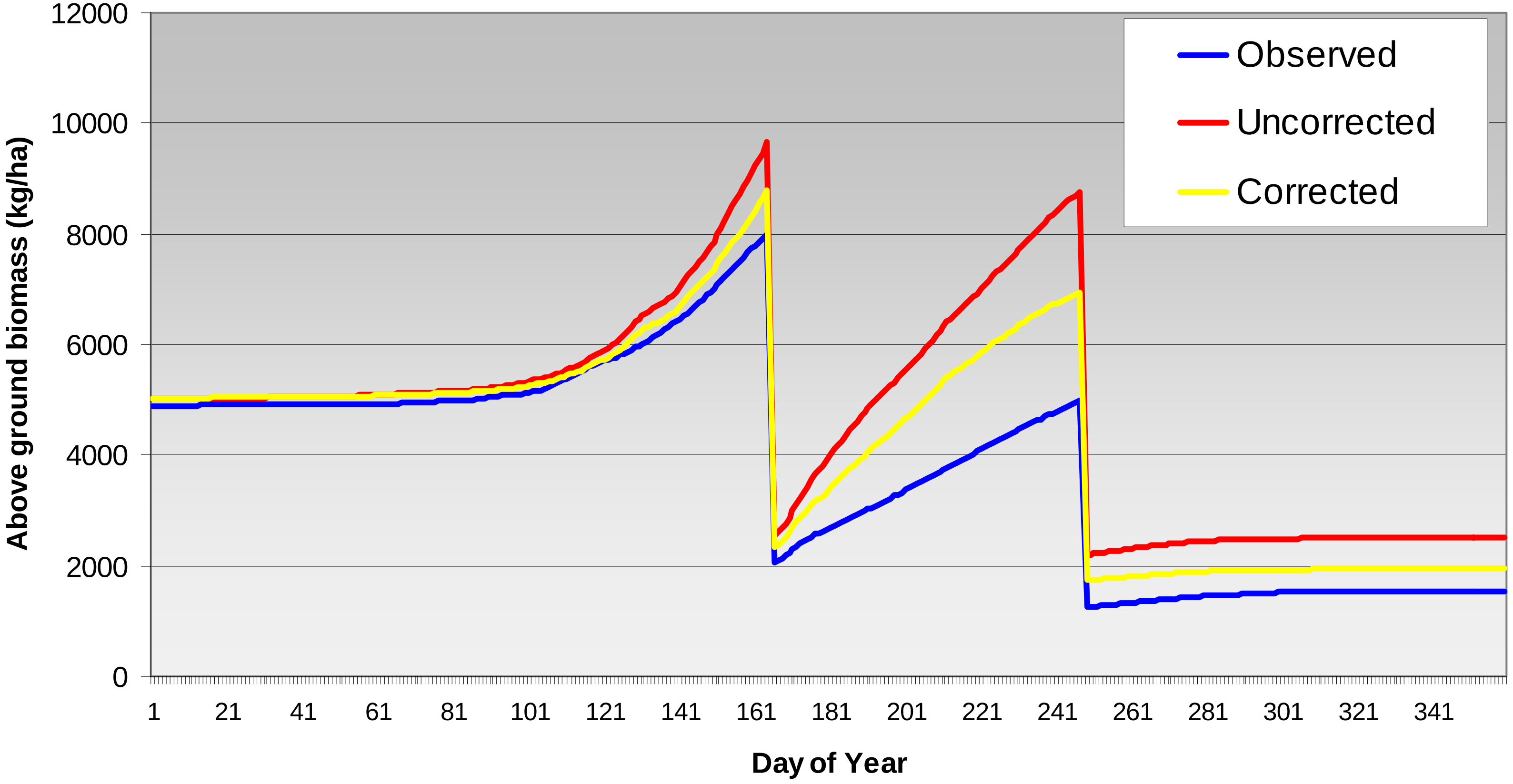
Wider Impacts



Modelling future scenarios

- The land use systems models are prone to errors due to introduced uncertainty, primarily from:
  - Future climate change data

Errors introduced to a 2-cut silage system by future climate change data (corrected and uncorrected)



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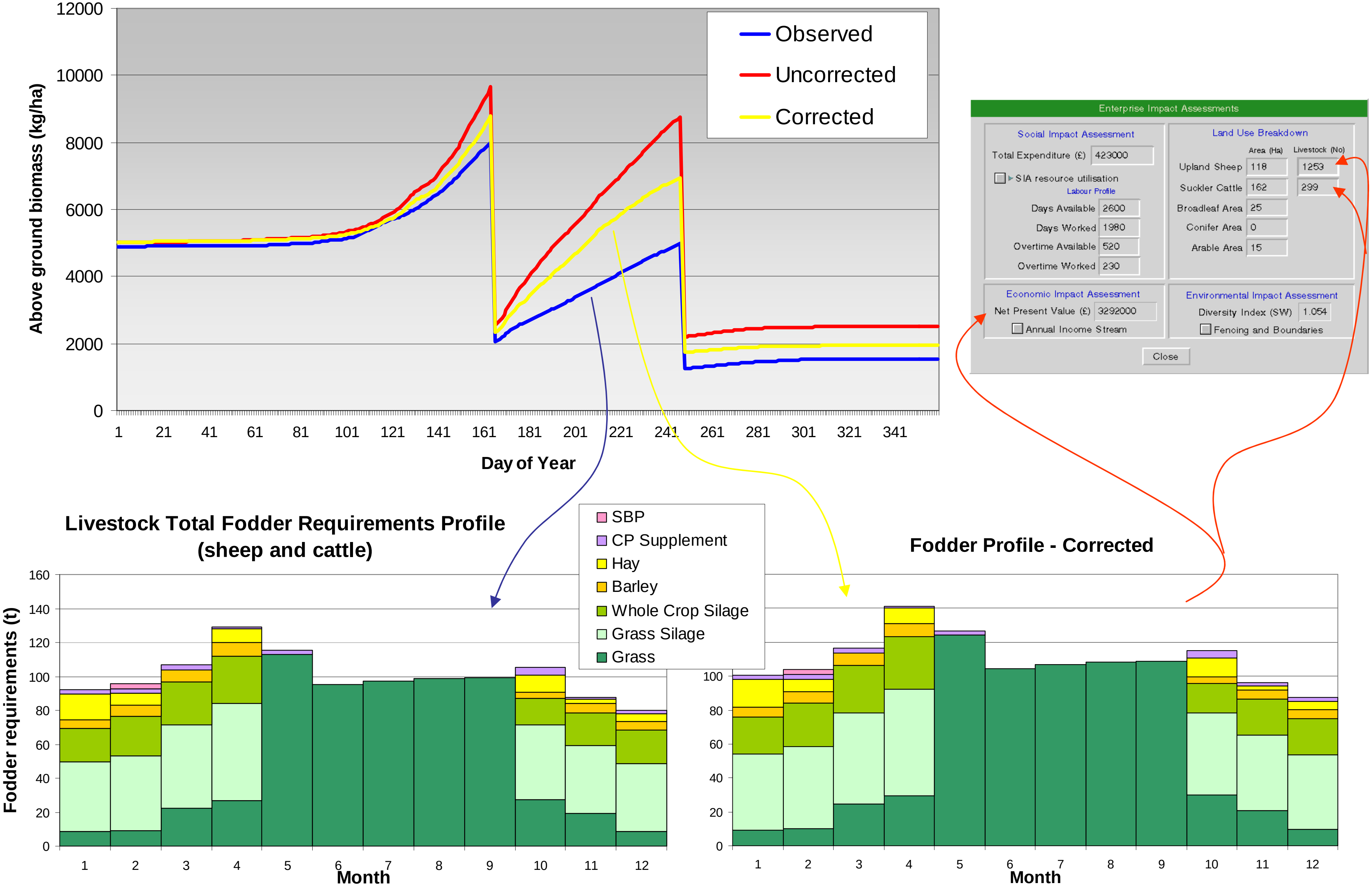
Impacts on grass production and downstream consequences:



All that extra grass will result in….

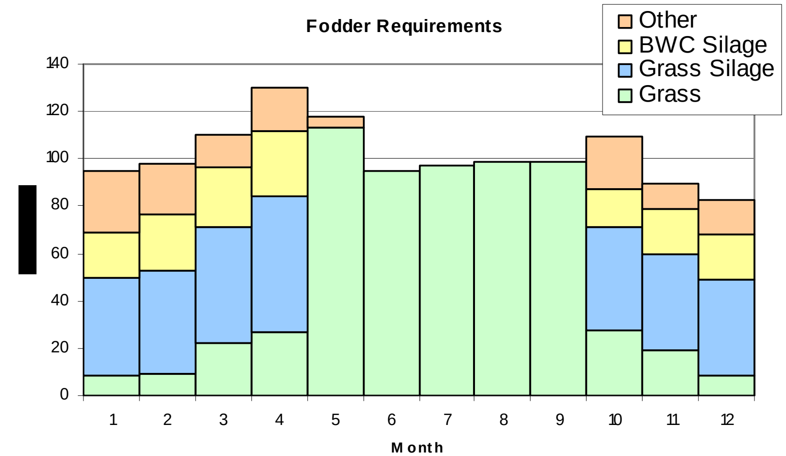
Huge coos…

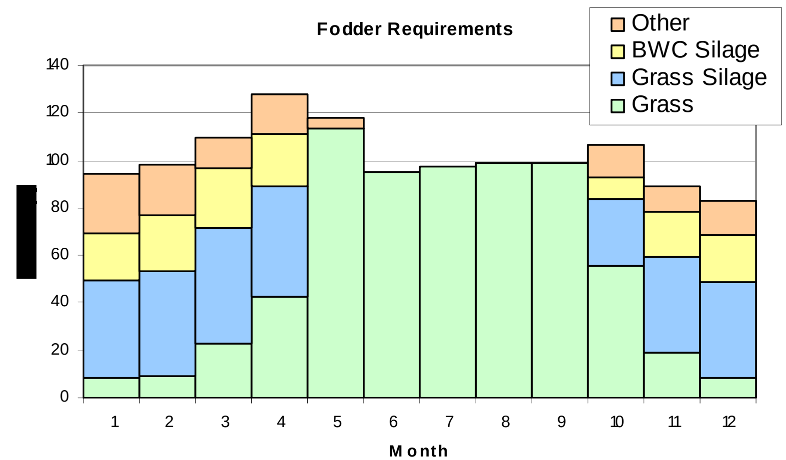
Modelling future scenarios

- The land use systems models are prone to errors due to introduced uncertainty, primarily from:
  - Future climate change data
  - Implications for management responses
    - Bearing in mind potentially:
      - No change to the date for end of or return to field capacity
      - No additional restriction to access periods?
      - Last spring air frost early May → late April
      - Mean air temperature >5 ºC 8 → 10 months
        (5.5 ºC is considered the base temperature for grass growth)

How will changes to the growing season affect livestock management?

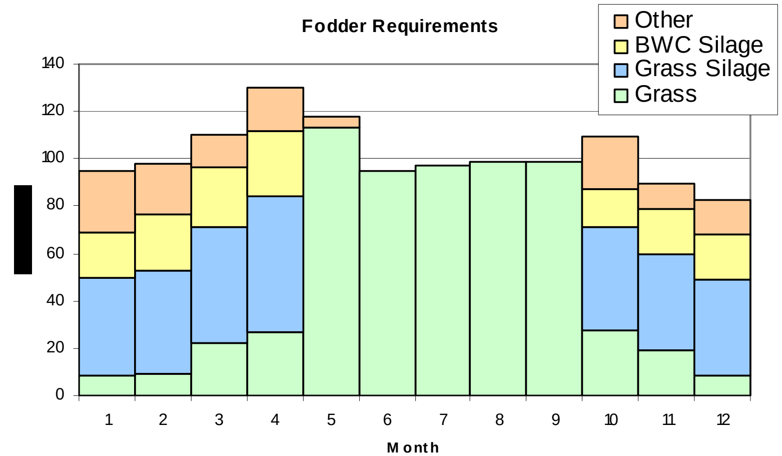
- More rapid establishment and growth may mean that the turn-out date can be brought forward
- Warmer temperatures may mean the growing season is extended to allow for a later housing date
- Longer grazing season may result in a reduction in silage and supplementary feeding requirements
- Earlier turn-out dates may mean that ground is unsuitable for grazing due to poaching

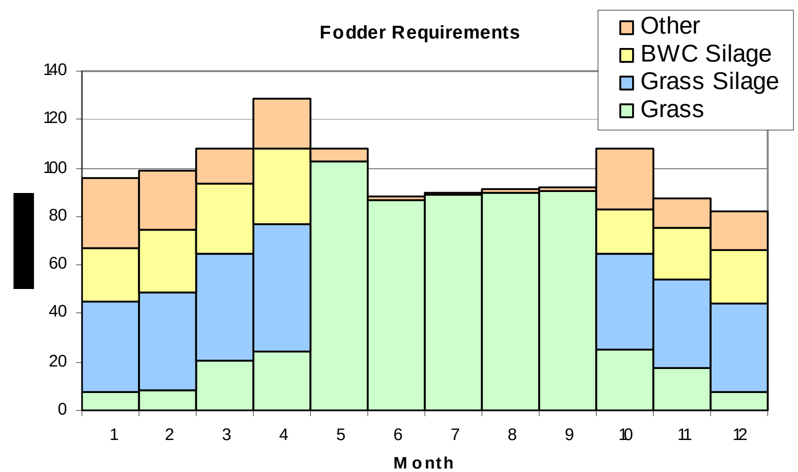




How will changes to crop yield and quality affect livestock management?

- Increased yield could increase stock capacity, however it could be at the expense of quality, which would reduce capacity
- Reduced quality may mean the dry matter intake limit is reached during periods of high energy demand (eg. lactating twin bearing ewes) - additional supplements may be required
- Will variability of yield and quality change? If so, how will risk management practices adapt?





Grazing semi-natural vegetation

- Need to consider the role of grazing on semi-natural vegetation and corresponding responses
  - Species dynamics / floristic composistion
  - Higher temperature may favour *Festuca* over *Nardus* (?)
  - How robust are plant / soil ecosystems?
  - Climate change may have a more significant impact on vegetation response than changes in management (?)
  - Role of muir burning ?
  - Montane vegetation ?

Land Use Change

- Crop and livestock systems will change due to climate
- Quantifying land use change is determined by the quality of input data
- Adaptation to change may be in the form of:
  - Changes in the land use composition
  - Subtle changes to management
- Potential for novel land uses:
  - Bio-energy crops
  - Land use combinations
  - ‘Southern’ crops – maize etc
- Diversification, Intensification, Extensification?

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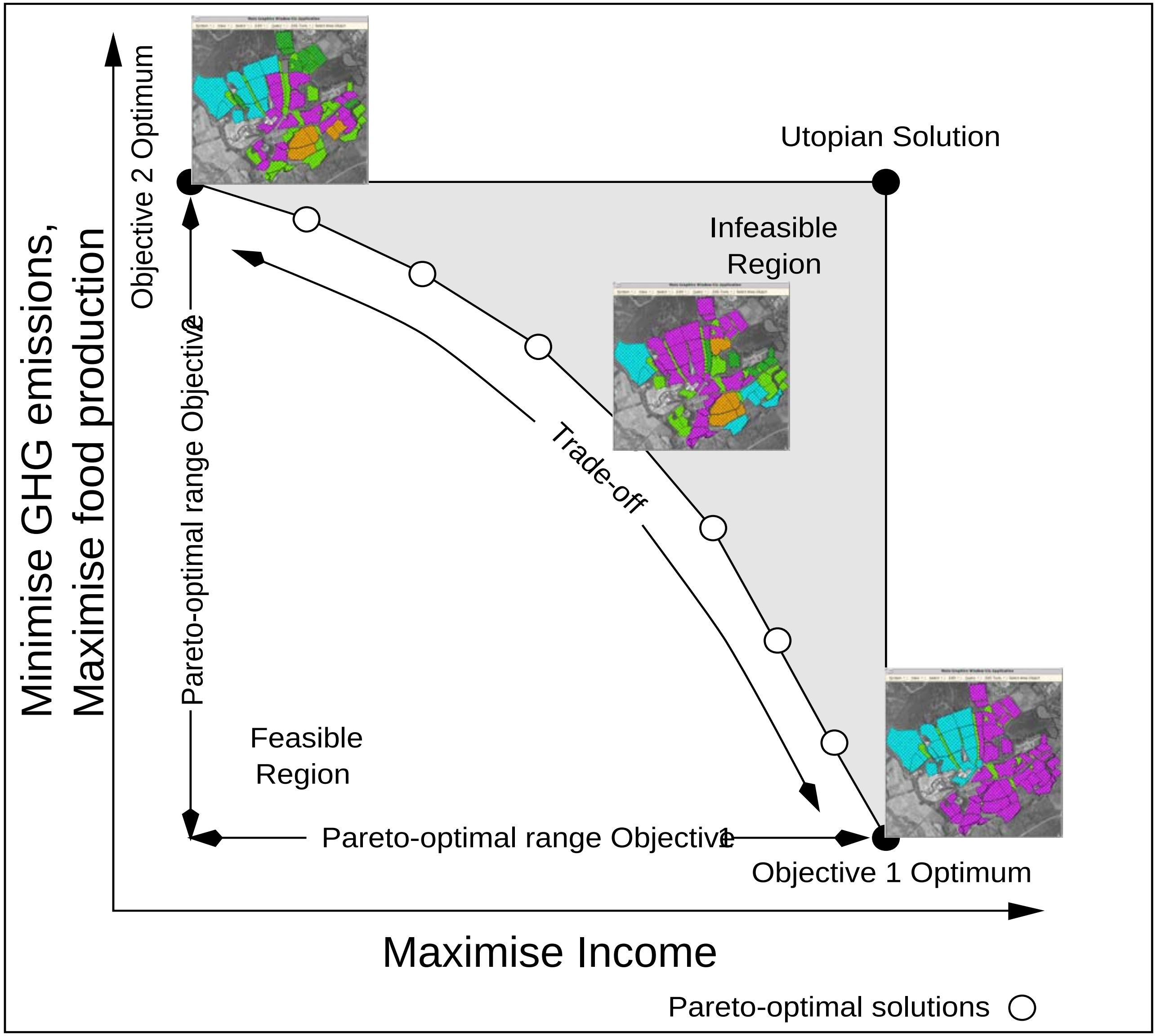
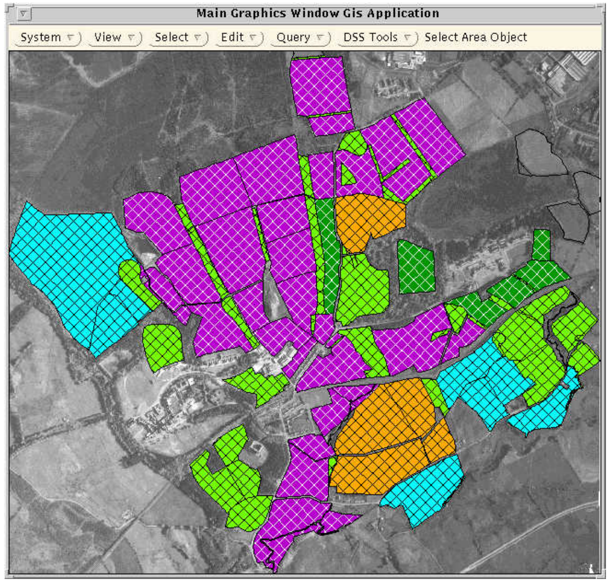
Are we looking for a compromise in multiple objectives?

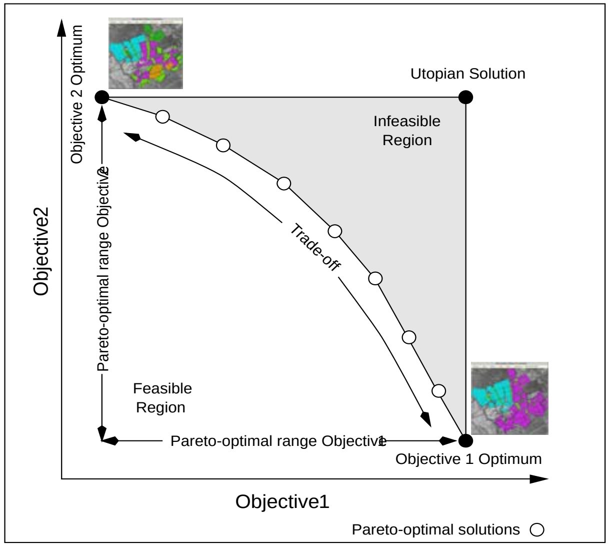


Are we looking for a compromise in multiple objectives?

Will a compromise solution satisfy enough requirements?

- Only partially achieve mitigation targets?
- Not provide sufficient:
  - Food production
    - Impacts on supply chains
  - Ecosystem services
  - Biofuels / renewable energy etc
- Not generate sufficient income?
  - Continued reliance on subsidies?
- New systems need to be resilient:
  - Withstand ‘shocks’
  - Vulnerability to extreme event frequency and severity





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Farming and climate change amelioration

- Strategic planning
  - Timescales beyond legislative term
  - Required investments
- What will drive amelioration - policy (subsidies) or markets?
- What are the practical steps that can be taken to achieve amelioration?
  - Can amelioration be treated as just another multiple-objective?
- What research support will there be to aid developments of amelioration approaches?
- Amelioration and adaptive capacity of agri-businesses
  - ‘Locked in’ to specific systems?
  - What are the thresholds / boundaries?
  - What flexibility do systems have?