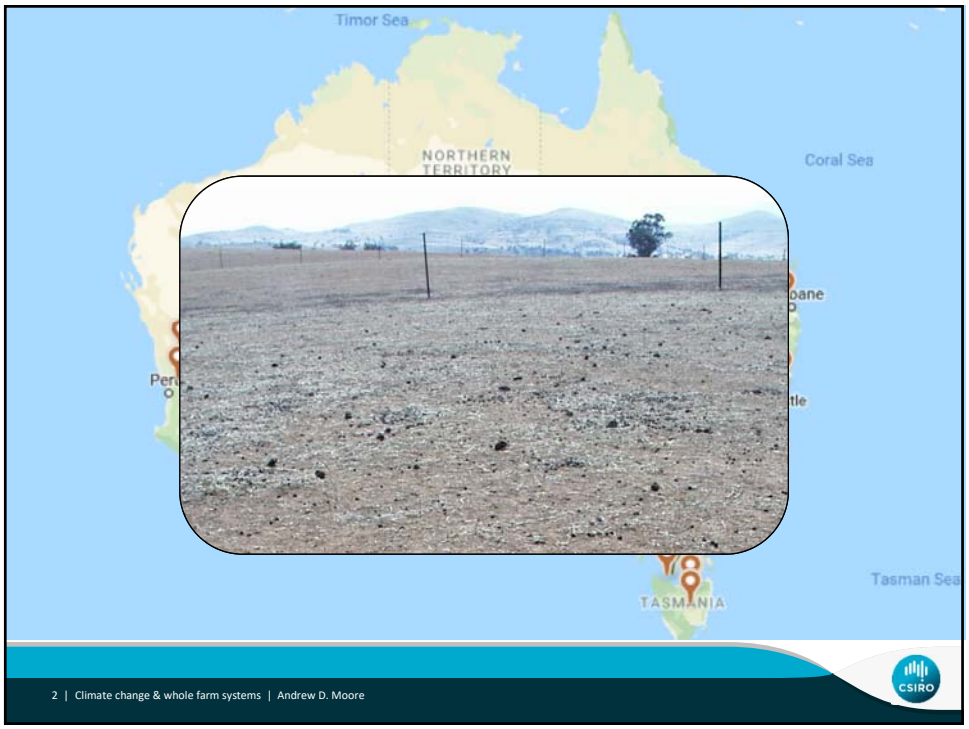
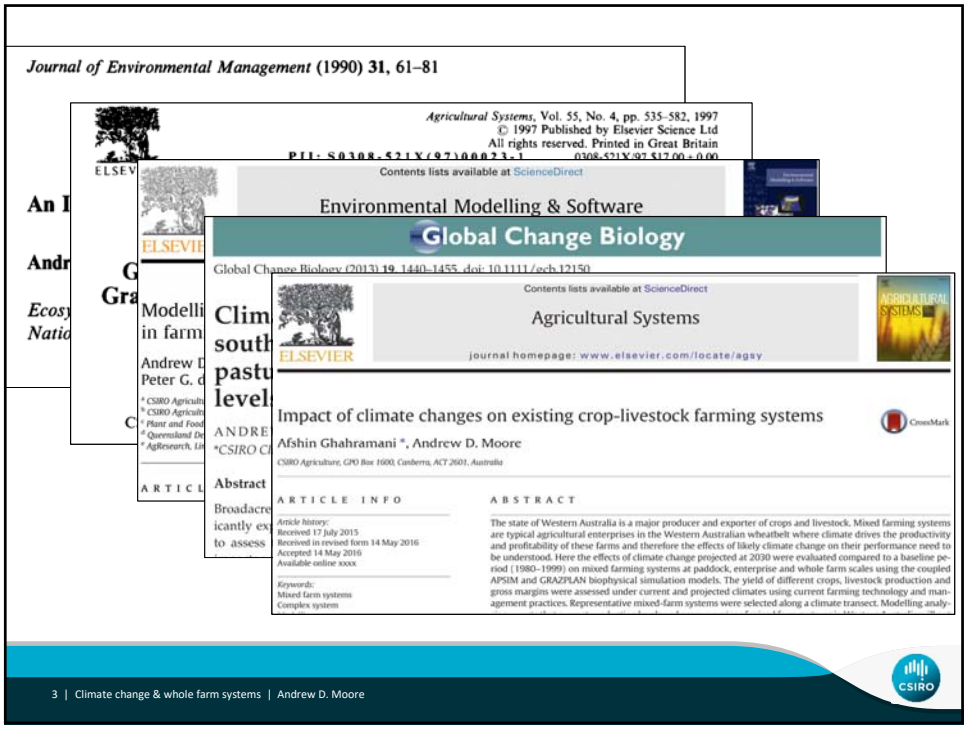
Modelling the impact of climate change on whole farm systems

Andrew D. Moore | Leader, Digiscape Future Science Platform

8 July 2018

AGRICULTURE & FOOD
www.csiro.au





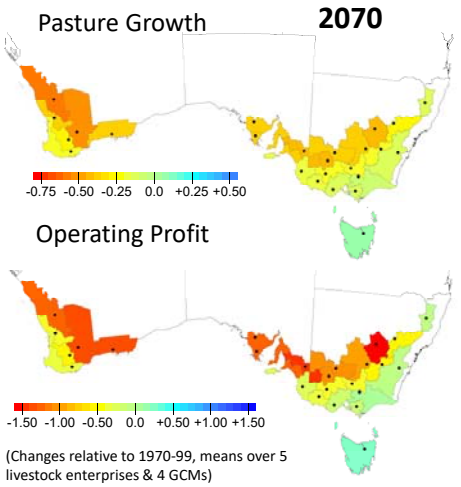
Climate change is a major industry threat

Decreases in pasture growth are largest at the dry margin of the cultivated zone

Operating profit reduces more than pasture production

- Driven by reductions in sustainable stocking rate
- Sizeable impact at 2030

Progressive increase in impacts to 2070



(Changes relative to 1970-99, means over 5 livestock enterprises & 4 GCMs)

Moore *et al.* (2013) *Global Change Biology*

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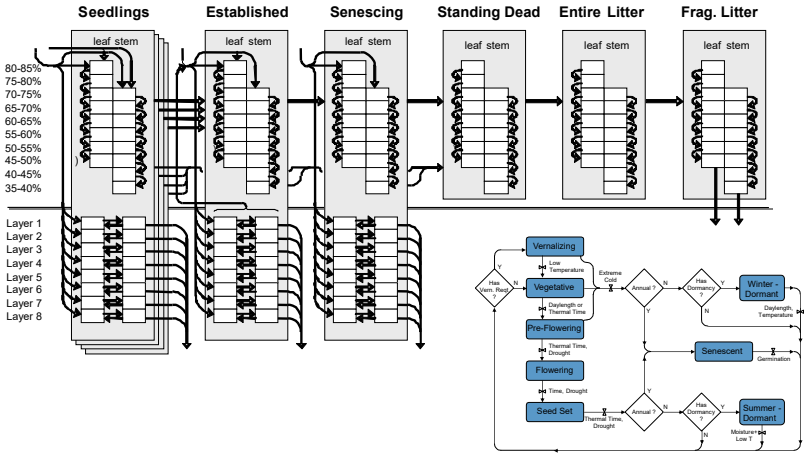
GRAZPLAN Grassland Model

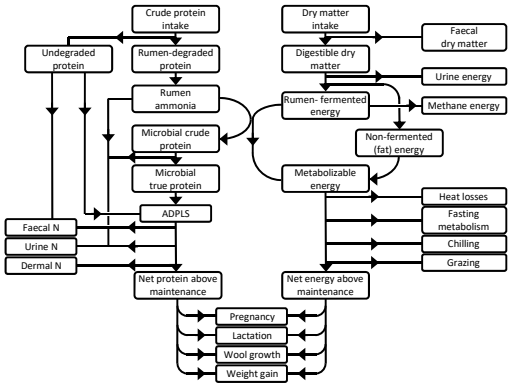


GRAZPLAN Ruminant Model

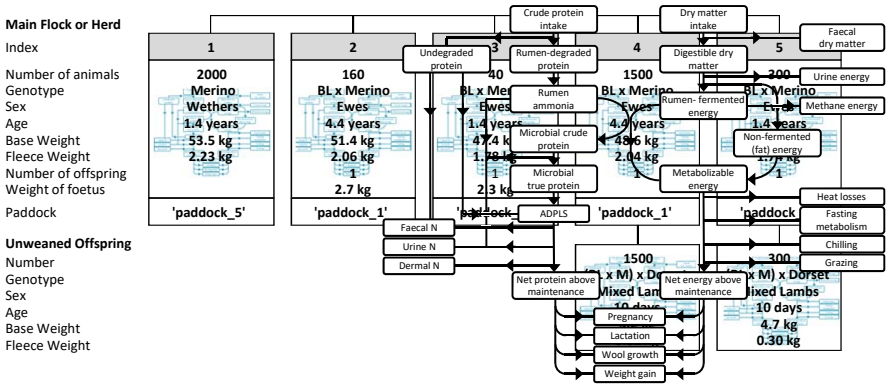
Cattle & sheep
Daily time step
Grazing animals
- Supplementary feeding in pasture or feedlot

Intake
- Potential intake
- Relative intake

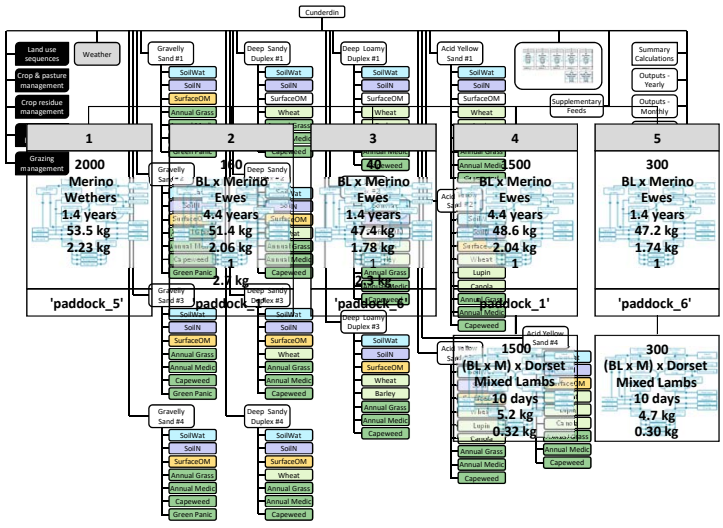
Energy & protein use
Reproduction
Mortality
Management



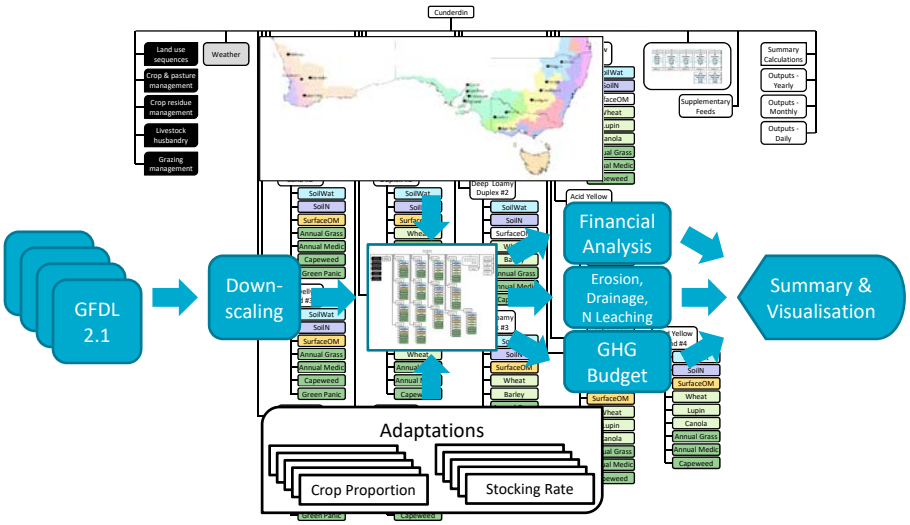
GRAZPLAN Ruminant Model



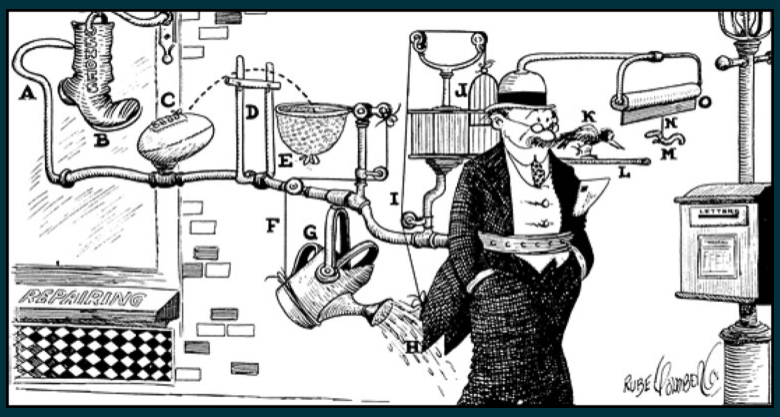
Agro-Ecosystem Model



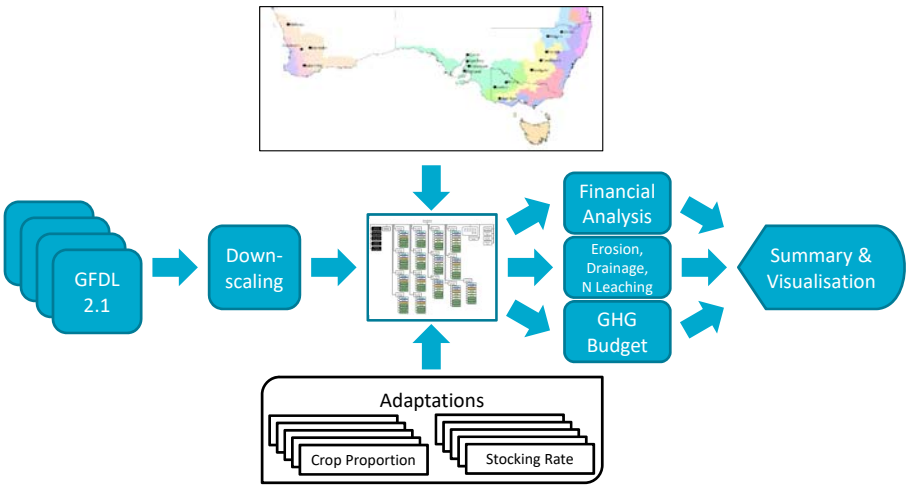
Climate Change Work Flow



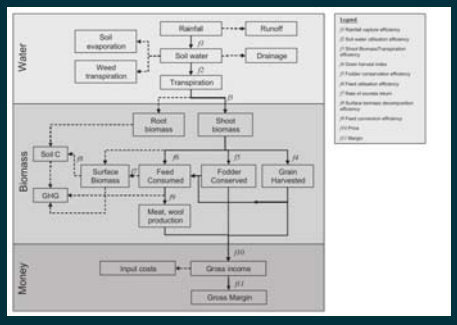
It's all about the work flow

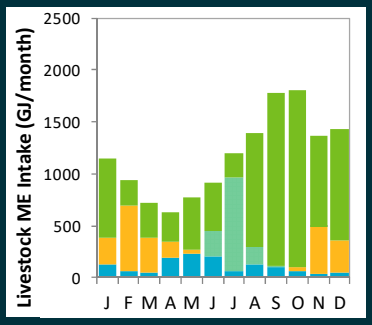


Climate Change Work Flow



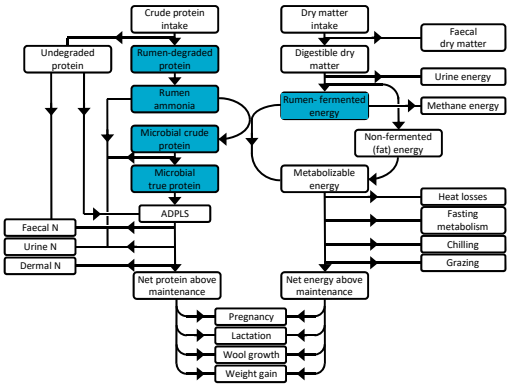
Simplicity beyond the complexity: farm-scale metrics





GRAZPLAN Ruminant Model

Empirical rumen submodel for both passage rate & digestion

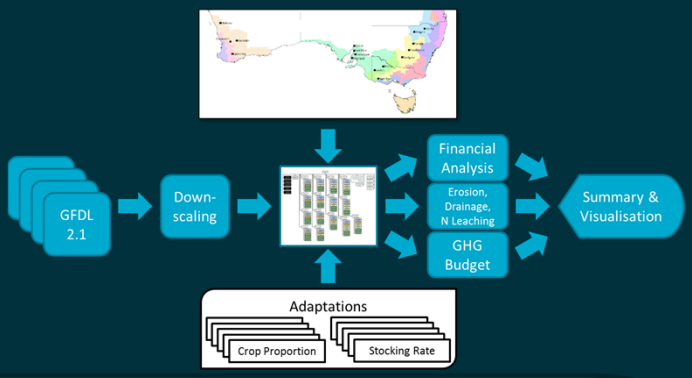


Freer *et al.* (1997) *Agricultural Systems*

Livestock & Climate Change Impact Studies

Study	Location	Livestock Model	Explicit Rumen?
Aghajanzadeh-Darzi *et al.* 2017	Europe	Conversion Efficiency	No
Rojas-Downing *et al.* 2018	Michigan	IFSM	No
Descheemaeker *et al.* 2018	Zimbabwe	LIVSIM	No
Boone *et al.* 2018	Global	Nil (G-RANGE)	No
Zhang *et al.* 2017	Qinghai-Tibet	Nil (DNDC)	No
Thamo *et al.* 2017	SE Australia	GRAZPLAN	No
Kalaugher *et al.* 2017	New Zealand	Dairy WFM/MOLLY	Yes
Harrison *et al.* 2017	SE Australia	DairyMod	No
Belem & Saqali 2017	Burkina Faso	MOWASIA	No

Uncertainties in workflows: inputs vs parameters vs model structure



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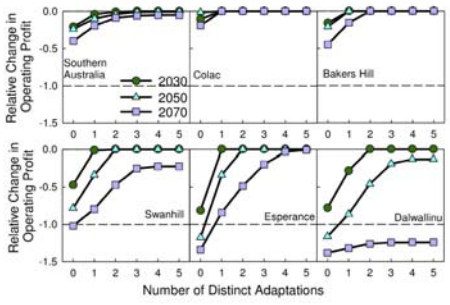
Opportunities for adaptation at whole farm scale

Set of possible adaptation policies is *very* large

Multiple trophic levels:
- Adapt the feedbase
- Adapt the livestock system

Adapt the enterprise mix
- Wool vs meat, sheep vs cattle
- Cropping vs livestock



Ghahramani *et al.* (2015) *Agricultural Systems*

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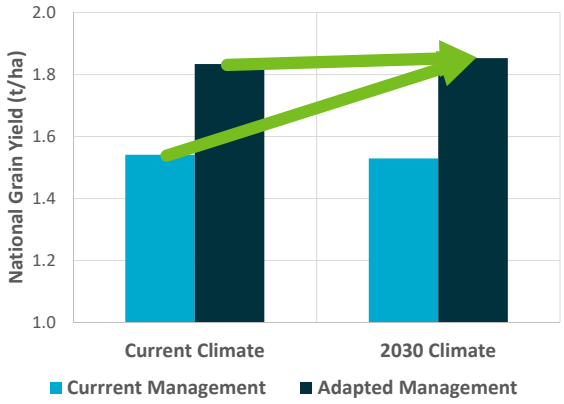
Thinking about adaptation: changes in practice

What is the "value of adaptation" here?



Ghahramani *et al.* (2015) *Agriculture, Ecosystems & Environment*

Thinking about adaptation: livestock systems

Human response typically conceived as *exogenous:*

"Impact" = the climate changes, people don't change

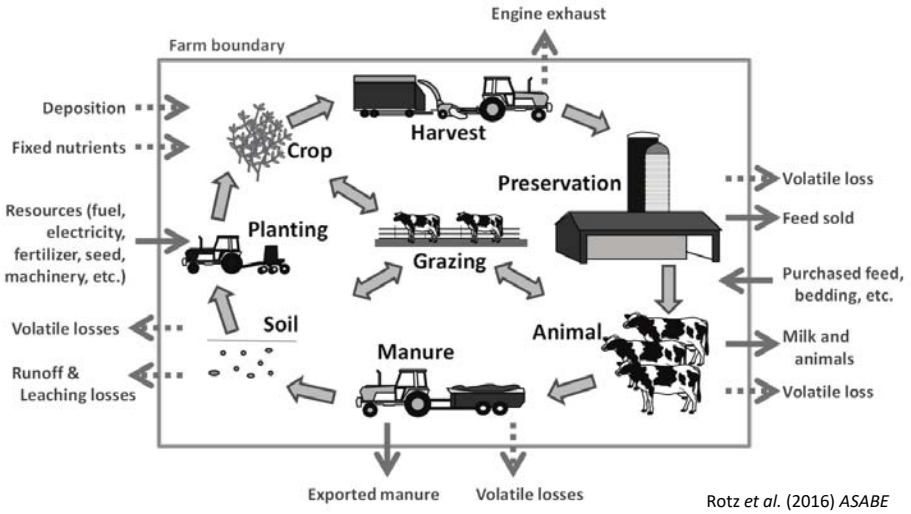
"Adaptation" = the climate changes, people do change

But… what happens when "impact" in this sense takes the system past a functional threshold?

When thinking about whole farms, it makes more sense to conceive the human actors as *endogenous*

This has consequences for model builders and users

Modelling the (responsive) manager



Rotz *et al.* (2016) *ASABE*

Modelling the (responsive) manager

(a) GPFARM

```
#RULE wheat_sow;
WHILE ( wheat IS TRUE)
{  IF ( NOT .wheat_planted )
   {   WHILE ( date.day_of_Year IS >= 115 and <=181 )
       {   IF ( soil.Water_Content IS >= 0.20 )
           {   THEN
               {   fertilize WITH urea USING 40.0 Kg_N/ha;
                   plant WITH wheat USING yitpi
                       AND USING 15.0 Cm_row_spacing
                       AND USING 150000 Plts/ha_seeding_rate;
                   SETVAR_TRUE ( .wheat_planted );
               } ENDTHEN();
           } ENDIF();
       } ENDRULE();
   } ENDIF();
} ENDRULE();
```

(b) APSIM

```
IF crop_phase = 'wheat' AND crop_planted = 0 THEN
  mean_theta = (sw_dep(1) + sw_dep(2)) / (dlayer(1) + dlayer(2))
  IF date_within('25-apr', '30-jun') = 1 AND mean_theta >= 0.20 THEN
    fertilise apply amount = 40 (kg/ha), type = 'urea', depth = 50(mm)
    wheat sow plants =150 (/m^2), sowing_depth = 25(mm),
          cultivar = 'yitpi', row_spacing = 150 (mm), crop_class = 'plant'
    crop_planted = 1
  ENDIF
ENDIF
```

(c) GRAZPLAN

```
define const integer first_sowing = 115; last_sowing = 181
define string crop_phase = 'wheat'
define logical crop_planted = FALSE

if (crop_phase = 'wheat') and not crop_planted
{  set mean_theta = (sw_dep(1) + sw_dep(2)) / (dlayer(1) + dlayer(2))
   If (day >= first_sowing) and (day <= last_sowing) and (mean_theta >= 0.20)
   {  fertilise.apply amount = 40.0, type = 'urea', depth = 50.0
      wheat.sow plants =150.0, sowing_depth = 25.0,
            cultivar = 'yitpi', row_spacing = 150.0, crop_class = 'plant'
      set crop_planted = TRUE
   }
}
```

(d) APSIM Manager-2

```
Const first_sowing as Integer = 115, last_sowing as Integer = 181
<Link> Dim Wheat As Plant
<Link> Dim Fert As Fertilizer
<Input> Private Today As DateTime
<Input> Private sw_dep As Single()

Dim crop_phase As String = "wheat"
Dim crop_planted As Boolean = False
Dim mean_theta As Single
Dim doy As Integer

If crop_phase = "wheat" And not crop_planted Then
  doy = Today.DayOfYear
  mean_theta = (sw_dep(1) + sw_dep(2)) / (dlayer(1) + dlayer(2))
  If doy >= first_sowing And doy <= last_sowing And mean_theta >= 0.20 Then
    Fert.apply(40.0, "urea", 50.0)
    Wheat.sow (150.0, 25.0, "yitpi", 150.0, "plant")
    crop_planted = True
  End If
End If
```

Moore *et al.* (2014) *Envirnmental Modelling & Software*

Critical features of future livestock nutrition models:

- Well-specified interface
- Embedded within herd dynamics
- Input uncertainties minimized
- Responsive to individual human actions
- All outputs tracked (including excreta!)

Knowledge Gaps #1

Models for the behavioural determinants of daily forage intake

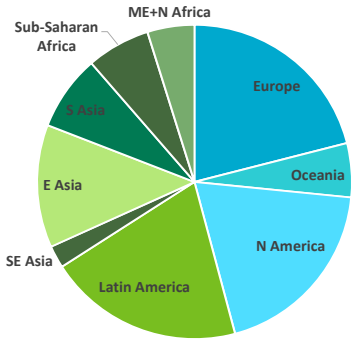
- especially under high temperatures

Picture: José Dubeux, North Florida Research & Education Center

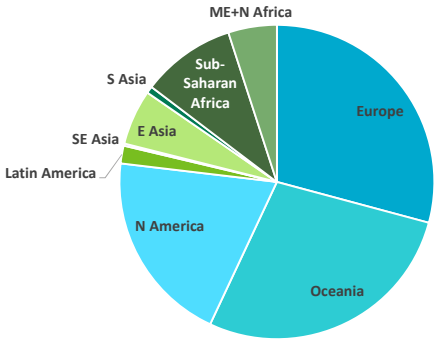
Knowledge Gaps #2

Climate change impacts analyses are largely an OECD game

Meat from Ruminants



Climate Change Studies



Knowledge Gaps #3

Exploring gene x environment x management interactions

- one prospect: construct economic breeding indices that take changing climates into account

Journal of Experimental Botany, Vol. 64, No. 12, pp. 3747–3761, 2013
doi:10.1093/jxb/ert209 Advance Access publication 19 July, 2013
This paper is available online free of all access charges (see http://jxb.oxfordjournals.org/open_access.html for further details)

Journal of Experimental Botany

RESEARCH PAPER

Quantification of the effects of *VRN1* and *Ppd-D1* to predict spring wheat (*Triticum aestivum*) heading time across diverse environments

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Thank you
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