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science for global insight

Modelling heat stress on livestock: how can we reach long-term and global coverage?

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15-16th June 2016

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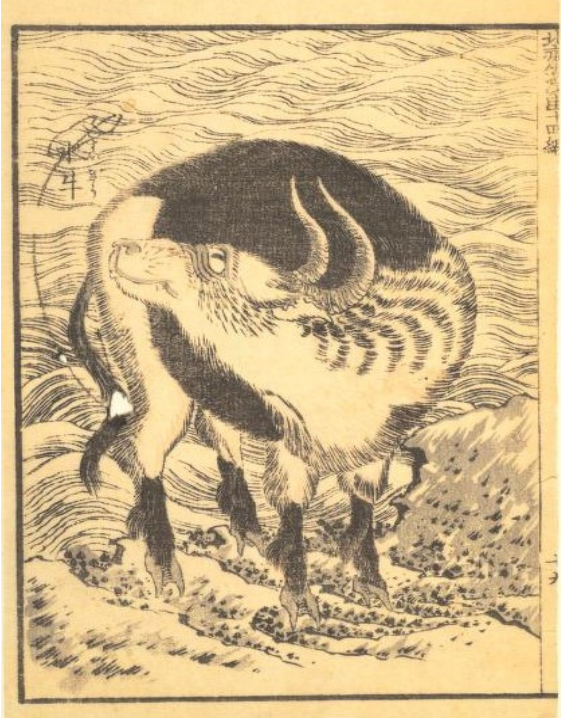

Water buffalo, *by Katsushika Hokusai*

Introduction

Introduction

- Exposure to heat stress is a large geo. driver of current global livestock:
  - "The thermal environment is the most important ecological factor determining the growth, development, and productivity of domestic animals." *(Collier & Gebremedhin, 2015)*
  - "Heat is a major constraint on animal productivity in the tropical belt and arid areas […]. The effect of heat stress is also substantial in the subtropical-Mediterranean zones […]" *(Silanikove, 2000)*

Introduction

- Exposure to heat stress is a large geo. driver of current global livestock
- Effects of heat stress on livestock is a long-studied topic (incl. models)

Reviews of the progress of dairy science

Section A. Physiology. Cattle in a hot environment

By W. BIANCA

Bianca (1965)

Review

Heat stress in cattle and the effect of shade on production and behaviour: a review

Judith K. Blackshaw[A] and A. W. Blackshaw[B]

Blackshaw & Blackshaw (1994)

Thermal balance of livestock

1. A parsimonious model

J.R. Turnpenny[a,1], A.J. McArthur[b], J.A. Clark[a], C.M. Wathes[c,*]

Turnpenny et al. (2000)

Introduction

- Exposure to heat stress is a large geo. driver of current global livestock
- Effects of heat stress on livestock is a long-studied topic (incl. models)
- It can have significant economic impacts on the livestock sector

J. Dairy Sci. 86:(E. Suppl.):E52–E77
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St-Pierre, Cobanov & Schnitkey (2003)

Economic Losses from Heat Stress by US Livestock Industries[1]

N. R. St-Pierre*, B. Cobanov*, and G. Schnitkey†
*Department of Animal Sciences
The Ohio State University, Columbus, OH 43210
†Department of Agricultural and Consumer Economics
University of Illinois, Urbana, IL 61801

- "Across the United States, heat stress results in estimated total annual economic losses to livestock industries that are between $1.69 and $2.36 billion" (per year)
  - Already accounting for adaptations
  - In one of the countries having highest ability to adapt

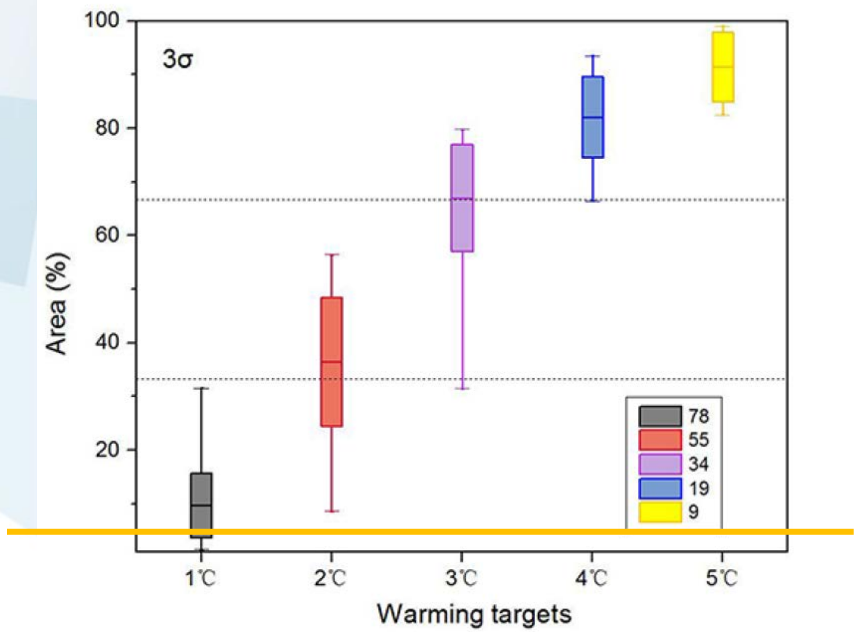
Introduction

- Exposure to heat stress is a large geo. driver of current global livestock
- Effects of heat stress on livestock is a long-studied topic (incl. models)
- It can have significant economic impacts on the livestock sector
- Yet, no global picture of current & future heat stress impact on livestock

Adapted from Gauly et al. (2013), based on data from Martinsohn & Hansen (2012)

Introduction

- Exposure to heat stress is a large geo. driver of current global livestock
- Effects of heat stress on livestock is a long-studied topic (incl. models)
- It can have significant economic impacts on the livestock sector
- Yet, no global picture of current & future heat stress impact on livestock
- Exposure to heat stress is expected to change considerably



Percentage of land affected by 'extremely hot' (> 3σ) summers

Wang et al. (2015)

Introduction

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- Yet, no global picture of current & future heat stress impact on livestock
- Exposure to heat stress is expected to change considerably

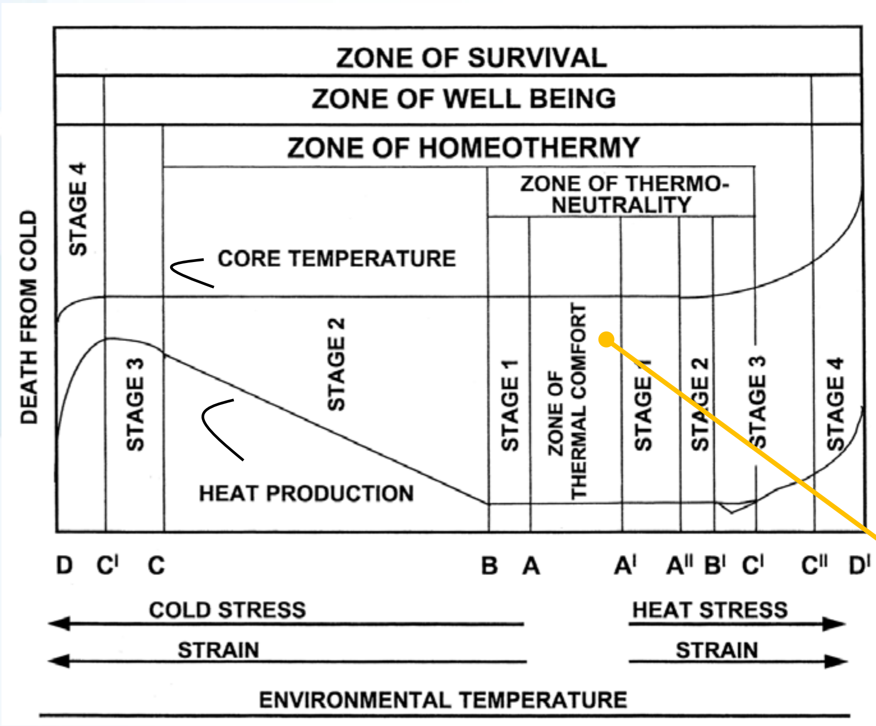
How to bring modeling tools to these scales (global, long-term)?

Relevant processes at various scales

Relevant processes at various scales

- The principle of heat stress for livestock
  - **Normal condition** (TNZ): homeothermy easy to maintain

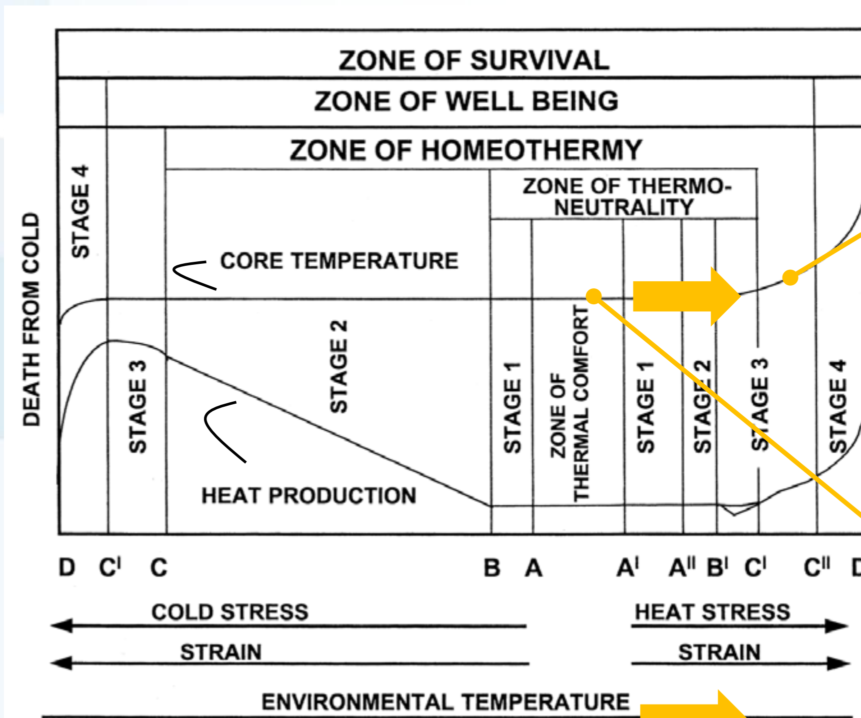
adapetd from Silanikove (2000)



Relevant processes at various scales

- The principle of heat stress for livestock
  - **Normal condition** (TNZ): homeothermy easy to maintain
  - **Heat stress condition** (outside TNZ): homeothermy strains animal or broken

adapetd from Silanikove (2000)

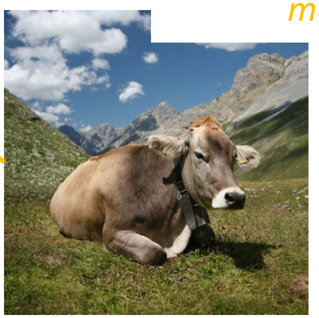


welfare ↘

DMI ↘

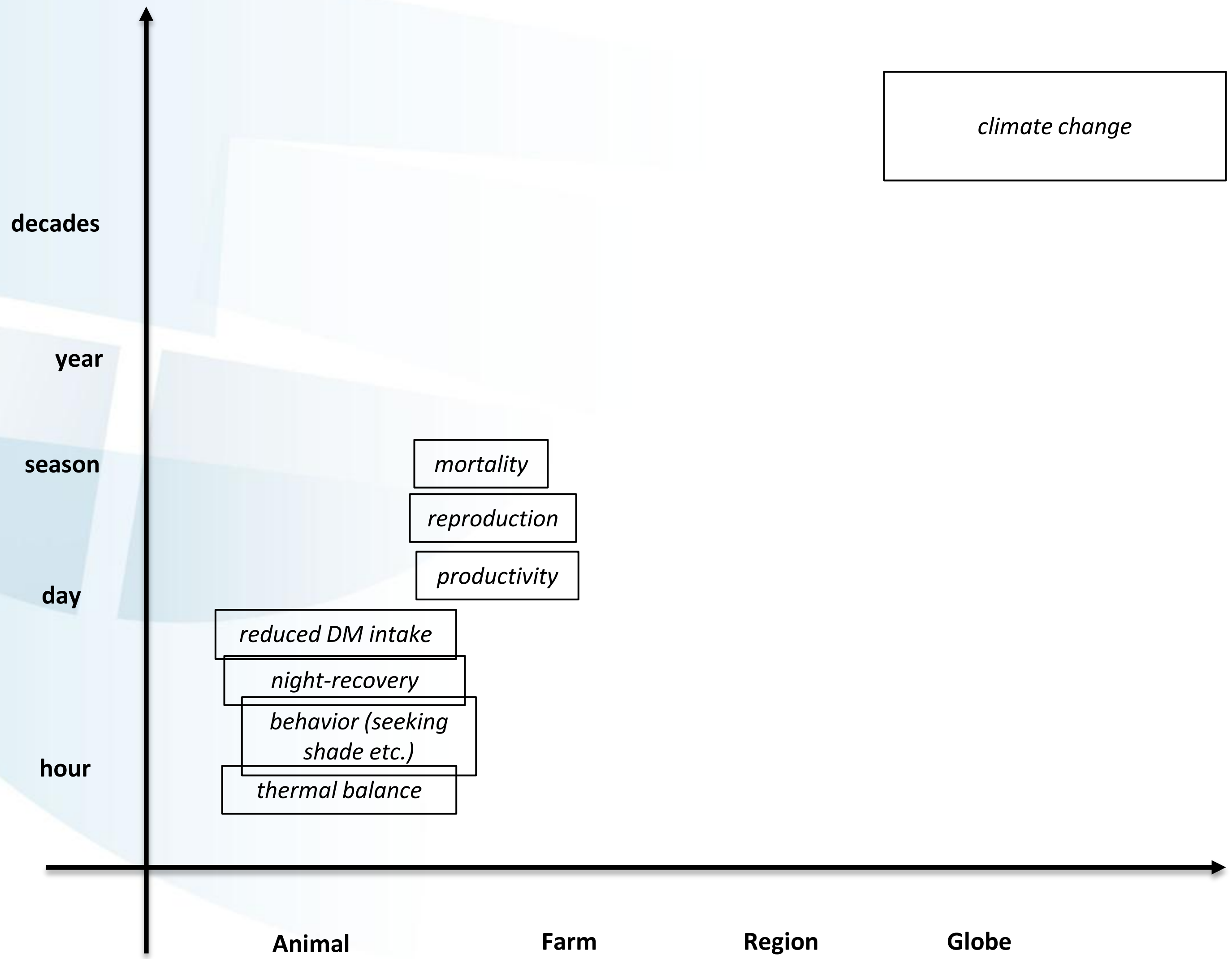
(re)productivity ↘

mortality ↗



Temperature ↗, humidity ↗, solar radiation ↗, wind ↘

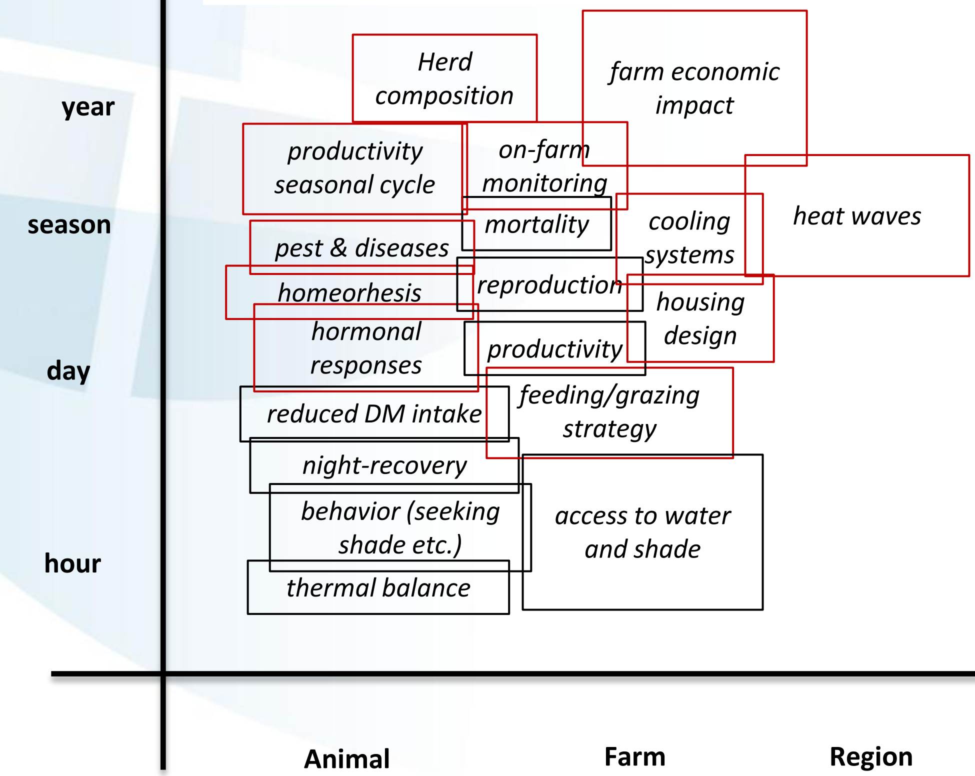
Relevant processes at various scales

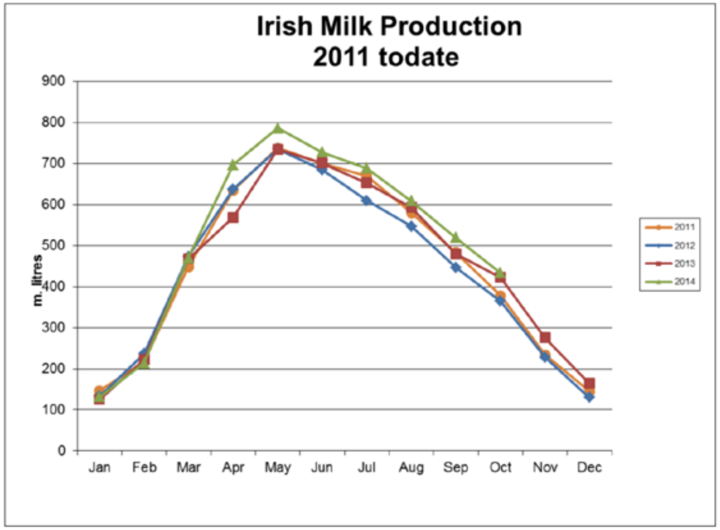


Relevant processes at various scales

Extending to **season & year time scale**:

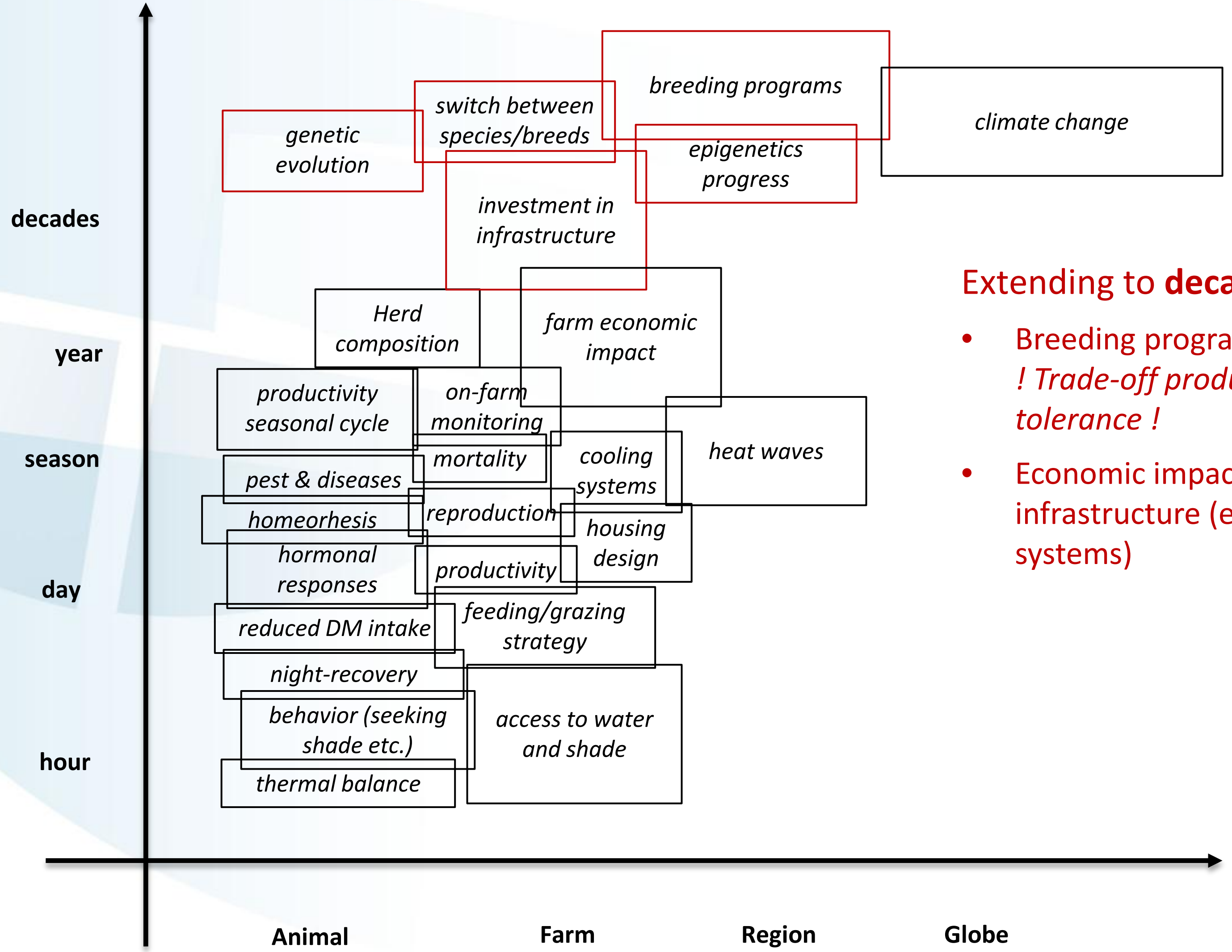
- Concomitance heat wave & productivity cycle
- Acclimati(zati)on processes
- Herd composition & harvest effect
- Availability of heat mitigating strategies
- Farm economic impact & choices





http://www.ifa.ie/sectors/dairy/dairy-fact-sheet/

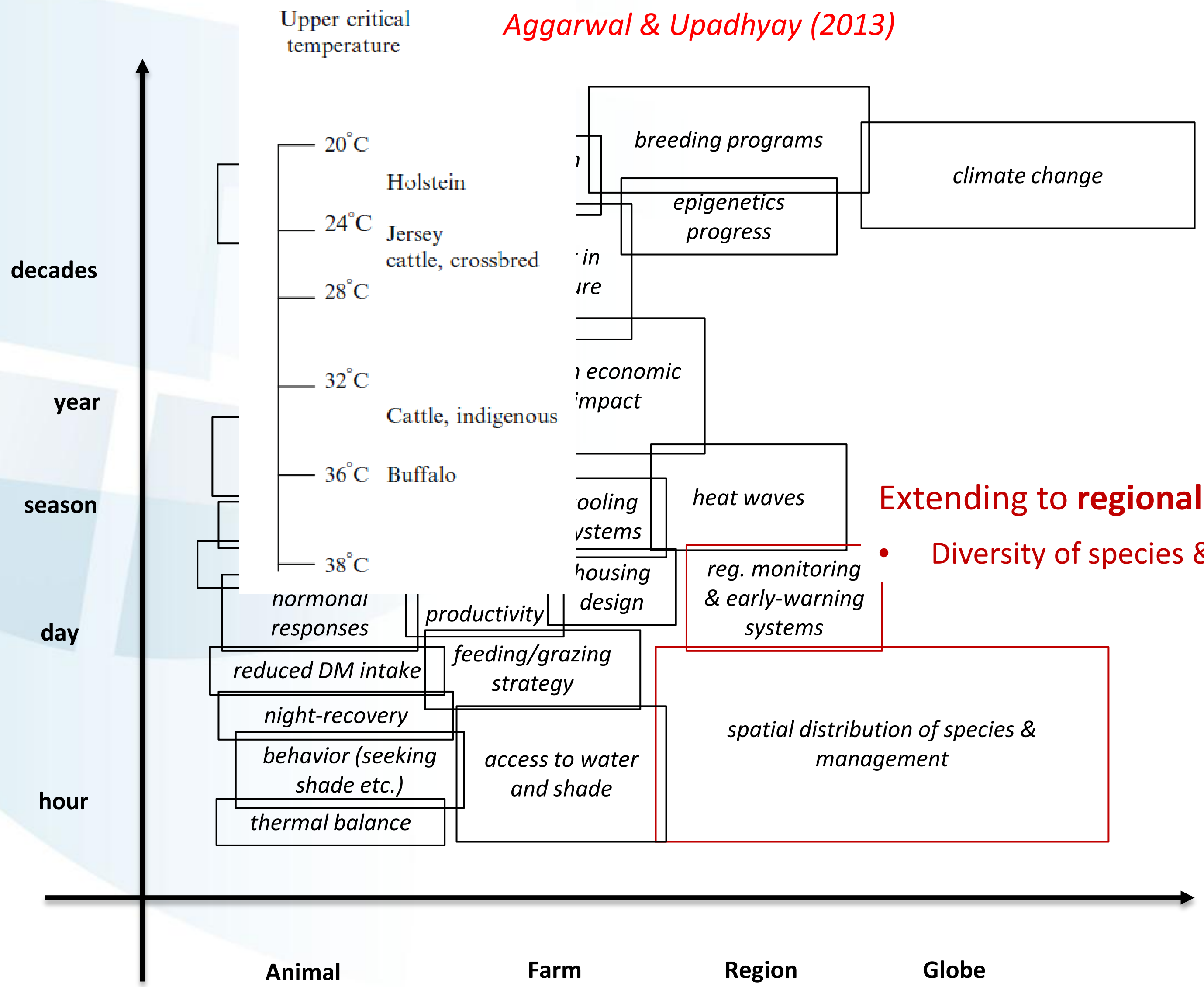
Relevant processes at various scales



Extending to **decadal time scale**:

- Breeding programs
  ! Trade-off productivity vs. heat tolerance !
- Economic impact & investment in infrastructure (e.g., barn, cooling systems)

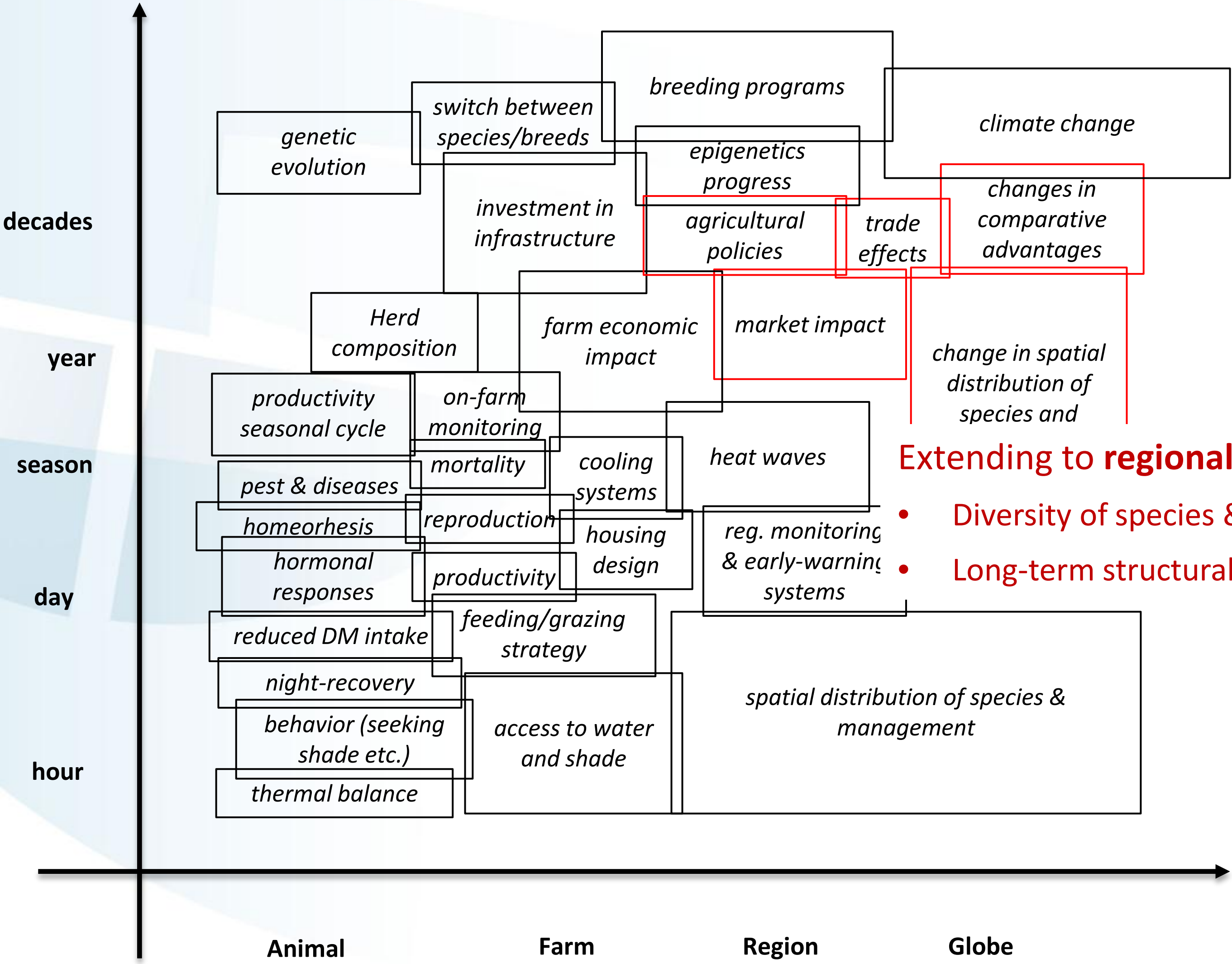
Relevant processes at various scales



Extending to **regional & global scale:**

- Diversity of species & systems

Relevant processes at various scales

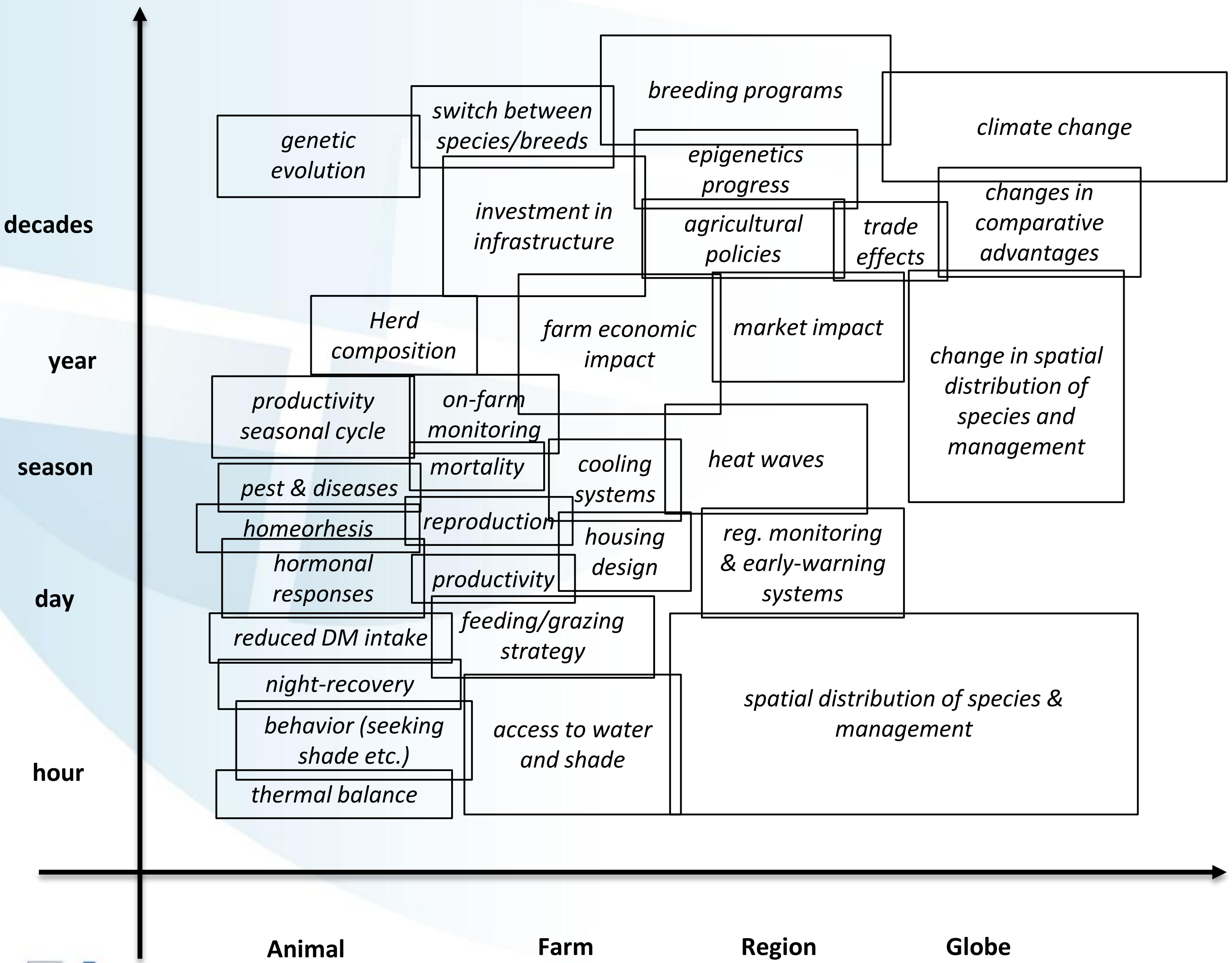


Extending to **regional & global scale:**

- Diversity of species & systems
- Long-term structural changes

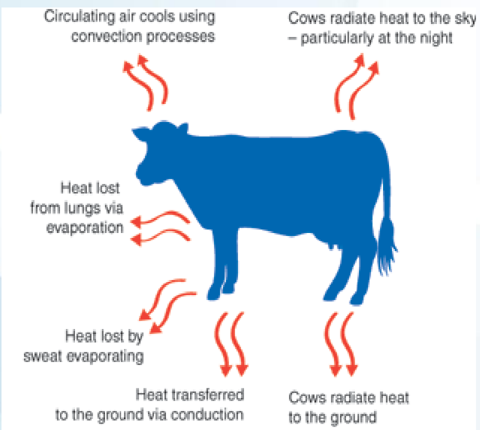
A review of existing models

A brief overview of existing models

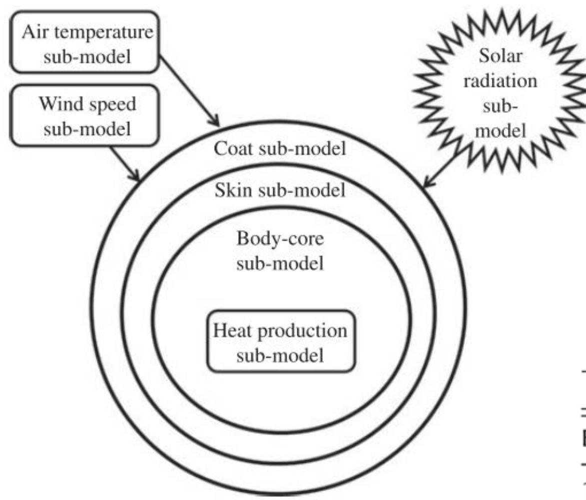


A brief overview of existing models

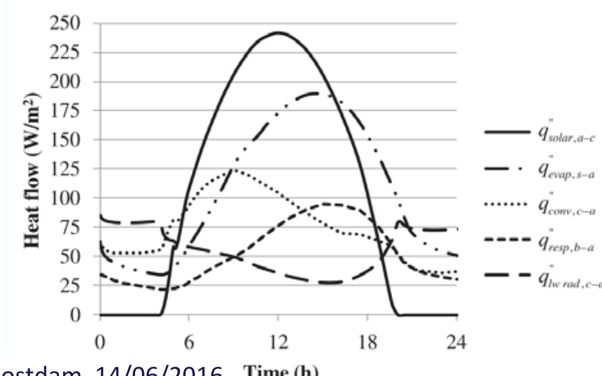
- Type I (thermal balance)
  - Complex mechanistic model of thermal exchange routes



http://www.coolcows.com.au/cows-and-heat/heat-exchange.htm



Bos taurus



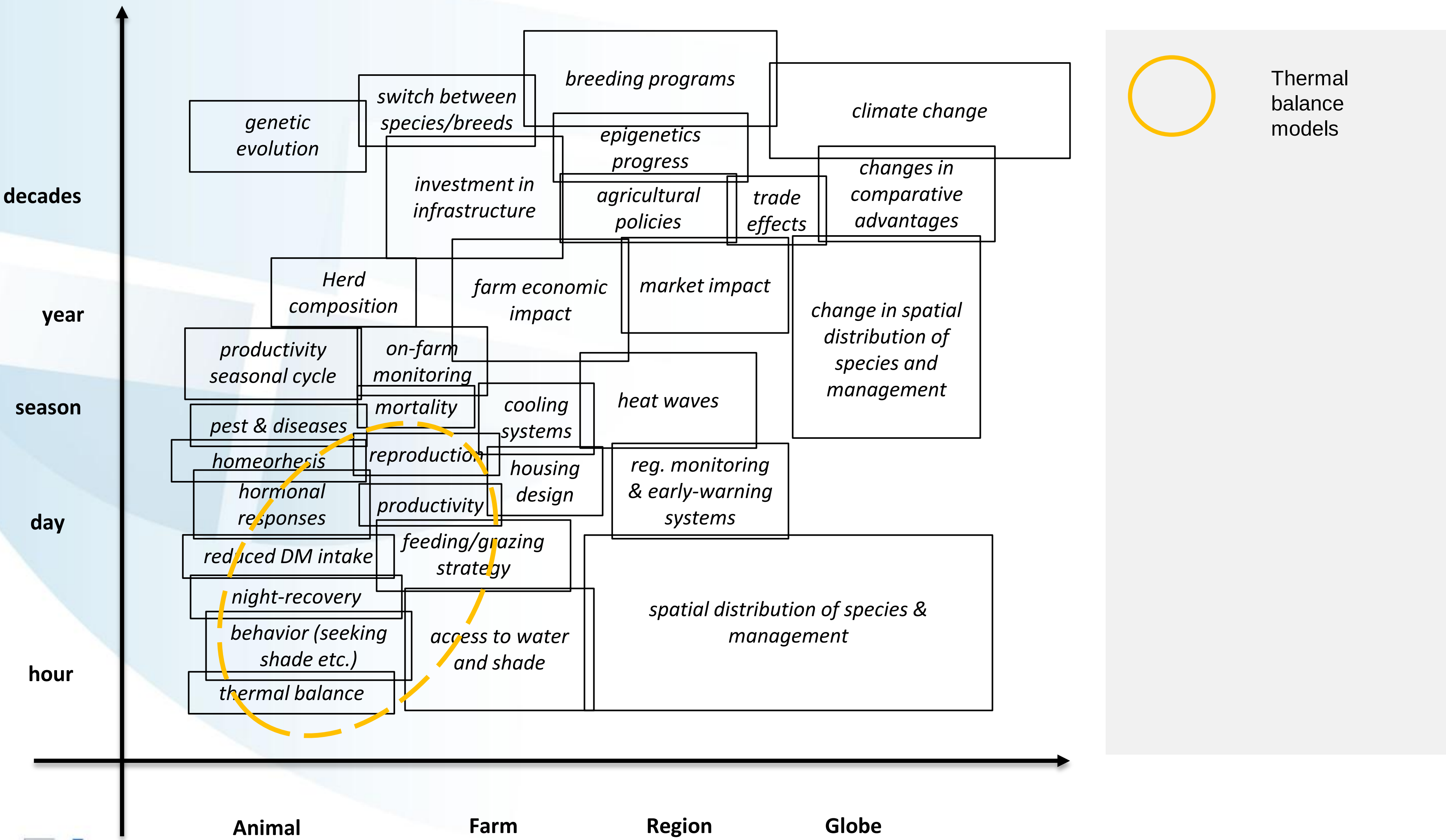
Thompson et al. (2014)

Table 2. *Body-core component**

Equation
1.0. $d(M_b \times c_{pb} \times T_b)/dt = \mathrm{HE} - A(q''_{cond,\,b-s} + q''_{resp,\,b-a})$
1.1. $q''_{cond,\,b-s} = \rho c_p / r_s (T_b - T_s)$

Parameters & Input data

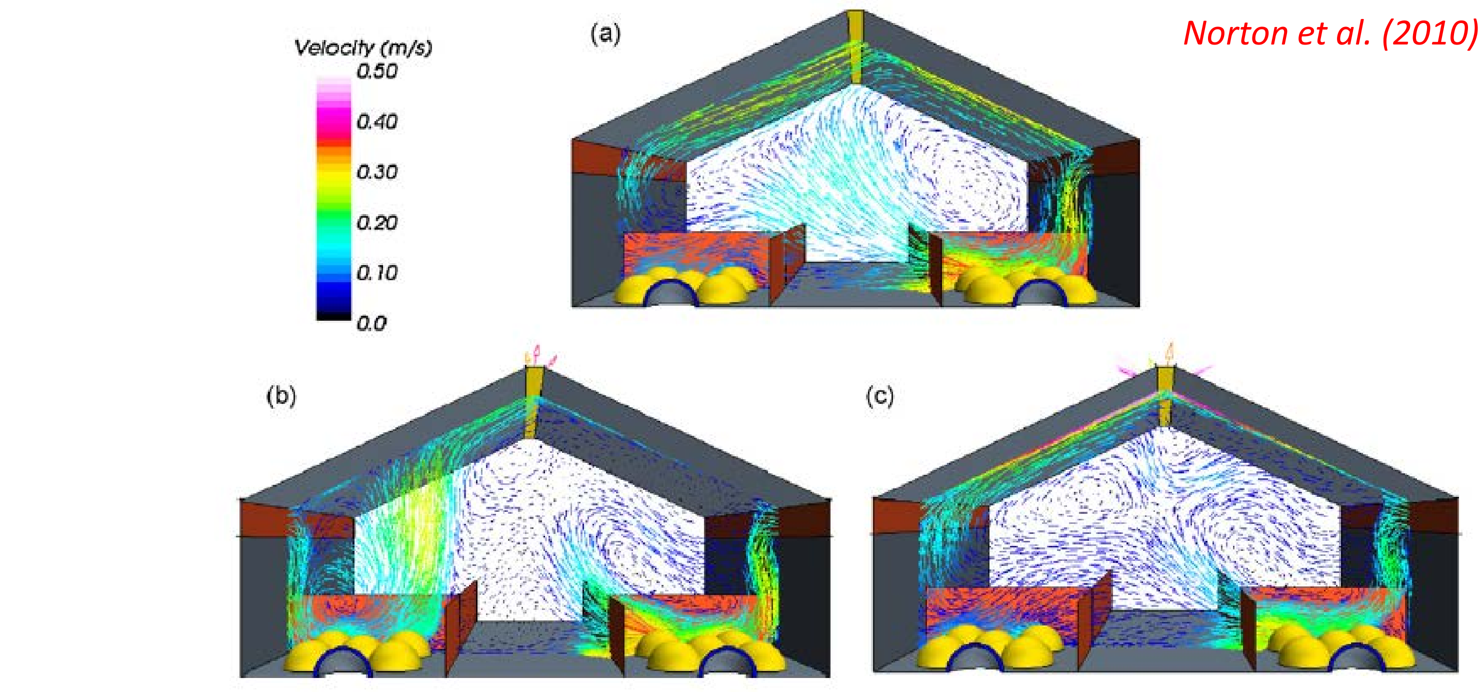
A brief overview of existing models



A brief overview of existing models

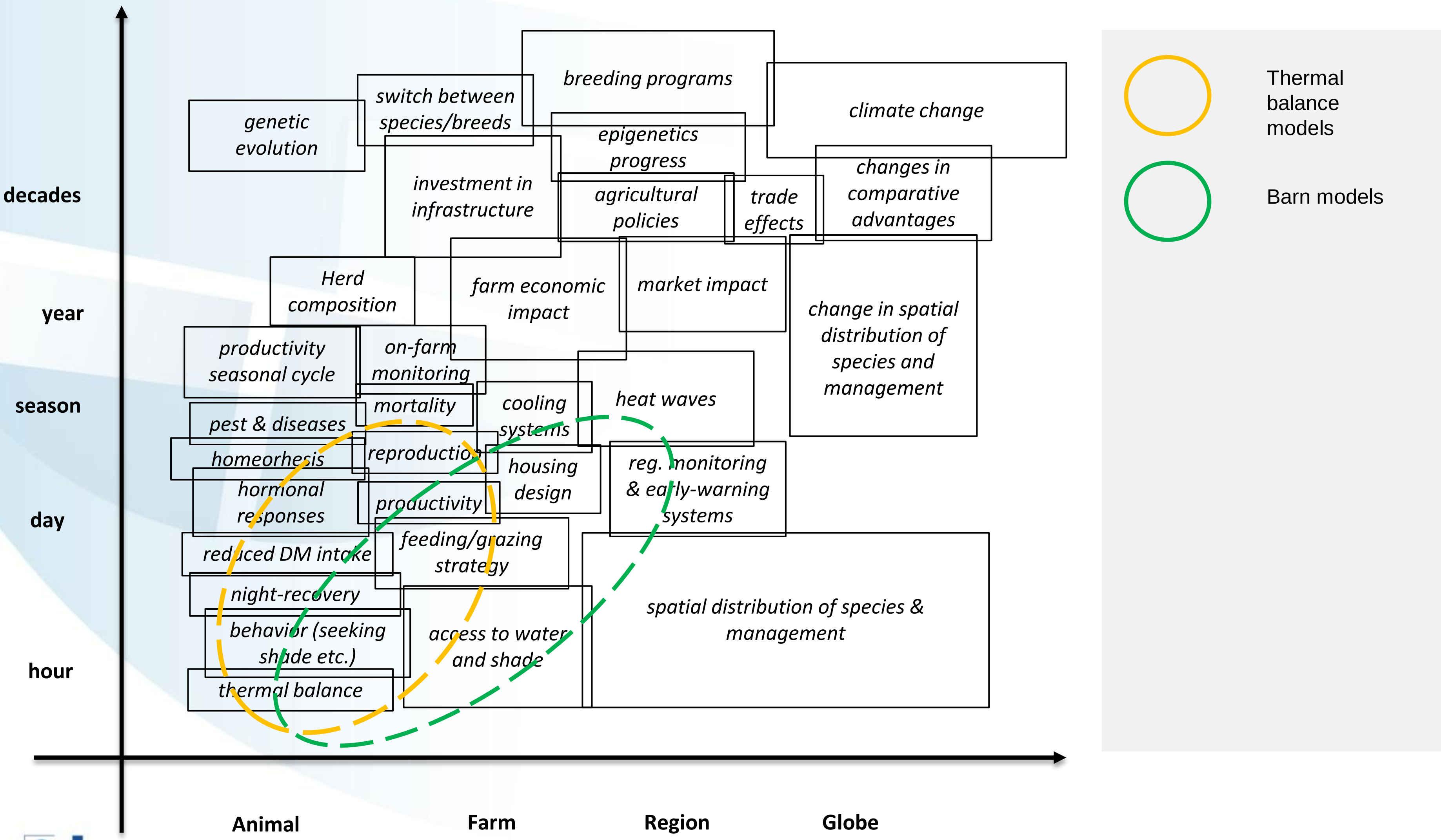
- Type II (barn climatic/optimization models)
  - Models of environmental conditions around the animal

Norton et al. (2010)



Full modeling of animals microenvironment in barns

A brief overview of existing models



A brief overview of existing models

- Type III (stress-strain statistical models)

Weather data

$$\mathrm{THI} = (1.8 \times \mathrm{AT} + 32) - (0.55 - 0.55 \times \mathrm{RH}) \times [(1.8 \times \mathrm{AT} + 32) - 58],$$

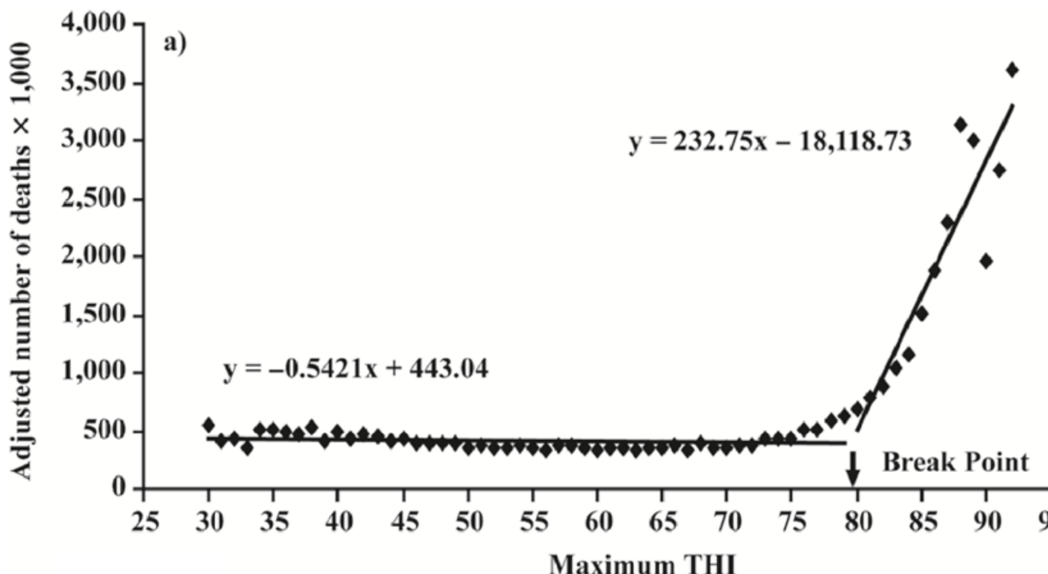
Simplified index of heat stress (temperature-humidity index)

+

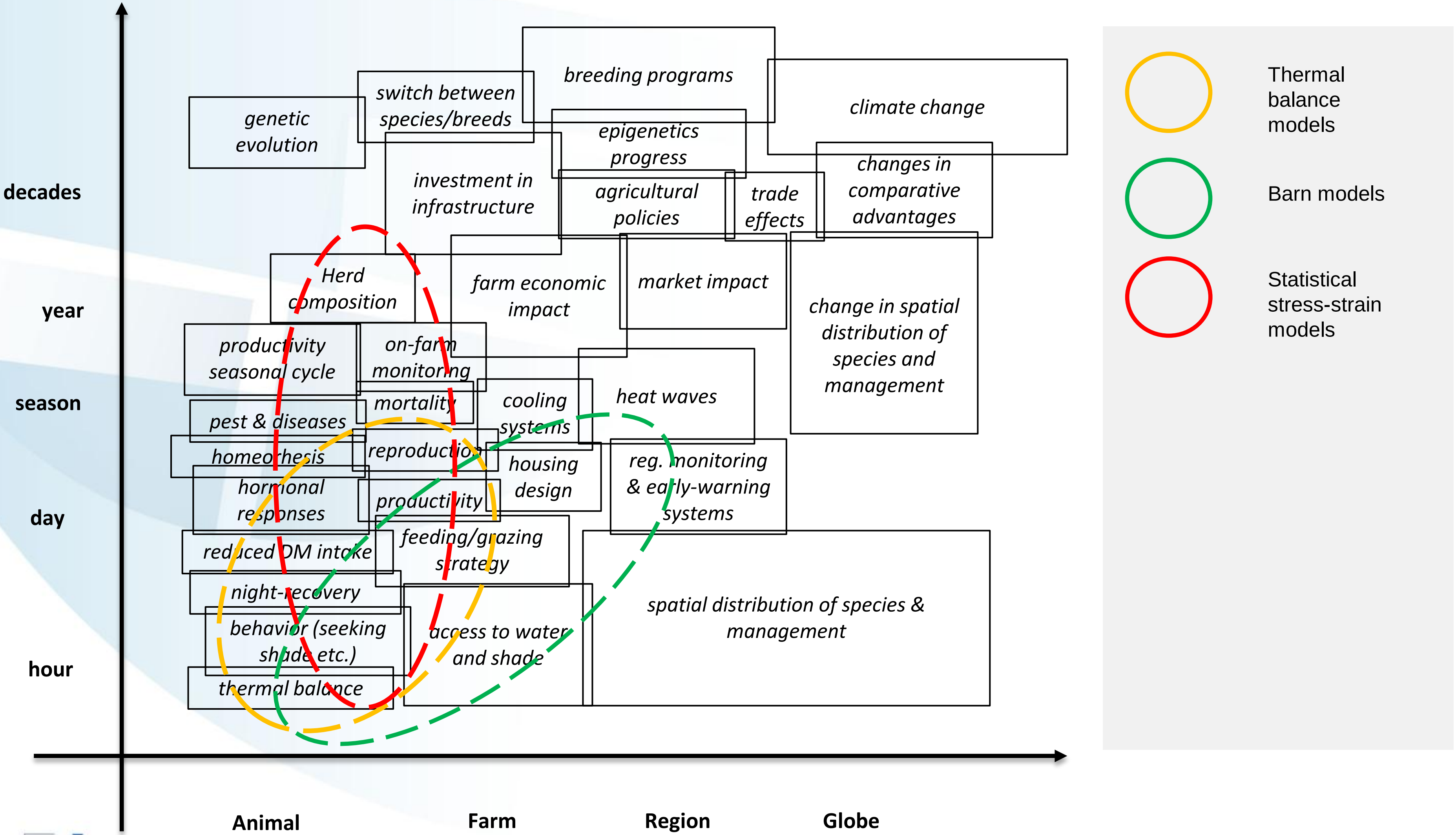
Mortality data

More or less simple models (one variable, few parameters)

Vitali et al (2009)

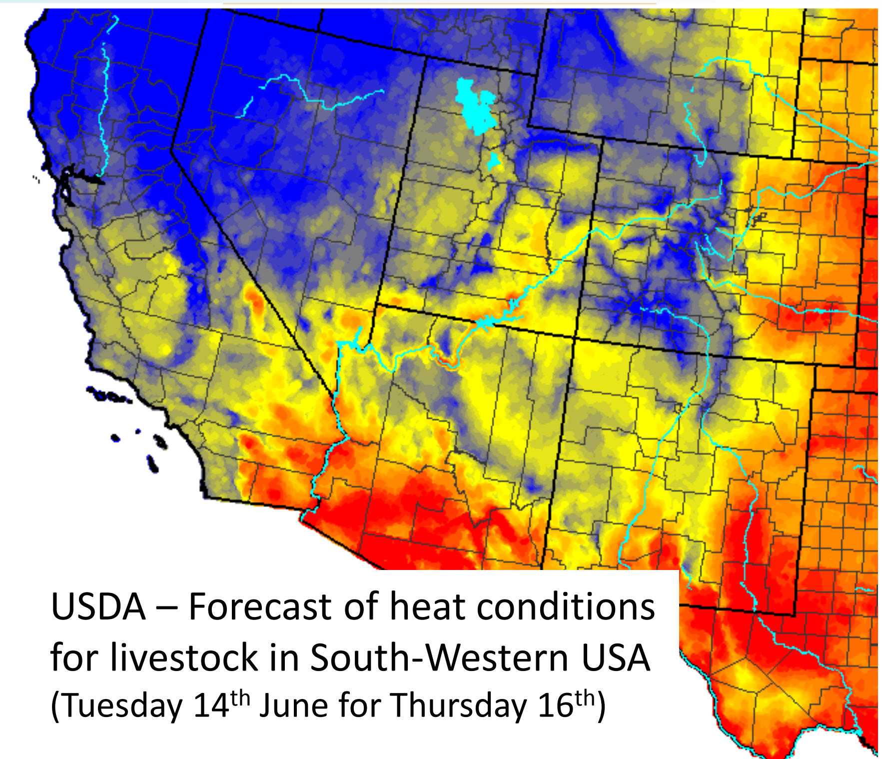


A brief overview of existing models



A brief overview of existing models

- Type IV (monitoring & early warning)



USDA – Forecast of heat conditions for livestock in South-Western USA
(Tuesday 14th June for Thursday 16th)

http://www.ars.usda.gov/Main/docs.htm?docid=25274&viewDay=3

Weather forecast

+ Computation of simple heat stress metric

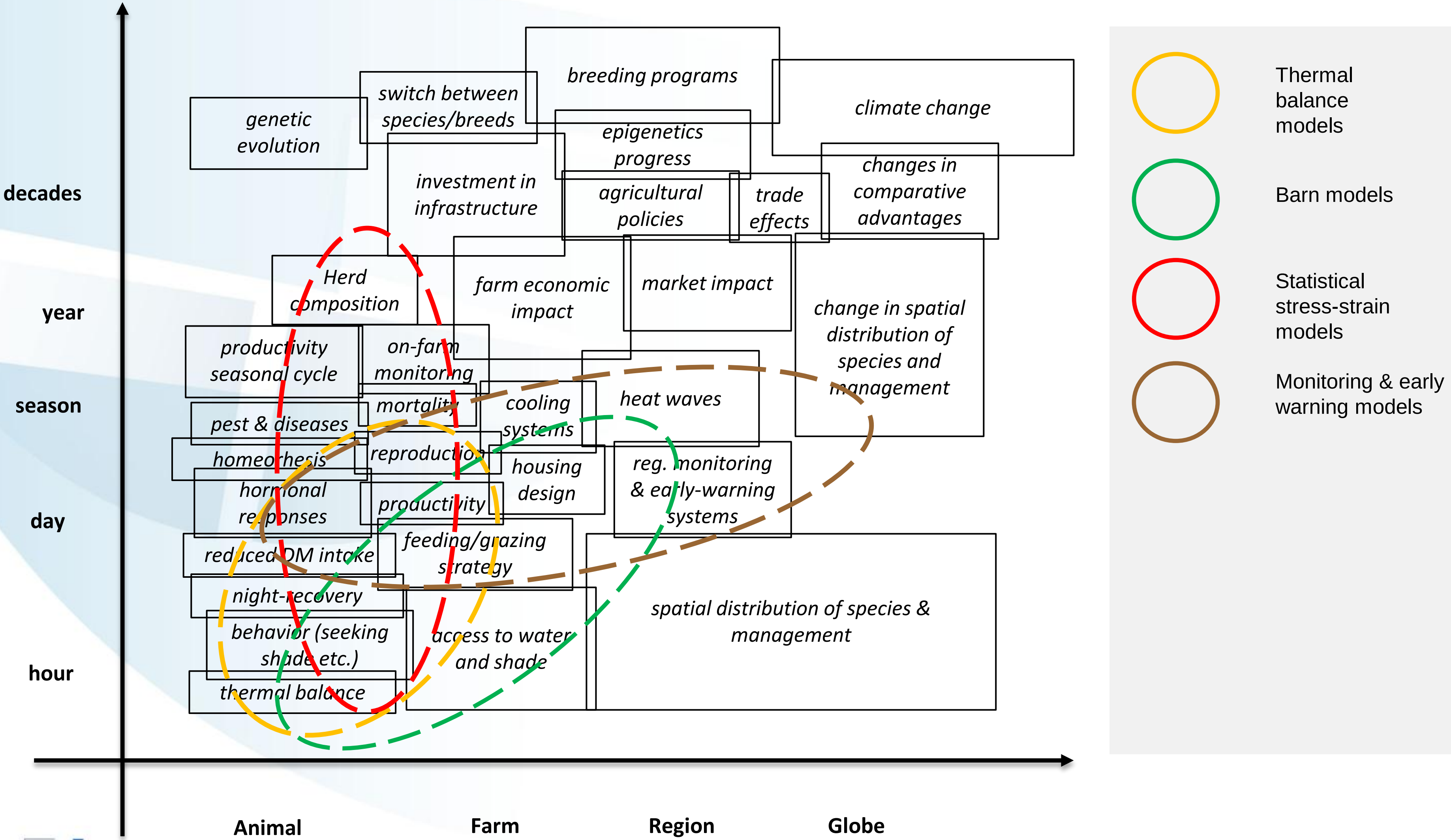
+ Classification in risk classes

Temperature, °C	Relative Humidity, %																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
21	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69	70	70
22	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
23	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
24	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
26	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
27	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
28	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
29	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
30	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
31	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
32	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
33	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
34	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
36	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
37	77	78	79	80	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97	98
38	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	100
39	79	80	81	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
40	80	81	82	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
41	81	82	84	85	86	88	89	90	91	93	94	95	97	98	99	101	102	103	105	106
42	82	83	85	86	87	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
43	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110

Categories of Livestock Weather Safety Index associated with THI values:
Normal: ≤ 74 Alert: 75-78 Danger: 79-83 Emergency: ≥84

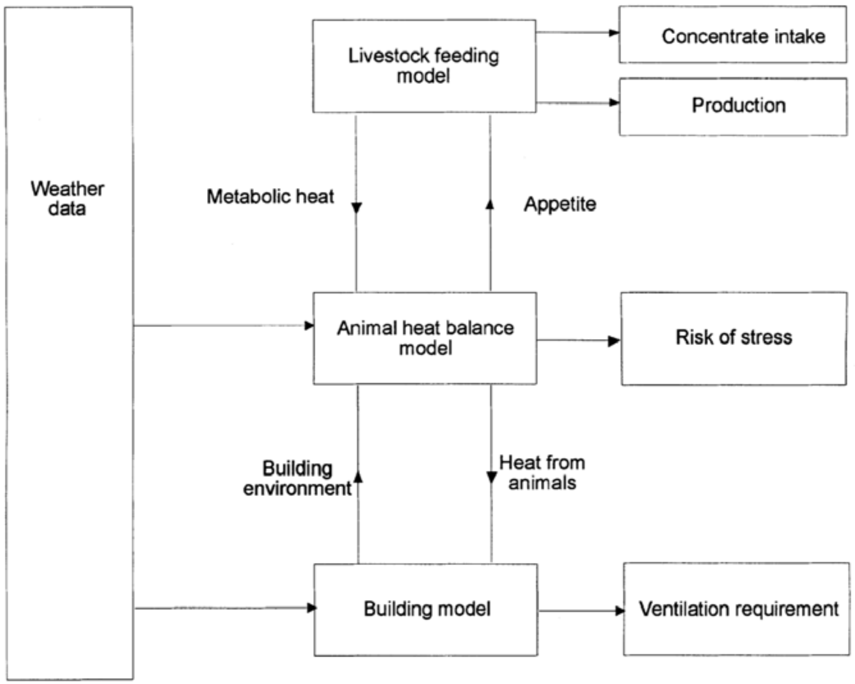
Hahn et al (2009)

A brief overview of existing models

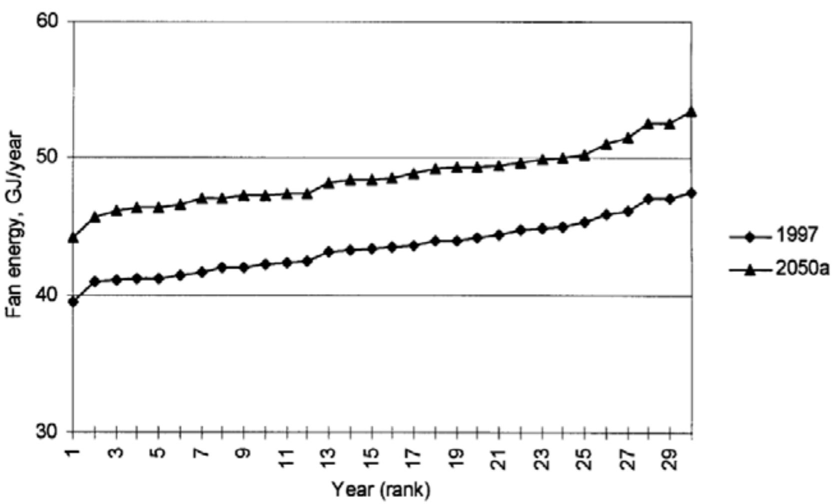


A brief overview of existing models

- Type V (farm-scale models)
  - Modeling farm impacts of altered traits, management options, economic/envtl consequences

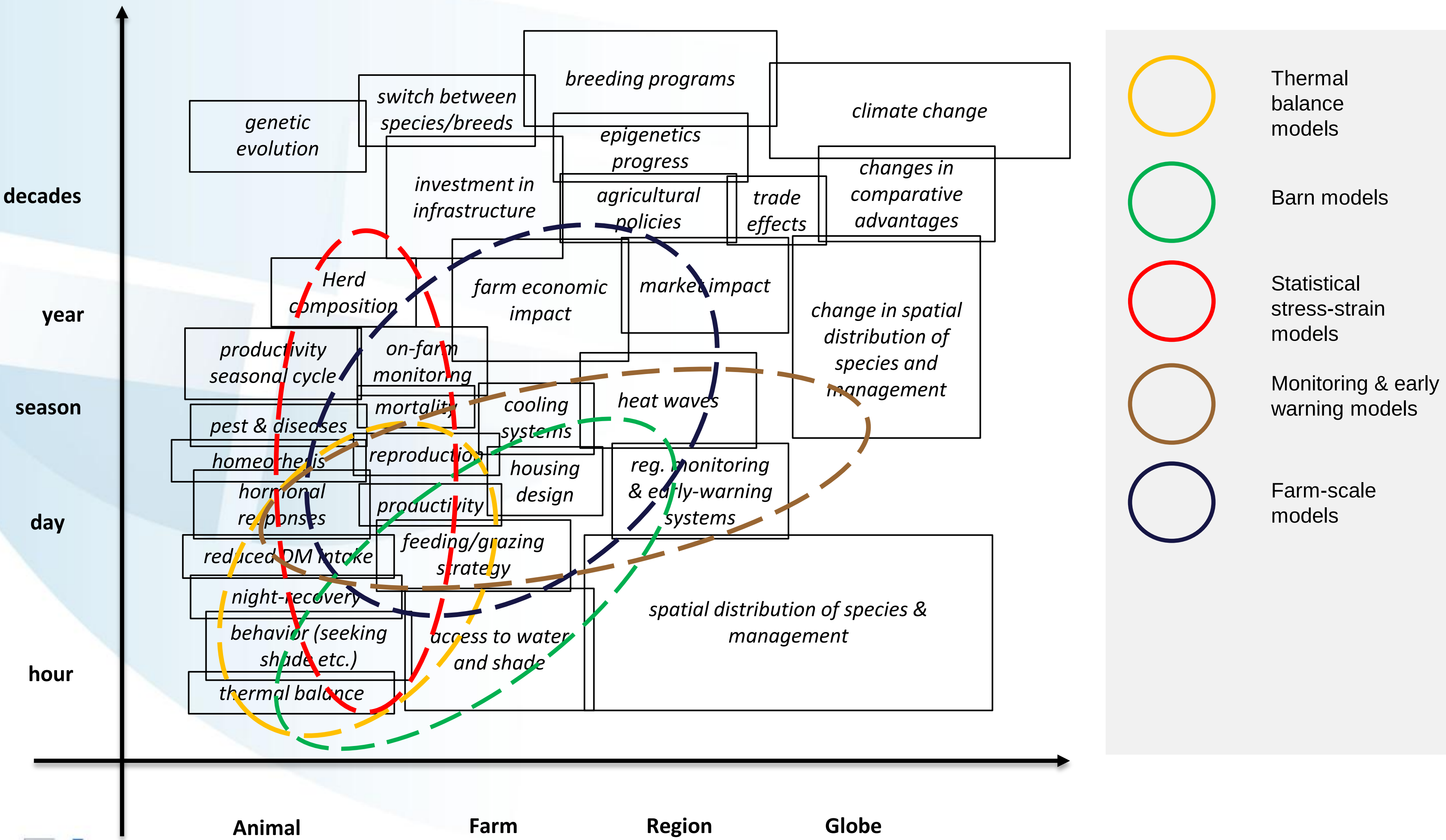


An intensive pig-farm in SE England



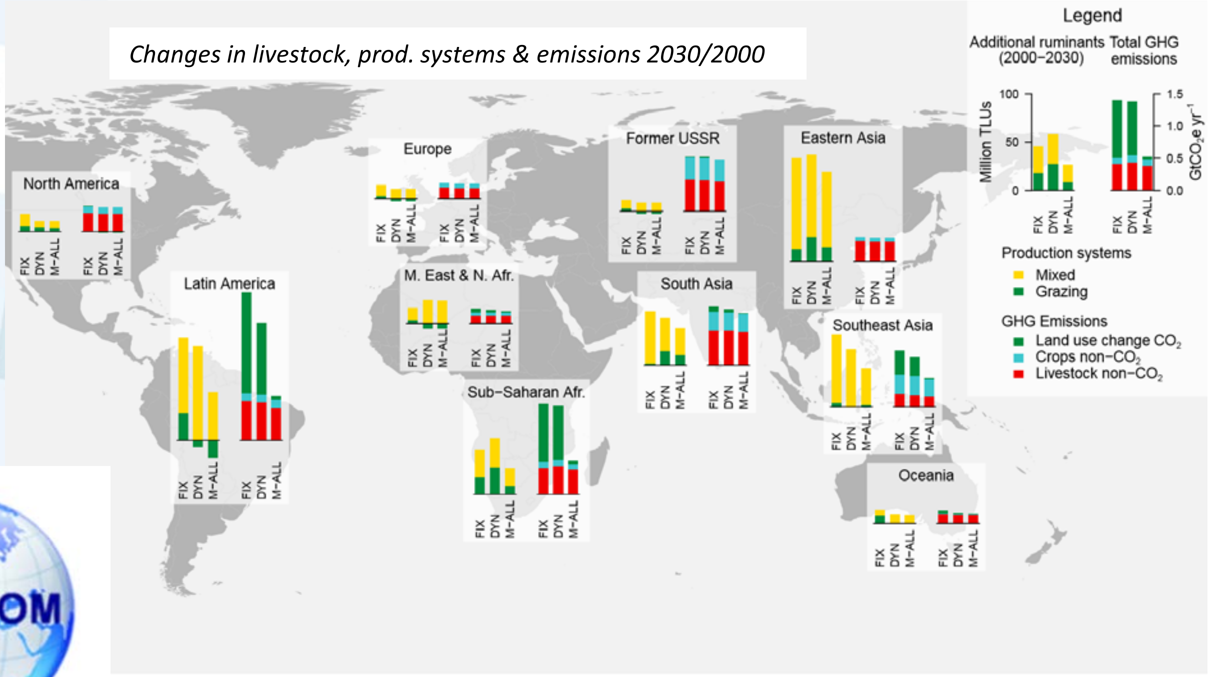
Turnpenny et al (2001)

A brief overview of existing models



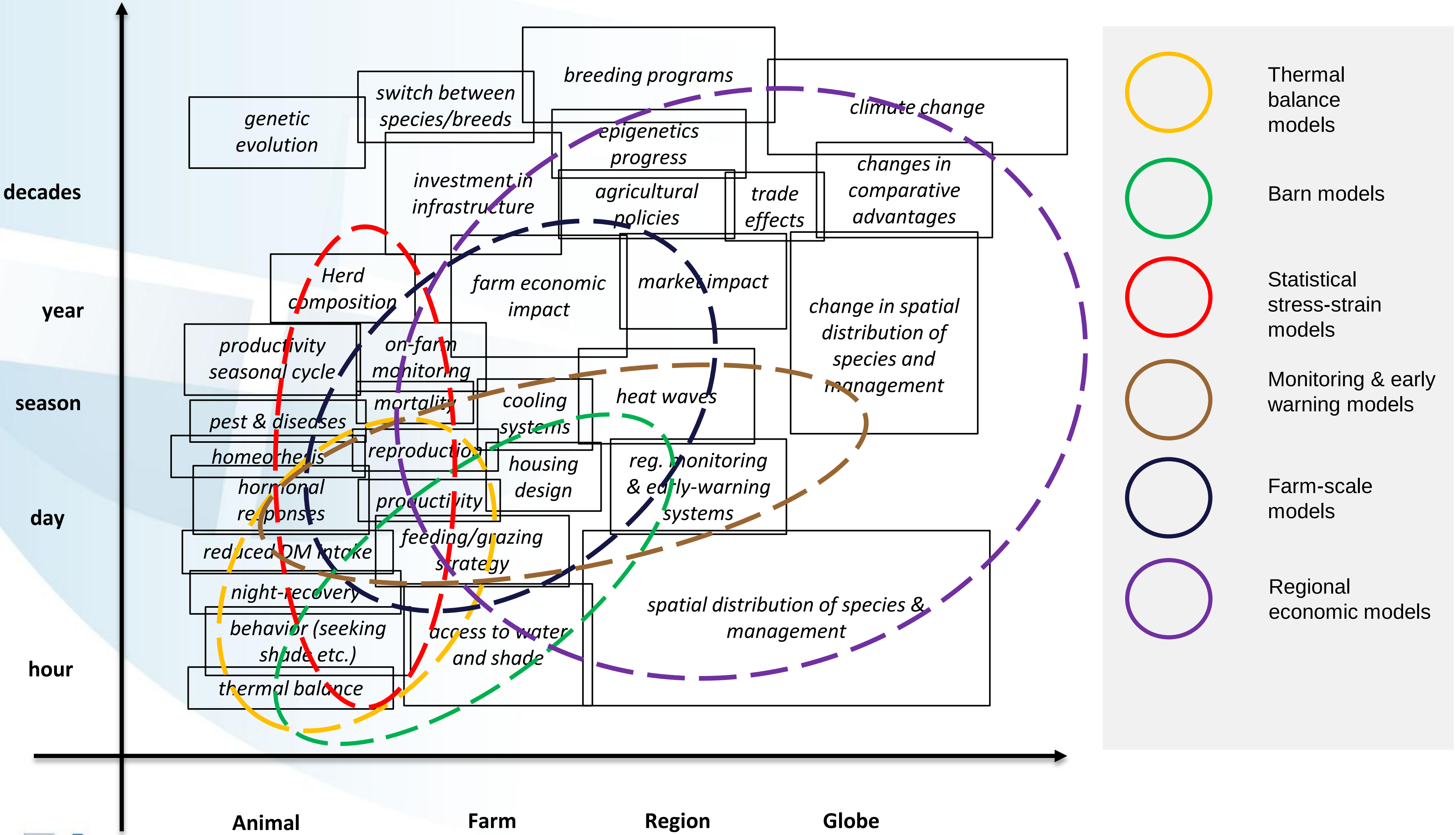
A brief overview of existing models

- Type VI (regional to global economic models)
  - Evolution of demand, trade, price, livestock & production systems



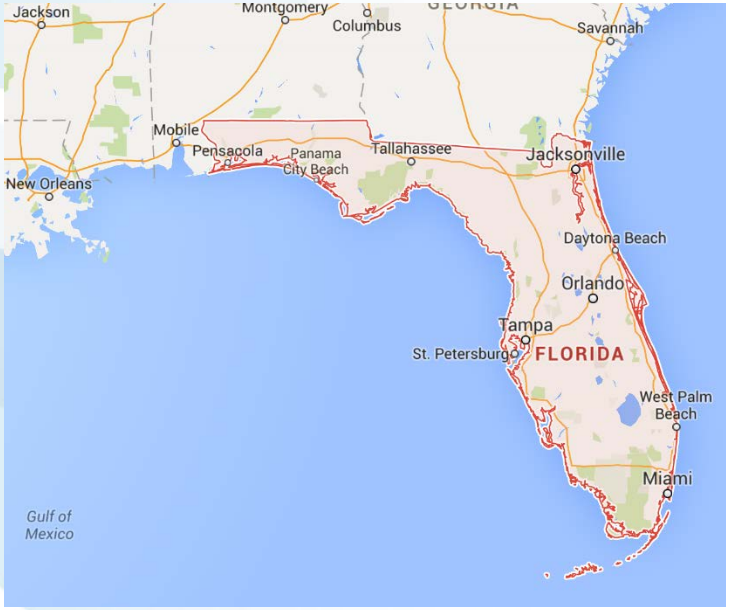
Havlík et al (2014)

A brief overview of existing models



A brief overview of existing models

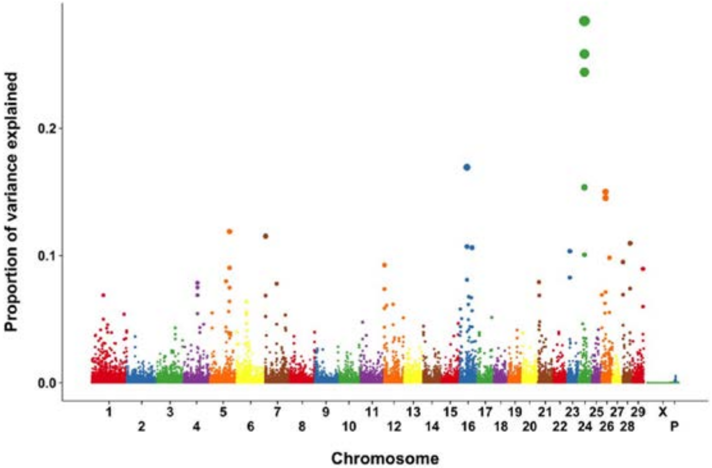
- Type VII (genetics)
  - Statistical models to explore phenotype & heat tolerance



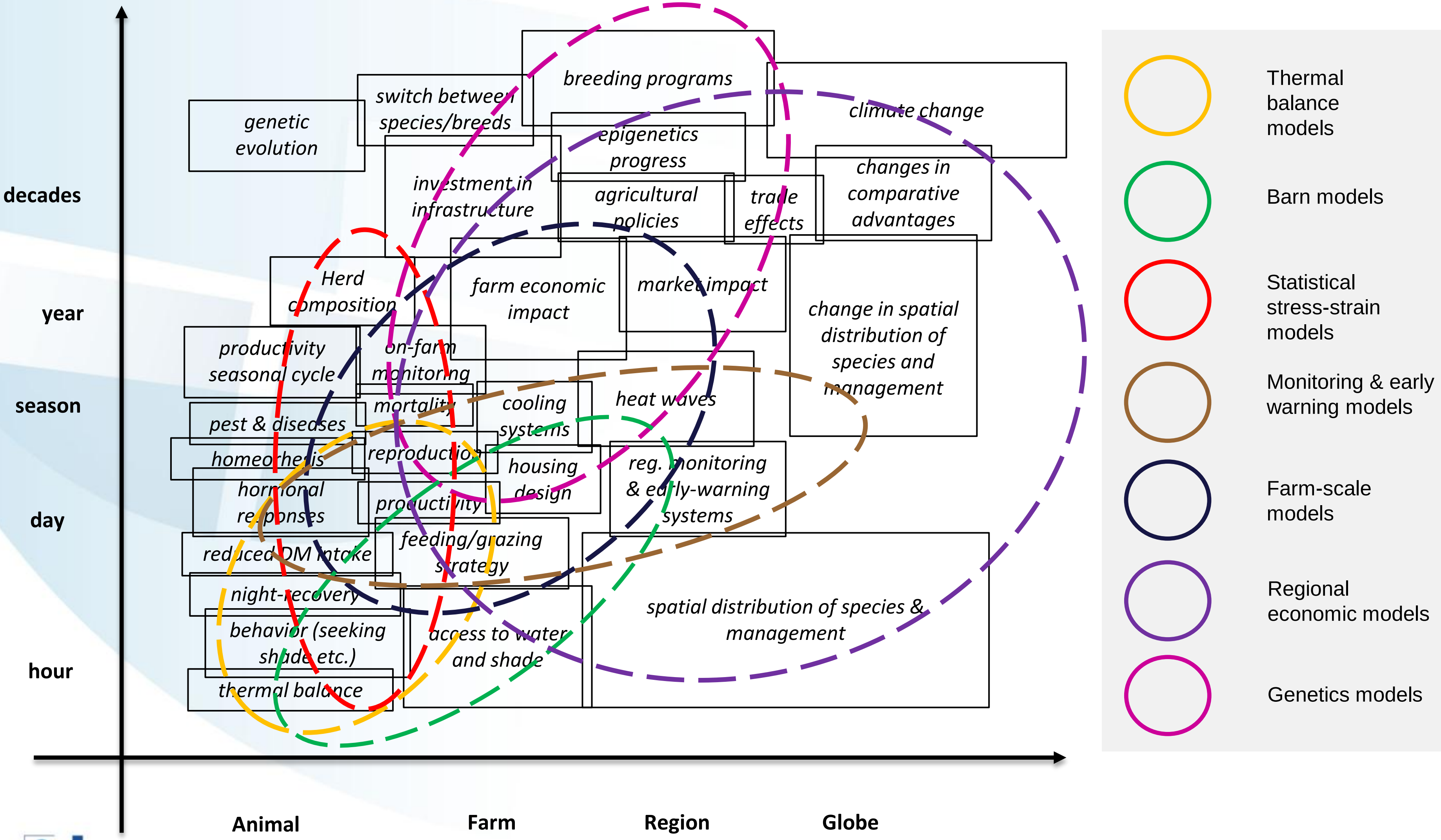
Dikmen et al (2013)

Observation data under heat stress conditions (~ 11k cows) with RT & DNA measurements

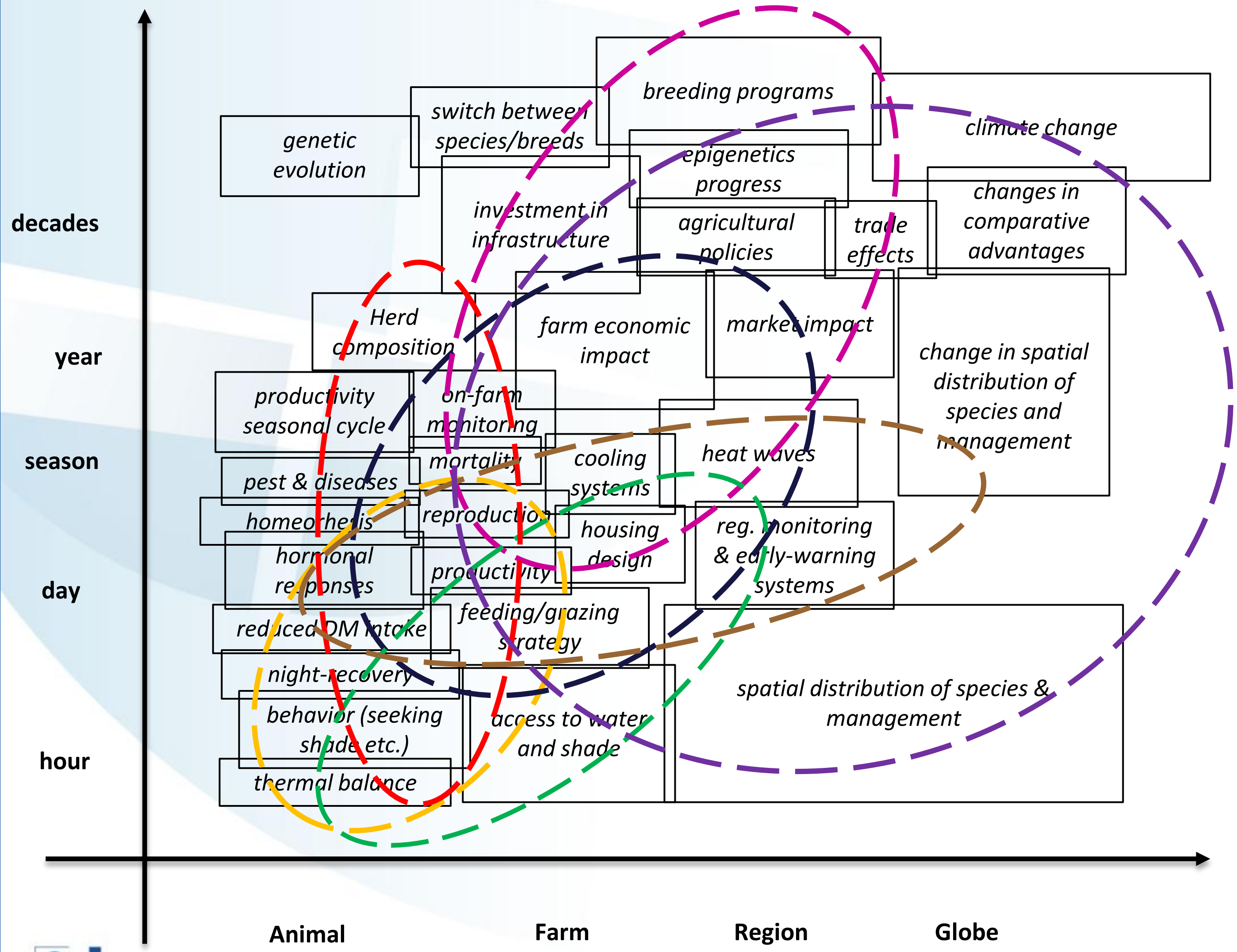
+ Genome-wide Quantitative Trait Locus analysis & statistical model



A brief overview of existing models



A brief overview of existing models

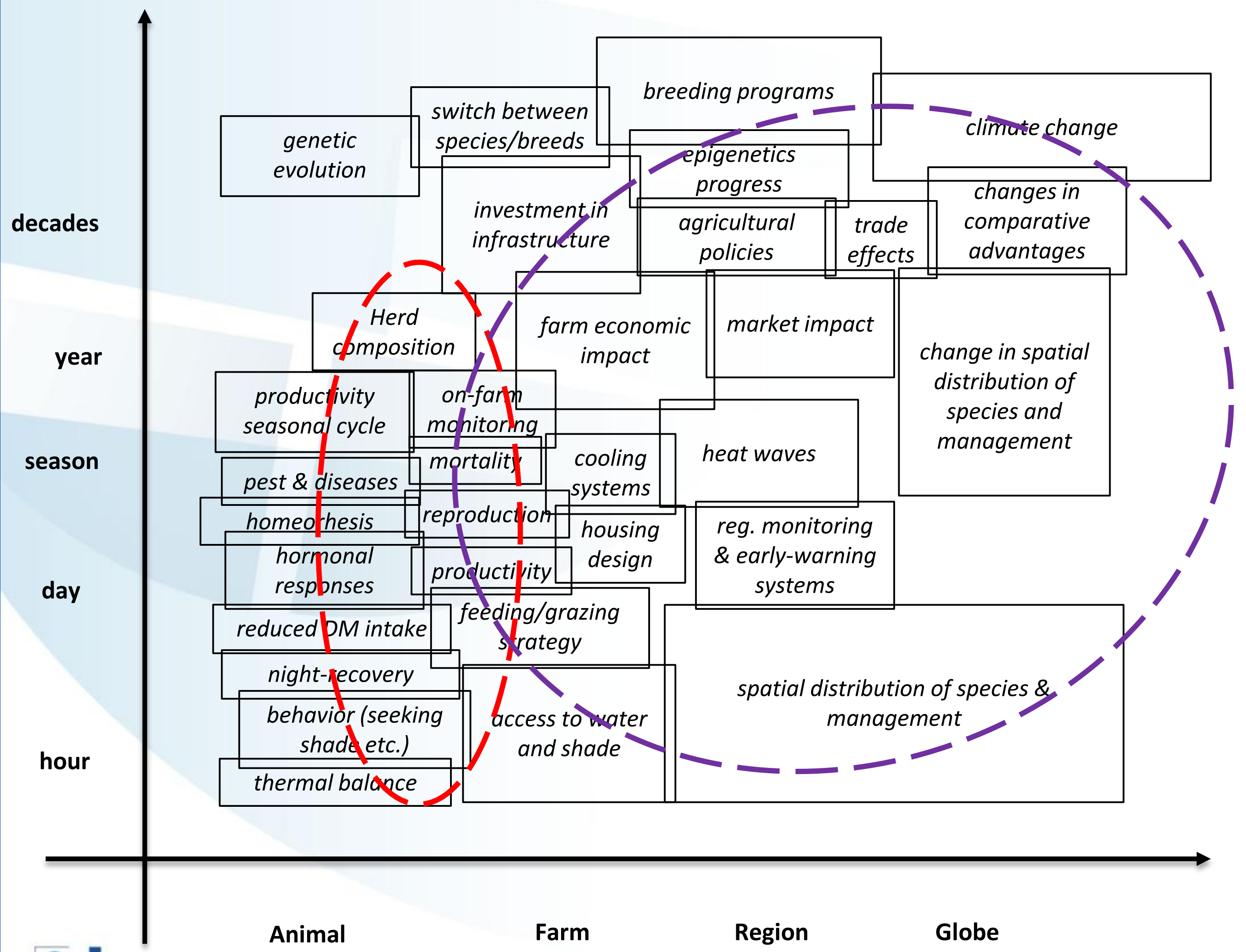


Main conclusions:

- Many models
- No issue not covered
- Some range of scales have a high biodiversity
- Extremes not connected

Potential ways forward & limits

Potential ways forward & limits



Connect the extremes!

Potential ways forward & limits

- What to do? Connect the extremes
- How to do it? Analogy to crop modelling:
  - Gridded approaches (i.e., gridded stat. stress-strain model)
  - Genericity (several species/breeds/types of management)
  - Point based calibration/validation

Potential ways forward & limits

- What to do? Connect the extremes:
- How to do it? Analogy to crop modelling:
- Limits?
  - Limited data availability for parameterization
    - Parsimonious approach to harvest from published case studies
    - Open-data approach as a strategy?
  - Do not valorize model biodiversity
    - Adopt modular approaches to allow complexity in data rich envts
    - Again open-source as a strategy?

Conclusion

Conclusion

- An important gap in climate change literature
  - No quantified estimate of global impact of HS on livestock
  - Exposure to heat stress might dramatically increase
- A complex issue where we already have experience
  - Many processes to account for in upscaling
  - A rich but not well connected array of model types
  - Rich experience from other fields such as crop modeling
- A matter of getting people started
  - A lot could be done within partners of MACSUR
  - Let’s talk proposal writing?

Thank you !

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