Bertrand DUMONT
INRAE Clermont-Ferrand

Review: Make ruminants green again – how can sustainable intensification and agroecology converge for a better future?

B. Dumont[1†], J. C. J. Groot[2] and M. Tichit[3]

animal

Why do we care?

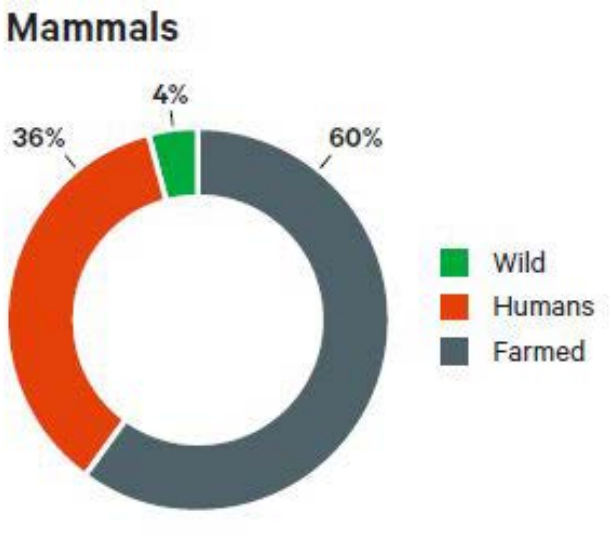
- Animal production systems undeniably contribute to improving human condition

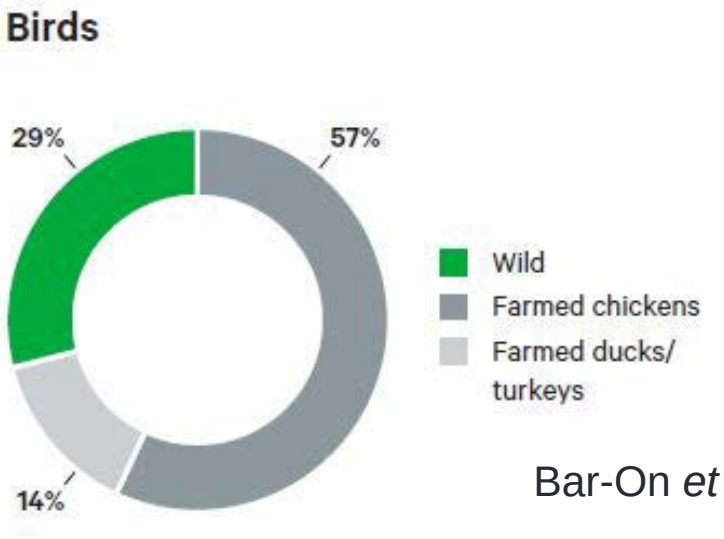
22% dietary energy

50% protein consumption

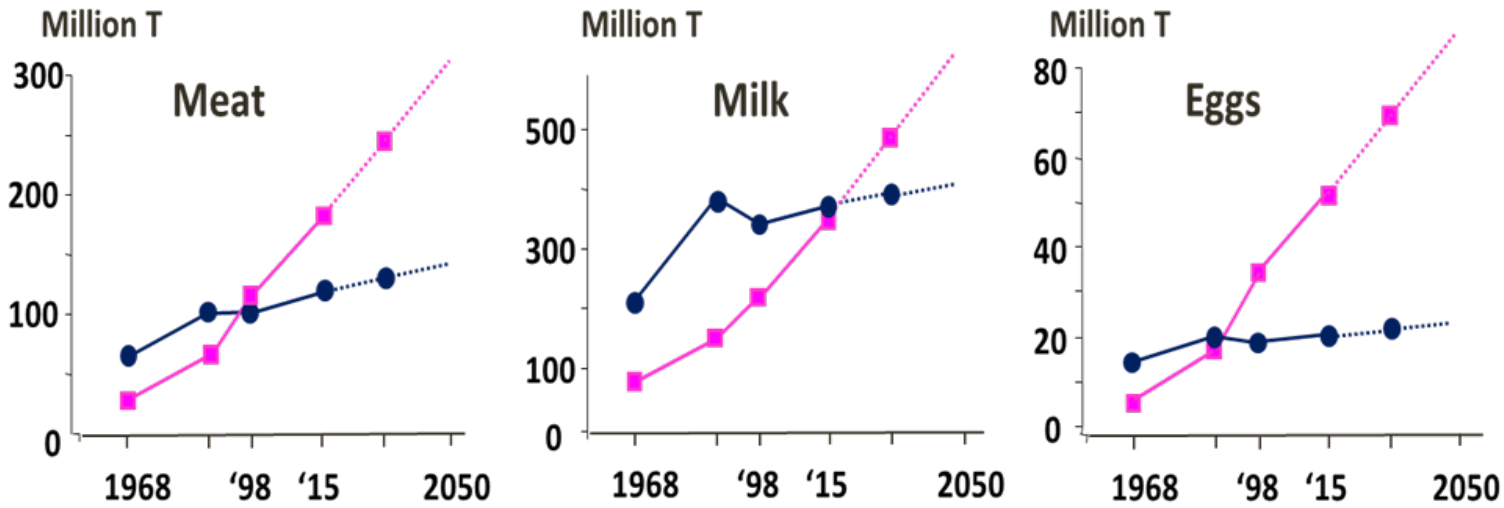
ATF 2013

- BUT…



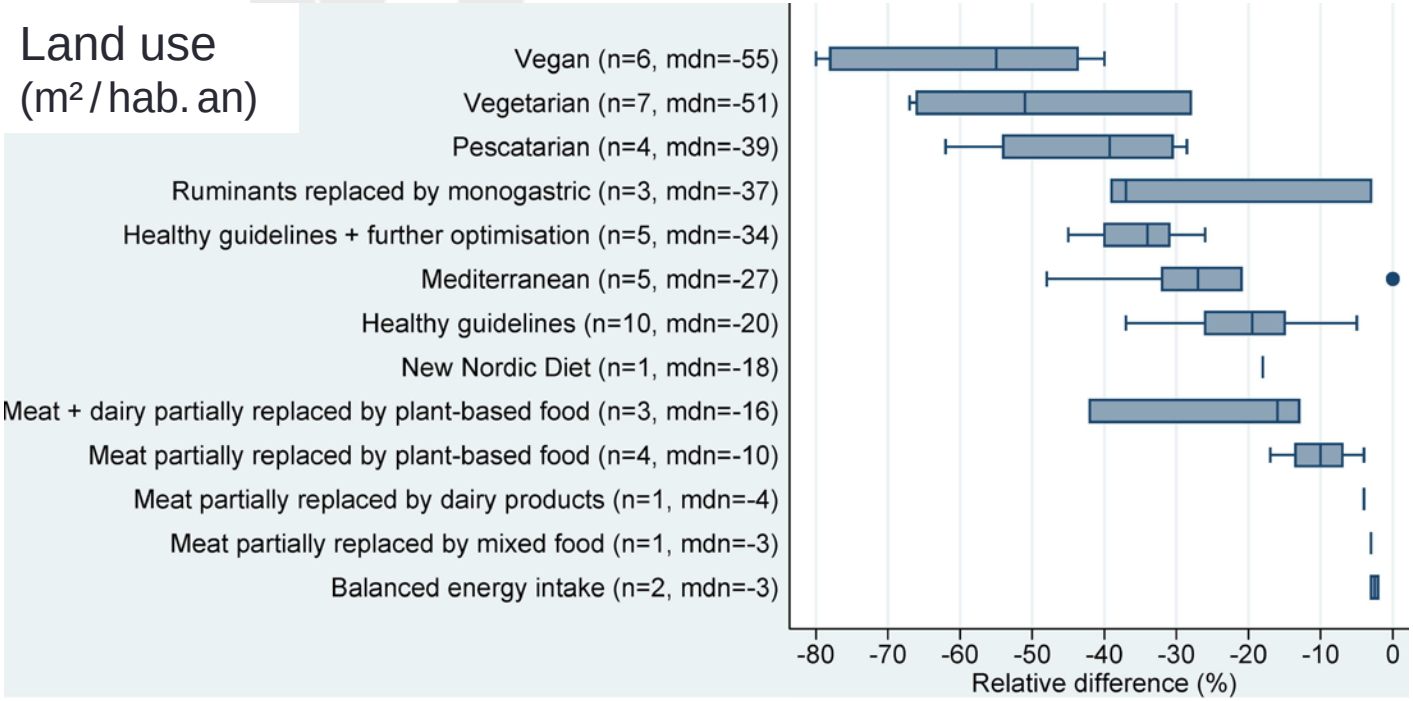


Bar-On *et al*. 2018



FAO Stats

Eating less meat is good for the planet!



Less animal protein consumption

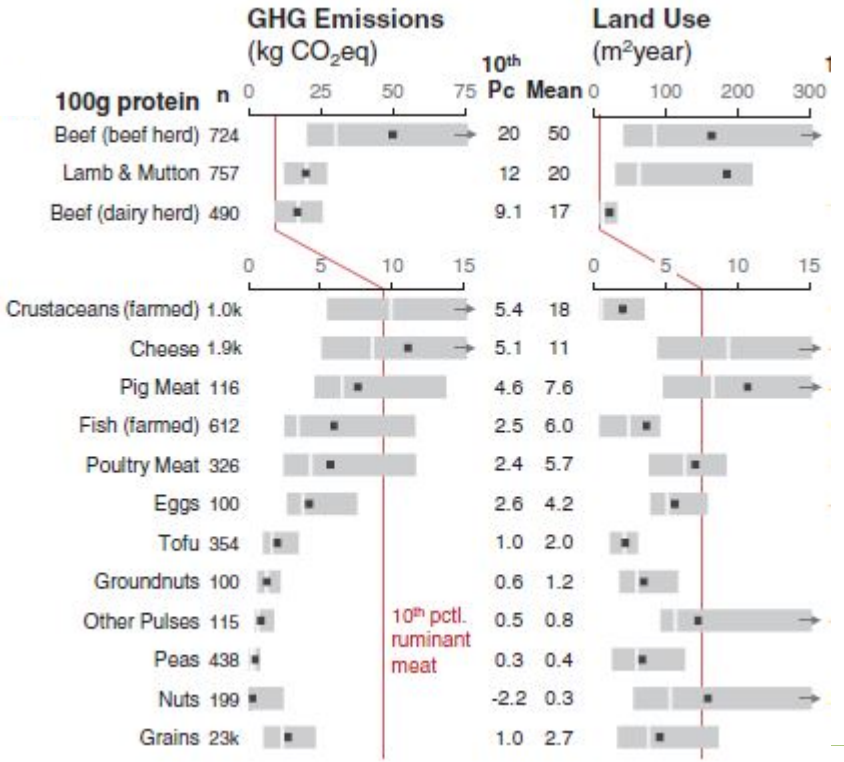
Less area is needed to feed people

Aleksandrowicz *et al*. 2016

SUSTAINABILITY

Reducing food's environmental impacts through producers and consumers

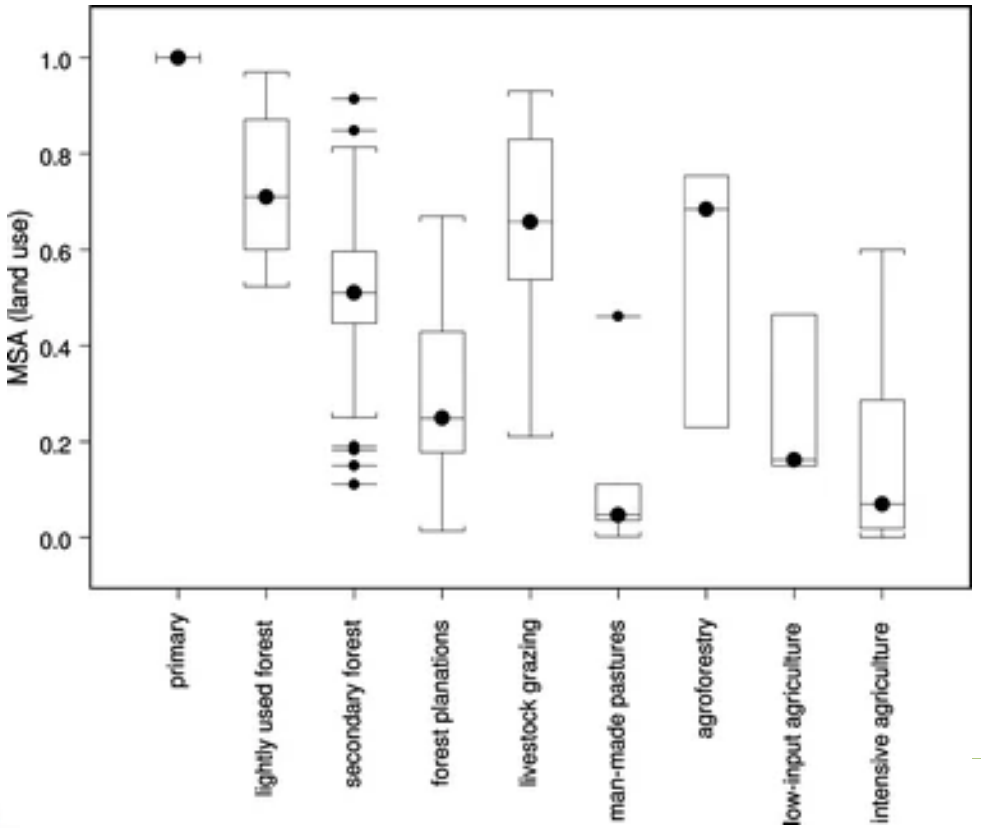
J. Poore[1,2]* and T. Nemecek[3]



Ecosystems (2009) 12: 374–390
DOI: 10.1007/s10021-009-9229-5

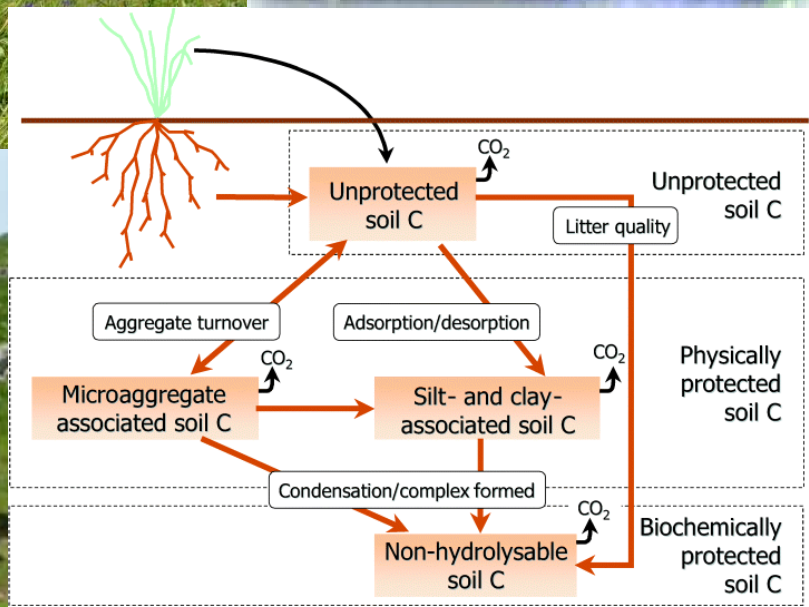
ECOSYSTEMS

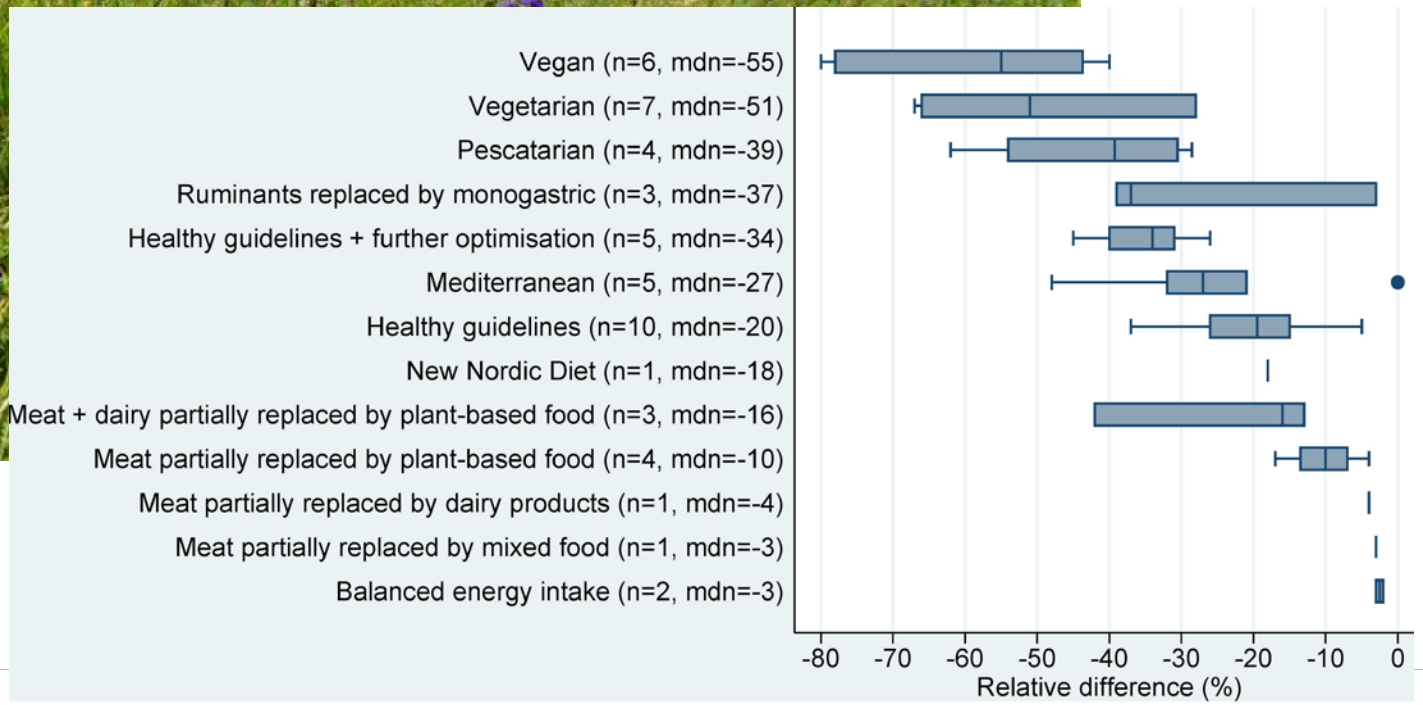
GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss



Alkemade *et al*. 2009


AVÈZE


CO2
Unprotected soil C
Litter quality
Unprotected soil C
Aggregate turnover
Adsorption/desorption
CO2
CO2
Microaggregate associated soil C
Silt- and clay-associated soil C
Physically protected soil C
Condensation/complex formed
CO2
Non-hydrolysable soil C
Biochemically protected soil C


Vegan (n=6, mdn=-55)
Vegetarian (n=7, mdn=-51)
Pescatarian (n=4, mdn=-39)
Ruminants replaced by monogastric (n=3, mdn=-37)
Healthy guidelines + further optimisation (n=5, mdn=-34)
Mediterranean (n=5, mdn=-27)
Healthy guidelines (n=10, mdn=-20)
New Nordic Diet (n=1, mdn=-18)
Meat + dairy partially replaced by plant-based food (n=3, mdn=-16)
Meat partially replaced by plant-based food (n=4, mdn=-10)
Meat partially replaced by dairy products (n=1, mdn=-4)
Meat partially replaced by mixed food (n=1, mdn=-3)
Balanced energy intake (n=2, mdn=-3)
-80
-70
-60
-50
-40
-30
-20
-10
0
Relative difference (%)

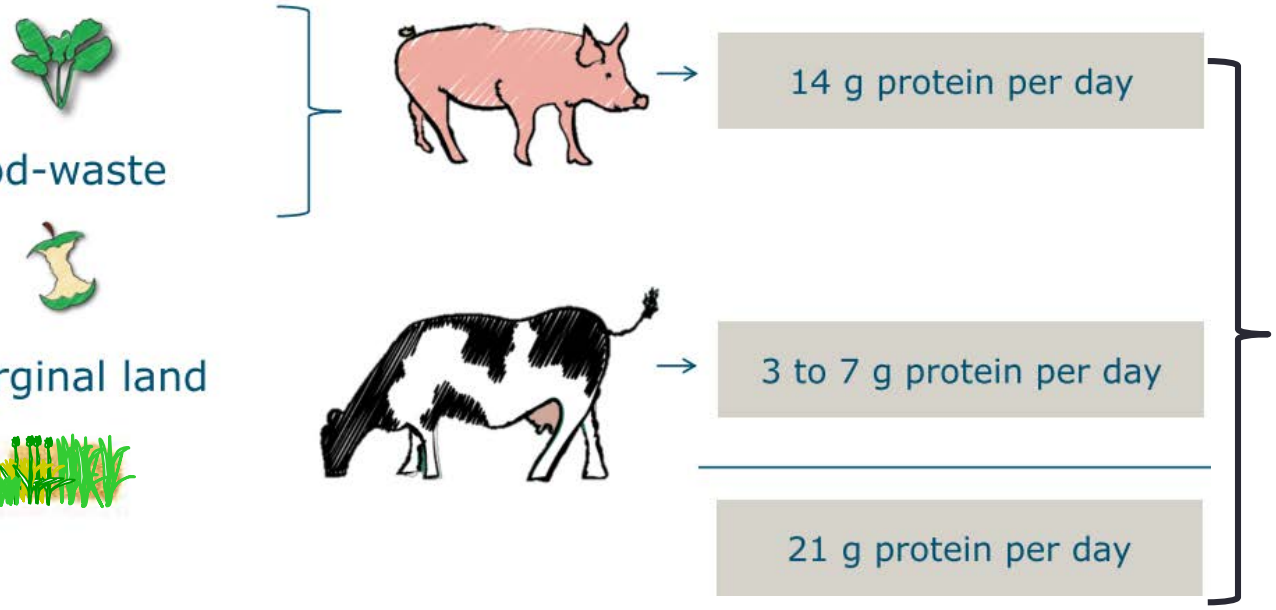
Global prospective scenarios

Global scenarios account for shifts in livestock feeding strategy in interaction with land use and food security

- Decreasing waste from the current one third of food produced down to 10%
- Avoiding feed-food competition

Van Zanten *et al*. 2016

- Co-products
- Food-waste
- Marginal land



About1/3 of the 60 g/day.pers. of total protein

Matches WHO recommendations at a global scale

Drivers of these changes (prices, EU animal feed legislation, social acceptability) were not considered so far

Consumption of animal products in public debate

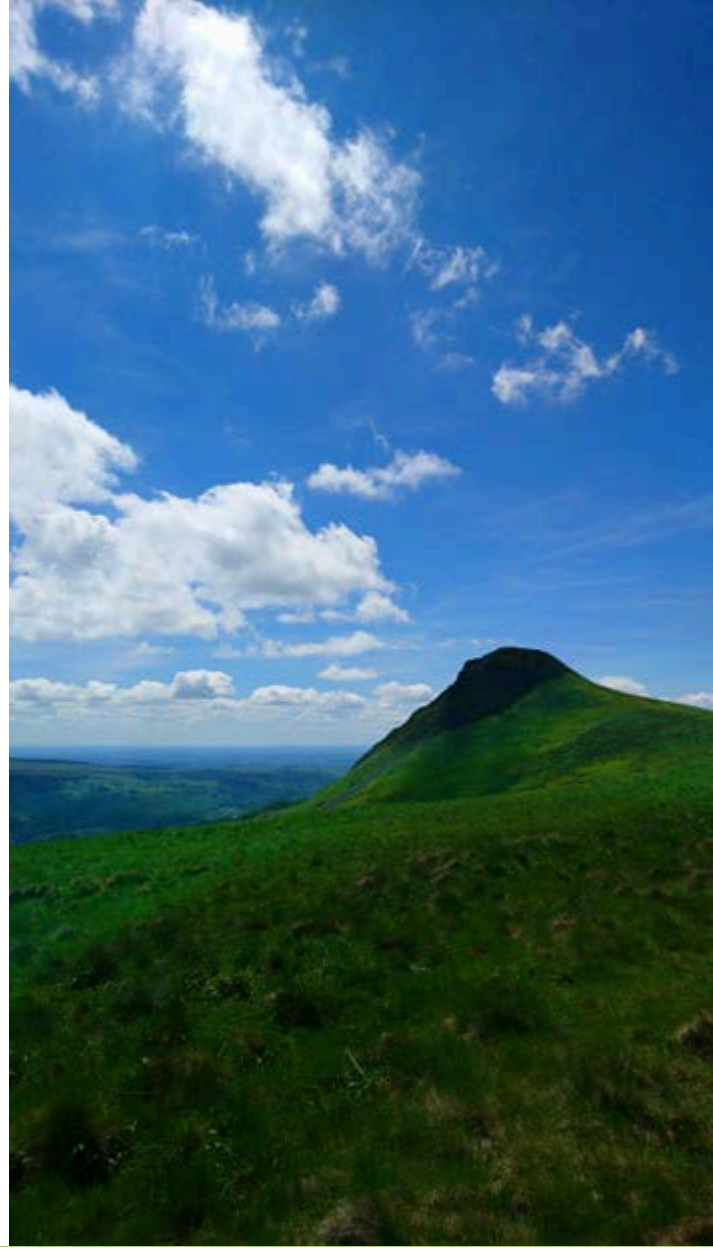
- Health and nutrition issues linked to overconsumption of meat and milk
- Veganism and the refusal of the animals use/suffering

What are the potentials of sustainable intensification (SI) and of agroecology (AE) to design sustainable ruminant systems?

- Two frameworks that have been seen as complementary steps away from industrial livestock farming systems (Smith 2013, Gordon *et al*. 2017, Makkar 2018)
- While for others, it is not necessary to endorse productionist agricultural models to feed the world's population (Fouilleux *et al*. 2017), and thus AE would not have to be combined with other approaches (Altieri *et al*. 2017)
- Anyway, the necessary transition of livestock production systems requires having a clear view on the different frameworks that aim to achieve livestock farming sustainability
- A common misunderstanding is that SI is just a mid-step in the transition towards agroecological systems

This talk

- History: Where do the two frameworks come from?
- Examples from herbivore production systems
- Analyse their main criticisms:
  - Is SI sustainable?
  - How much can AE contribute to feeding the world?
- Convergence between the two frameworks



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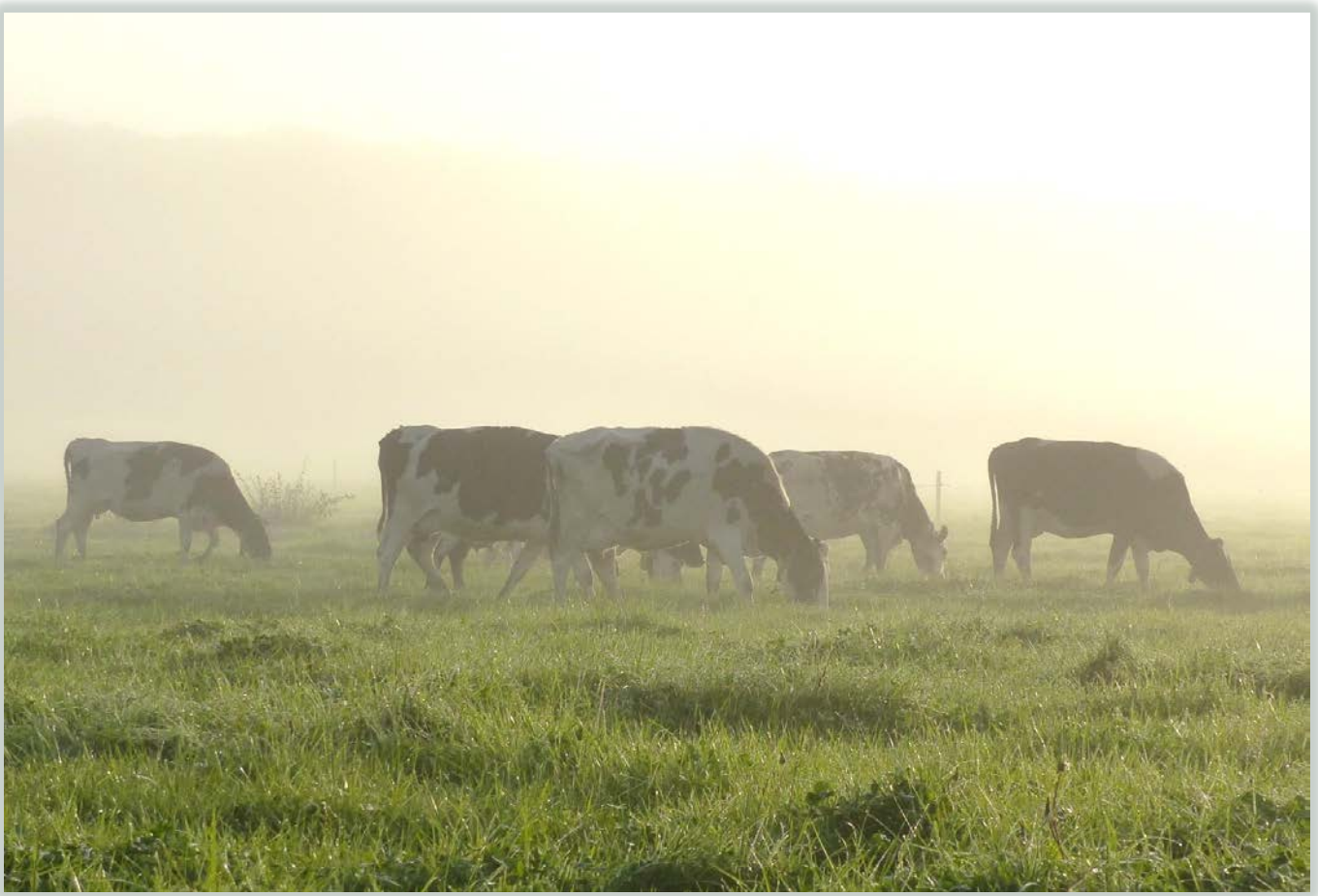


SUSTAINABLE INTENSIFICATION

Historical perspective

- The term sustainable intensification originated from development efforts that aimed to increase the productivity of sub-Saharan agriculture in the 1990s (Pretty, 1997)

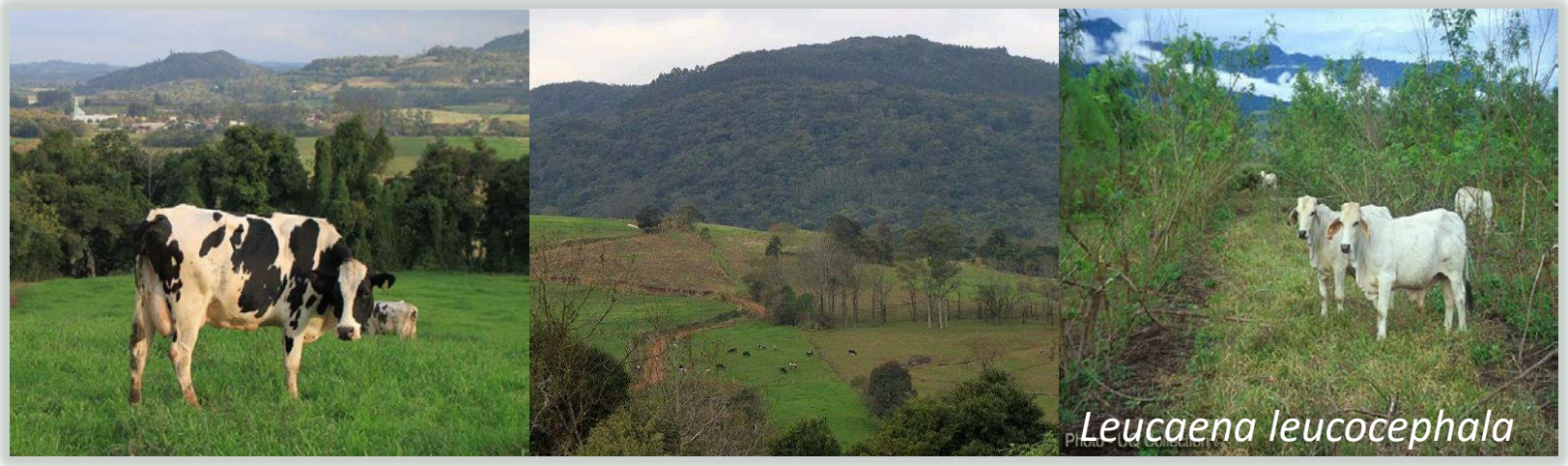
- Increasing production from existing land => Feeding populations without further loss of natural ecosystems



- Proponents of SI originally emphasized the importance of local knowledge, but the term remained loosely defined, and SI was embraced by the industry and by a number of international organisations (FAO, ILRI, CGIAR)
➔ A wide range of top-down technologies

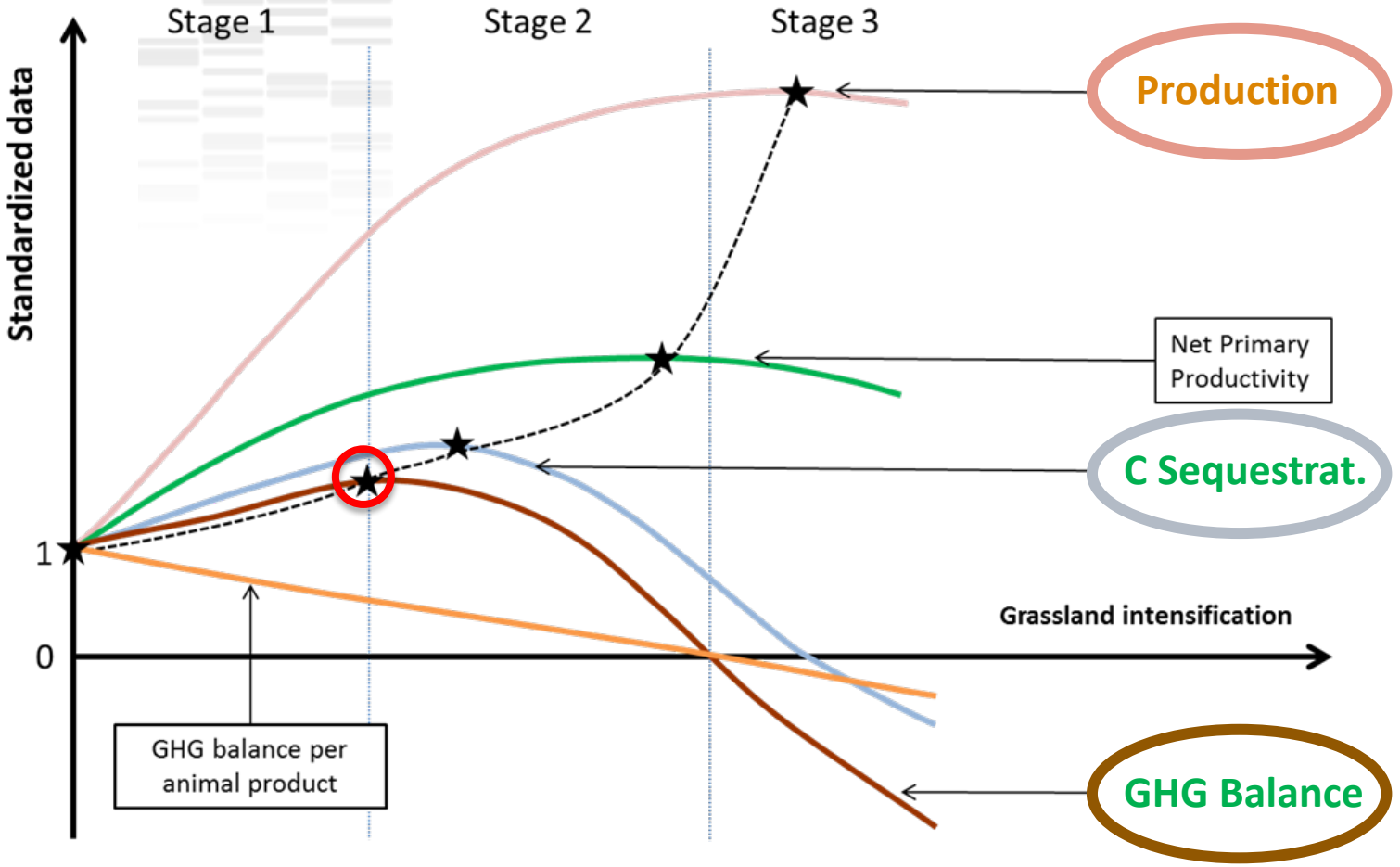
Sustainable intensification in practice

- Priority is to close yield gaps (the ≠ between actual and attainable yield) to produce more food per land unit area => Genetic intensification, use of grass and legume cultivars selected for higher biomass, nutritive value, etc.



- Increase in stocking rate (1.2x ➔ 4.7x) and of productivity (1.3x ➔ 4.9x) in beef cattle systems from Brazilian Amazon (zu Ermgassen *et al.* 2018), while providing a number of regulating services (limitation of erosion, climate regulation via C sequestration)

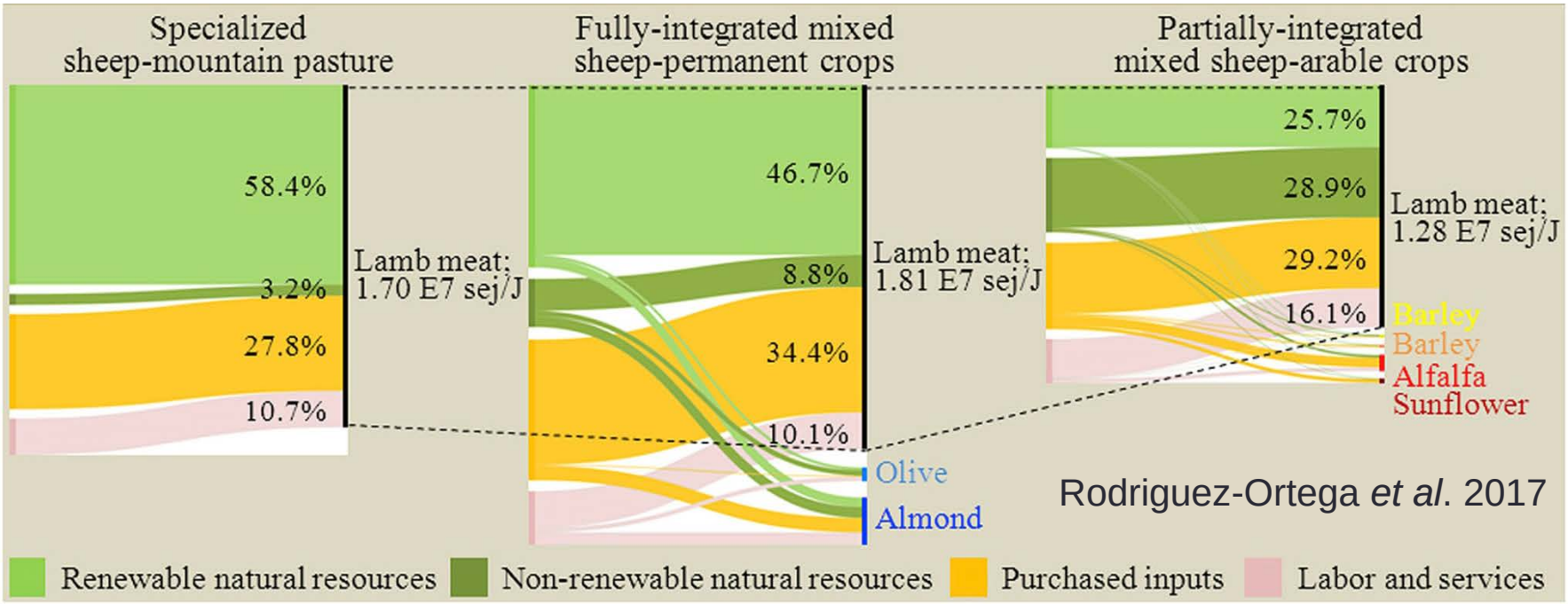
Benefits of grassland intensification have limits



From stage 2, **production** increases at the cost of **ES**, then levels-off as ES collapse (Soussana & Lemaire 2014)

Well-conducted intensification does not necessarily enhance system sustainability

A cradle-to-gate analysis of 3 Mediterranean sheep-crop farming systems



Partially integrated lamb-crop farming systems have the highest production efficiency and intensity but the lowest sustainability

Is sustainable intensification sustainable?

- 'Sustainable' and 'intensification' are often not assigned equal weights (Struik & Kuyper 2017). Priority is to reduce harmful effects and little attention is paid to producing positive environmental outcomes

- By interpreting SI as an inevitable response to population growth and increase in animal protein consumption, it is only after productivity concerns are covered that most environmental and social issues are addressed

  ➔ Limits the emergence of solutions that meet the expectations of all types of stakeholders (Groot *et al*. 2010, Howe *et al*. 2014)

- In addition, improving resource use efficiency may not necessarily lead to a reduction in land needed for production

  ➔ Efficient agricultural systems in the Brazilian Amazon region were seen as profitable to farmers, which resulted in the expansion of agricultural area and further deforestation (Lambin & Meyfroidt 2011)

In summary

	Sustainable intensification	Agroecology
Production / unit area	Aims at ↑ yield through intensification of existing land	
Use of inputs	↑ nutrient use efficiency. No *a priori* for levels required	
Biodiversity and Ecos. Serv.		
Role of digital technology		
Knowledge transfer		

In summary

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Role of digital technology	Technology used to optimise inputs, and adjust diet to animal requirements (PLF)	
Knowledge transfer	Mainly top-down	

_02

AGROECOLOGY

Historical perspective

- The term agroecology can be traced back to the 1930s and has been used as a scientific discipline, a set of agricultural practices, and/or a social movement

Agron. Sustain. Dev. 29 (2009) 503–515
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DOI: 10.1051/agro/2009004

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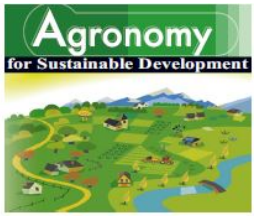


Review article

Agroecology as a science, a movement and a practice. A review

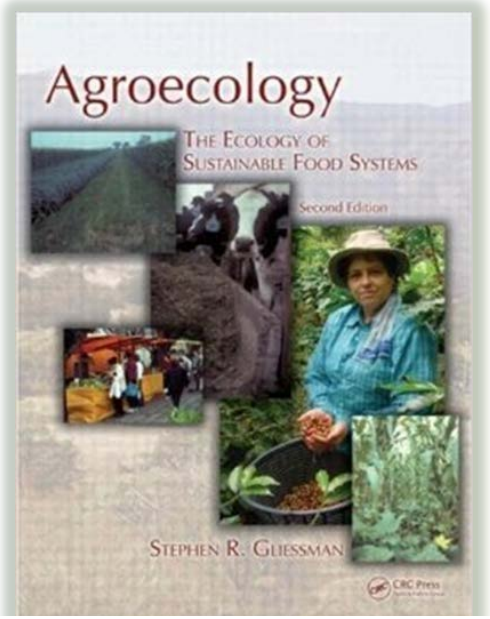
A. Wezel[1]*, S. Bellon[2], T. Doré[3], C. Francis[4], D. Vallod[1], C. David[1]

- As a scientific discipline AE applies ecological theory to the design and management of sustainable agroecosystems (Altieri 1987, 2002) or of the entire food system (Francis *et al*. 2003)

- It aims to stimulate natural processes to design agricultural systems that are weakly artificialised (less dependent on inputs), productive, environmentally-friendly and socially-fair

Historical perspective

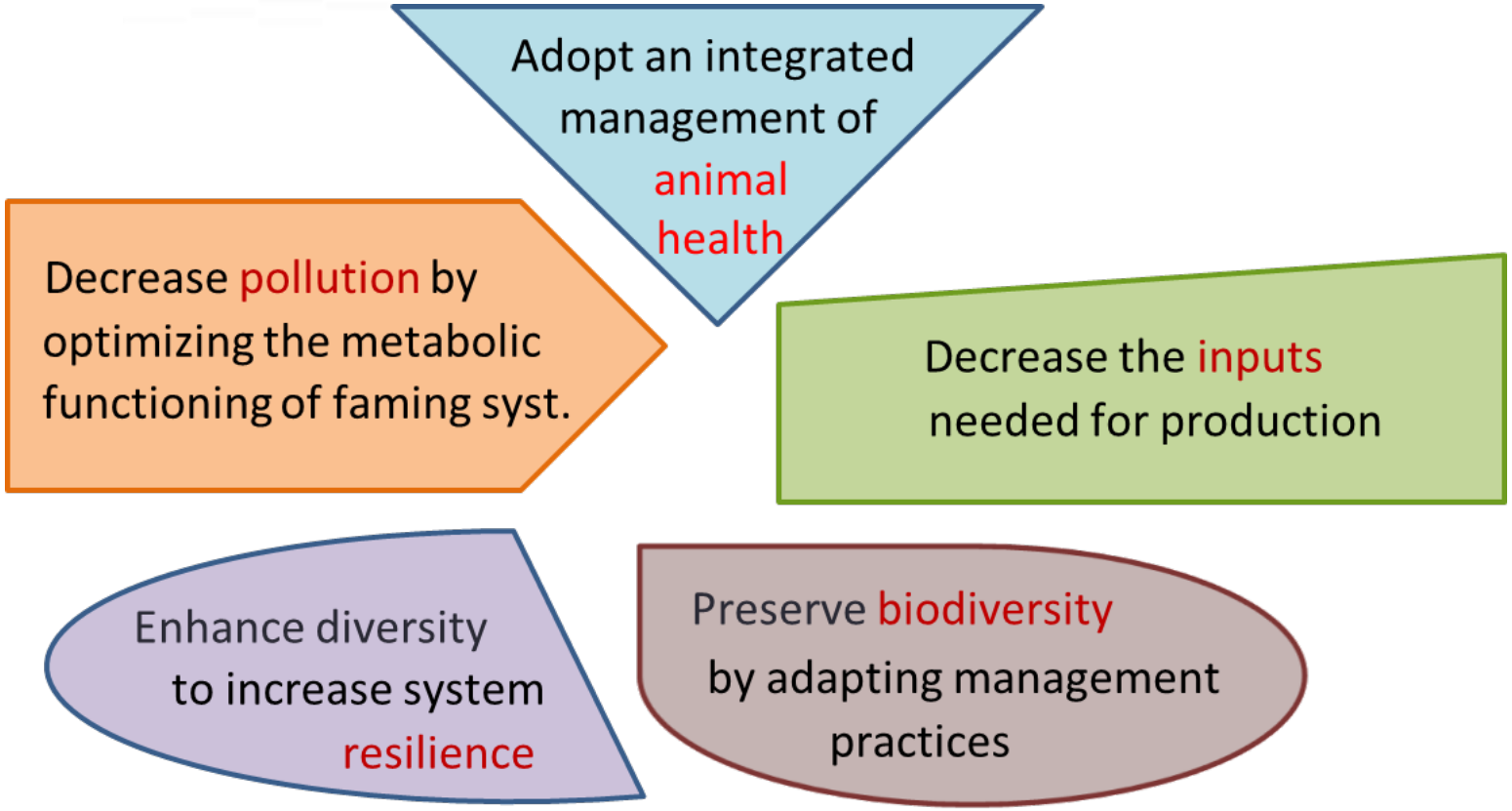
- Despite the recent surge in academic literature on agroecology, animal production systems have been ignored in most agroecological thinking



'The problem lies not in the animals themselves or in the consumption of animal products, but rather in the way they are integrated into agroecosystems. [...] Understanding the integration of the animal in its agroecosystem provides levers to ensure sustainable environmental and economic concerns' (Gliessman 2007)

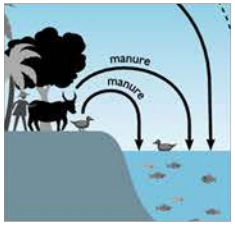
Agroecological principles for livestock farming

- Principles can be used as guidelines to implement combinations of agroecological practices adapted to local conditions



Dumont *et al*. 2013







Managing animal health	***			*	**	
↓ inputs	**	***	**	***	**	**
↓ pollution		**	**	***		
Enhancing diversity	**	**	**	**	***	*
Preserving biodiversity	**	*				***

Dumont *et al*. 2013

Several principles apply in each system ➔ Redesign

Self-suffient low-input dairy systems: when less is more!

Less pesticides, -1/3 mineral N
-1/3 NRE / 1000 l. ↑ Hedgerows
C sequestration => net GHG emissions: -14% CO_2-eq/l

+26%

Inputs

Feeding costs 78 *vs* 120 €/1000l

Environ-ment

Production

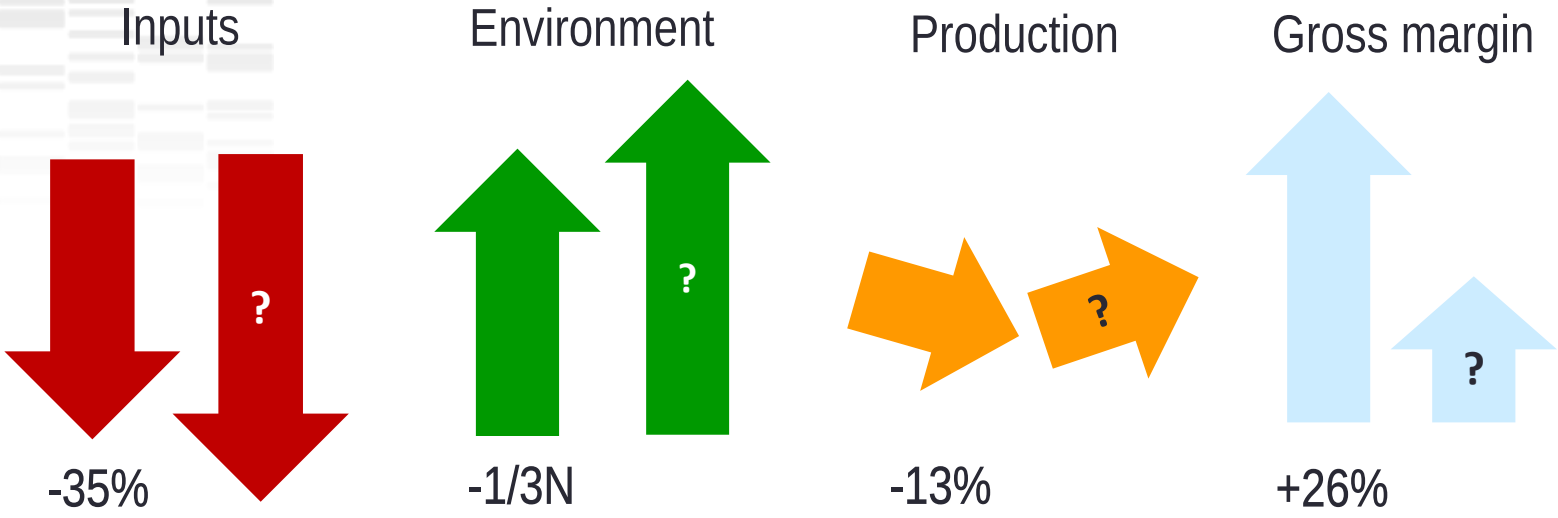
Gross margin

More complex crop rotations
↑legume mixtures. Late grazing
Grouping calving periods

Slight ↓ in productivity
-13%

Duru & Therond 2015

Digital technology for better monitoring the system



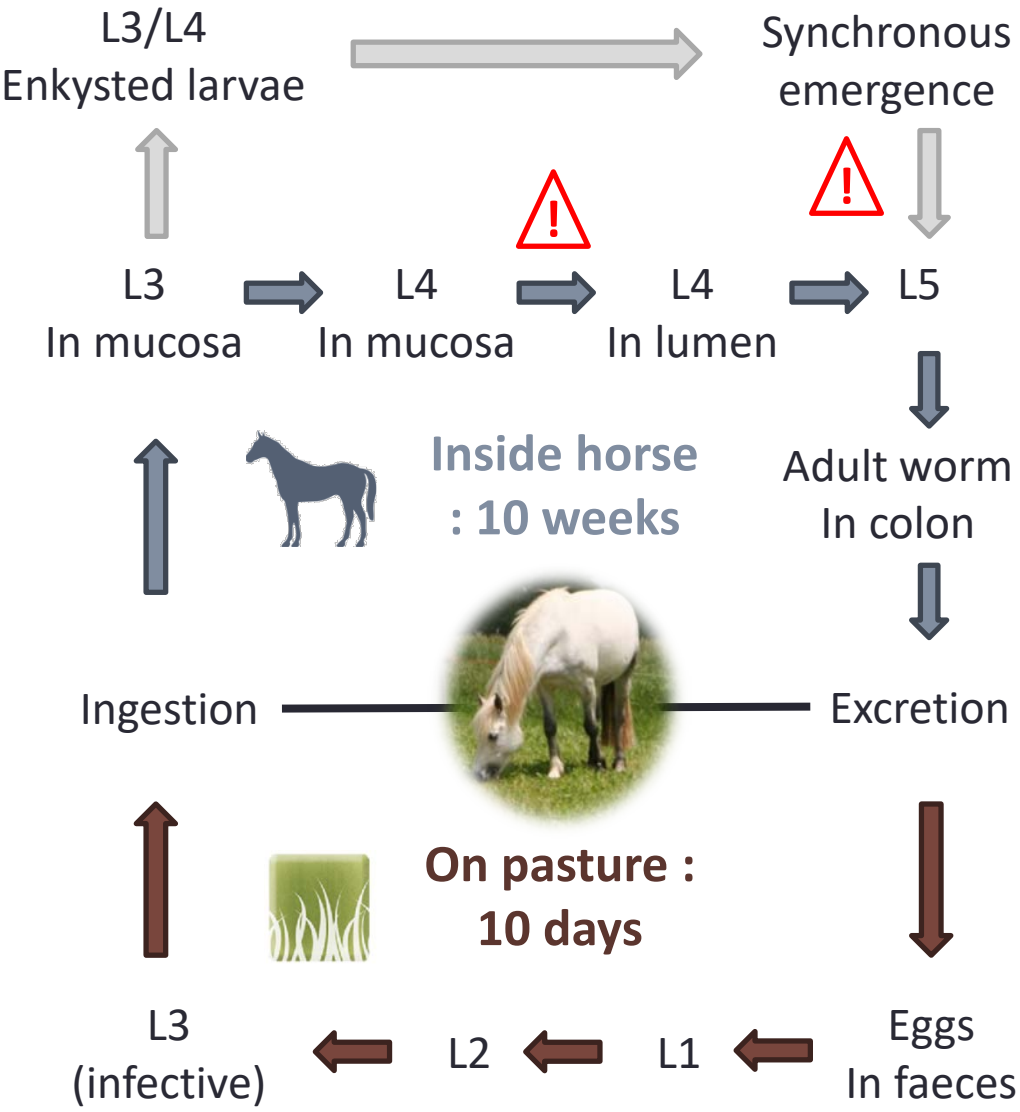
- An opportunity or/and a new form of dependency?
- The key issue for making digital science part of the agroecological transition is that it remains at a low cost and is thus accessible to smallholder farmers

Integrated health management in grassland-based systems

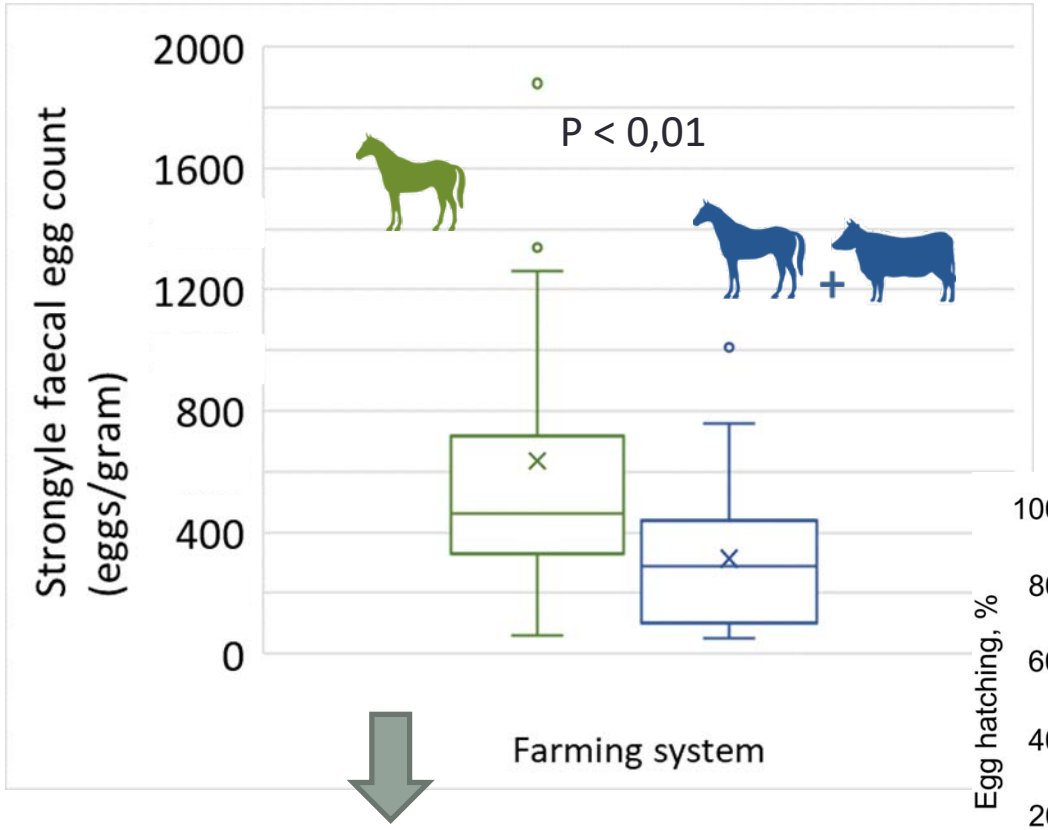
- Based on the analysis of relationships between herbivores and their pathogens to reduce the use of anthelminthics

Mixed grazing with a non susceptible species is assumed to reduce strongyle load on the pasture thanks to parasite dilution

Forteau *et al*. 2020

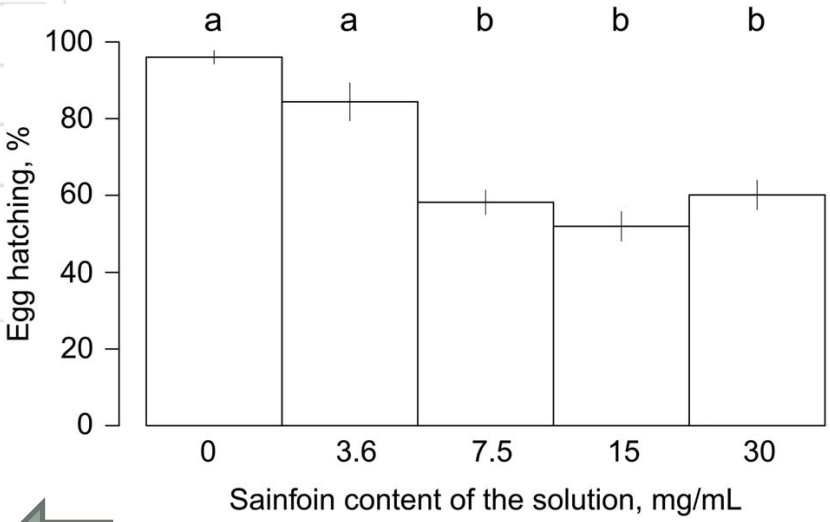


Integrated health management in grassland-based systems



In vitro tests have revealed that sainfoin can reduce both strongyle larval development and egg hatching

Collas *et al*. 2020



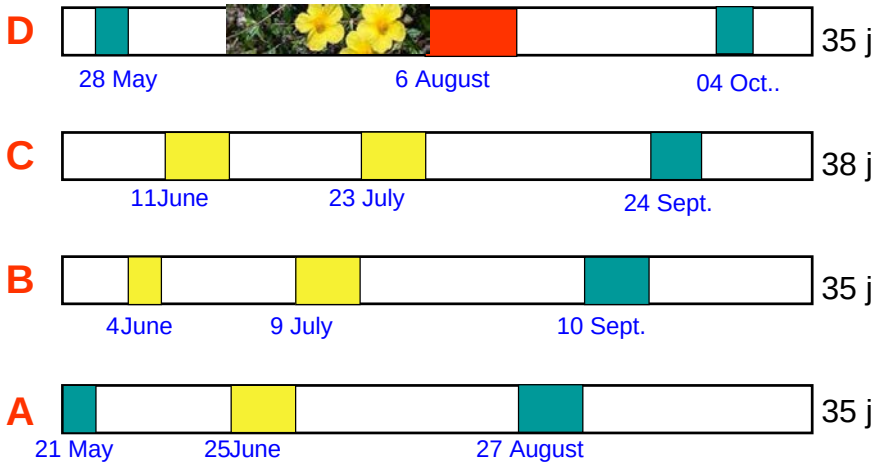
Reduces vet. costs, benefits dung beetles

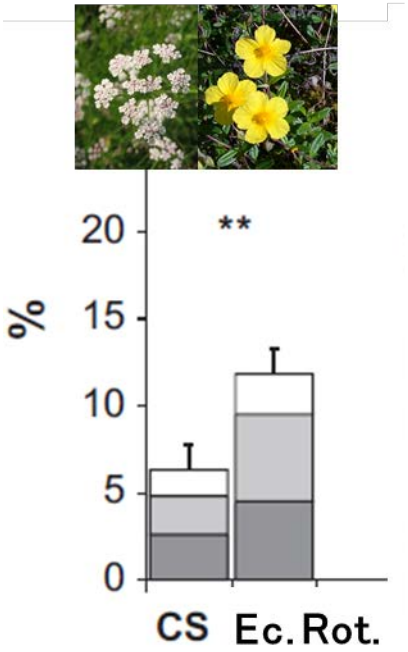
Increases horse resistance to parasites

Biodiversity-friendly practices in grassland-based systems

A	B
C	D

vs Continuous at the same Stocking Rate





Farruggia et al. 2012

In line with the habitat heterogeneity hypothesis and the tropic hypothesis

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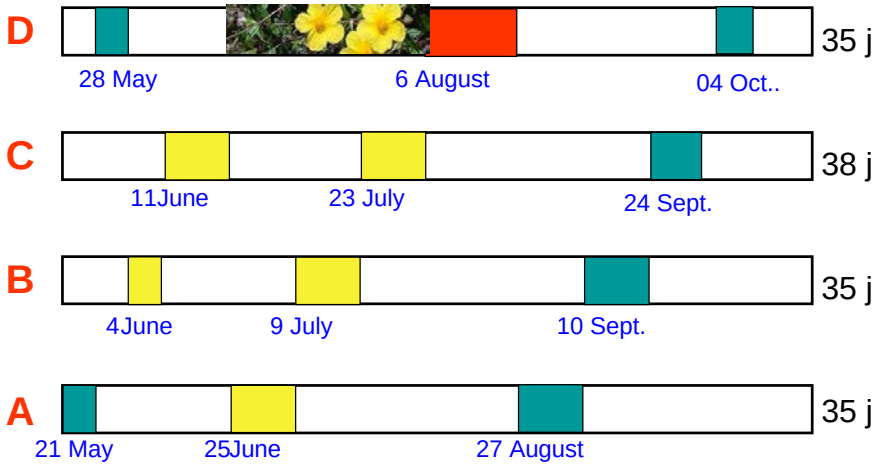
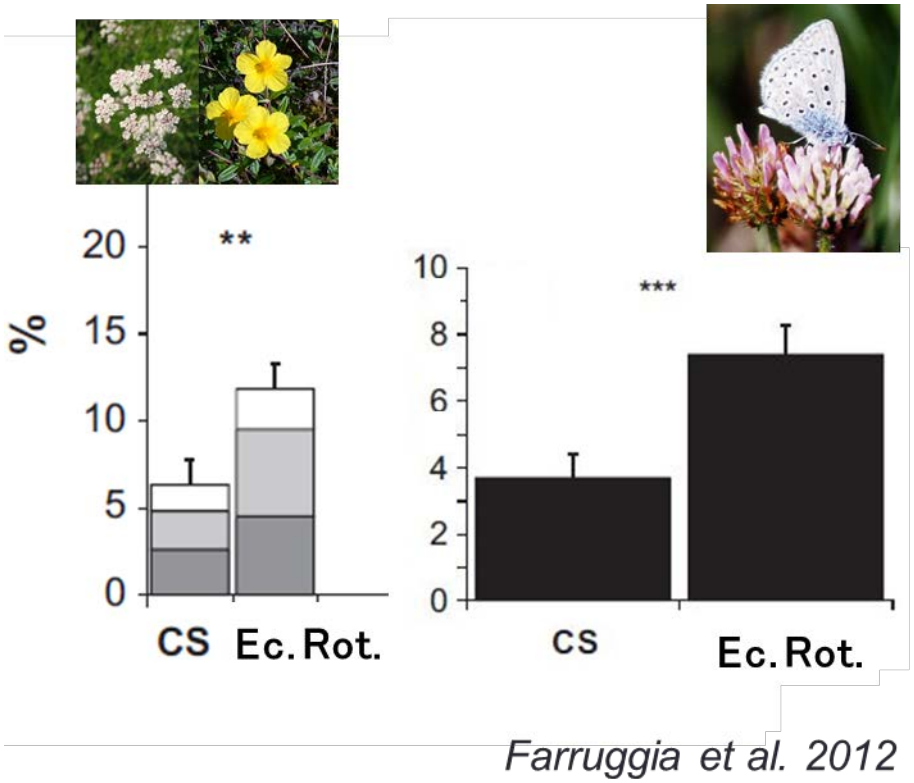




Farruggia et al. 2012

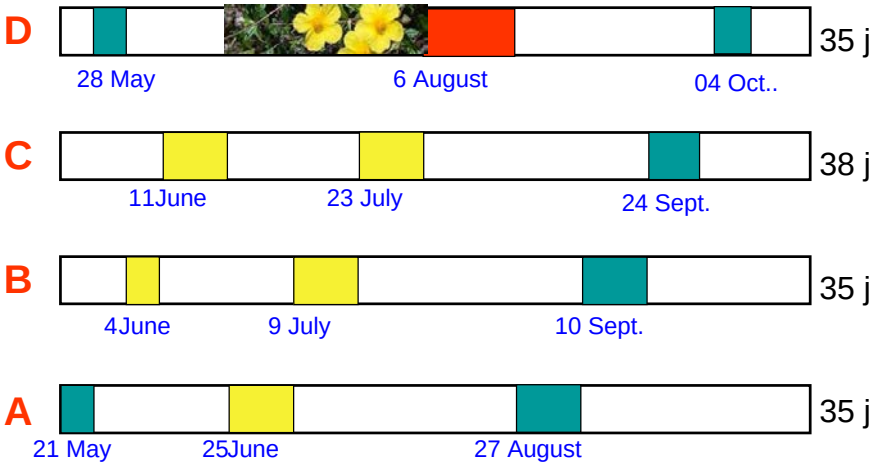
In line with the habitat heterogeneity hypothesis and the tropic hypothesis

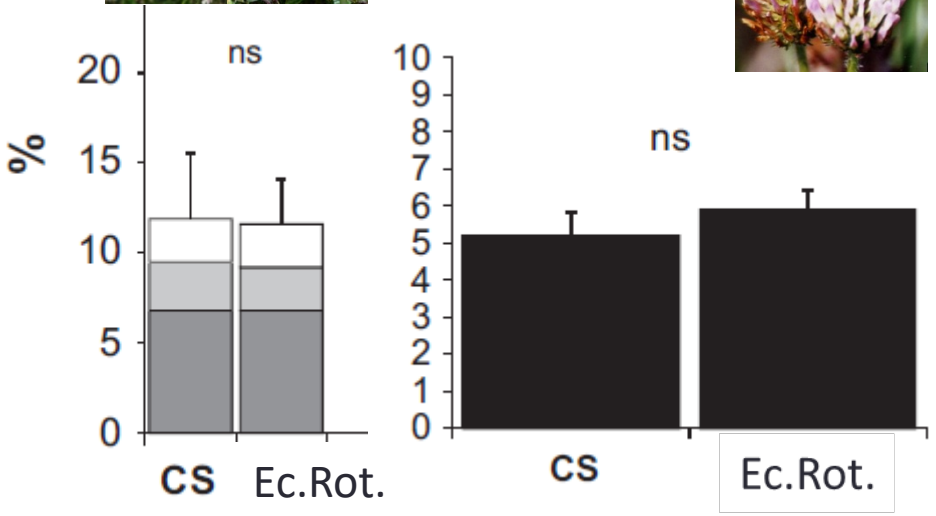
But -19% grazing days a year with poor spring grass growth !!

Biodiversity-friendly practices in grassland-based systems

A	B
C	D

vs Continuous at the same Stocking Rate





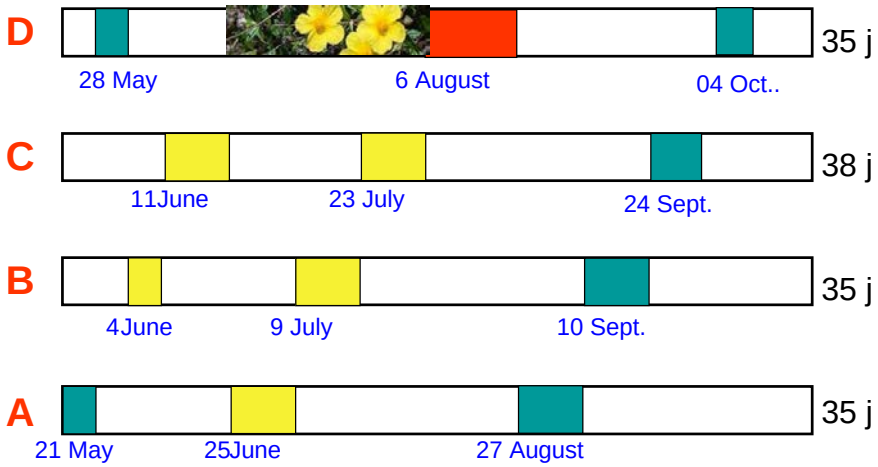
Farruggia et al. 2012

Same comparison at a lenient stocking rate

Biodiversity-friendly practices in grassland-based systems

A	B
C	D

vs Continuous at the same Stocking Rate



Beyond stocking density…

- Less efficient under sheep grazing (Scohier *et al*. 2013; Ravetto Enri *et al.*, 2017)
- Strong effects on bumblebees but no effect on *Carabidae*,…

Generic principles apply but practices need to be adapted to local/annual conditions (≠ from “turn-key” solutions)

Knowledge intensive systems

How much can AE contribute to feeding the world?

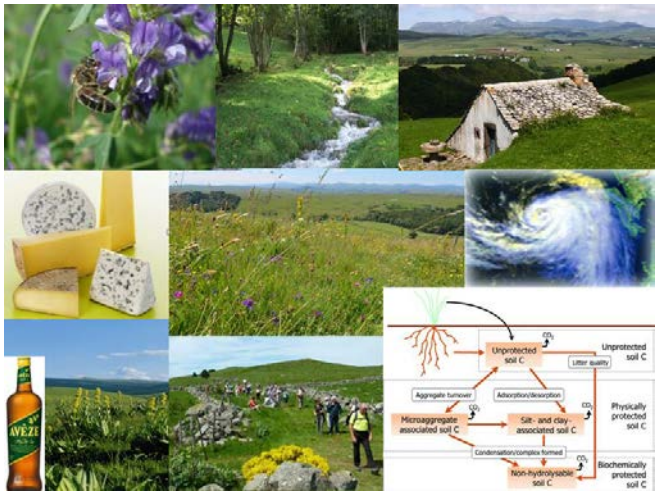
- Productivity is assumed to be lower… but this is not always the case
  - Traditional mixtures of crop and cereals (méteils, milpa) ↑ production (Barbieri *et al.* 2017)
  - Tropical agroforestry systems: ↑ milk production by 130% (Murgeitio *et al.* 2011), biodiversity and system resilience (Altieri *et al*. 2017)

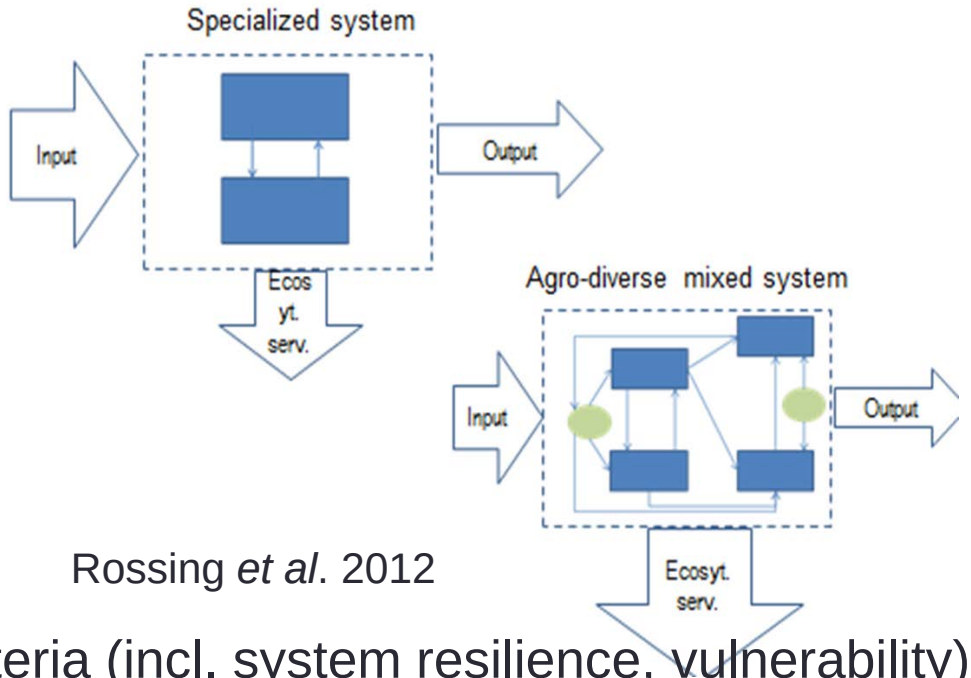
- A knowledge of underlying mechanisms (functional redundancy, portfolio effect, etc.) that lend system resilience properties
- System intensification has received the majority of governmental funding and almost the total investment in research by the private sector

➔ A fair answer to the question of how much can AE contribute to feeding the world requires the opening of a vast research agenda for the animal science community

Agroecological perspective for animal research

- Analyze the (behavioural, physiological, genetic, epigenetic) bases of animal adaptation in the medium/long term as levers to enhance animal robustness
- Assess the ecosystem services provided by agro-diverse livestock farming systems





Rossing *et al*. 2012

- Propose new performance criteria (incl. system resilience, vulnerability) to guide system evaluation ➔ Multicriteria evaluation is needed

In summary

	Sustainable intensification	Agroecology
Production / unit area	Aims at ↑ yield through intensification of existing land	No *a priori* for intensification. Production can slightly ↓ Profitability ↑ due to less inputs
Use of inputs	↑ nutrient use efficiency. No *a priori* for levels required	Aims to be less dependent on inputs, to use on-farm processes
Biodiversity and Ecos. Serv.	Land sparing. Up to some levels ES can be provided, but no incentive for using ES	
Role of digital technology	Technology used to optimise inputs, and adjust diet to animal requirements (PLF)	
Knowledge transfer	Mainly top-down	

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Knowledge transfer	Mainly top-down	Local knowledge. Farmer-to-farmer network is key for transfer

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Efficiency *vs.* Redesign (Horlings & Marsden 2011) ➔ Different worldviews about our relationship to nature, role of technology, …

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CONCLUSION: CONVERGENCE BETWEEN SI AND AGROECOLOGY

Different worldviews that tend to converge

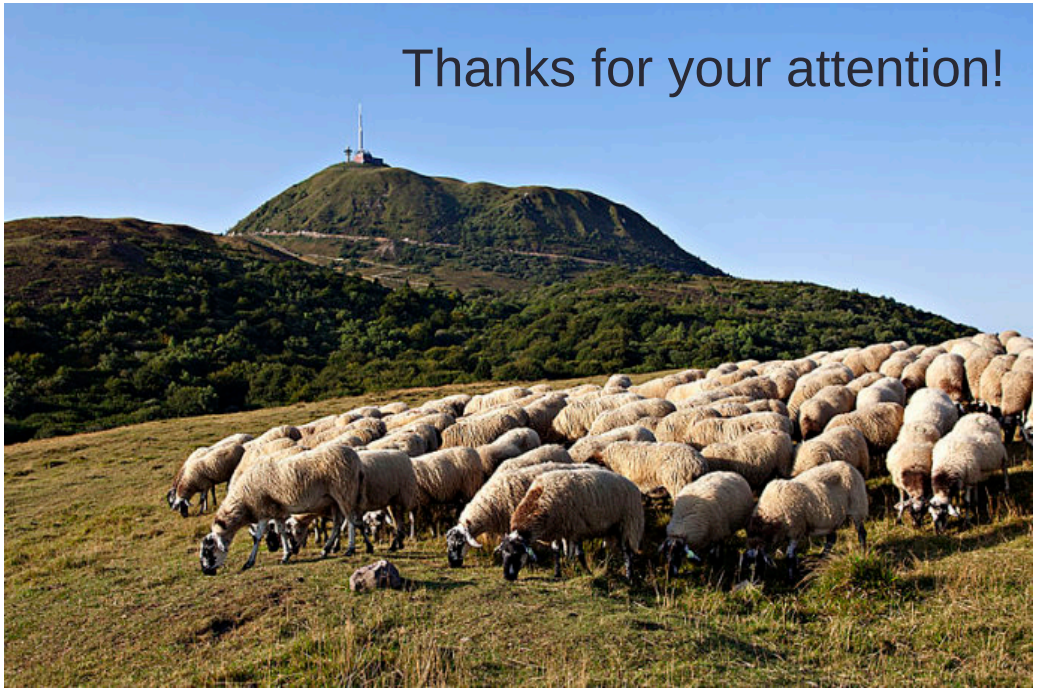
- Sustainable intensification is evolving
  - SI has long been focused on production and has thus been criticised for lacking engagement with the social pillar of sustainability (Loos *et al*. 2014)
  - Garnett *et al*. (2013) have proposed the adoption of a food system transformation perspective for SI (support of rural economies, equity of access to food) ➔ SI no longer considered as a 'business as usual' food production with 'marginal' improvements in sustainability
  - SI should be regarded as a 'guiding principle in decisions about land-use rather than as a end-point' (Smith 2013)

- Where food should be produced?
  - Integrated global markets have been advocated by SI proponents and by the livestock business (Röös *et al*. 2017)
  - AE has given priority to local autonomy and control of land since the very beginning
- As no space is available for agricultural land expansion (e.g. India) local production will imply a search for methods to increase yield, as an ↑ in cropping intensity (double or triple cropping within a year), and multi-strata forage systems

Take-home message

- Although underpinned by different worldviews on our relationship to nature, the role of digital technology and where food should be produced, our view is that we should not be locked into a single approach

- Applying SI to industrial systems could be seen as a green-washing strategy. Identifying first the key ecological processes to be optimised is more likely to lead in the direction of a strong form of ecological modernisation



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