Agroecological efficiency and transition at different scales of ruminant production systems

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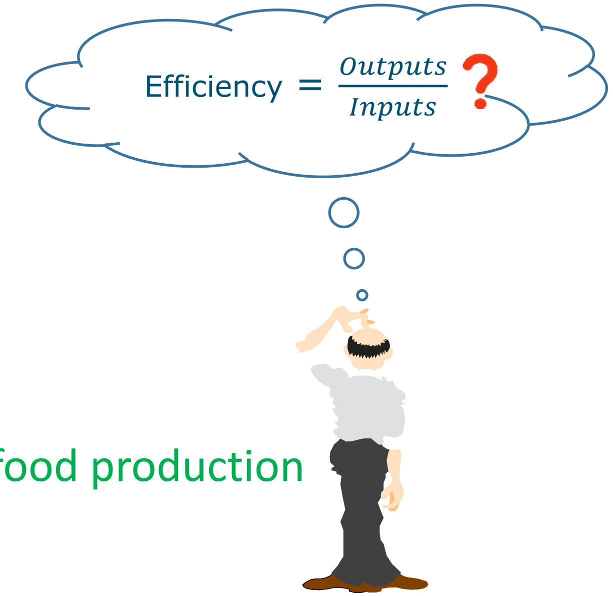
Introduction

Does efficiency *per se* mean sustainability?

$$\uparrow \text{Efficiency} = \frac{\uparrow Outputs}{Inputs} \quad \text{or} \quad \uparrow \text{Efficiency} = \frac{Outputs}{\downarrow Inputs}$$

↑ Outputs

- Is achieved in high-input intensive systems (Capper et al., 2011; Capper and Cady, 2020)
- Despite using a large amount of inputs, they produce a much higher level of outputs
- Consequences (Garnett et al., 2015):
  - Feed-food competition
  - Land and water contamination
  - Biodiversity losses, animal welfare concerns and rural unemployment, etc.



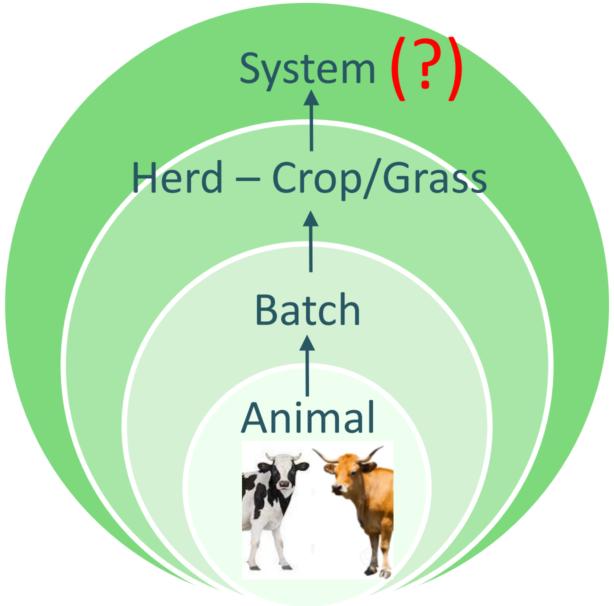
↓ Inputs

- Low-input systems make use of natural processes and inputs
- Agroecology aims to (Dumont et al., 2013; Bonaudo et al., 2014):
  - Reduce dependencies on synthetic and fossil resources
  - Bring more added values to farmers, society and nature
- Ruminants play an essential role in agroecological context → judged beyond food production and environmental emissions

Introduction

Gains of efficiency at lower scales do not always retain when evaluated at higher scales (Faverdin et al., 2022)

Inputs



Outputs

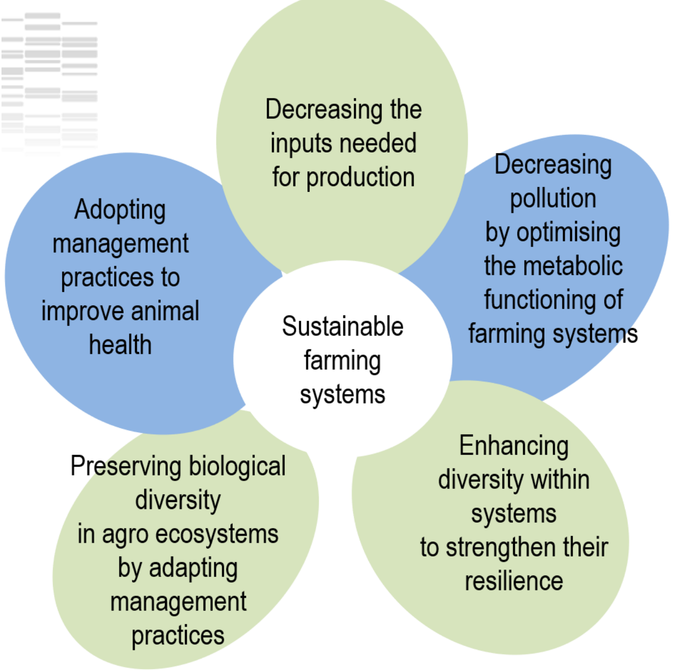
Objectives:

1. Conceptualize a new holistic criteria for efficiency in agroecological ruminant production systems (**AE efficiency**)
2. Literature evidences for impacts of scale changes on efficiency:
    - Possible gains/losses of efficiency due to scale changes (animal → herd → system)

Material and methods

Literature review

1. Conceptualize a new AE efficiency :
   - 5 principles for the design of agroecological livestock production systems
   - Discussions with INRAE experts
   - Literature review



(Dumont et al., 2013)

2. Impacts of scale changes on efficiency of ruminant production systems: systematic review
   - Selection criteria for papers:
     i. Peer-reviewed and written in English or French
     ii. Simultaneously study at least two scales
     iii. Impacts of improving efficiency at one scale on efficiency gains/losses at another scale
   - Search string was run on Web of Sciences (May 16th 2023) → 86 articles
   - Screening titles and abstracts → **15 articles** (mostly dairy cattle)

Results and discussion

Overall AE efficiency criteria of ruminant production systems

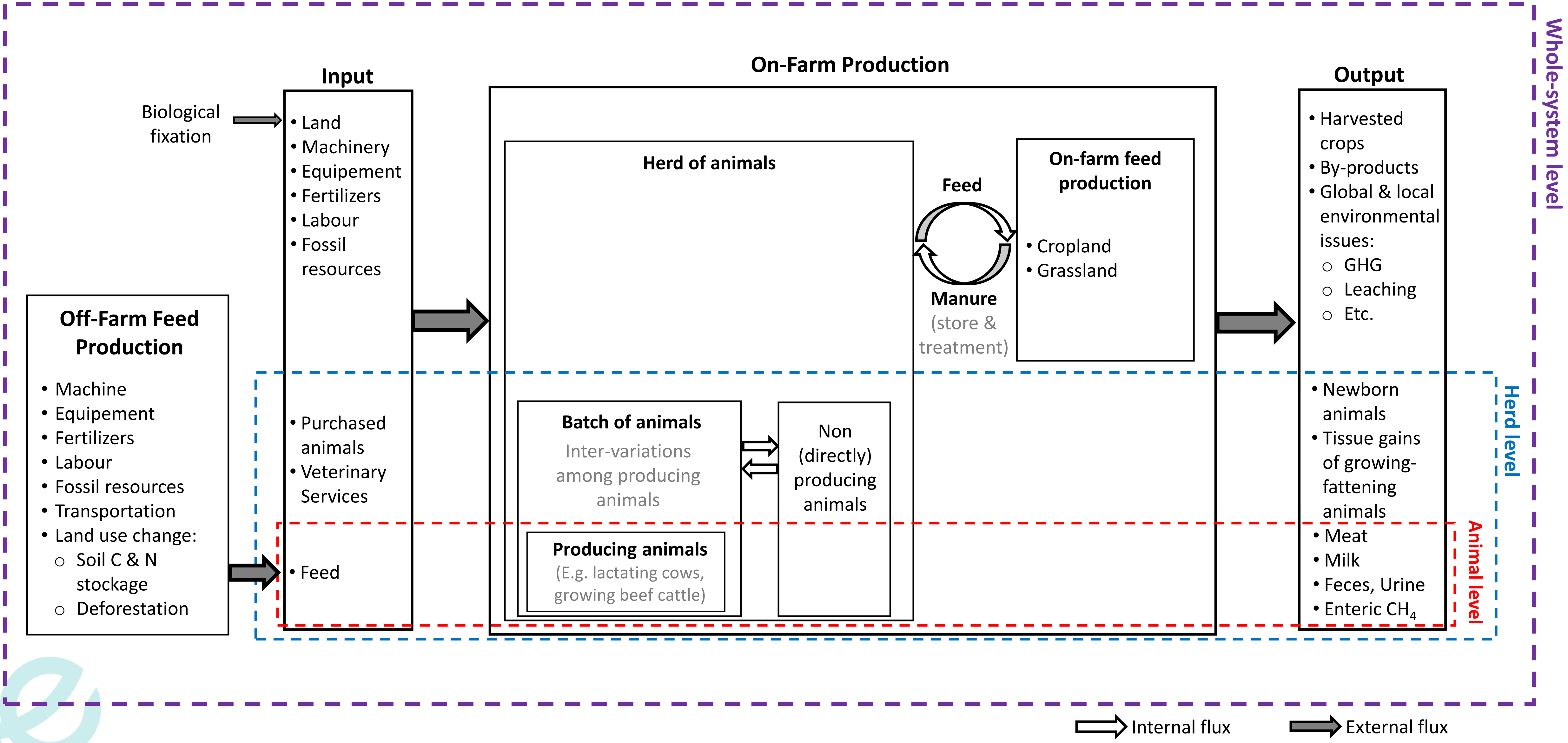
- AE efficiency = multi-criterial efficiency = $\int$ (production, environment, economy, work)

  1. $\downarrow$ Use of intermediate consumptions (purchased goods and services)
  2. $\downarrow$ Pollution and losses by closing nutrient cycle of the system
  3. $\downarrow$ Feed-food competition
  4. $\uparrow \dfrac{\text{Added value}}{\text{Gross value of production}}$
  5. $\downarrow$ Overburdened workload

- To improve AE efficiency:
  - $\uparrow$ Efficiency $= \dfrac{Outputs}{\downarrow Inputs}$ or $\uparrow$ Efficiency $= \dfrac{\downarrow Outputs}{\downarrow\downarrow Inputs}$
  - **Animal health**, **biodiversity** and **interactions** between components of the system are key levers
  - Synergies/Trade-offs between 4 dimensions

Results and discussion

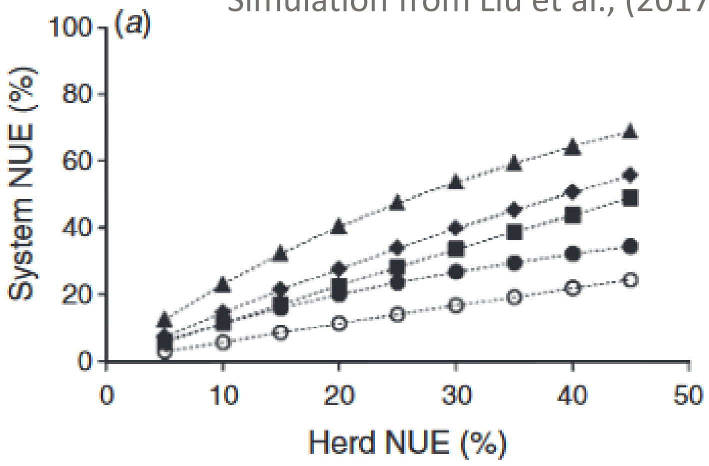
Perimeters of each scale within ruminant production systems



Results and discussion

Impacts of scale changes on overall efficiency of the system

Simulation from Liu et al., (2017)



- NUE varies much more at the system scale than at animal scale:
  - France: animal scale (23-29%) vs. system scale (23-53%) (Godinot et al., 2022)
  - Global: animal scale (13-36%) vs. system scale (8-64%) (Klein et al., 2017)

- Determinants of efficiency at different scales are different:
  - NUE and PUE of dairy and beef systems (Bai et al., 2013; Oenema and Oenema, 2022):
    - Herd scale: animal production level, feed quality
    - System scale: recycle of nutrient flows, animal-plant coupling
  - GHG emission of a German dairy farm after 1 year of conversion into organic (Gross et al., 2022):
    - Animal scale: ↑12% enteric CH_4 intensity (kg CO_2/kg ECM)
    - System scale: ↓ 9% GHG intensity (kg CO_2/kg ECM) due to ↓ emissions from on-farm (17%) and off-farm (29%) feed production

NUE = Nitrogen Use Efficiency
GHG = Greenhouse Gas
PUE = Phosphorus Use Efficiency
ECM = Energy Corrected Milk

Results and discussion

Impacts of scale changes on overall efficiency of the system

- Poorly understood interactions between system's components → trade-offs between scales:
  - Increasing maize silage in cow diet at the expense of grass (Vellinga and Holving, 2011; Van Middelaar et al., 2013):
    - Animal scale: ↓ GHG emissions (enteric CH_4)
    - System scale: ↑ GHG emissions because loss of soil Carbon stock due to **land use change** (grassland → maize land)
  - Increasing milk production per cow (Zehetmeier et al., 2012; Vellinga and Vries, 2018; Lehmann et al., 2019; Faverdin et al., 2022)
    - Animal scale: ↓ Enteric CH_4 intensity
    - System scale:
      - ↓ Beef meat produced per dairy farm
      - If demand for beef unchanged → if compensated by suckler systems → ↑ enteric CH_4 intensity

Take home message

- Efficiency in agroecological ruminant production systems:
  - Relies on reduction of external inputs and interactions between components
  - Multicriterial Efficiency = $\int$ (production, environment, economy, work)
- Gains of efficiency at animal scale do not always retain at the whole-system scale:
  - Only impacts on production and environment were found
- Future researches are needed for:
  - Validation of AE efficiency in practices
  - Impacts of scale changes on different dimensions of AE efficiency in ruminant production systems

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Thank you for your attention!