Towards future sustainable dairy farming systems: An integrated, adapted and circular approach

Xabier Díaz de Otálora, Aurelie Wilfart, Joanna Fratczak-Müller, Lorraine Balaine, Giorgio Ragaglini, Federico Dragoni, Barbara Amon

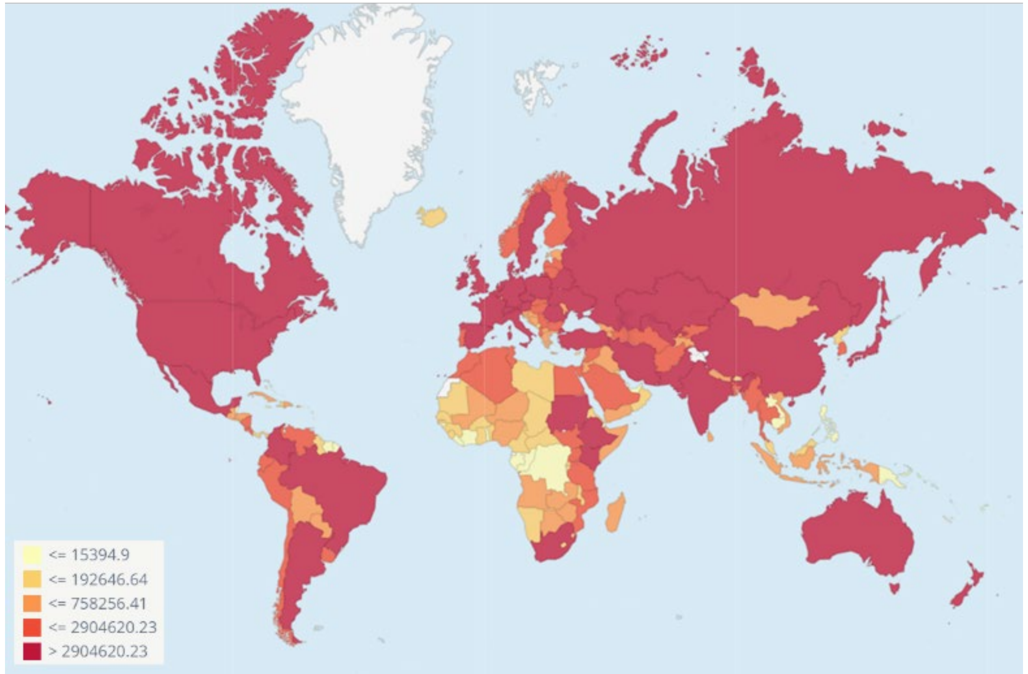
xdiadeo@upv.es

Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages

EAAP 2024, 1-5 September (Florence, Italy)
Session 46

Dairy production in the Global and European context

Average cattle milk production per country 2000-2021



Source: FAOSTATS

0.9 Gt of milk produced in 2021 (*FAO 2022*).

80% of the global population consumes milk regularly (*FAO and GDP, 2019*).

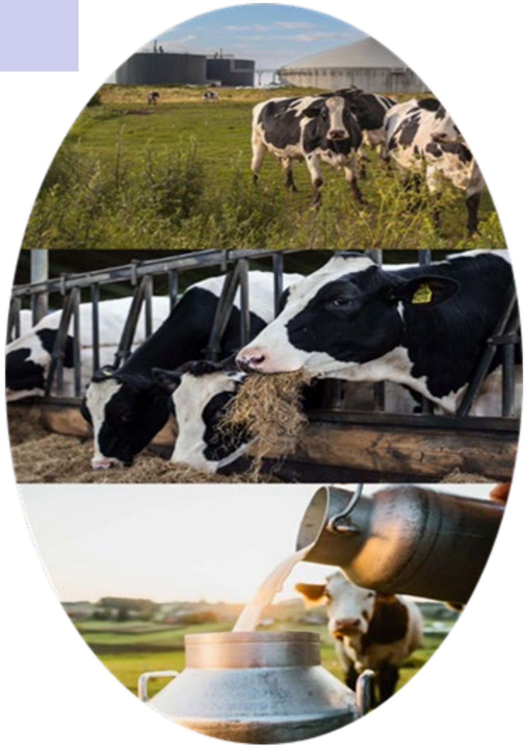
81% of global milk production comes from cattle with Europe as the second largest producer (**33%**) (*FAO 2023*).

20.2 million cattle heads in 2021 in Europe with an average yield of **7700** kg milk cow^{-1} day^{-1} (*European Commission 2023*).

The role of dairy production systems in our society

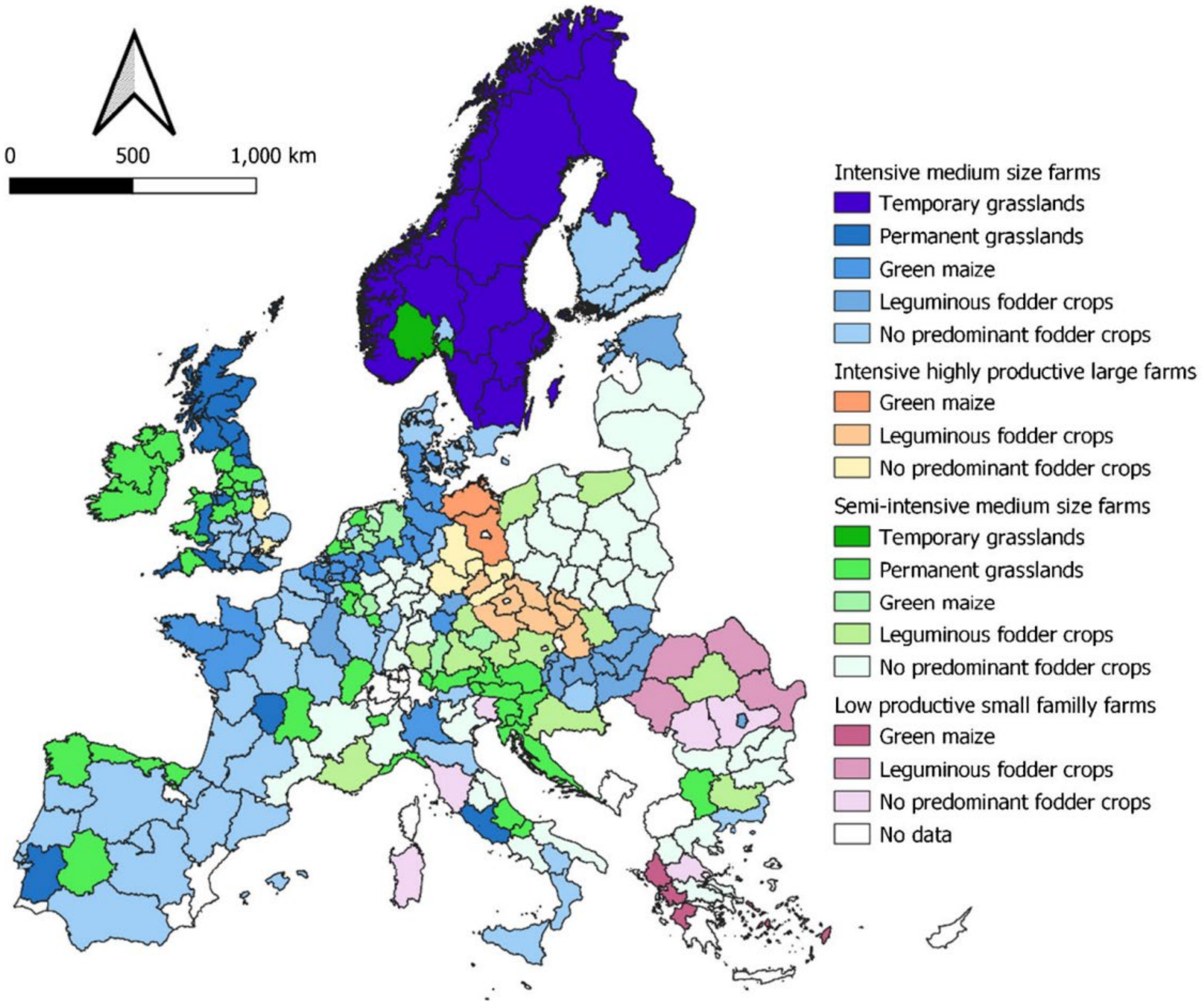
1. Efficient protein producers.
2. Feed on fibrous feedstuffs not edible by humans or monogastric animals.
3. Contribute to carbon fixation in grasslands.

1. Contributors to the global food security.
2. Constituents of a healthy and balanced diet.
3. Provision of ecosystem services.



1. 1 million jobs in Europe, specially in rural areas.
2. Sector deeply rooted to the territory and its economy.

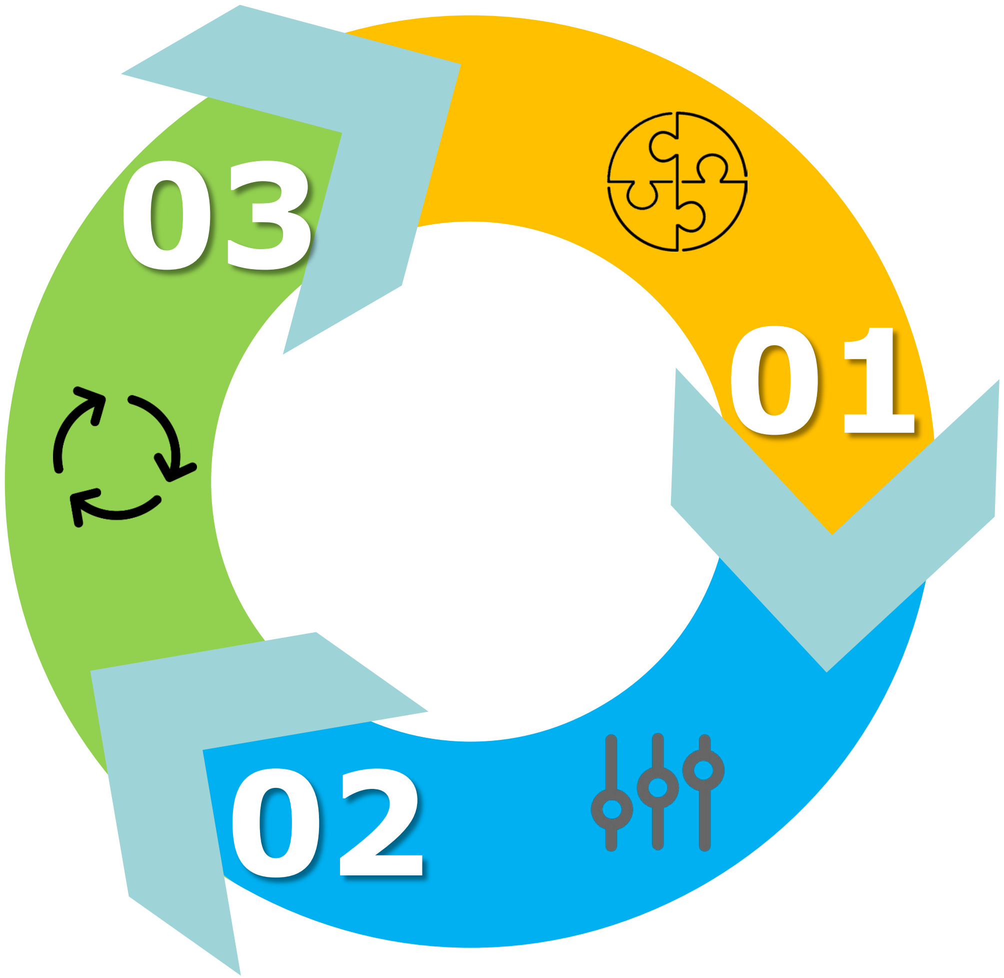
Systems diversity: Weakness or Strength?



Source: Díaz de Otálora et al., 2023

How should we address the challenges of the sector?

Integrated, circular, and adapted approaches are needed



Circularity

Closing of carbon and nutrient cycles, protein self-sufficiency and improved manure nutrient utilization.

Integration

Identify trade-offs and synergies between sustainability indicators by applying multi-criteria assessment approaches.

Adaptation

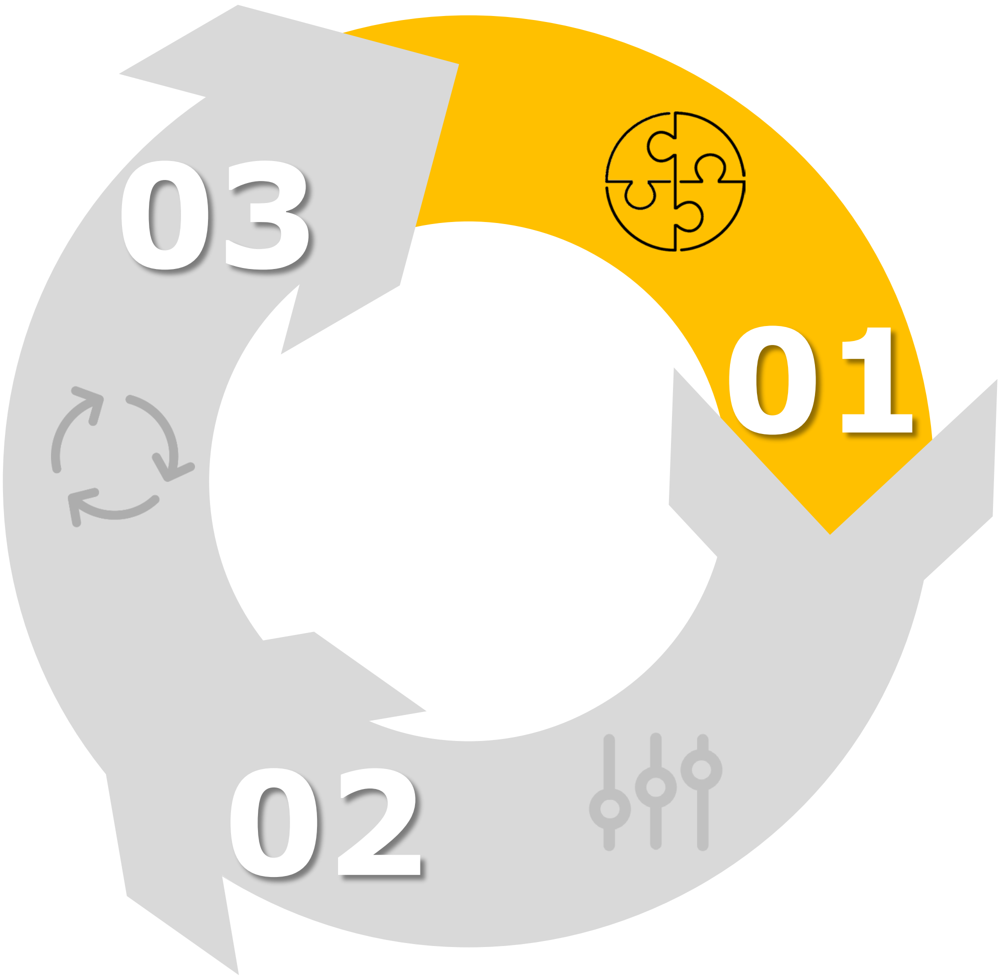
Assess effects of adapted mitigation measures, facilitating the application of context-specific policies

ATB

Integrated, circular, and adapted approaches are needed

Circularity

Closing of carbon and nutrient cycles, protein self-sufficiency and improved manure nutrient utilization.



Integration

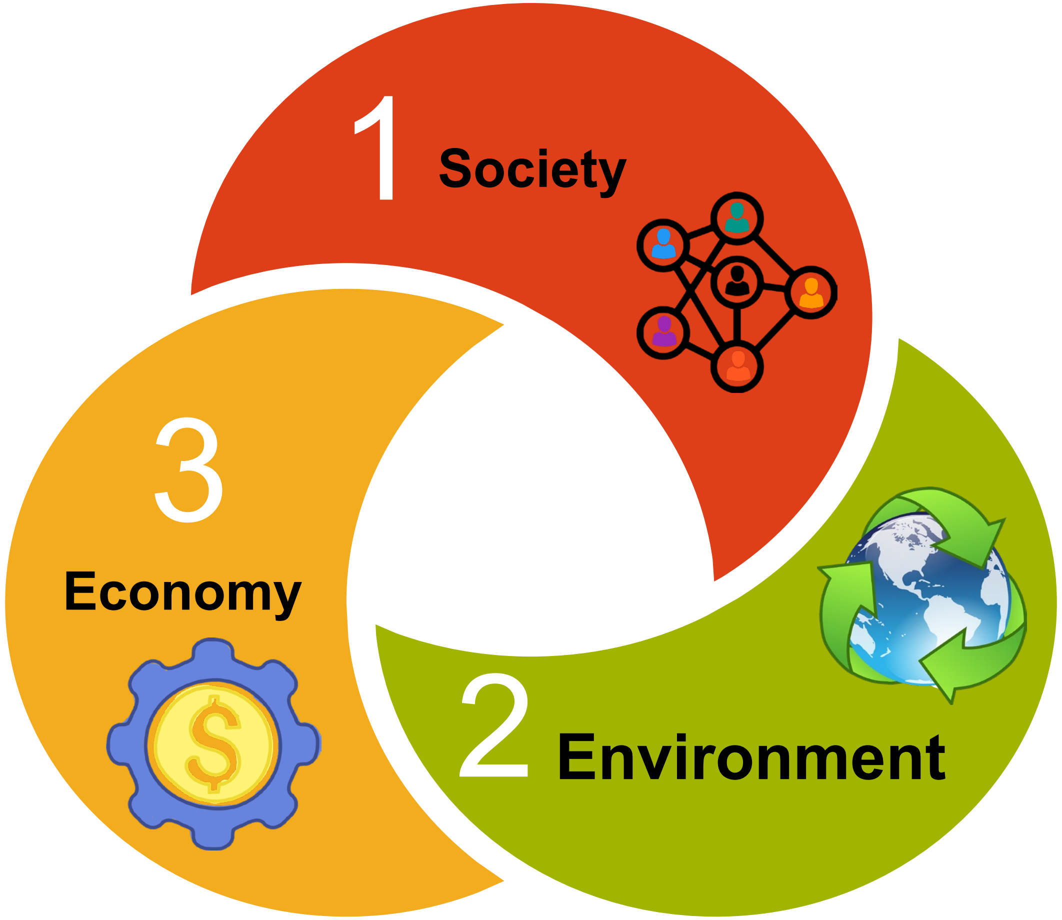
Identify trade-offs and synergies between sustainability indicators by applying multi-criteria assessment approaches.

Adaptation

Assess effects of adapted mitigation measures, facilitating the application of context-specific policies

ATB

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

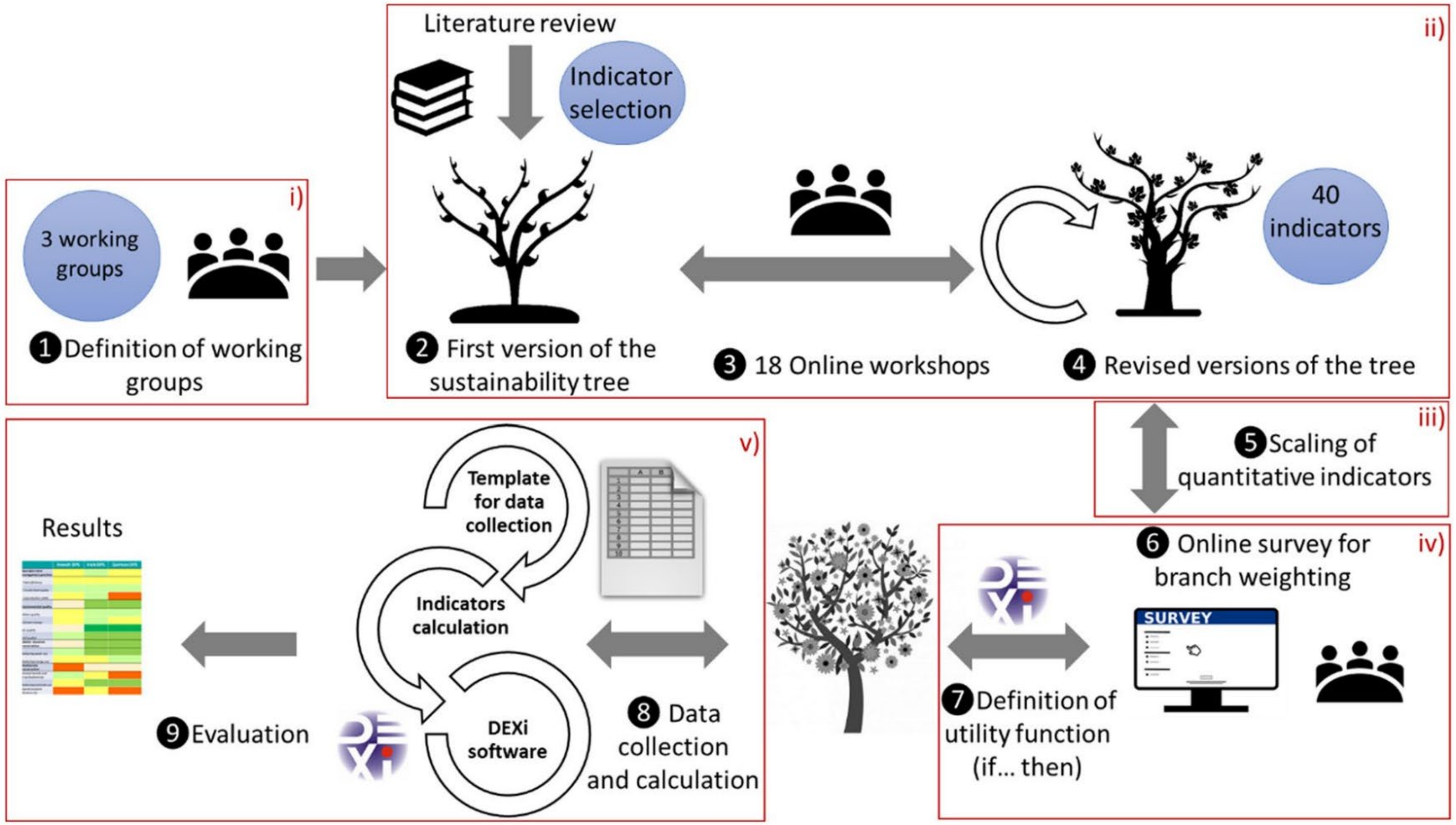


Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

DexiDairy

- ✓ Multi-attribute decision-making.
- ✓ Interactive and participative.
- ✓ Break down decision problems.
- ✓ Hierarchical decision model
- ✓ Tree-shaped structure
- ✓ Dependencies are considered

Sustainability pillars	Environment
Themes	Environmental quality
Subthemes	Contribution to climate change
Indicators	Global warming potential

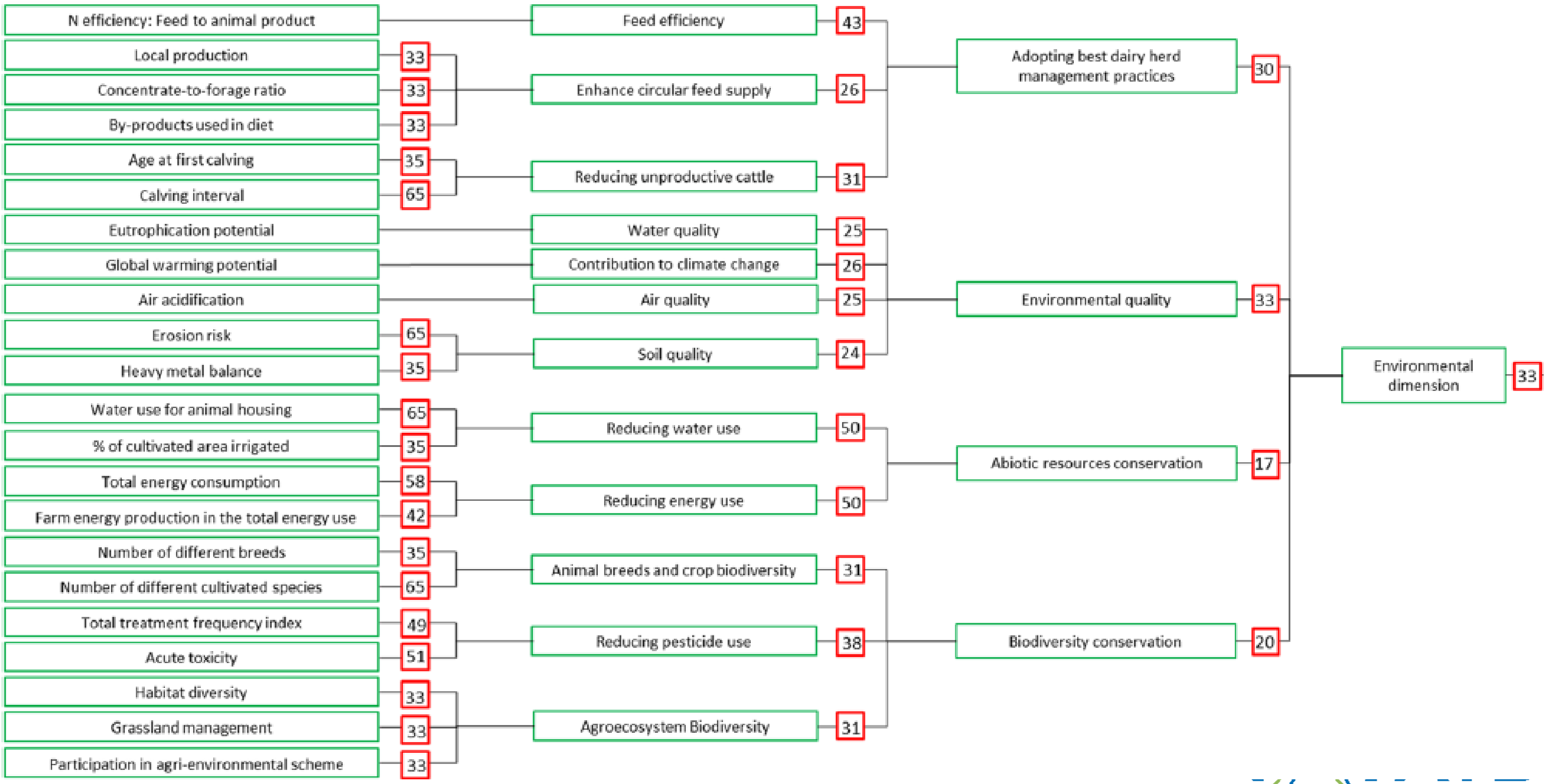


ATB

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

Indicators **Subthemes and Themes** **Pillar**

Environmental Pillar

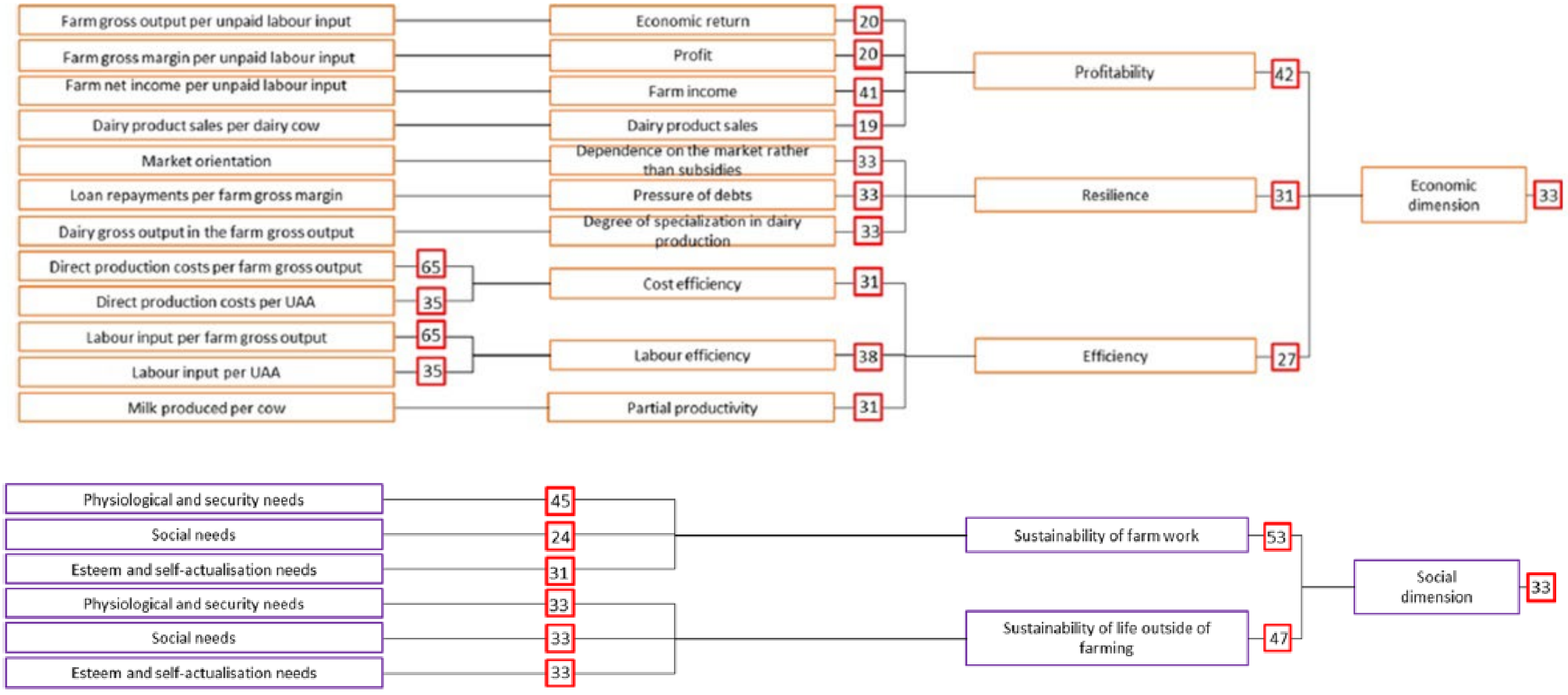


Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

Indicators | **Subthemes and Themes** | **Pillars**

Economic Pillar

Social Pillar



ATB

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

Some detailed examples….

- Environmental dimension
  - Environmental quality
    - Water quality
      - Eutrophication potential
    - Contribution to climate change
      - Global warming potential
    - Air quality
      - Air acidification
    - Soil quality
      - Erosion risk
      - Heavy metal balance

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

- Economic dimension
  - Resilience
    - Reliance on market
      - Market orientation
    - Pressure of debts
      - Loan payments per farm gross output
    - Degree of specialization
      - Dairy gross output in the total gross output

- Social dimension
  - Sustainability of farm work
    - Physiological and security needs
    - Social needs
    - Esteem and self-actualization needs

ATB

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

- ✓ Tested in 6 contrasting DPS across Europe.
- ✓ Overall sustainability scores were calculated.
- ✓ Trade-offs between sustainability attributes were identified.
- ✓ Avenues for future research were selected.

\- +

Attributes	Case Studies					
	FR_{01}	FR_{02}	DE_{01}	DE_{02}	IR_{01}	IR_{02}	NO_{01}
Environmental sustainability[1]	Medium	Medium	Medium to high	Medium	Medium to high	Medium to high	Low to medium
Environmental quality[2]	Medium	Medium	High	Medium	High	High	Very low
Water quality[3]	Medium to low	Low	Medium to high	Medium to low	Medium to high	Medium to high	Low
Eutrophication potential[3]	Medium to High	High	Medium to low	Medium to High	Medium to low	Medium to low	High
Contribution to climate change[3]	High	High	Medium to low	High	Medium to high	Medium to high	High
Global warming potential[3]	High	High	Medium to low	High	Medium to high	Medium to high	High
Air quality[2]	Medium	Medium	Very high	High	Very high	Very high	Very low
Air acidification[2]	Medium	Medium	Very low	Low	Very low	Very low	Very high
Soil quality[3]	Medium to High	High	Medium to High	High	High	High	Low to medium
Erosion risk[2]	Low	Very low	Low	Very low	Very low	Very low	Very high
Heavy metal balance[4]	Low	Low	Low	Low	Low	Low	Low

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

\- +

Attributes	Case Studies						
	FR$_{01}$	FR$_{02}$	DE$_{01}$	DE$_{02}$	IR$_{01}$	IR$_{02}$	NO$_{01}$
Social sustainability[1]	Medium	Medium	Medium	Medium to high	Medium	High	Very low
Sustainability of farm work[2]	Medium to low	Medium to high	Medium to high	Medium to high	Medium to low	High	Low
Physiological and security needs[3]	Medium	Medium	Medium	Medium	Medium	High	Low
Social needs[3]	Medium	Medium	Medium	Medium	Low	High	Medium
Esteem and self-actualisation needs[3]	Low	Medium	Medium	Medium	Medium	Medium	Low
Sustainability of life outside of farming[2]	Medium to high	Medium to low	Medium to low	Medium to high	Medium to high	Medium to high	Low
Physiological and security[3]	Medium	Medium	Medium	Medium	High	Medium	Low
Social needs[3]	Medium	Low	Medium	Medium	Medium	Medium	Low
Esteem and self-actualisation needs[3]	Medium	Medium	Low	Medium	Medium	Medium	Low

Integration: Multicriteria assessment of sustainability to reveal trade-offs and synergies

Agronomy for Sustainable Development (2023) 43:82
https://doi.org/10.1007/s13593-023-00935-3

RESEARCH ARTICLE

Check for updates

DEXi-Dairy: an ex post multicriteria tool to assess the sustainability of dairy production systems in various European regions

Aurelie Wilfart[1] · Vincent Baillet[1] · Lorraine Balaine[2] · Xabier Díaz de Otálora[3,4] · Federico Dragoni[3] · Dominika Joanna Krol[5] · Joanna Frątczak-Müller[6] · Anna Rychła[7] · Divina Gracia P. Rodriguez[8] · James Breen[9] · Vasileios Anestis[10] · Cathal Buckley[2] · Habtamu Alem[8] · Wilfried Winiwarter[7,11] · Nouraya Akkal-Corfini[1] · Barbara Amon[3,7]

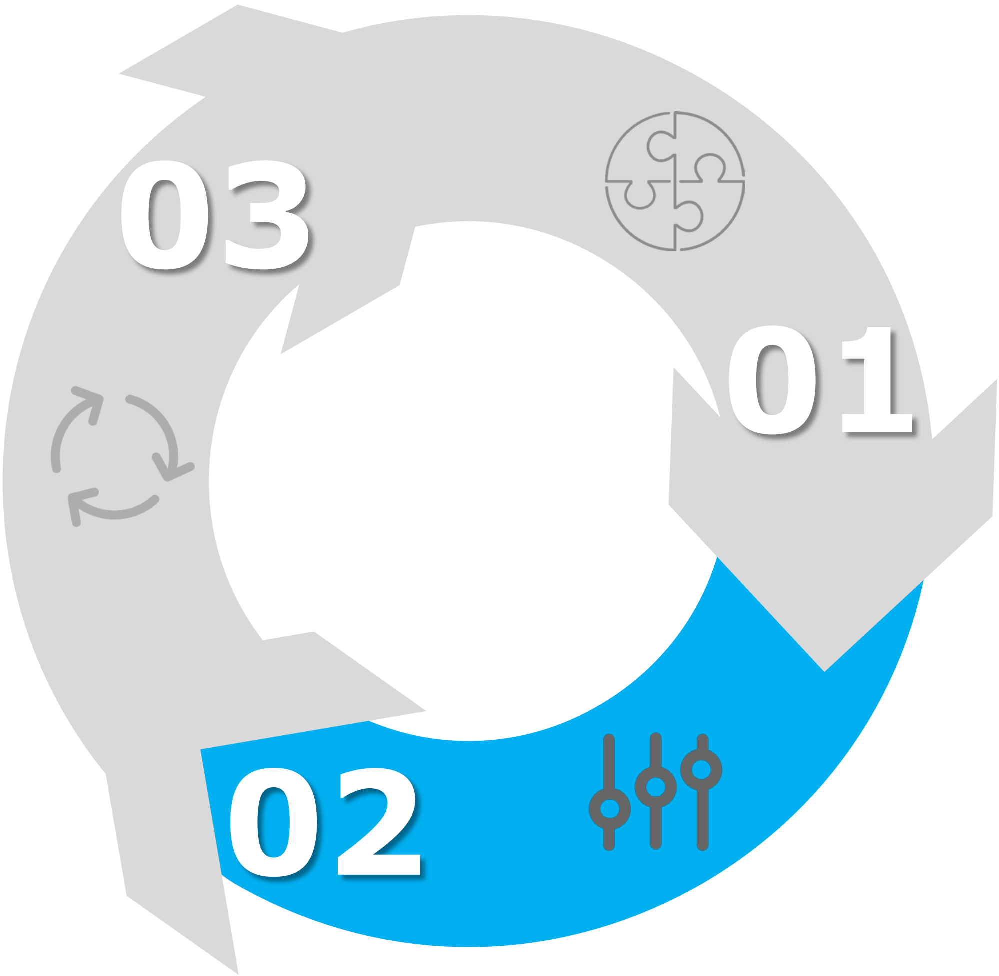
Accepted: 17 November 2023 / Published online: 14 December 2023

ATB

Integrated, circular and adapted approaches are needed

Circularity

Closing of carbon and nutrient cycles, protein self-sufficiency and improved manure nutrient utilization.



Integration

Identify trade-offs and synergies between sustainability indicators by applying multi-criteria assessment approaches.

Adaptation

Assess effects of adapted mitigation measures, facilitating the application of context-specific policies

Adaptation: Context-specific mitigation measures to reduce emissions

- ✓ System and whole-farm perspective.
- ✓ Understanding of trade-offs and synergies in emission mitigation.
- ✓ Implement context-specific and adapted strategies to the diversity of existing DPS

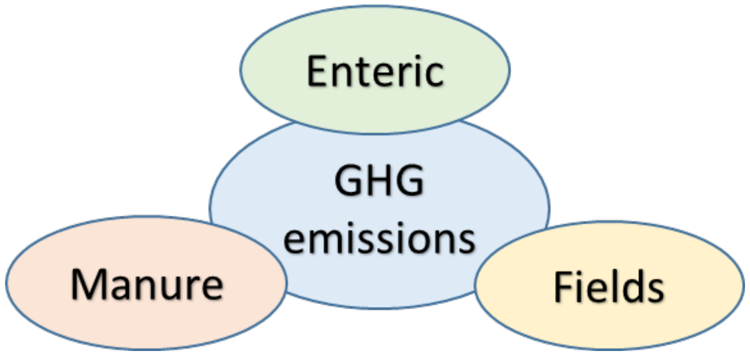
Housing systems

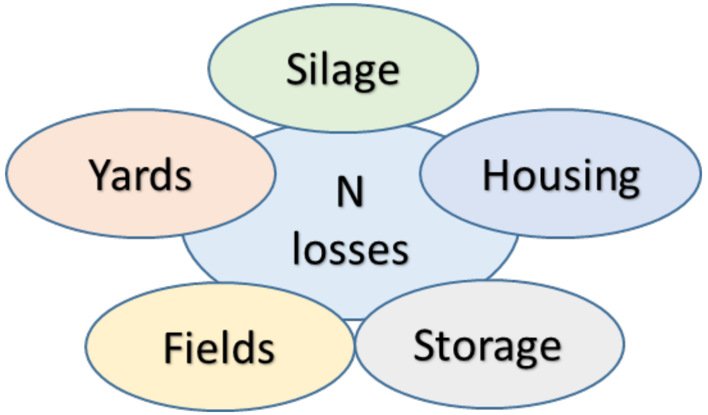
Manure handling and fertilization

Diets

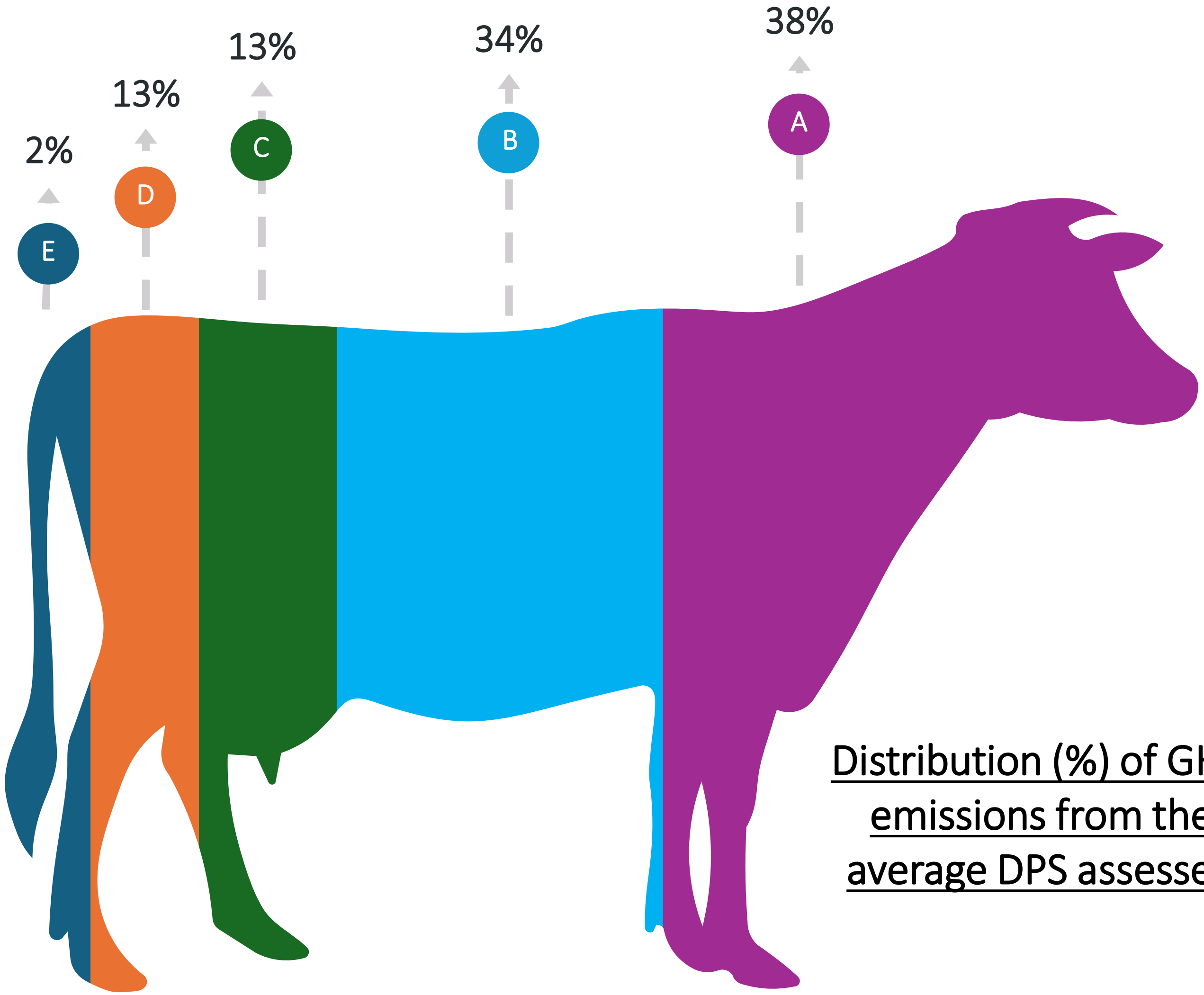
Adaptation: Context-specific mitigation measures to reduce emissions

- ✓ Whole-farm model (Del Prado et al., 2011) able to estimate GHG emissions (CH_4, N_2O and CO_2) and N losses (NO_3^-, NH_3, N_2O and NO_X) from dairy production systems.
- ✓ System-based approach simulating nutrient fluxes and loops between farm components (animal, fields, manure management chain, etc.).
- ✓ Up-to-date EF factors and approaches (i.e., EMEP 2019, IPCC 2019 refined Guidelines).
- ✓ Contrasting DPS across Europe were selected.





Adaptation: Context-specific mitigation measures to reduce emissions



Distribution (%) of GHG emissions from the average DPS assessed

A
Enteric CH_4
CH_4 emissions from enteric fermentation

B
Other CO_2 sources
CO_2 emissions from feed purchases, fertiliser purchased and energy use

C
Manure management CH_4
CH_4 emissions from manure management and storage

D
Field N_2O
Direct and Indirect emissions of N_2O from field management (i.e., grazing, fertiliser application, etc.)

E
Manure management N_2O
Direct and Indirect emissions of N_2O from manure management and storage

Adaptation: Context-specific mitigation measures to reduce emissions

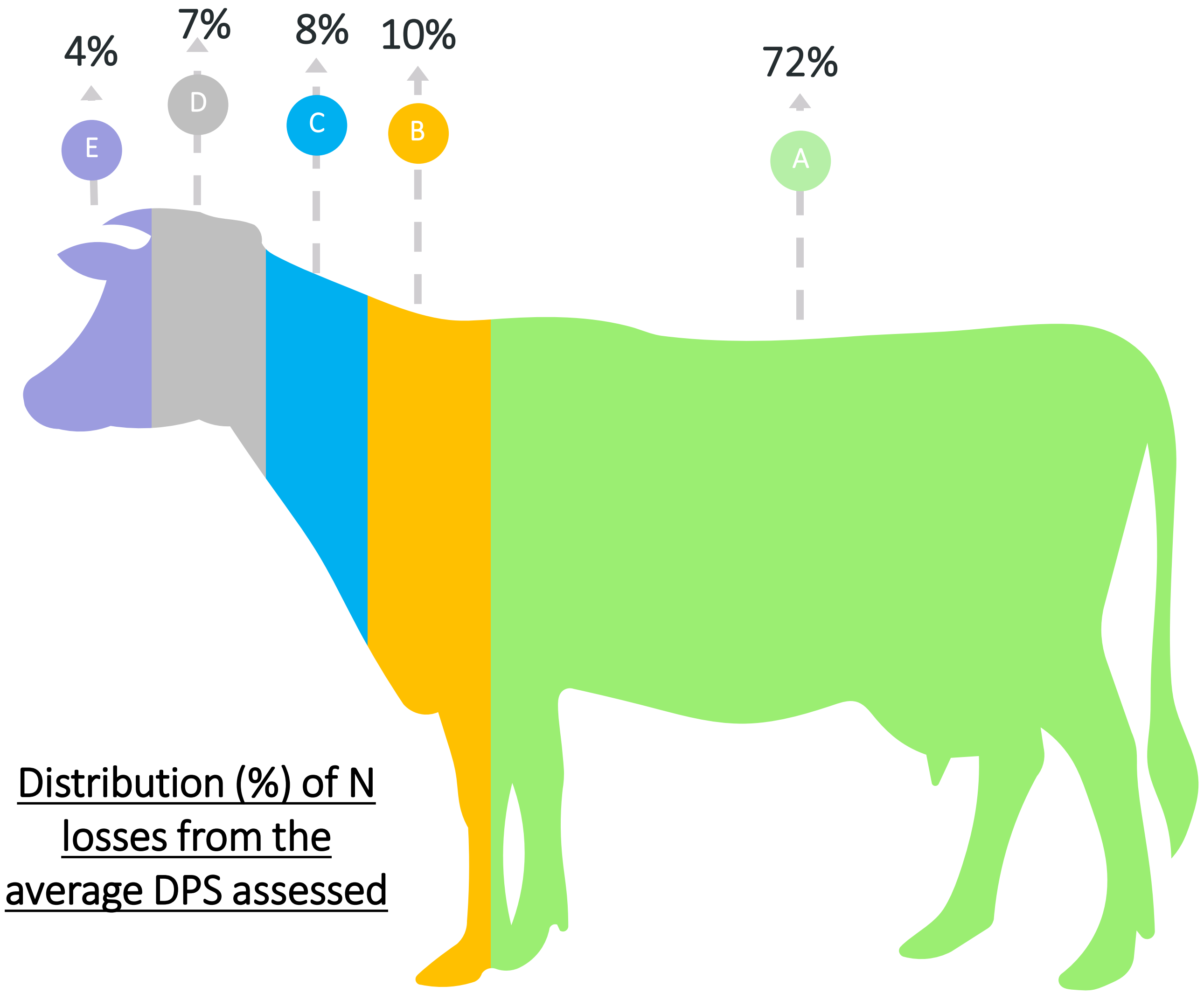
A
Fields
N losses from field management (i.e., grazing, manure application, mineral fertilisation, etc.)

B
Housing
N losses from animal housing

C
Storage
N losses from the storage from solid manure or slurry

D
Silage
N losses derived from silage making

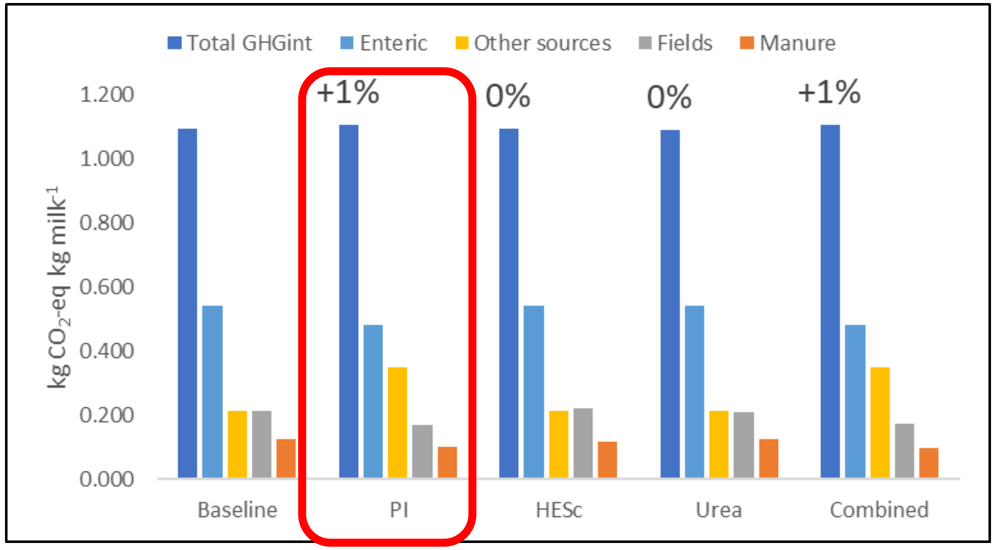
E
Yards
N losses from the walking yards of the animals



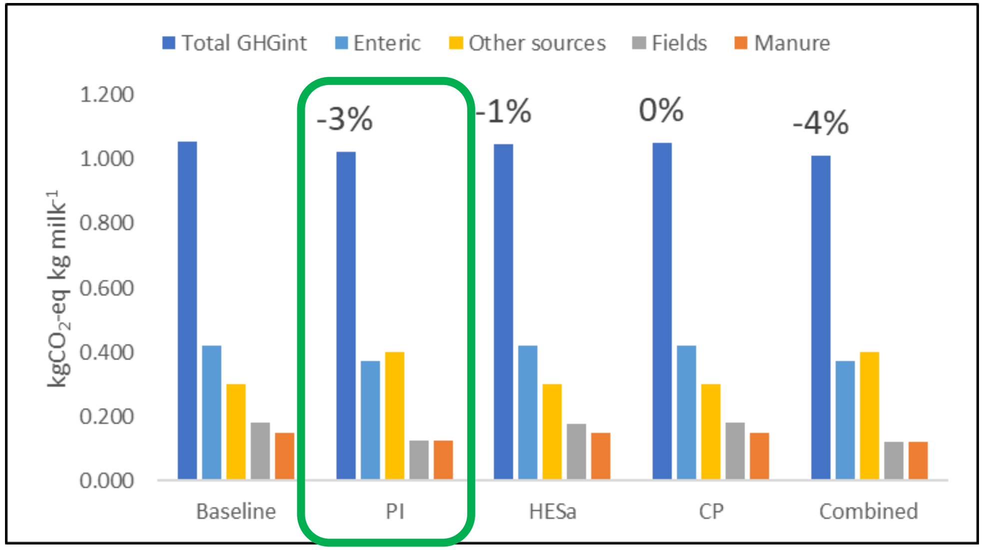
Distribution (%) of N losses from the average DPS assessed

Adaptation: Context-specific mitigation measures to reduce emissions

Atlantic European Conventional Semi-extensive DPS



Eastern European Conventional Semi-extensive DPS



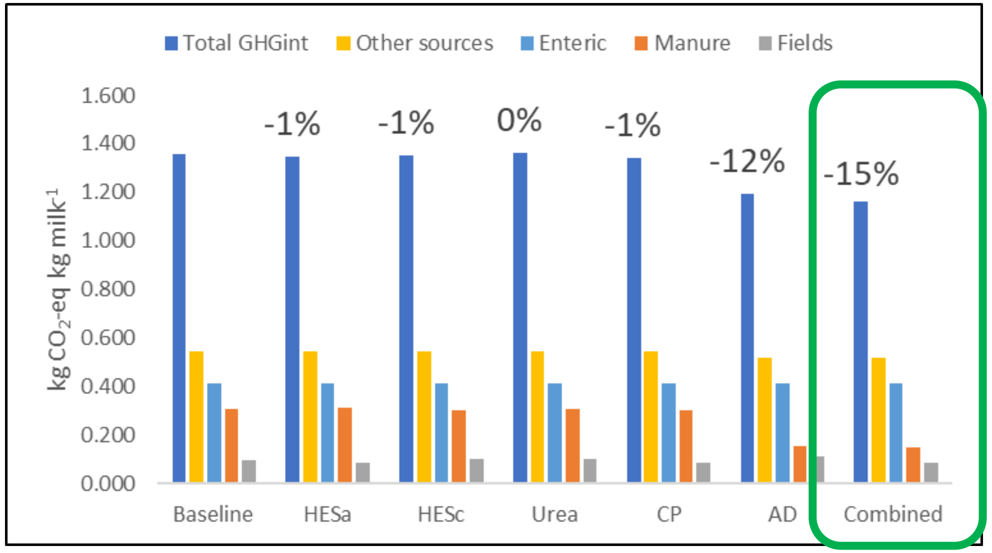
PI: Lower F:C ratio to 60:40 and increase in milk production by 15%

The same mitigation option applied in different DPS could present **contrasting effects**

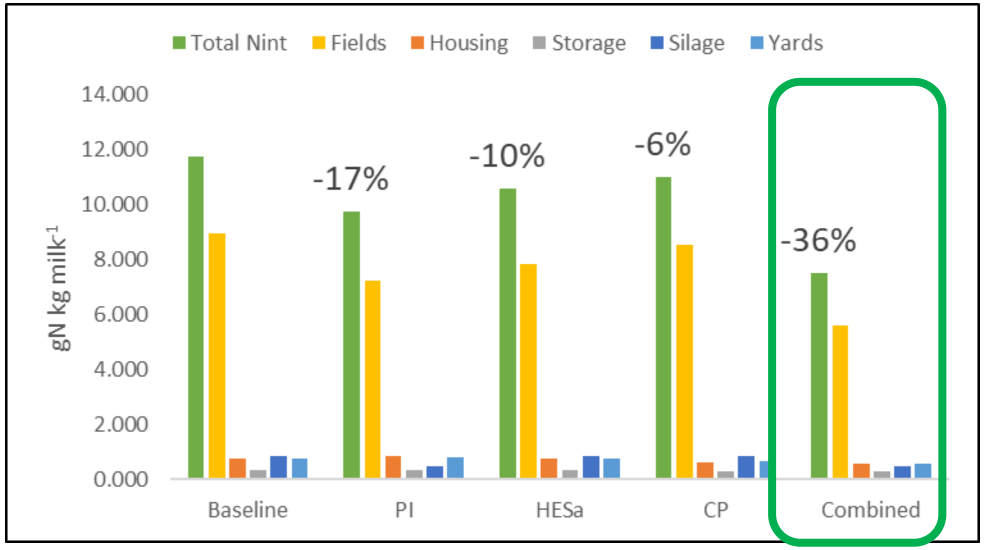
ATB

Adaptation: Context-specific mitigation measures to reduce emissions

Mediterranean Conventional Intensive DPS



Eastern European Conventional Semi-extensive DPS



Combined: Combined application of multiple adapted mitigation measures

Adapted and combined application of context-specific mitigation measures derive in **positive synergies**

Adaptation: Context-specific mitigation measures to reduce emissions

Agricultural Systems 216 (2024) 103902

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

ELSEVIER

Influence of farm diversity on nitrogen and greenhouse gas emission sources from key European dairy cattle systems: A step towards emission mitigation and nutrient circularity

X. Díaz de Otálora [a,b,c,*], B. Amon [a,d], L. Balaine [e], F. Dragoni [a], F. Estellés [c], G. Ragaglini [f], M. Kieronczyk [d,g], G.H.M. Jørgensen [h], A. del Prado [b,i]

[a] Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), 14469 Potsdam, Germany
[b] Basque Centre for Climate Change (BC3), 48940 Leioa, Spain
[c] Institute of Animal Science and Technology (ICTA), Universitat Politècnica de València, 46022 Valencia, Spain
[d] Faculty of Civil Engineering, Architecture and Environmental Engineering, University of Zielona Góra, 65-417 Zielona Góra, Poland
[e] Teagasc, Agricultural Economics and Farm Surveys Department, Mellows Campus, H65 R718 Athenry, Co. Galway, Ireland
[f] Department of Agricultural and Environmental Sciences, University of Milan, 20133 Milan, Italy
[g] Institute of Technology and Life Sciences – National Research Institute, Falenty, 3 Hrabska Ave, 05-090 Raszyn, Poland
[h] NIBIO, Norwegian Institute of Bioeconomy Research, P.O. Box 34, N-8860 Tjøtta, Norway
[i] Basque Foundation for Science (Ikerbasque), 48940 Leioa, Spain

Agronomy for Sustainable Development (2024) 44:4
https://doi.org/10.1007/s13593-023-00940-6

RESEARCH ARTICLE

Modelling the effect of context-specific greenhouse gas and nitrogen emission mitigation options in key European dairy farming systems

Xabier Díaz de Otálora [1,2,3] · Agustín del Prado [2,4] · Federico Dragoni [1] · Lorraine Balaine [5] · Guillermo Pardo [2] · Wilfried Winiwarter [6,7] · Anna Sandrucci [8] · Giorgio Ragaglini [8] · Tina Kabelitz [1] · Marek Kieronczyk [7,9] · Grete Jørgensen [10] · Fernando Estellés [3] · Barbara Amon [1,7]

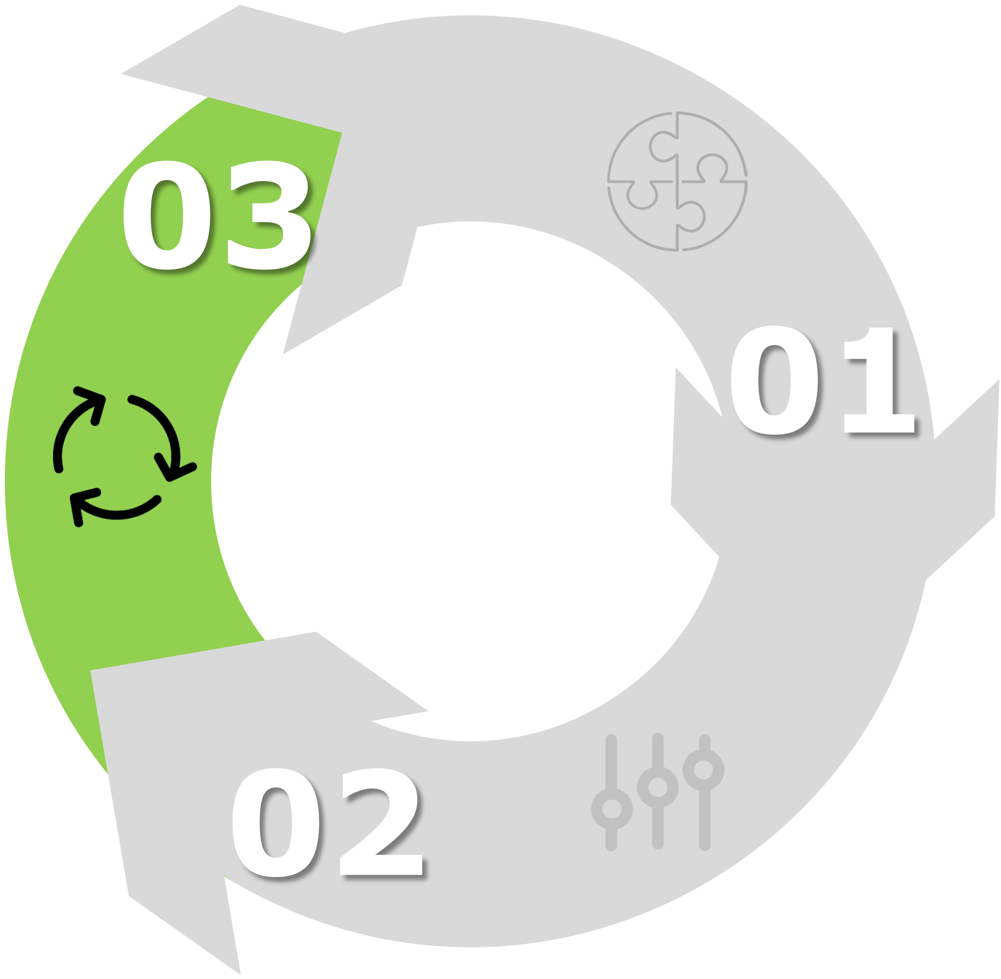
Accepted: 15 December 2023 / Published online: 10 January 2024

ATB

Integrated, circular and adapted approaches are needed

Circularity

Closing of carbon and nutrient cycles, protein self-sufficiency and improved manure nutrient utilization.



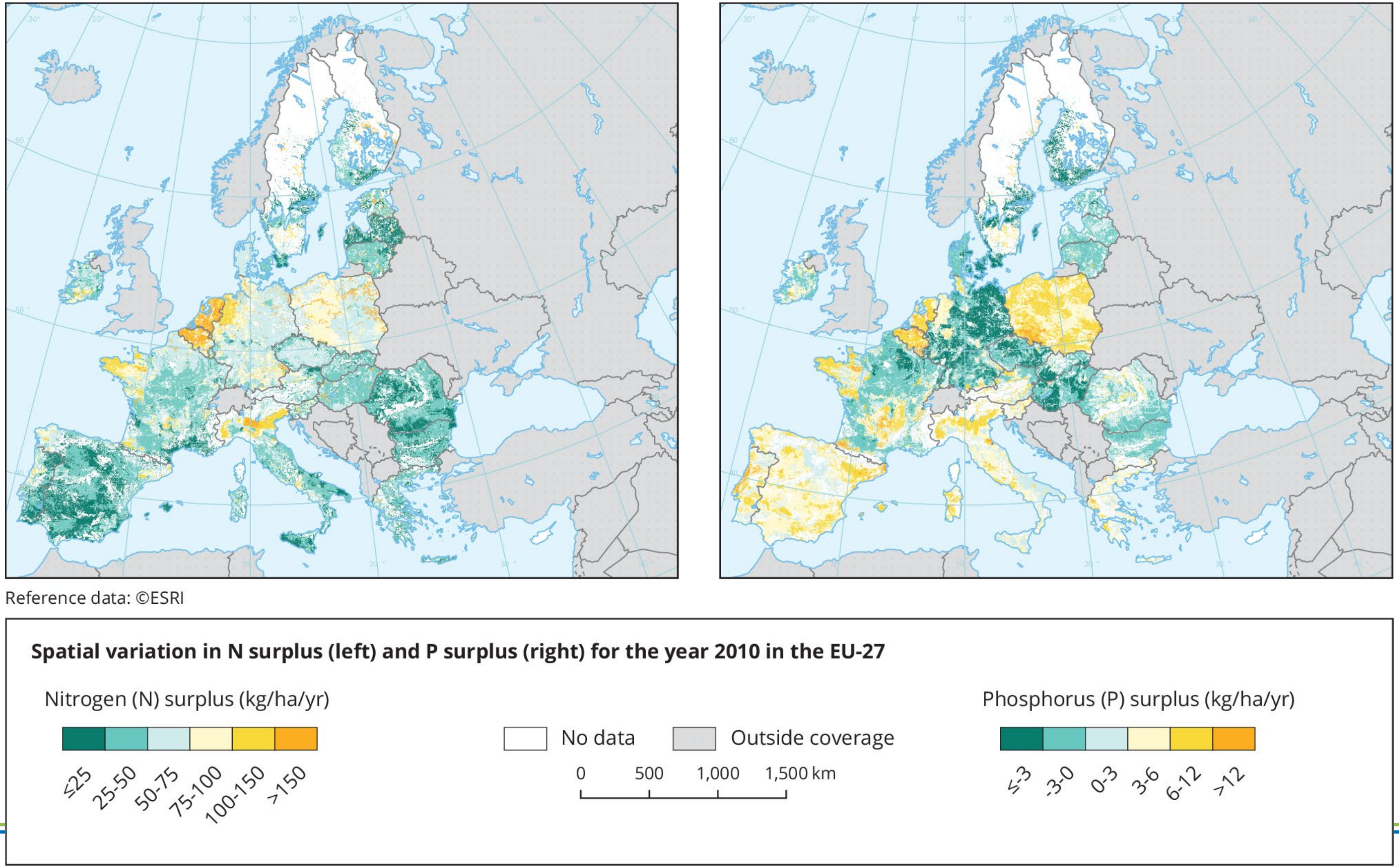
Integration

Identify trade-offs and synergies between sustainability indicators by applying multi-criteria assessment approaches.

Adaptation

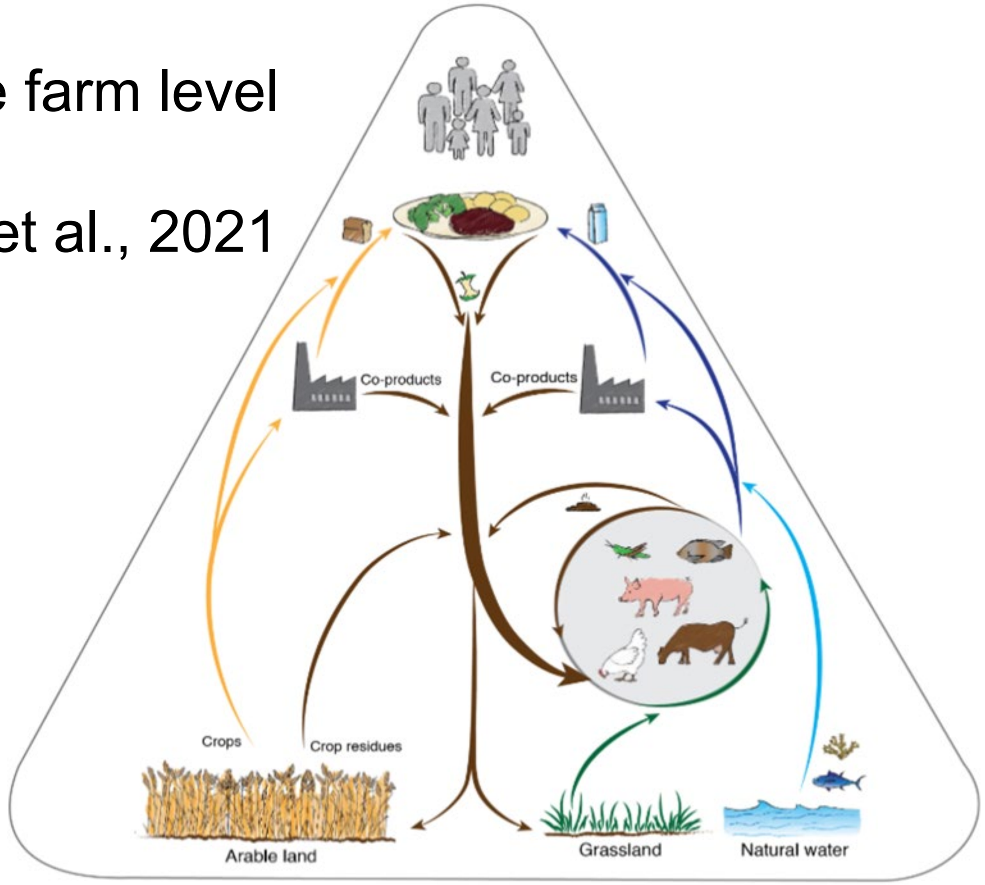
Assess effects of adapted mitigation measures, facilitating the application of context-specific policies

Circularity: closing nutrient cycles and optimizing dairy production



Circularity: closing nutrient cycles and optimizing dairy production

- ✓ Coupling and integration of dairy and crop systems at the farm level
- ✓ Approach based on the 5 principles proposed by Muscat et al., 2021
  - ✓ Safeguarding
  - ✓ Avoiding
  - ✓ Prioritizing
  - ✓ Recycling and reusing
  - ✓ Entropy
- ✓ Ad-hoc indicators are needed to tackle circularity



Circularity: closing nutrient cycles and optimizing dairy production

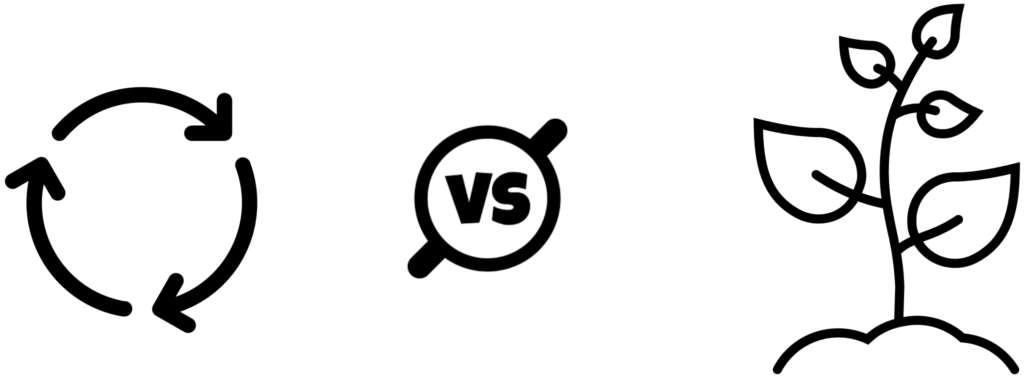
DairyMix Circularity approach

Safeguarding		Avoiding		Recycling and reusing						Prioritizing		Entropy
Nutrient loss	Nutrient efficiency	Milk wasted	Water loss	Nutrient self-sufficiency	Manure recycling	Crop residue returning	Nutrient origin	Nutrient cycling	Local production	Edible protein conversion	By-product use	Renewable energy

ATB

Circularity: closing nutrient cycles and optimizing dairy production

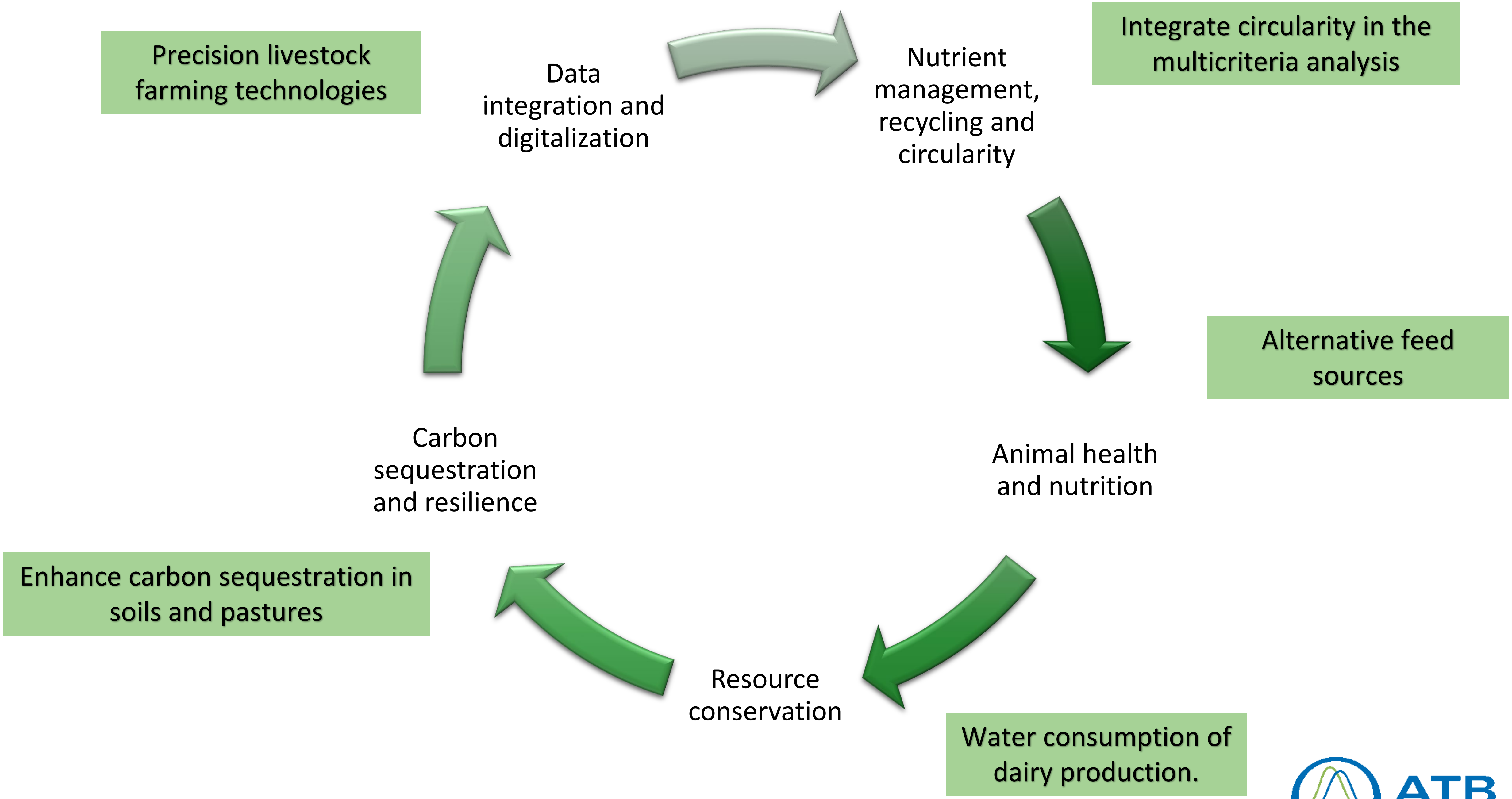
The circularity dilemma



- ✓ Is a sustainable farm circular?
    - ✓ Benchmarking of dairy farms according to sustainability and circularity indicators.
    - ✓ Identification of trade-offs between sustainability and circularity.

Integrate circularity in the sustainability assessments

What is next?


Precision livestock farming technologies
Data integration and digitalization
Nutrient management, recycling and circularity
Integrate circularity in the multicriteria analysis
Alternative feed sources
Animal health and nutrition
Resource conservation
Water consumption of dairy production.
Carbon sequestration and resilience
Enhance carbon sequestration in soils and pastures

ATB

Acknowledgements

DairyMix

MILKEY

The project has received funding from national research funding parties in Germany, Poland, Greece, Belgium, Ireland, France and Norway, in the framework of the 2018 Joint Call of three ERA-NET projects (i.e. FACCE ERA-GAS, ERA-NET SusAn and ICT-AGRI 2) on novel technologies, solutions and systems to reduce greenhouse gas emissions in animal production systems.

Gefördert durch:

Bundesministerium für Ernährung und Landwirtschaft

aufgrund eines Beschlusses des Deutschen Bundestages

ATB Leibniz-Institut für Agrartechnik und Bioökonomie

Teagasc Agriculture and Food Development Authority

University of Zielona Góra

UCD Dublin

Poznań University of Life Sciences

INRAE

Institut de l'Elevage idele

ILVO

NIBIO Norwegian Institute of Bioeconomy Research

ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
Agricultural University of Athens

INTA

Università degli Studi di Milano

Ruralis

Towards a more sustainable dairy cattle sector by optimizing resources, adapting strategies, and promoting circularity