75th EAAP 2024
Firenze, Italy, 1-5, September 2024

Environmental impact drivers of sheep milk in mixed farms: insights from a combined LCA and multivariate statistical analysis approach

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Aims and LCA parameters

Estimation of the environmental impact of sheep milk production in the southern Tuscany

Functional Unit: 1 kg of FPCM (6.5% fat; 5.8% protein)

System boundary: *"from cradle to farm gate"*

Economic allocation for lamb meat production

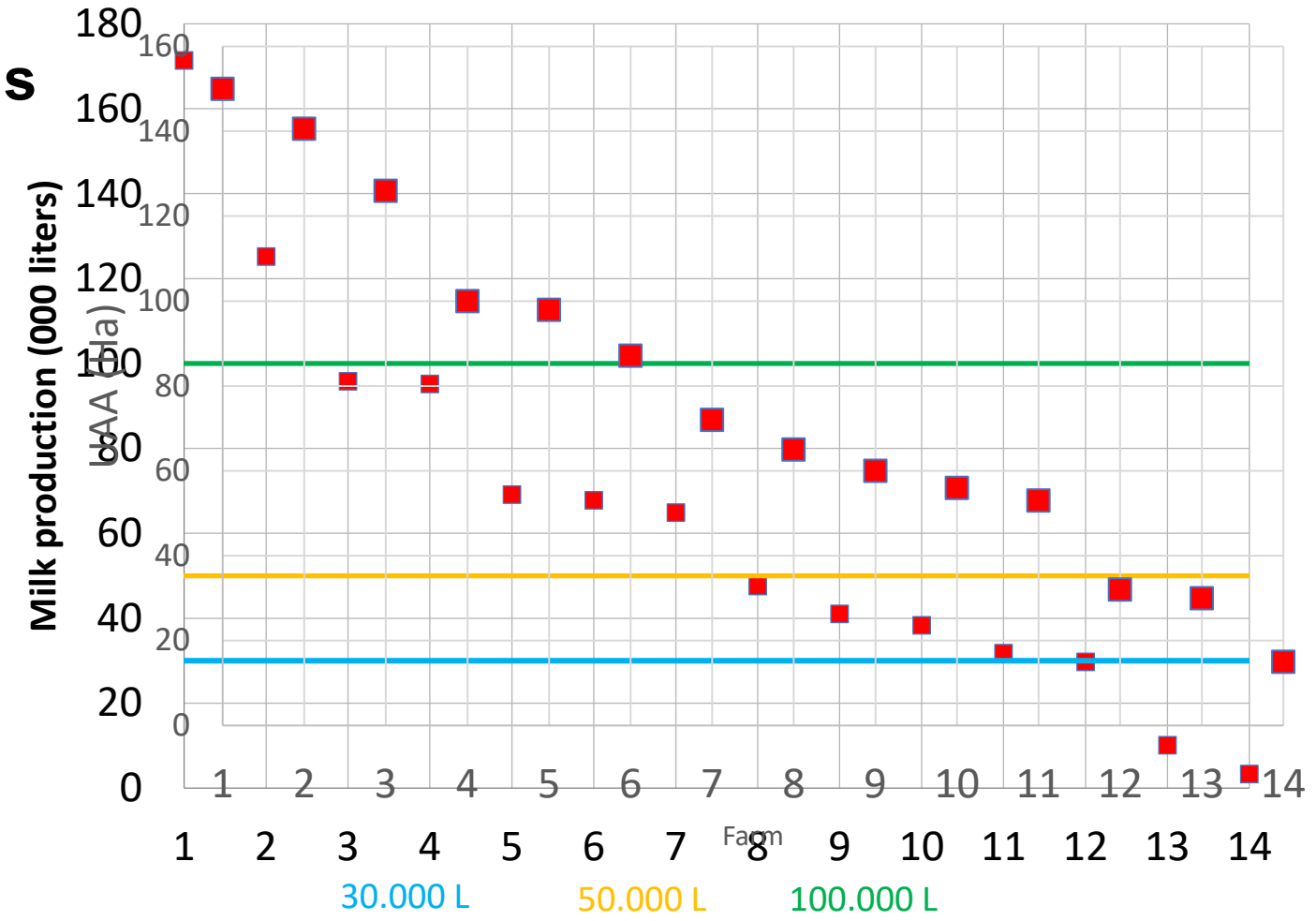
EN **15804 impact analysis**

Farm Characteristics

We selected a sample of **14 farms** out of approximately 200

The selection criteria included:

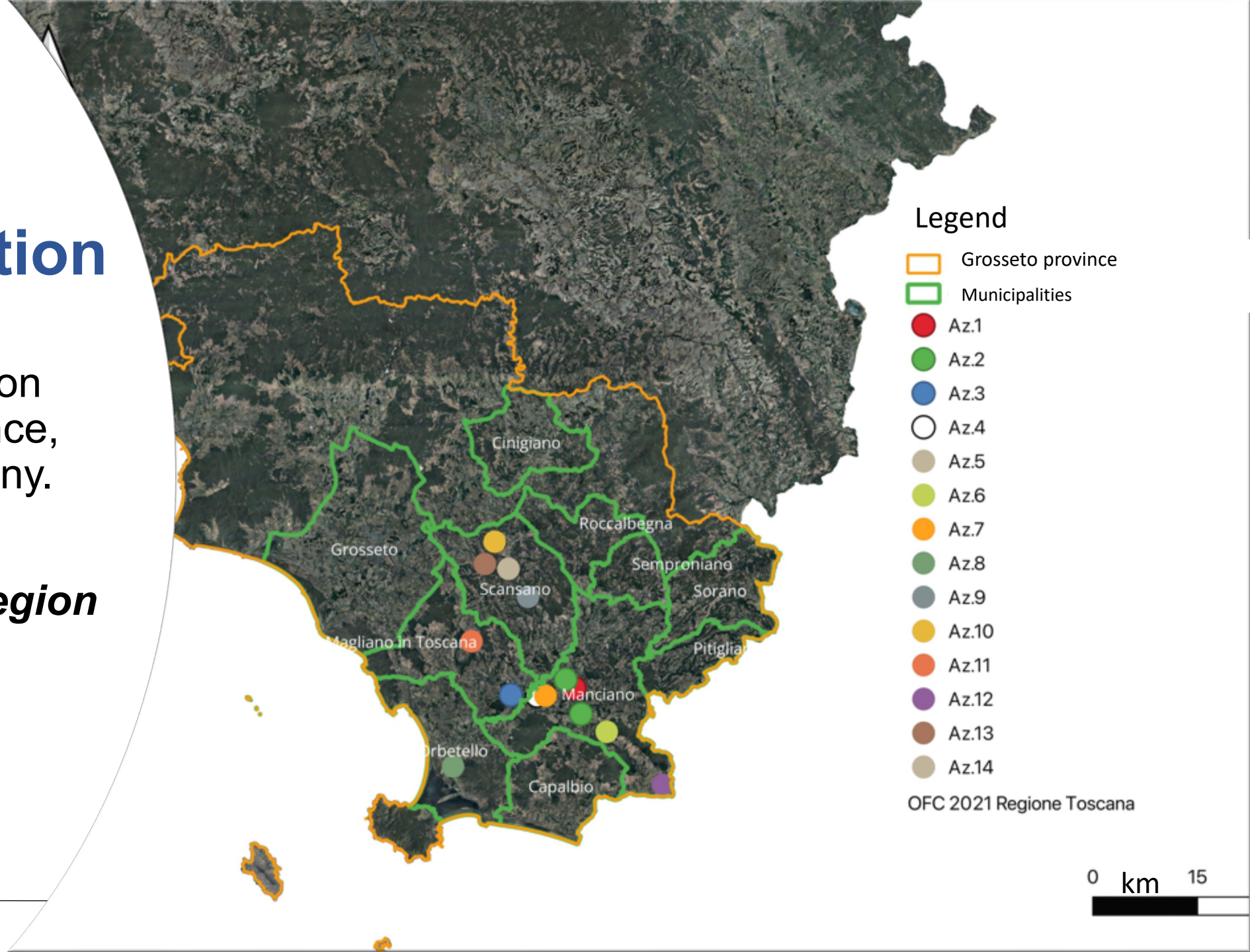
- **Milk production**
- **Farm size**
- Distance from the coast
- Altitude of the farm center



Farms location

Maremma region
Grosseto province,
southern Tuscany.

Mediterranean region



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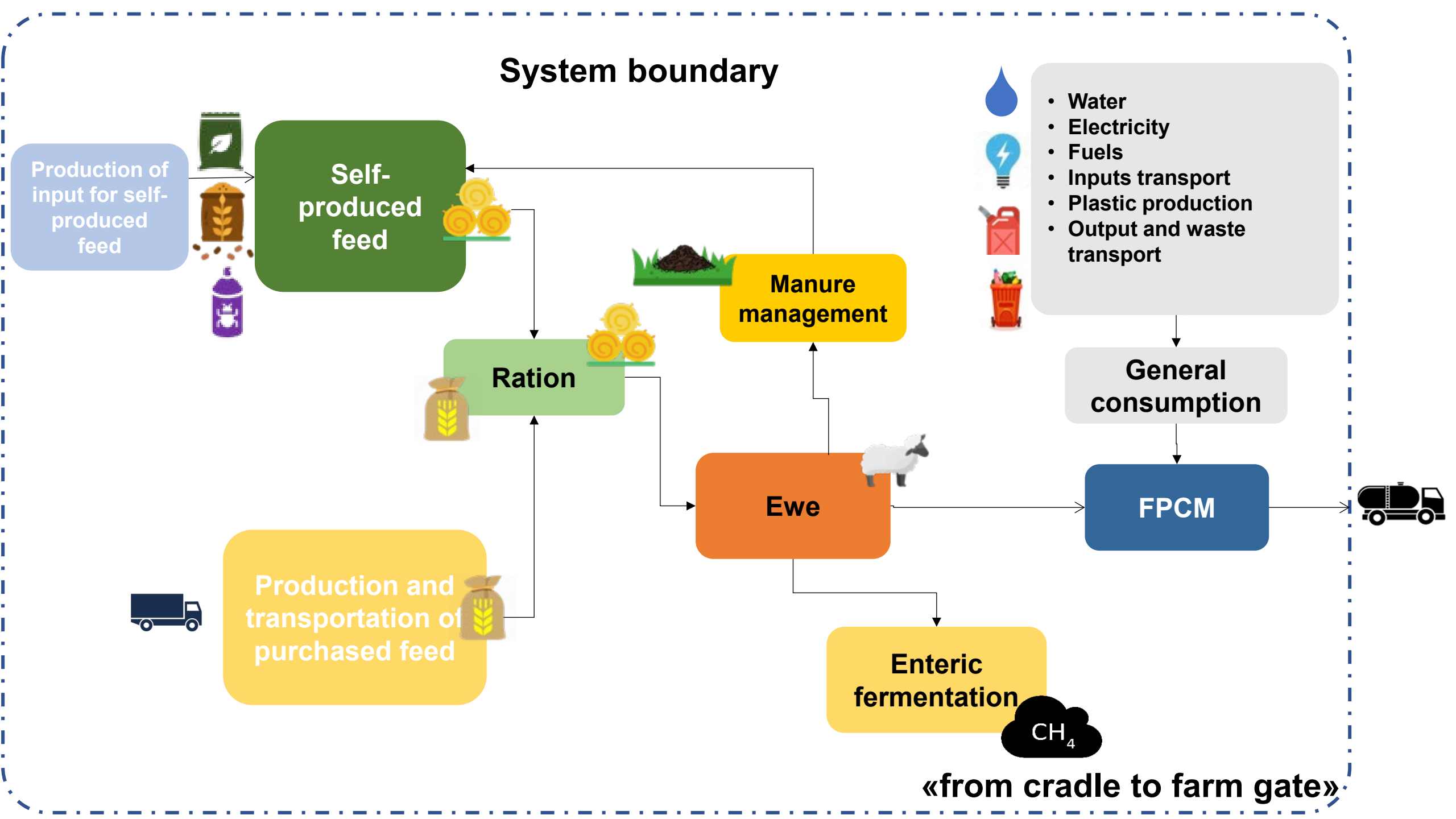
System boundary



«from cradle to farm gate»

CH_4 and N_2O estimation

Methane from **ruminal fermentation**: Equations from CNCPS model

(Van Amburgh et al., 2015)

Methane and **N_2O** from **manure management**: **IPCC** 2019 Tier 2

GHGs emissions from ruminants

EN 15804 calculation (GWP 100Y)

1kg *Methane* = 36.8 kg of CO_2 eq

1 kg *Dinitrogen monoxide* = 298 kg of CO_2 eq

Methane from enteric fermentation

- **Weekly** ewe ration from farm technician

- **Nutritional characteristics** of feed
  - We have analyzed nutritional values *(NDF, ADF, ADL, CP, Starch, WSC, …)* of:
    - *Forages*: hay and pasture
    - *Concentrate*: cereal and legume grains
    - *Commercial feed*

- 5 different animal groups
  - **Lactating** ewes in **spring** period
  - **Lactating** ewes in **winter** period
  - Dry ewes
  - **Non - lactating** ewes
  - **Rams**

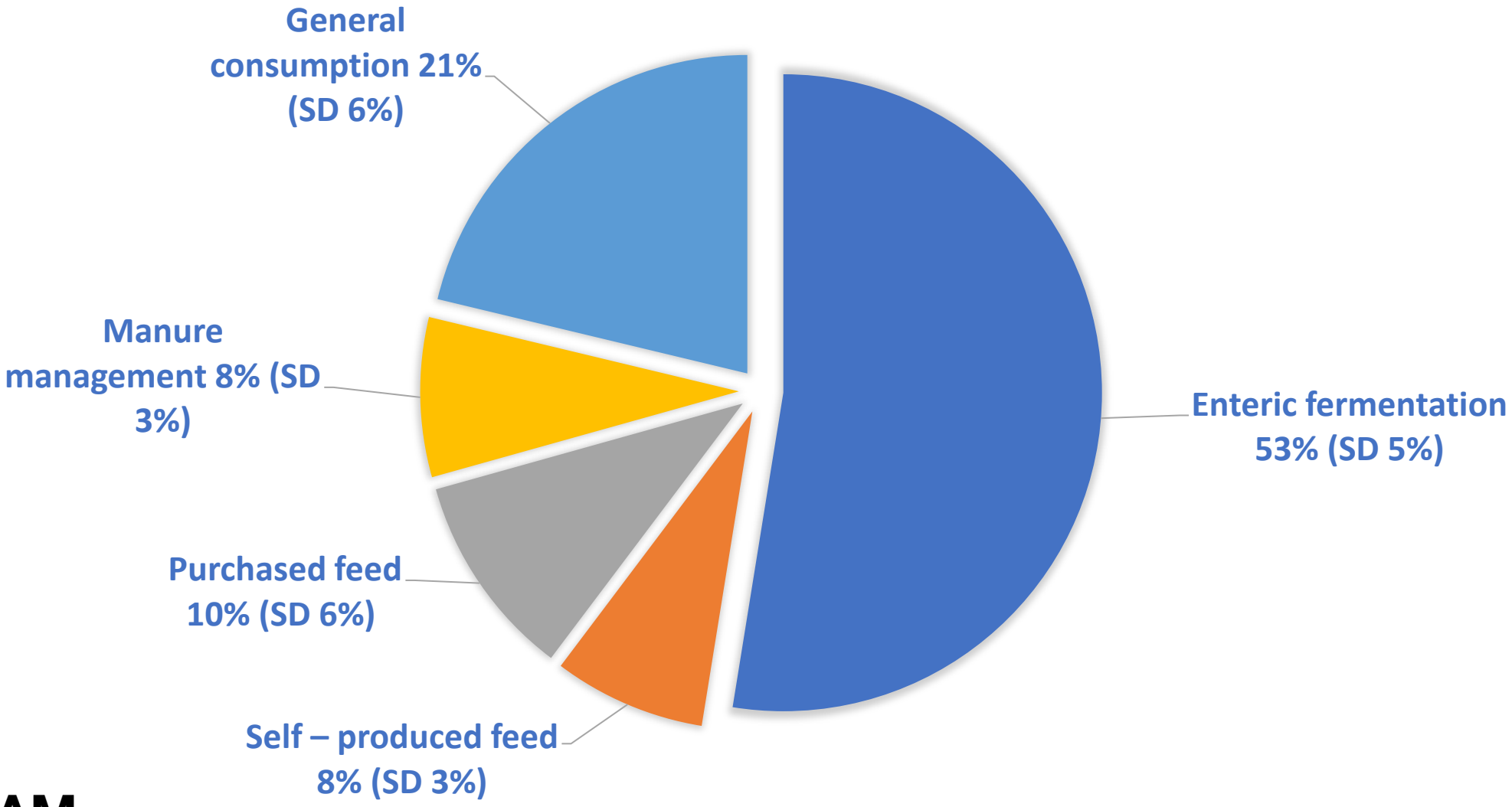
LCA software and databases

Processing of data collected through modeling in the **OpenLCA** software with the help of parallel processes extrapolated from the **Agribalyse** and **Ecoinvent** databases.

Results

	Impact category	Value	U.M.	SD
1	Global warming potential - Biogenic	2,254	kg CO_2 eq	0.83
2	Global warming potential - Fossil	1,615	kg CO_2 eq	0.54
3	Global warming potential - LULUC	0,089	kg CO_2 eq	0.092
4	**Global warming potential - Total**	**3,959**	**kg CO_2 eq**	**1.28**
5	Acidification	0,039	mol H^+ eq	0.08
6	Eutrophication fresh water	0,001	kg P eq	0.0009
7	Eutrophication marine	0,019	kg N eq	0.02
8	Eutrophication terrestrial	0,164	mol N eq	0.17
9	Photochemical ozone formation	0,008	kg NMVOC eq	0.011

Global Warming Potential: Total



Statistical analysis

1. Hierarchical Cluster Analysis (HCA)

Purpose: to group farms into clusters based on their characteristics.

2. One-Way ANOVA

Model: $Y_j = \mu + [\![cluster]\!]_i + \varepsilon_{ij}$

Y_j = Dependent variable

μ = Mean

Cluster = Fixed effect of the i^{th} cluster (2 levels)

ε_{ij} = Random error

3. Principal Component Analysis (PCA)

Purpose: to individuate variables associated to the environmental impact descriptors

HCA results

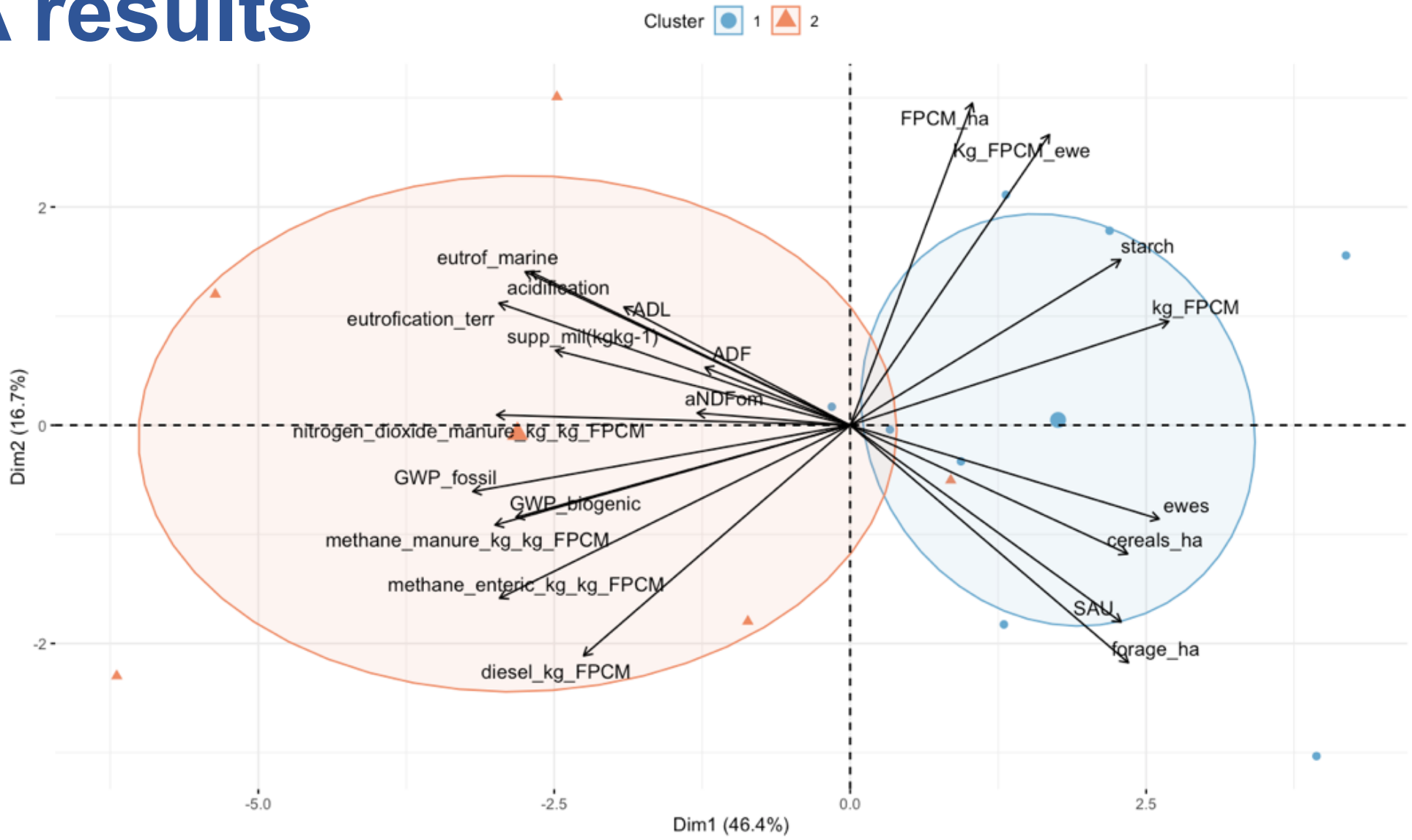
Variables	Farm cluster 1 (n=8)	Farm cluster 2 (n=5)
Ewes per farm	453	258
Total heads per farm	527	277
UAA (ha)	102.45	46.60
Forage (ha)	71.94	35.34
Cereals (ha)	14.54	3.42
Milk production (kg FPCM)	92,026	32,419
Milk yield (kg FPCM per ewes)	212.24	128.5

ANOVA Results

Variables	Farm cluster 1 (n=8)	Farm cluster 2 (n=5)	SE	P value
GWP_biogenic (kg CO_2 eq)	2.16	3.04	0.726	**0.056***
GWP_fossil (kg CO_2 eq)	1.58	2.17	0.0498	0.254
GWP_total (kg CO_2 eq)	3.84	5.25	0.0475	0.475
Methane enteric (kg kg $FPCM^{-1}$)	0.07	0.11	0.030	**0.026***
Methane manure (kg kg $FPCM^{-1}$)	0.004	0.007	0.002	**0.001****
Nitrogen dioxide (kg kg $FPCM^{-1}$)	0.0007	0.001	0.0002	**0.039***

LS mean values from ANOVA applied to farm clusters obtained by HCA analysis. SE means standard error of the mean.

PCA results


Cluster 1 2
FPCM_ha
Kg_FPCM_ewe
starch
kg_FPCM
ewes
cereals_ha
SAU
forage_ha
eutrof_marine
acidification
eutrofication_terr
ADL
supp_mil(kgkg-1)
ADF
aNDFom
nitrogen_dioxide_manure_kg_kg_FPCM
GWP_fossil
GWP_biogenic
methane_manure_kg_kg_FPCM
methane_enteric_kg_kg_FPCM
diesel_kg_FPCM
Dim2 (16.7%)
2
0
-2
-5.0
-2.5
0.0
2.5
Dim1 (46.4%)

Conclusions

Farm Size & Environmental Efficiency:

Larger farm size (up to 150 ha) reduces environmental impact per litre of F
by the increasing of milk yield per ewe and feeding self-sufficiency

Diet & Environmental Impact:

Feeding regimens richer in starch were associated with a lower environmental impact and purchasing concentrates increases environmental impact and decreases self-sufficiency

Strategies for Impact Reduction:

Improve forage nutritive value, especially for preserved forage

Enhance self-production of starchy concentrates by cereal cultivation (e.g. winter cereals)

Thank you for your attention

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