Multi-indicators approach for the evaluation of sustainability of livestock farming in mountainous areas

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Introduction – dairy sector in Italy

Variable	Mountain	Hill	Lowland	Total
Cattle farms (No)	45,021	49,631	29,558	124,210
Cattle heads (No)	1,018,064	1,587,470	2,987,166	5,592,700
Dairy cattle farms	22,129	14,911	13,297	50,337
Dairy cows (No)	307,596	376,722	915,124	1,599,442
Cows/farm	13.9	25.2	68.8	31.8
Average milk production (tons/farm)	96	165	479	270

Istat, 2010

Multifunctionality of mountain livestock systems

Traditional mountain livestock systems are largely based on the use of meadows and pastures, providing several market and non-market services:

- Dairy products (and meat)
- Conservation of local breeds
- Biodiversity and landscape maintenance
- Risk prevention
- Recreation and ecotourism
- Cultural heritage

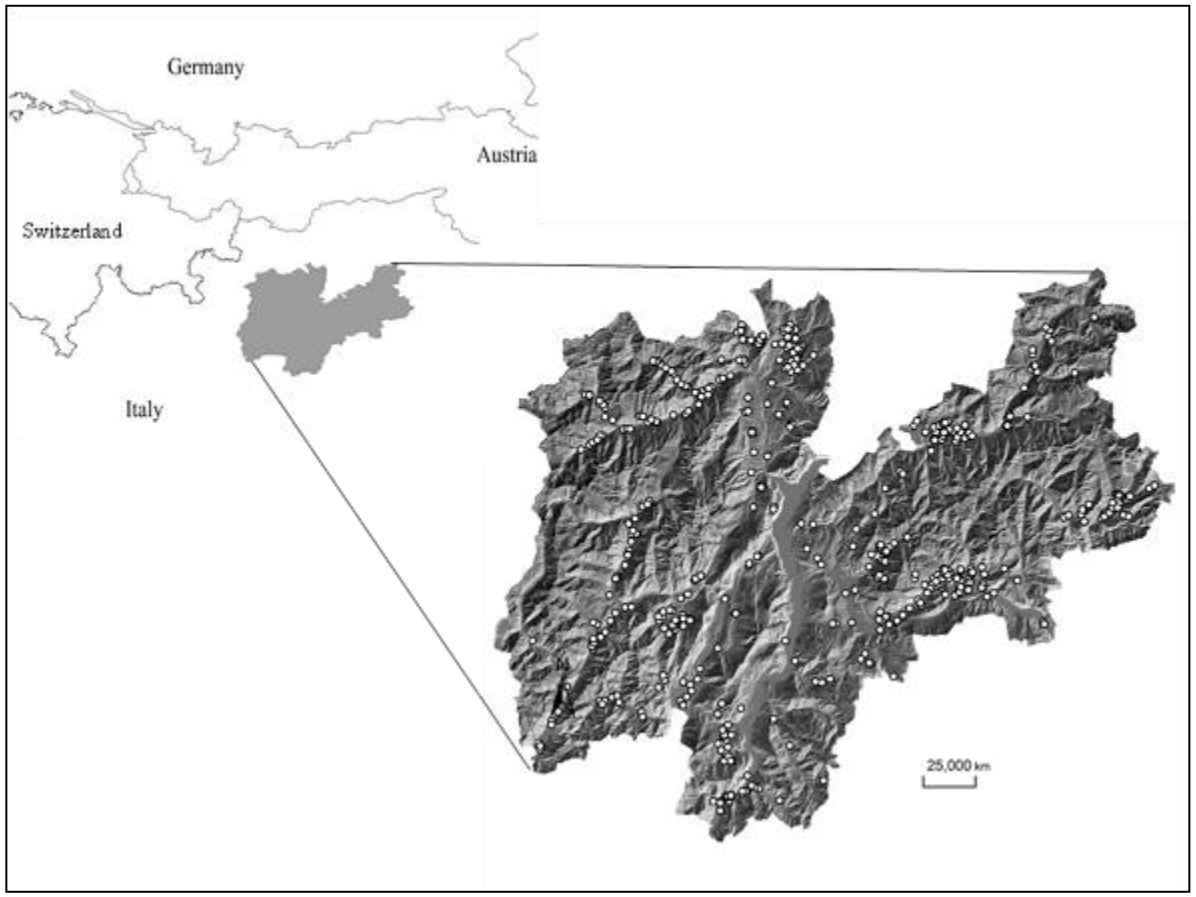
Aim

1) to assess the sustainability of dairy farms in mountainous areas by using a multi-indicators approach:

- environmental impact categories computed according to Life Cycle Assessment approach
- competition with human-edible feedstuffs for the production of energy into human-edible livestock products

2) to analyse synergies and trade-offs among different indicators

Study area and sampled farms



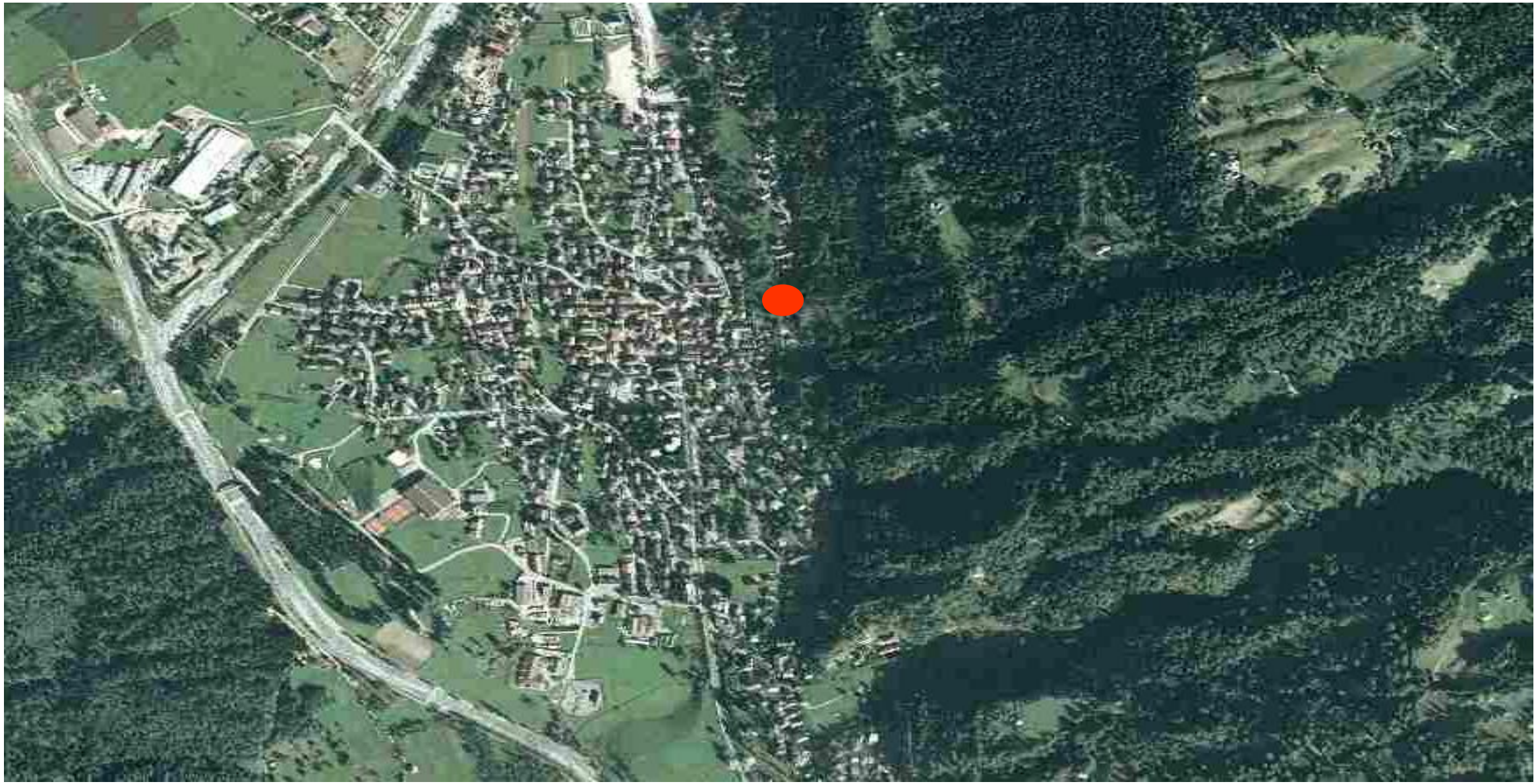
Study area → Trento province:

- Mountainous area 6,212 km^2
- 1,372 km^2 UAA, mainly grassland
- 1,075 dairy farms: the majority are members of cooperative dairies producing PDO cheeses

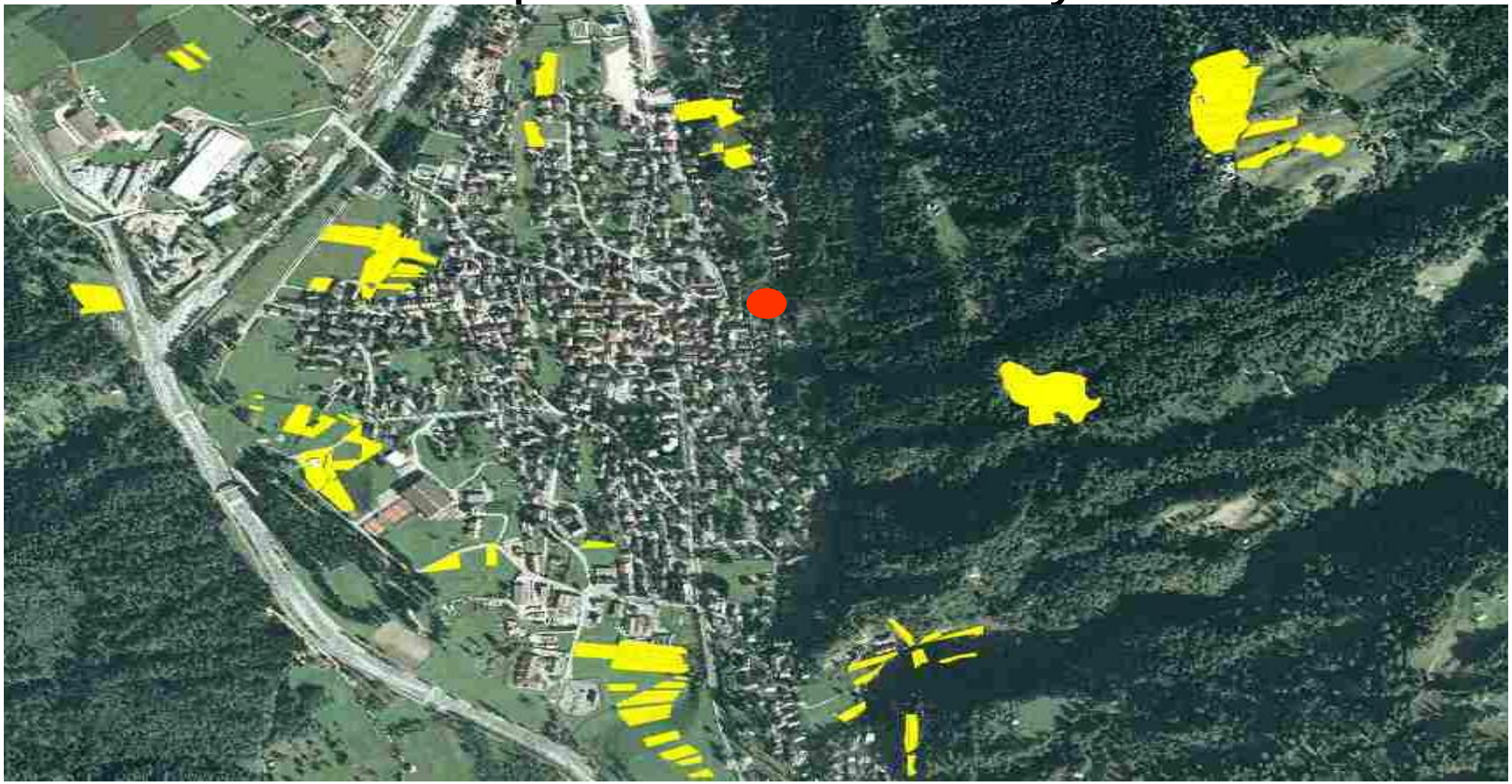
Sampled farms:

- 38 dairy farms with mixed breed herds (2 or more of these breeds: Holstein Friesian, Brown Swiss, Simmental, Rendena, Alpine Grey)

Landscape of traditional dairy farm



Landscape of traditional dairy farm



Goal and scope

- ✓ ***System boundary and delimitations****:* this work studied the dairy farms from cradle-to-farm-gate for a one-year period (2013)
- ✓ ***Functional unit:*** 1 kg of Fat and Protein Corrected Milk (FPCMilk) at the farm gate
- ✓ ***Allocation***: mass allocation for inputs derived by multifunctional system and for the two main farm outputs (meat and milk)

Life Cycle Inventory - LCI

- Collection of general data on farm facilities and management
- Recording of specific data:
  - Animal: at herd level, collection of data on productive performances, diet composition and administration
  - Crop: estimation of environmental impact of each on-farm feed used at farm level - all production inputs (fuel, mineral and organic fertilizers, pesticides, seeds), extension of land use and yields were recorded for each crop destined to on-farm feed
  - Off-farm and materials used on farm: Emission factors (EF) for off-farm feed, plastic and lubricant were derived by EcoInvent 3.0 and Agri-footprint 1.0 database provided with Simapro software

Life Cycle Impact Assessment - LCIA

Impact Categories:

- Greenhouse gas emission (GHG, kg CO_2-eq)
- Acidification potential (AP, kg SO_2-eq)
- Eutrophication potential (EP, kg PO_4-eq)
- Cumulative Energy Demand (CED, MJ)
- Land occupation (LO, m^2)

Competition with human-edible resources

Use of human-edible feedstuffs → Competition between feedstuffs' destination: Feed vs Food

$$\text{Human-edible Feed Conversion Ratio (HeFCR)} = \frac{\text{MJ (GEI) into the human-edible feedstuffs}}{\text{MJ (GEI) into FPCMilk produced per farm}}$$

Value for MJ (GEI) per each feedstuff: INRA (2007) reference
Human-edible ratio per each feedstuff: Wilkinson (2011)
Human-edible gross energy per 1 MJ into the milk: Wilkinson (2011)

Results: descriptive statistics of the 38 sampled farms

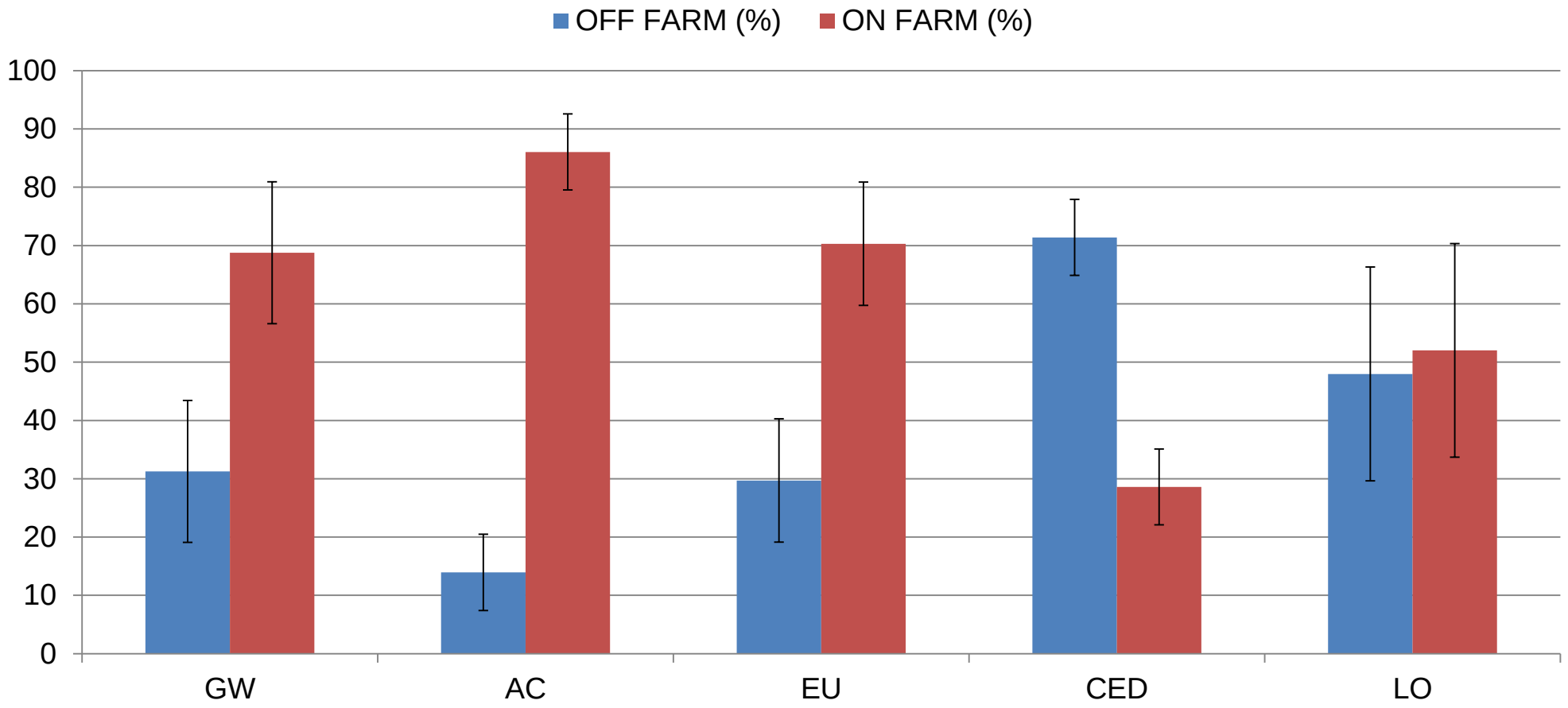
Variable	Mean ± SD
Lactating cows/farm (No.)	42.0 ± 28.8
Herd size (Livestock Unit, LU)	61.7 ± 30.8
Agricultural surface (ha)	22.3 ± 11.9
Milk production (kg/cow/d)	23.0 ± 6.5
Grassland of total surface (%)	93.1 ± 15.8
Stocking rate (LU/ha)	2.9 ± 1.4

Feed administration: 19/38 farms used total mixed ration
10/38 farms used silages

Results

	Unit	Mean ± SD
Impact categories per FPCMilk (mass allocation)		
Global warming potential	kg CO_2-eq	1.06 ± 0.23
Acidification potential	g SO_2-eq	19.97 ± 4.10
Eutrophication potential	g PO_4-eq	5.82 ± 1.07
Cumulative energy demand	MJ	5.06 ± 1.97
Land occupation	m^2/year	1.38 ± 0.46
Competition with human-edible (He) resources		
He Feed Conversion Ratio	MJ feed/MJ milk	0.72 ± 0.46

Results: ON-farm vs OFF-farm emissions



GW: global warming potential; AC: acidification potential; EU: eutrophication potential; CED: cumulative energy demand; LO: land occupation.

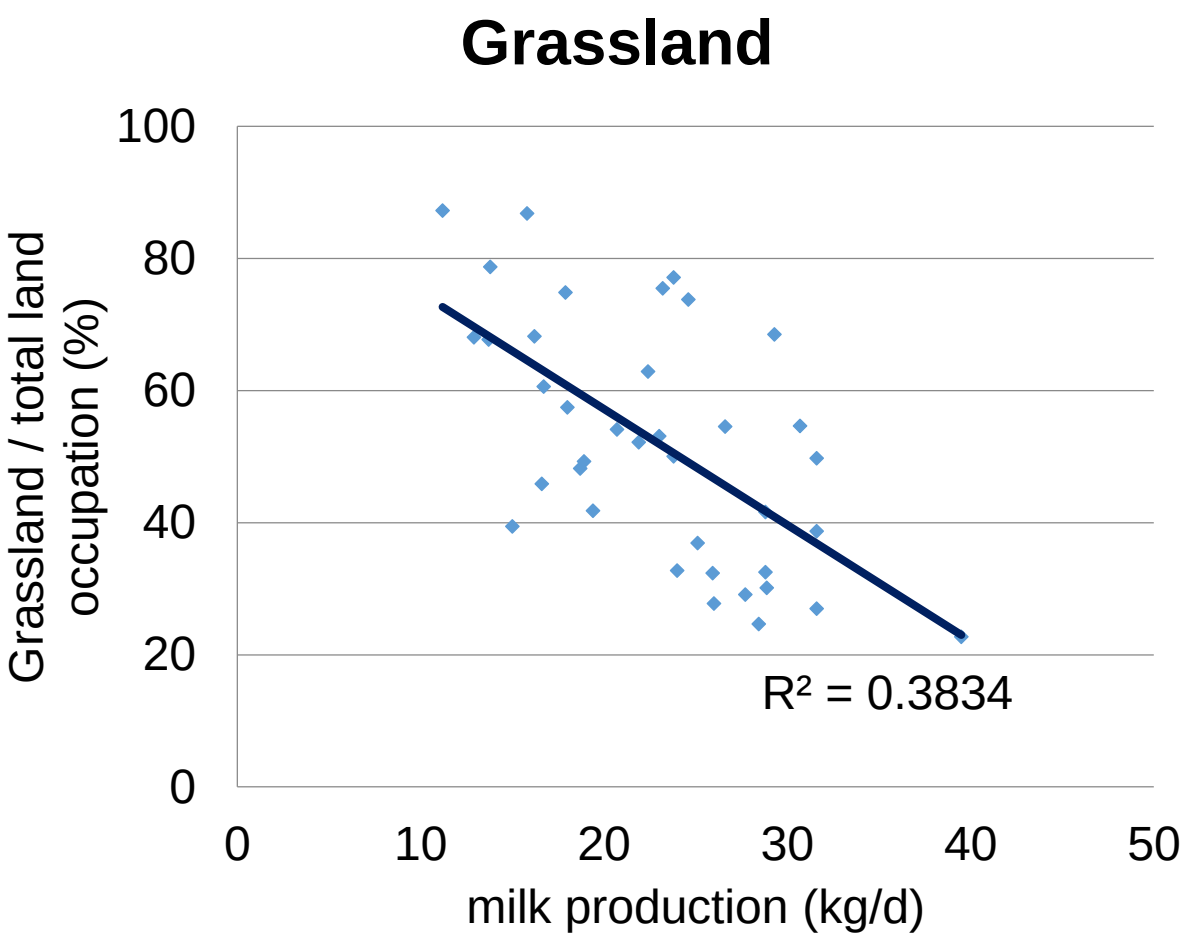
Correlation between the multiple-indicators

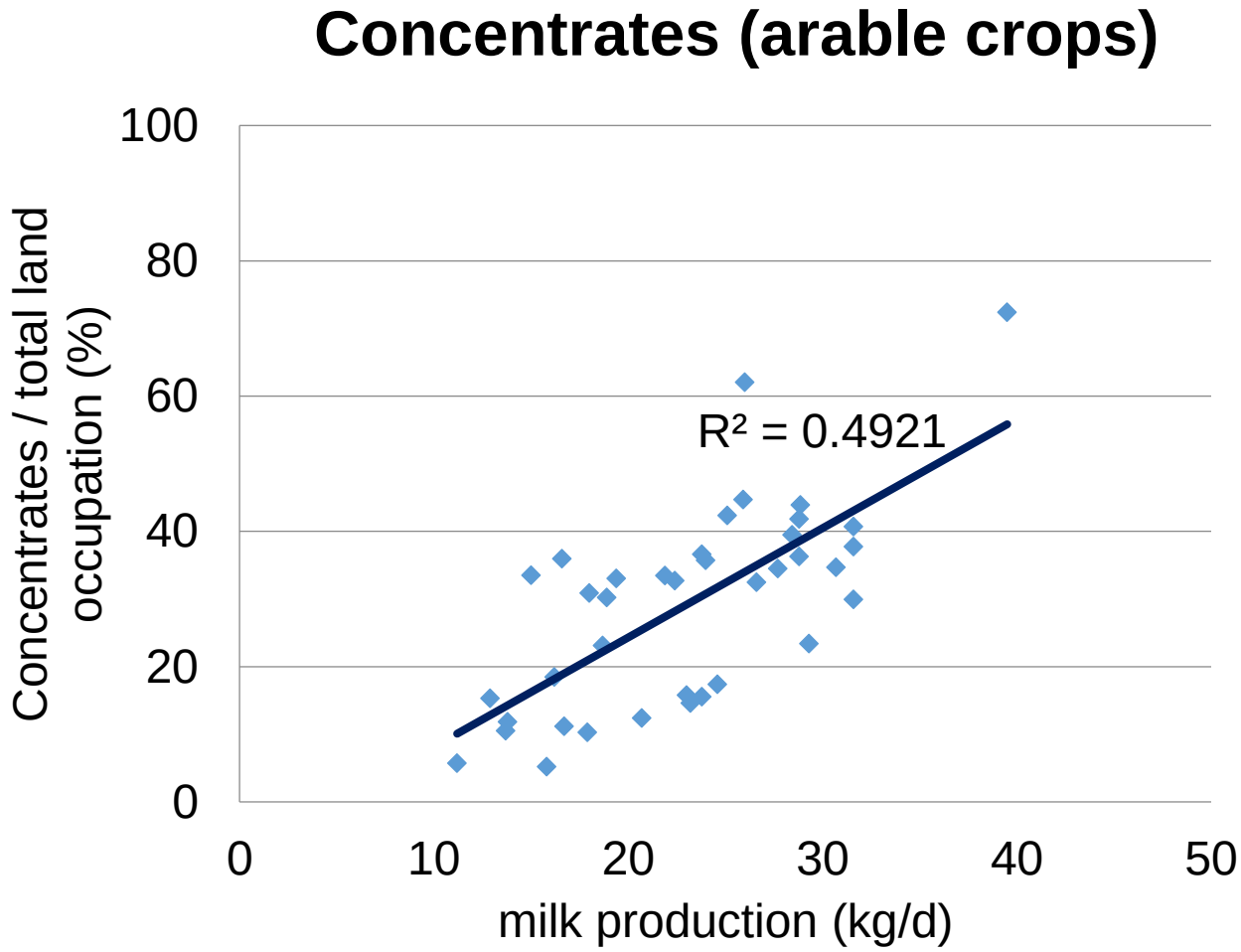
	GW	AC	EU	CED	LO	HeFRC
GW		***	***	***	*	**
AC	0.67		***	**	***	**
EU	0.81	0.88		**	**	*
CED	0.64	0.45	0.44		*	**
LO	0.34	0.53	0.47	0.36		**
HeFRC	-0.48	-0.46	-0.37	-0.45	-0.47	

*: P<0.05, **: P<0.01; ***: P<0.001

GW: global warming potential; AC: acidification potential; EU: eutrophication potential; CED: cumulative energy demand; LO: land occupation

Competition with human edible resources: land occupation and milk production





Discussion: methodology

Key points for the assessment of sustainability of grassland based livestock systems:

- LCA approach is a useful tool, but keep attention to:
  - Functional unit
  - GHG: how to account for carbon storage in the soil?
  - Quality of data and homogeinty of methods
- Competition with human edible resources: trade-off with impact categories
- Ecosystem services?

Discussion: comparison with other livestock systems

Sustainability of the integrated France-Italy beef production system assessed through a multi-indicator approach (Berton et al., 2016)

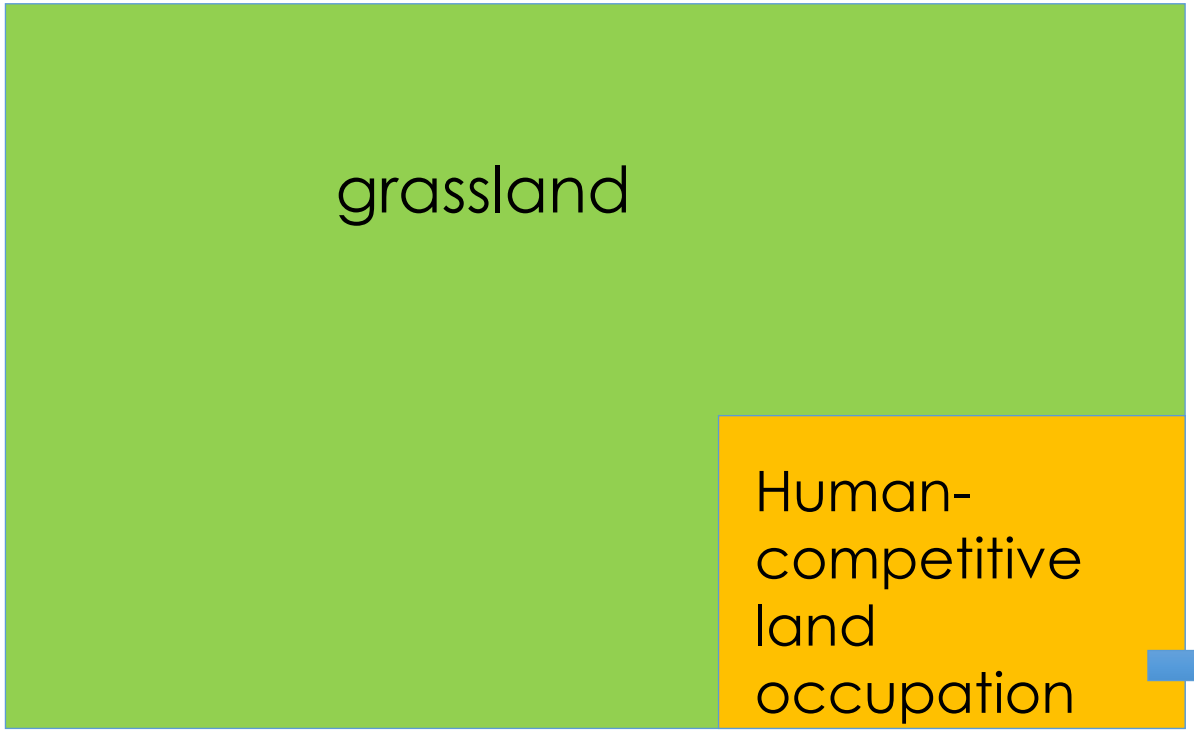
North East Italy beef sector is included in a two-steps livestock farming system

- Geographically separeted
- Based on different production systems and outputs

Grass *vs* crop land occupation for beef production

Land occupation per 1 kg BW

Integrated France-Italy beef sector: **19.2 m²/year**



3.9 ± 0.3 m²/year

Pig sector
4.1 m²/year
(Gonzales-Garcia et al., 2015)
5.4 m²/year
(Basset-Mens and van der Werf, 2005)

Conclusions

- The sustainability of mountain dairy farms is strongly linked to the grassland management
- The impact categories commonly used in LCA for livestock products penalize mountain dairy farms
- The low competition with the use of human-edible feedstuffs has a consequent positive effect on the total food provisioning of mountain dairy farms.
- The sustainability assessment of the mountain dairy sector has to include different types of indicators in order to take into account the characteristics and environmental conditions as well as the products and ecosystem services supplied.