Effects of anaerobic digestion on nutrient cycles, productivity and sustainability

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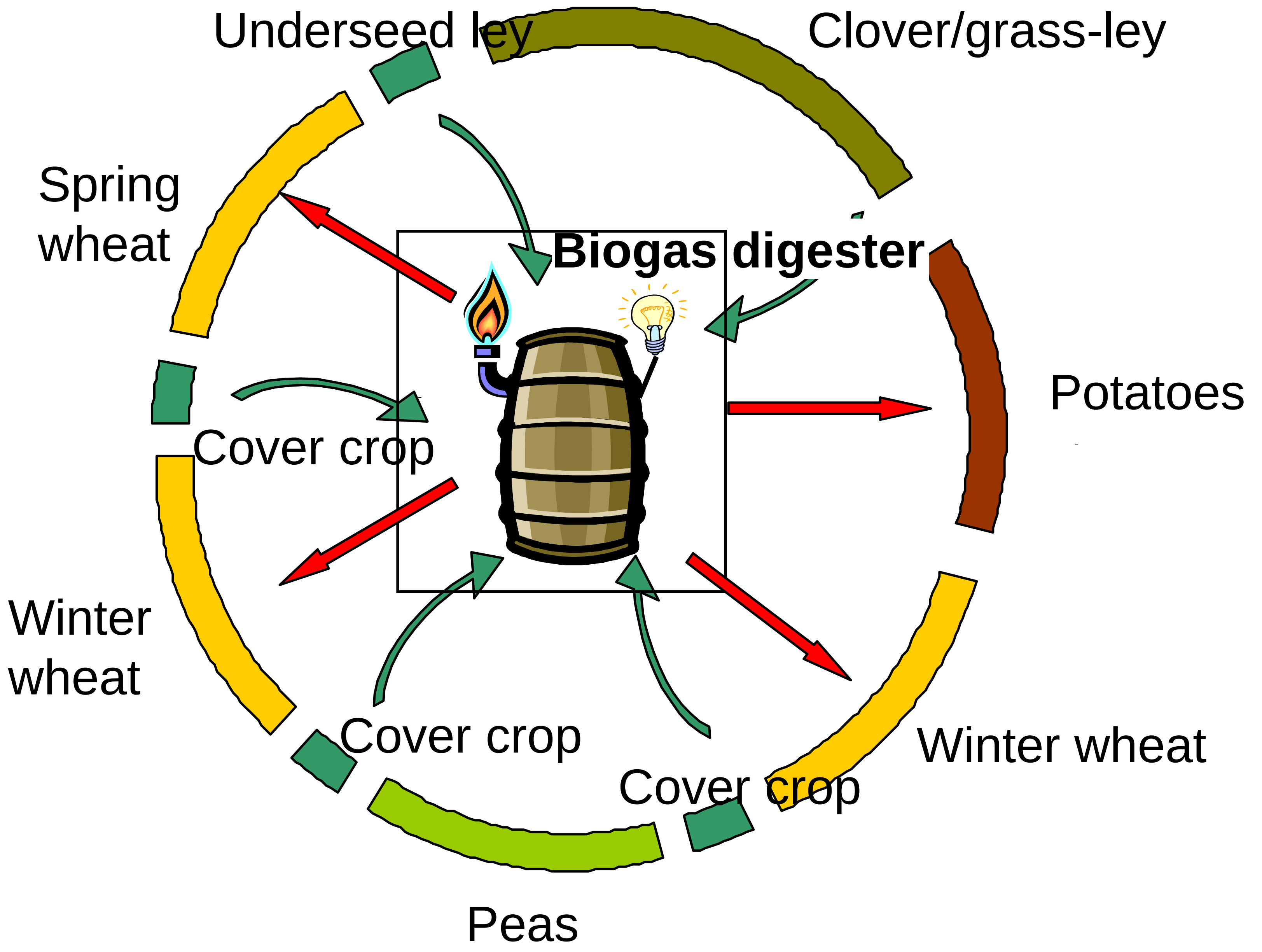
Outline

- Introduction
- Effects of AD in stockless systems on nutrient flows
- Effects on productivity
- Effects on N emissions
- Effects on soil fertility
- Conclusions

Expectations on anaerobic digestion

- Higher N availability,
- lower N losses including nitrate leaching risk, ammonia volatilization, nitrous oxides,
- lower greenhouse gas emissions,
- substitution of fossil fuels,
- alternative use-pathway for leys, grassland, etc.

Stockless System with digestion



Performed stockless farming systems

Crop rotation: 1 x clover/grass, 5 x cash crops (1 legume)

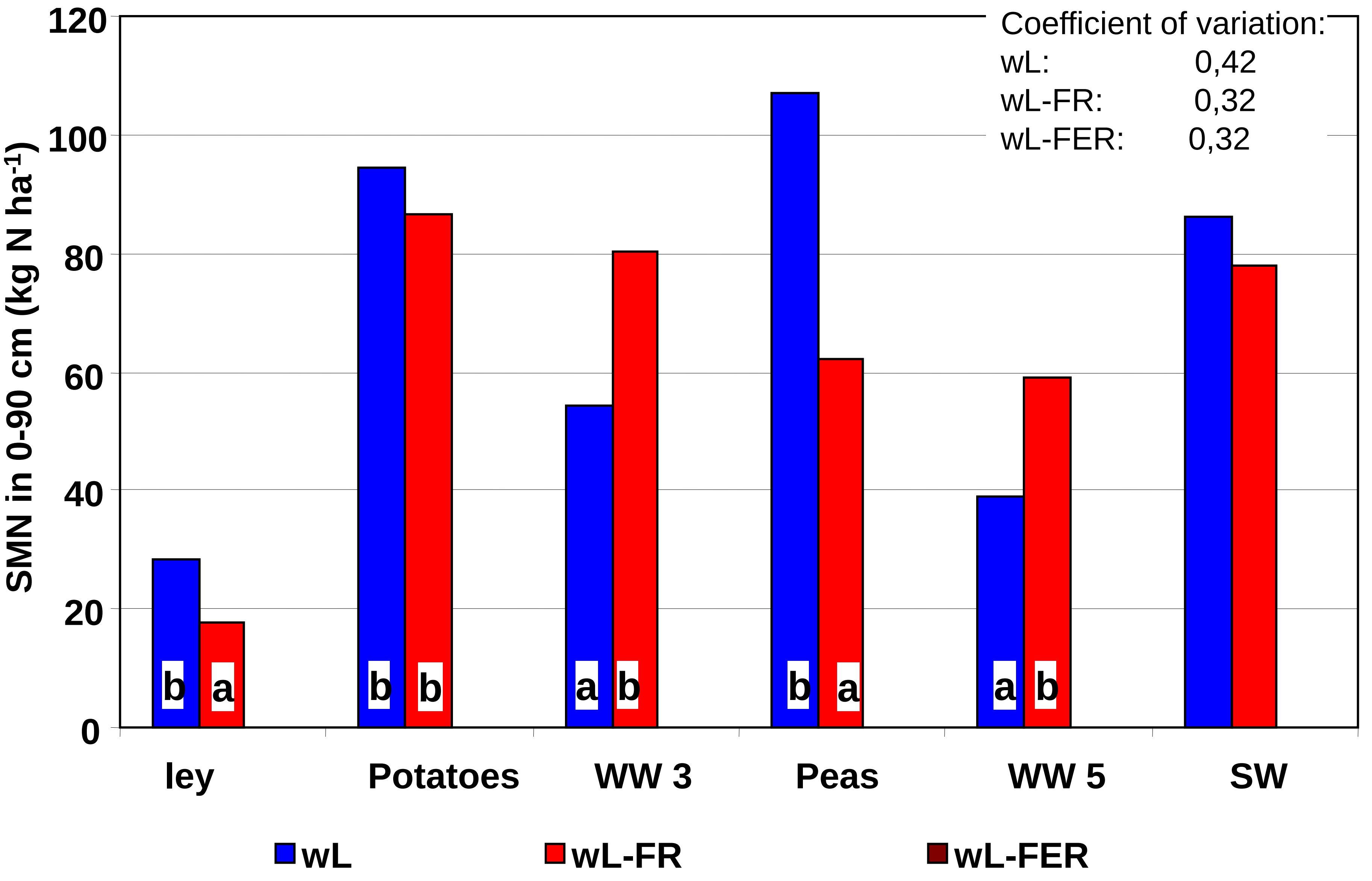
System	Abbre-viation	Management of the ley, crop residues and cover crops
Usual stockless management	**wL**	Remained on the field (ploughed in, mulched)
Digestion of crop residues	**wL-FR**	Harvested, digested, effluents reallocated as manure within the same crop rotation
Digestion of crop residues + external substrates (40 kg N ha-1)	**wL-FER**	Harvested, digested, effluents reallocated as manure within the same crop rotation

Effects on the organic matter and nutrient flows (Stinner et al. 2008, Möller 2009)

	wL	wL-FR	wL-FER
organic DM (t ha^{-1})	6.47	2.53	3.08
C supply (t ha^{-1})	3.20	1.40	1.70
Total N supply (kg N ha^{-1})	128	126	154
Mobile N (kg N ha^{-1})	0	104	132
N supplied to non-legume crops	150	180	223
N supplied to legumes	83	10	10
C/N ratio organic manures	25,2	11,0	11,1
Ammonium-N (kg N ha^{-1})	0	43,2	54,5

Effects on spring soil mineral N content

(Stinner et al. 2008)

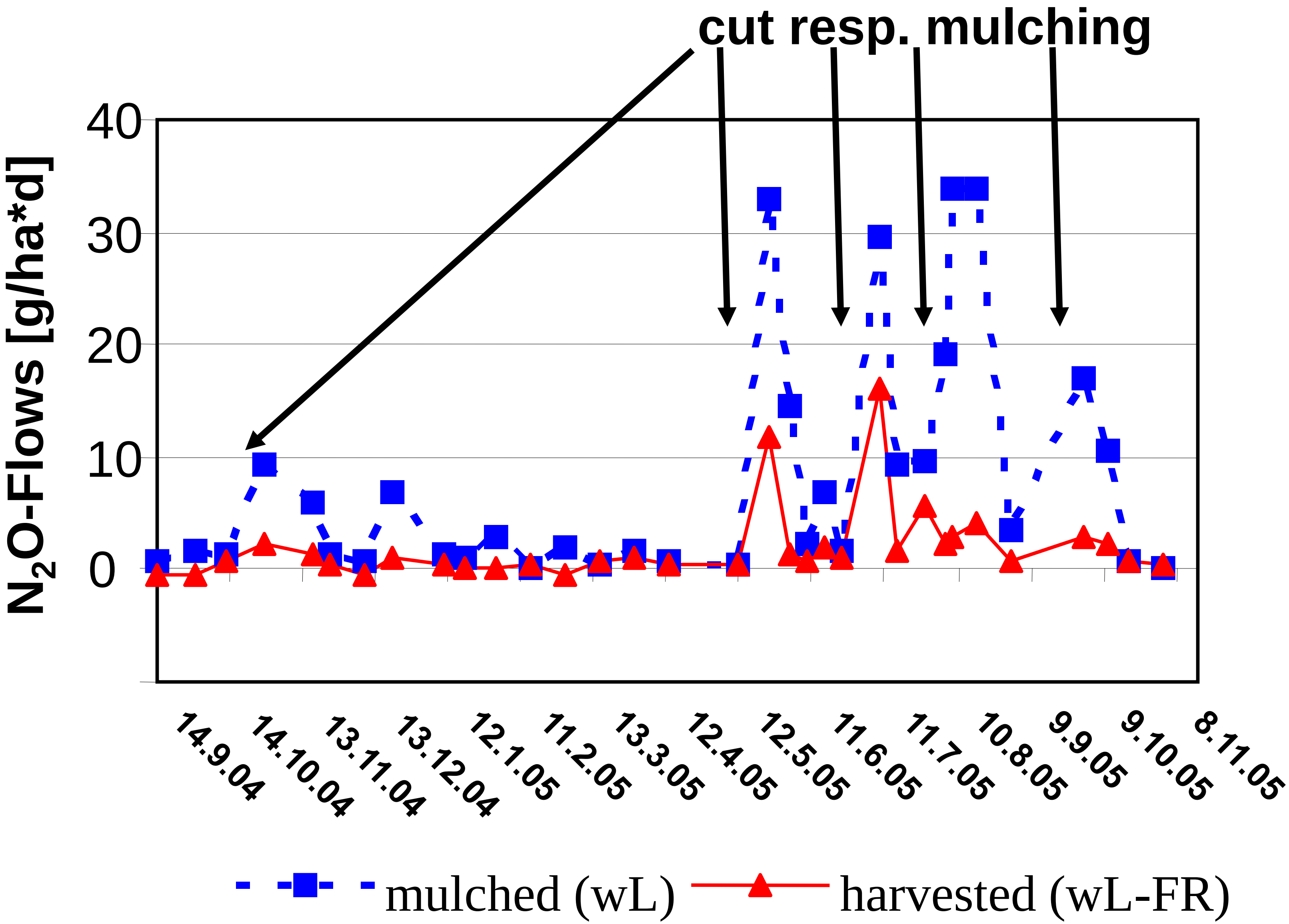


Relative impact on crop N uptake (%)

(Stinner et al. 2008)

	wL	wL-FR
CG	100	100
Potatoes	100	100
WW 3	100	117
Peas	100	100
WW 5	100	130
SW	100	117
Sum NL	100	116
Sum cereals	100	122

N_2O emissions under clover/grass-ley depending on the management (Möller & Stinner 2009)

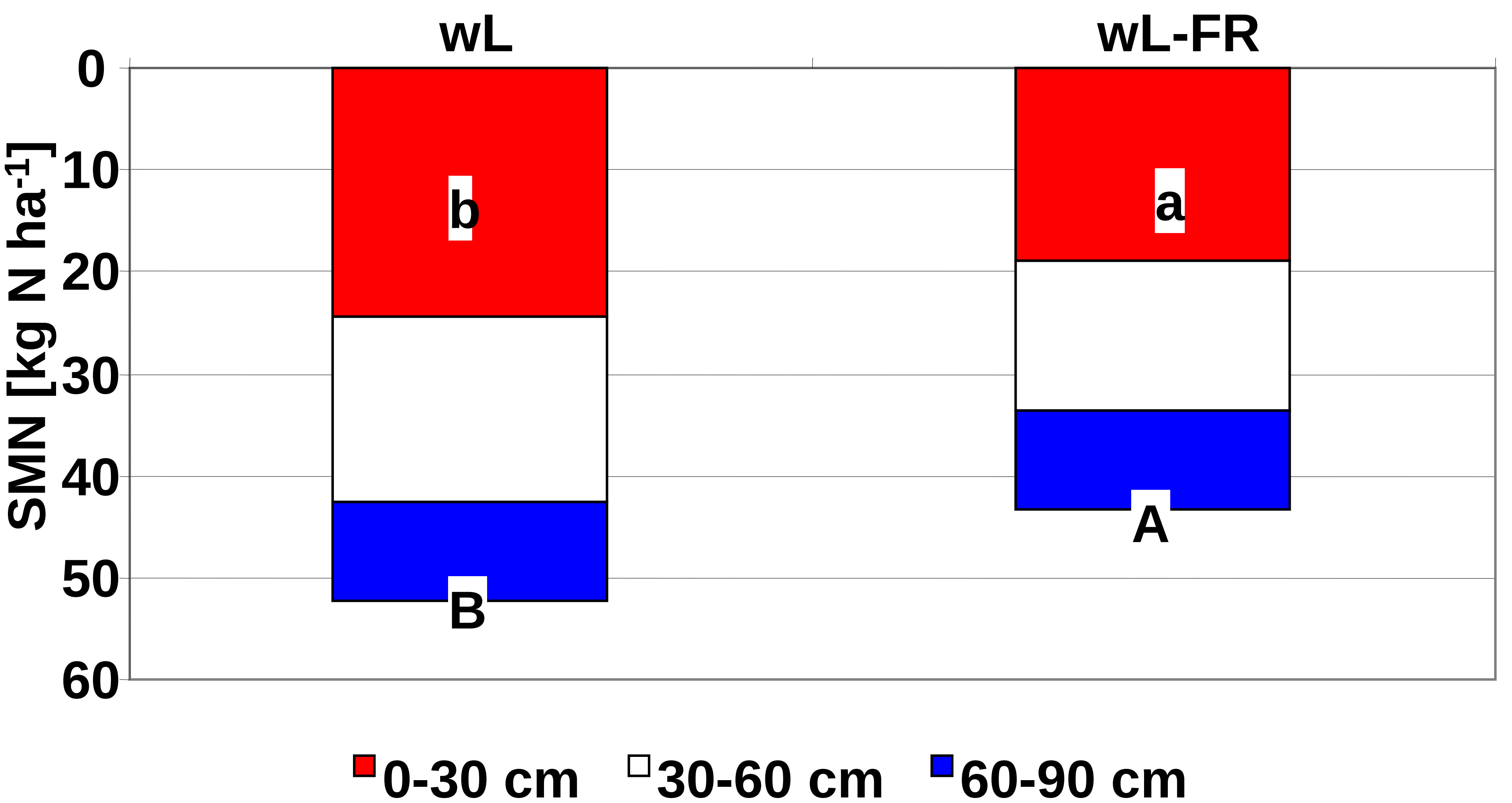


Sum of soilborne N_2O-emissions

(g N_2O-N $ha^{-1}*y^{-1}$) (Möller & Stinner 2009)

	wL	wL-FR
Clover grass ley	6.808	844
Potatoes	2.963	2.217
Winter wheat	761	1.748
Spring peas	1.399	944
Winter wheat	4.378	3.355
Spring wheat	1.175	1.800
Sum crop rotation	**17.484**	**10.908**
Mean value crop rotation	2.914	1.818

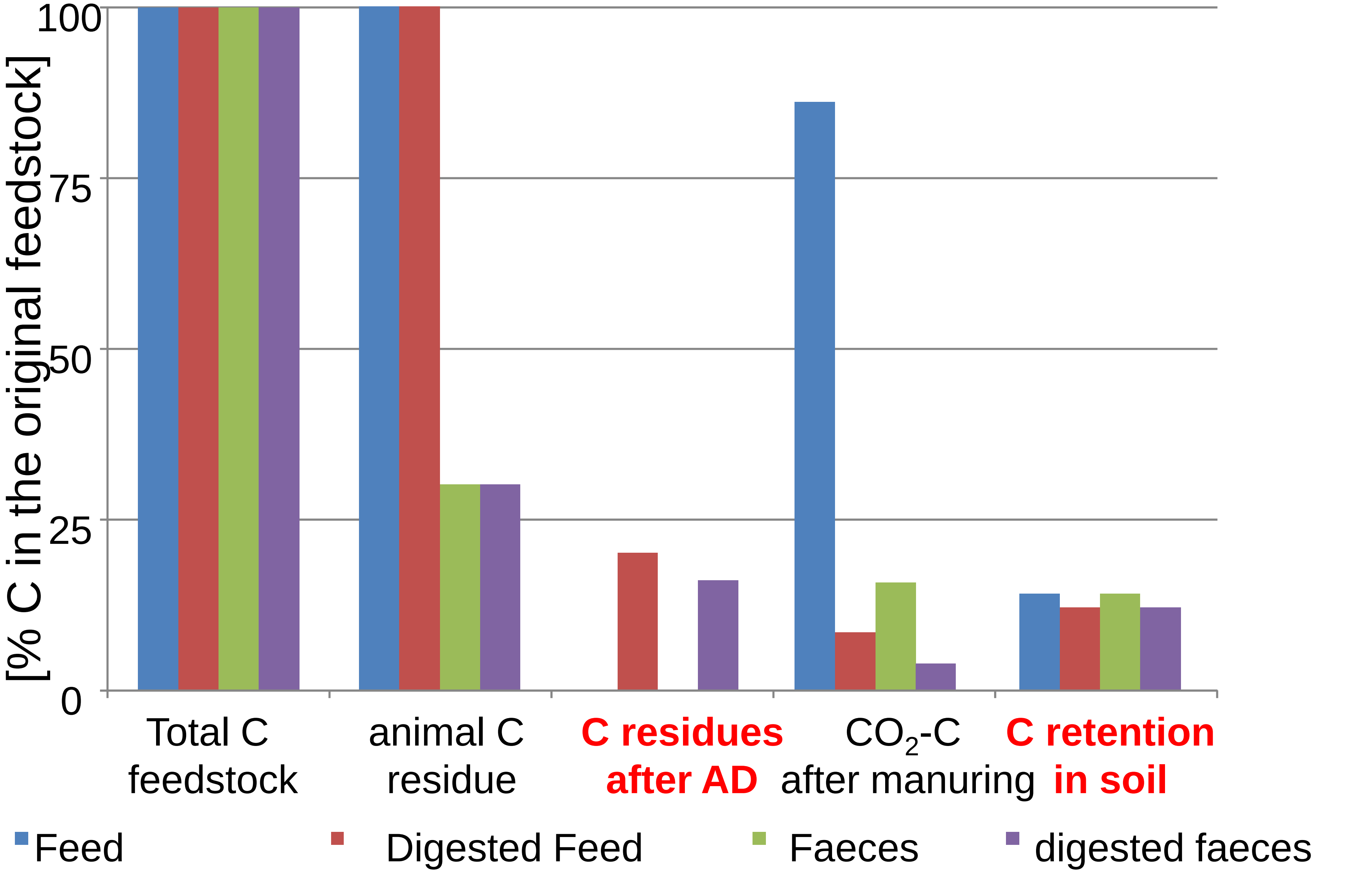
Soil mineral N content in autumn - MV crop rotation (Möller & Stinner 2009)



Effects on soil structure and soil biological activity

- In comparison to untreated soils:
  - improved physical properties (*Tiwari et al. 2000, Garg et al. 2005, Alburquerque et al. 2012*)
  - enhanced soil biological activity (*Alburquerque et al. 2012, Bachmann et al. 2011, Galvez et al. 2012, etc*.)
- in comparison to undigested feedstock: soil biological activity mostly affected under fallow experimental conditions, not in cropped soils
- changes of soil microbial community/structure:
  - increase in organisms linked to nutrient supply (N & P cycle) (*Katz & Rauber 2007, Alburquerque et al. 2012, Chen et al. 2012*)
  - no changes in organisms linked to the carbon cycle (*Alburquerque et al. 2012, Chen et al. 2012*)
  - slowly growing microorganism dominant → transition from r- to K-strategists

Estimated long term retention of C in soil depending on handling strategy for organic materials (Thomsen et al. 2013)

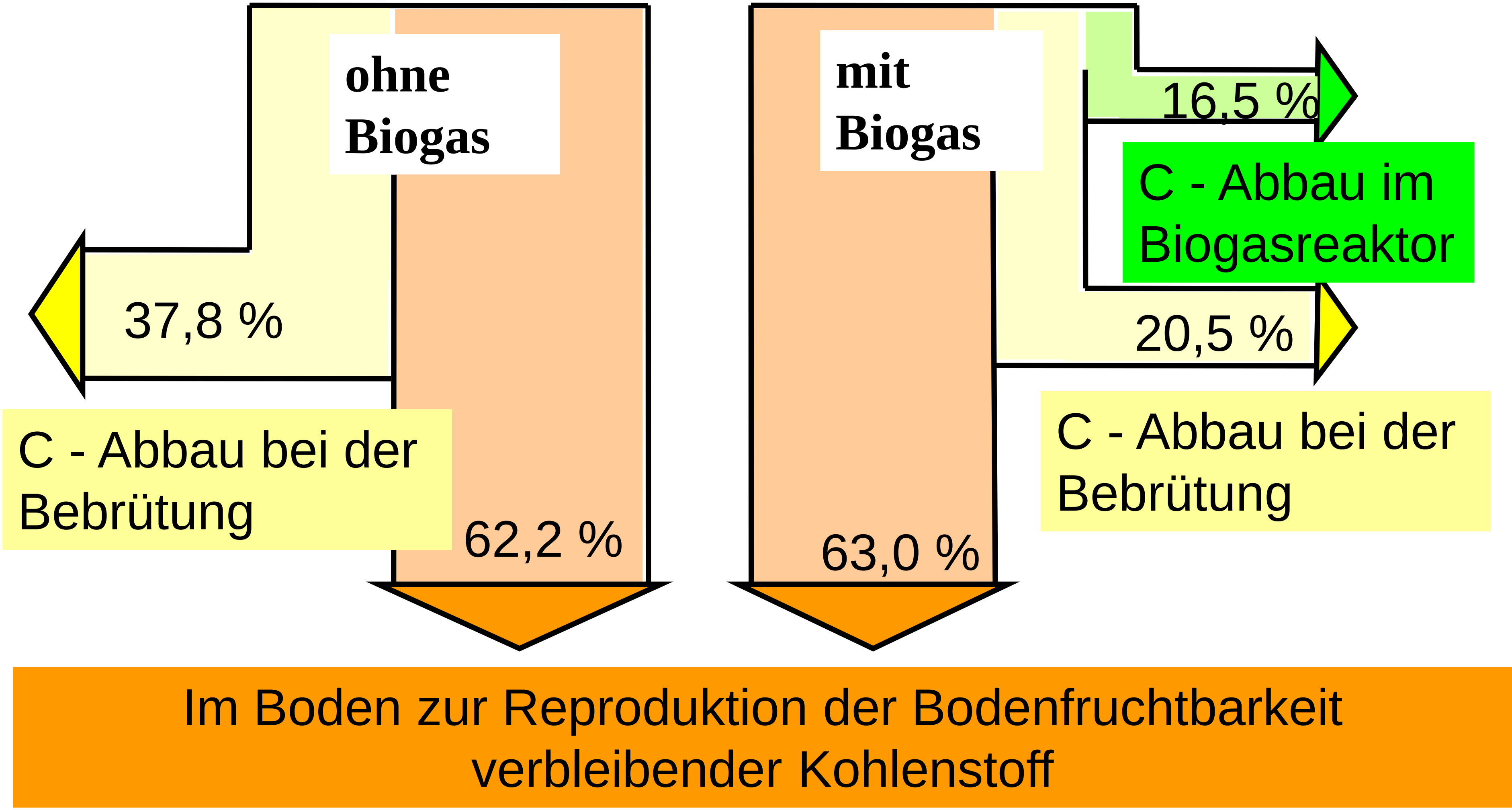


Conclusions

- AD increases of degree of freedom in manuring, leading to:
  - significant increase of yields (+16%) and N uptake (+19%) of non-legumes & of the cereal protein content (+0,6% absolute),
  - reduction of the nitrate leaching risk (ca. 20%),
  - reduction of soilborne N_2O-Emissions (ca. 40%),
- Driving forces are:
  - enhanced N-Inputs via BNF,
  - better adapted allocation of nutrients in space and time,
  - higher NUE of digested residues compared to the undigested substrates,
  - lower N losses due to “safe” storage during autumn & winter.
- the ecological function of some soil organisms is no longer fully necessary → decomposition takes place in the digester under more controlled conditions.

Thank you for your attention

Kohlenstoffabbau durch Biogas und nach Ausbringung unvergorener und vergorener Gülle (*Reinhold et al. 1991*)



Nitrogen in organic farming systems

- The **key** growth limiting factor
- Soil N supply not well matched to crops N demand
  - → Low N use efficiency
- Green manuring important N source
  - N immobile → increased N-loss risk during winter time
  - No reallocation towards the most N demanding crops
  - → N surpluses in some segments of crop rotation, N deficiencies in other segments
- Low N availability of the organically bound N
- high gaseous N losses (stable, stores, soil application)

Carbon in organic farming systems

- Strongly linked to the N cycle
- Soil organic matter is considered to be a key attribute of soil fertility in organic farming
- Soil C balances showed large surpluses in organic farming systems
  - → Dilemma: balanced N budgets are commonly related to very large C surpluses, or: balanced C budgets are connected to deficient N budgets

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