How to detect and quantify inefficient use of nutrients in livestock systems?

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- Why do inputs generally exceed outputs nowadays?
- Metrics: inputs, outputs, surpluses and (in)efficiencies
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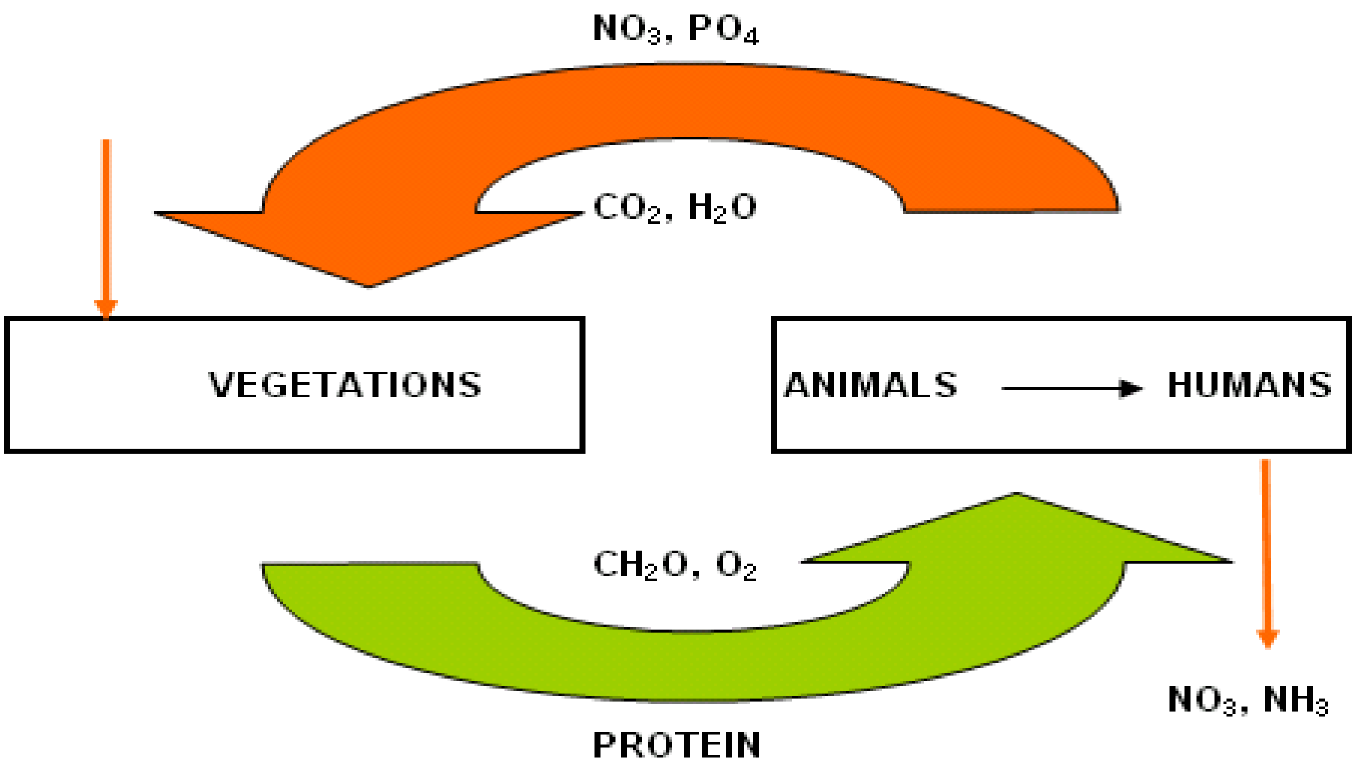
- Pros and cons of intensification

- Conclusions

What agriculture once looked like (1)

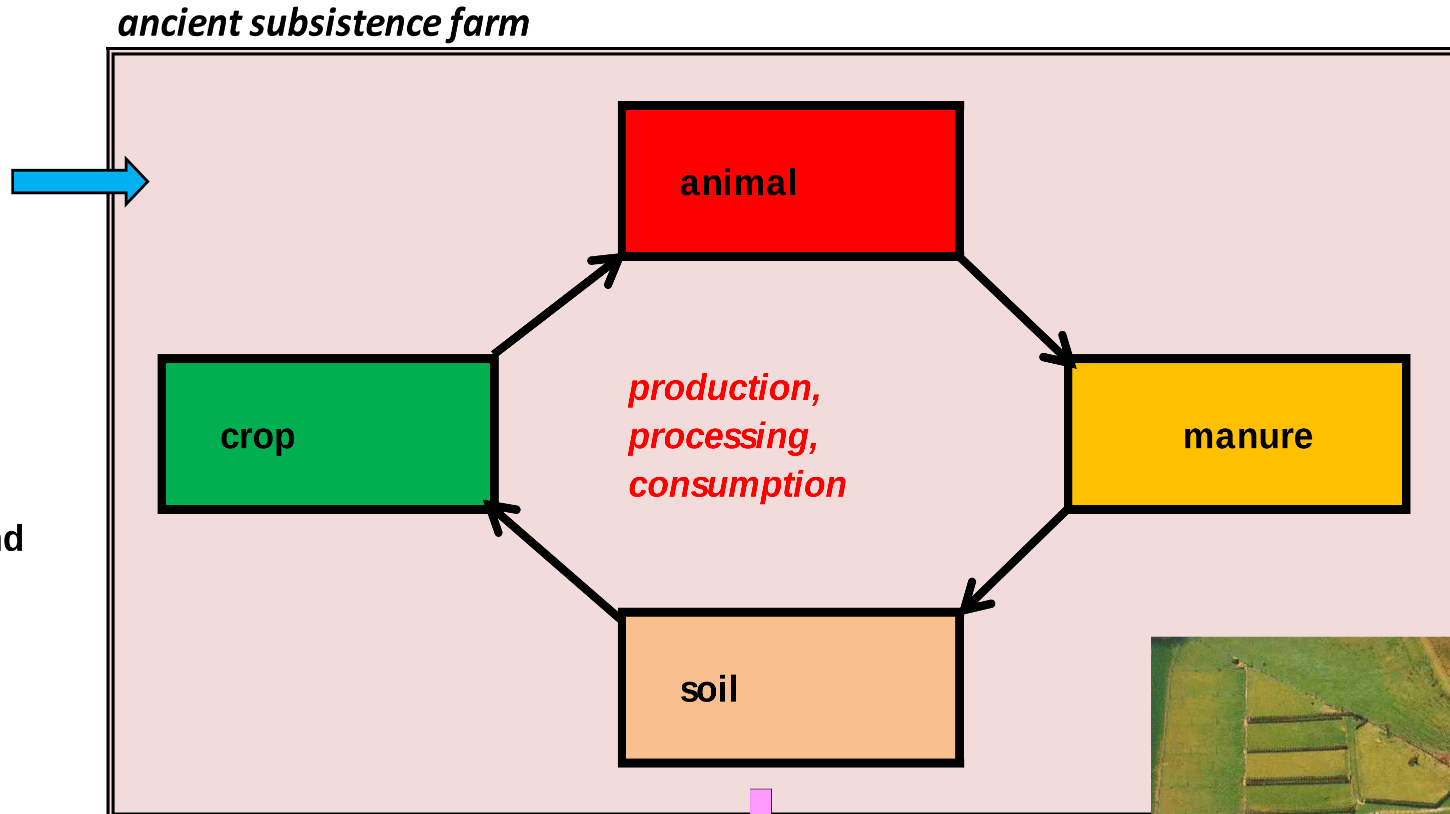


What agriculture once looked like (2)

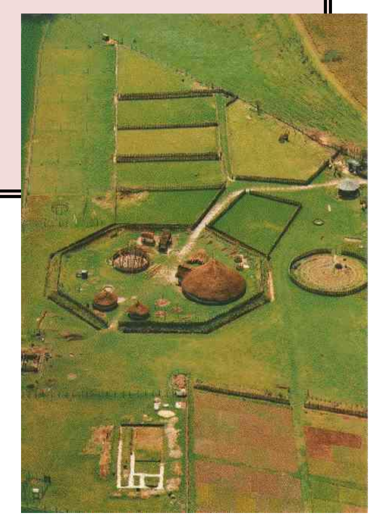
NP Inputs

flooding, deposition, 'clover' N

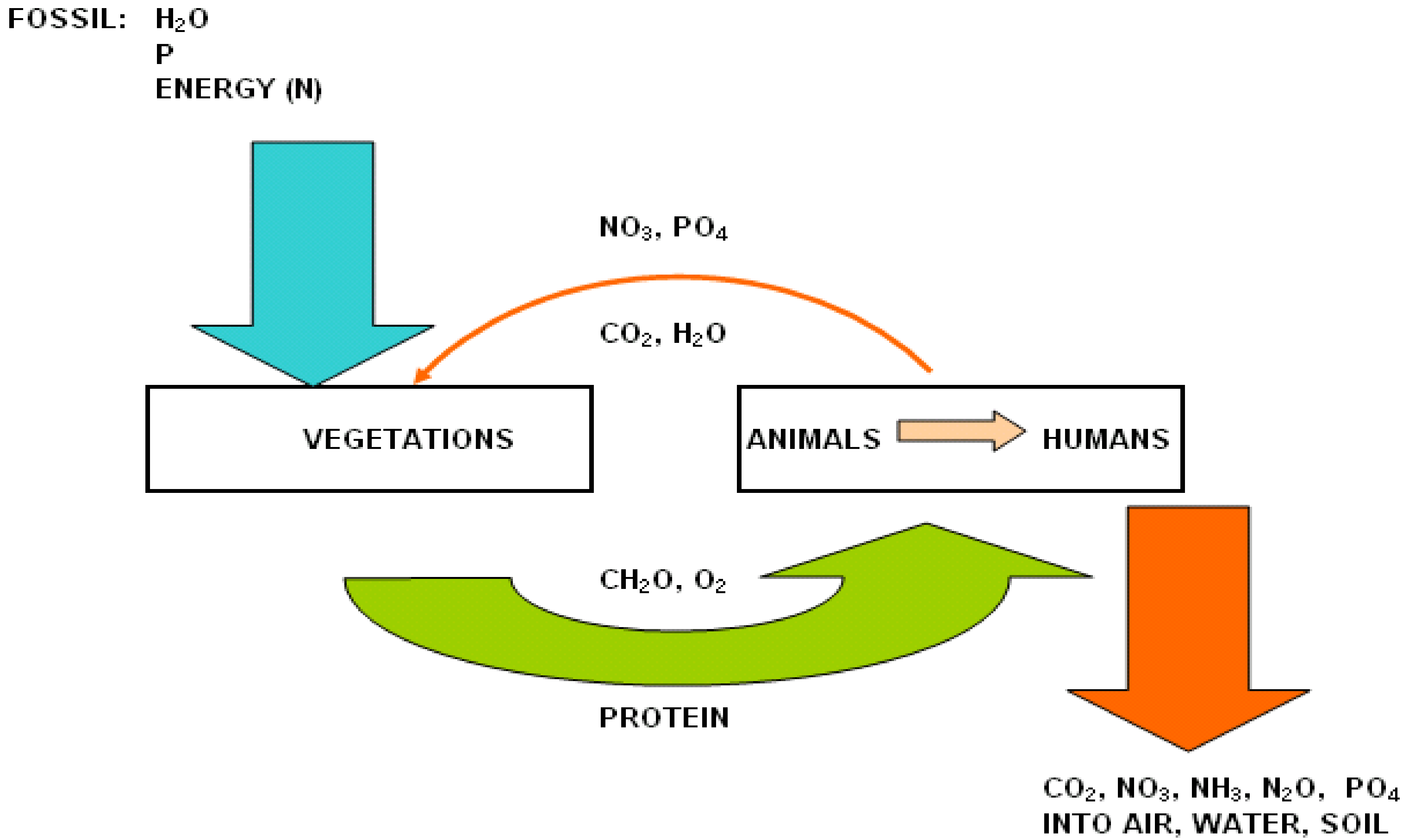
NP collected via grazed range land



NP emissions



What agriculture looks like today (1)



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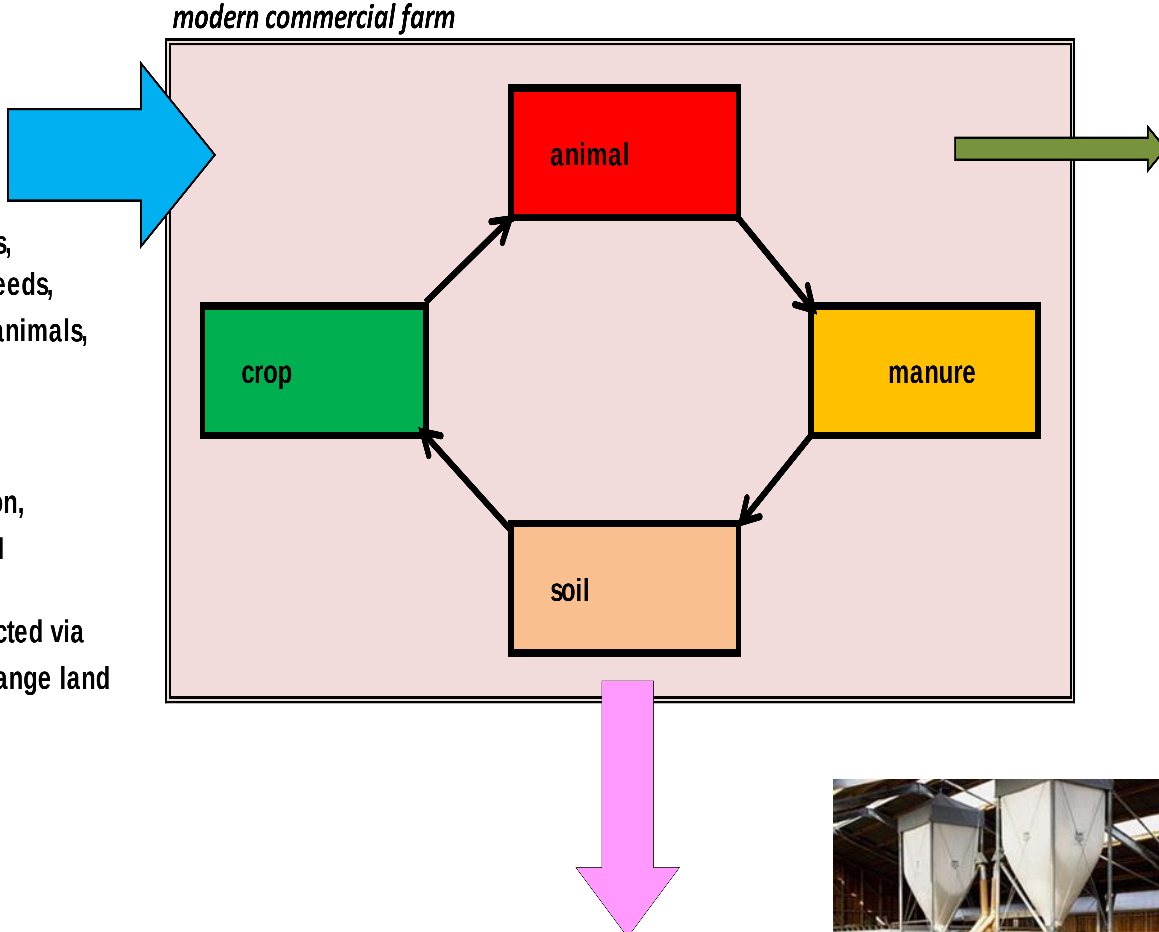
What agriculture looks like today (2)

NP
Inputs

fertilizers,
animal feeds,
(young) animals,
bedding,

flooding,
deposition,
'clover' N

NP collected via
grazed range land



NP
Outputs to processors and consumers 'elsewhere'

milk, meat, eggs, wool, leather
(old) animals

arable crops

NP emissions

Why do NP inputs generally exceed NP outputs?

- Any conversion in living systems is associated with losses

- Moreover:
  - Specialisation and globalisation complicate recycling and made ‘wastes’ out of what were once ‘by-products’,
  - Maximization of profits: NP suppletions based on fossile reserves pay!
  - Productivity improvement may initially require ‘idle’ investments (P)
  - Innoscence, indolence, indifference concerning manure appreciation

- NP use efficiency will not be improved by knowledge transfer only: carrots and sticks are inevitable

- Indicators are needed to target these policy measures
- NP surpluses may serve as indicators

Inputs, outputs, surpluses, (in)efficiencies

- Definitions:
  - N surplus = N input – N output: $S = I - O$,
  - N efficiency = N output / N input = O/I,
  - N inefficiency = $(1 - O/I)$
- N surplus ≈ N losses to the environment
- Identical reasonings, *mutatis mutandis*, for phosphorus (P)

Inputs, outputs, surpluses, (in)efficiencies

- **Local loss issues**:
  - e.g. nitrate, ammonia, ammonium
  - kg N surplus/ ha = kg N input /ha – kg N output/ha: S = I – O = I * (1 – O/I)
  - So: surplus *per unit area* is the relevant indicator

- **Global loss issues**:
  - e.g. N_2O, nitrate
  - kg N surplus = population * (ha's/capita * N output/ha) * (N surplus/ha) / (N output/ha)
  - = population * N output/capita * (N surplus/ha) / (N output/ha)
  - = 'population x diet' * S / O
  - So: surplus *per unit product* is the relevant indicator

- Identical reasonings, *mutatis mutandis*, for phosphorus (P)

What a balance sheet could look like:

Terms:		kg per ha per year: N	P (P_2O_5)	
Inputs:	fertilizers	+	+	book keepings
	imported feeds	+	+	book keepings (weight x default concentrations)
	(young) animals	+	+	numbers x weight x default concentration
	bedding material	+	+	book keepings (weight x default concentrations)
	atmospheric deposition	+		regional default value
	flooding	+	+	regional default value
	'clover N'	+		weighted % legumes in fields x default value
	nutrients brought home via grazed range land	+	+	time fraction x uptake per day x default value
	subtotal	Σ	Σ	
Outputs:	sold milk	-	-	book keepings (weight x default concentrations)
	removed dead and living animals	-	-	numbers x weight x default concentrations
	sold eggs, wool, leather	-	-	book keepings (weight x default concentrations)
	sold arable crops	-	-	book keepings (weight x default concentrations)
	subtotal	Σ	Σ	
Surplus	summed inputs - summed outputs	+/-	+/-	
	=			
	emissions to water and air			
	+ accumulation/depletion of soil stocks			
	+ stock changes in farm storages			

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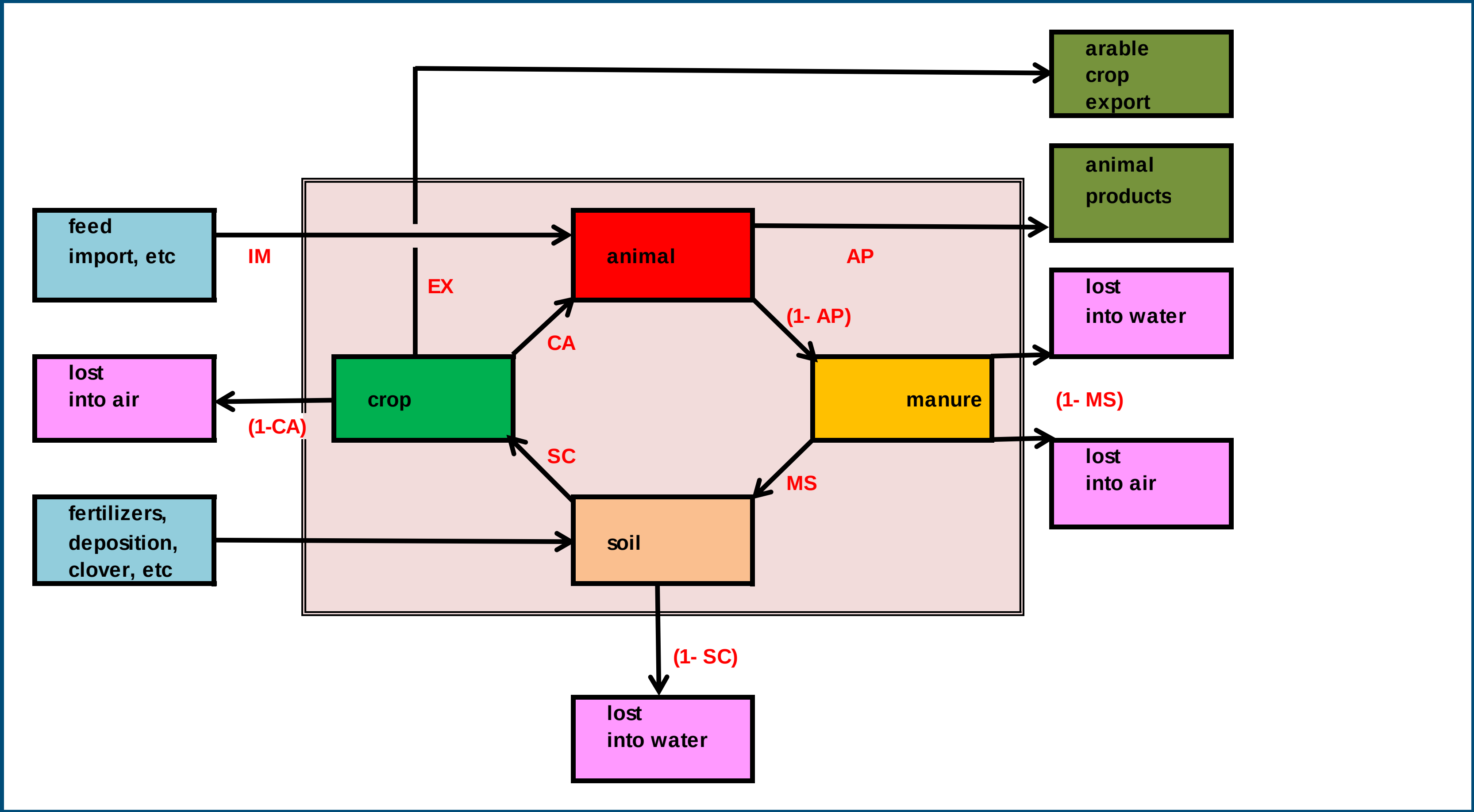
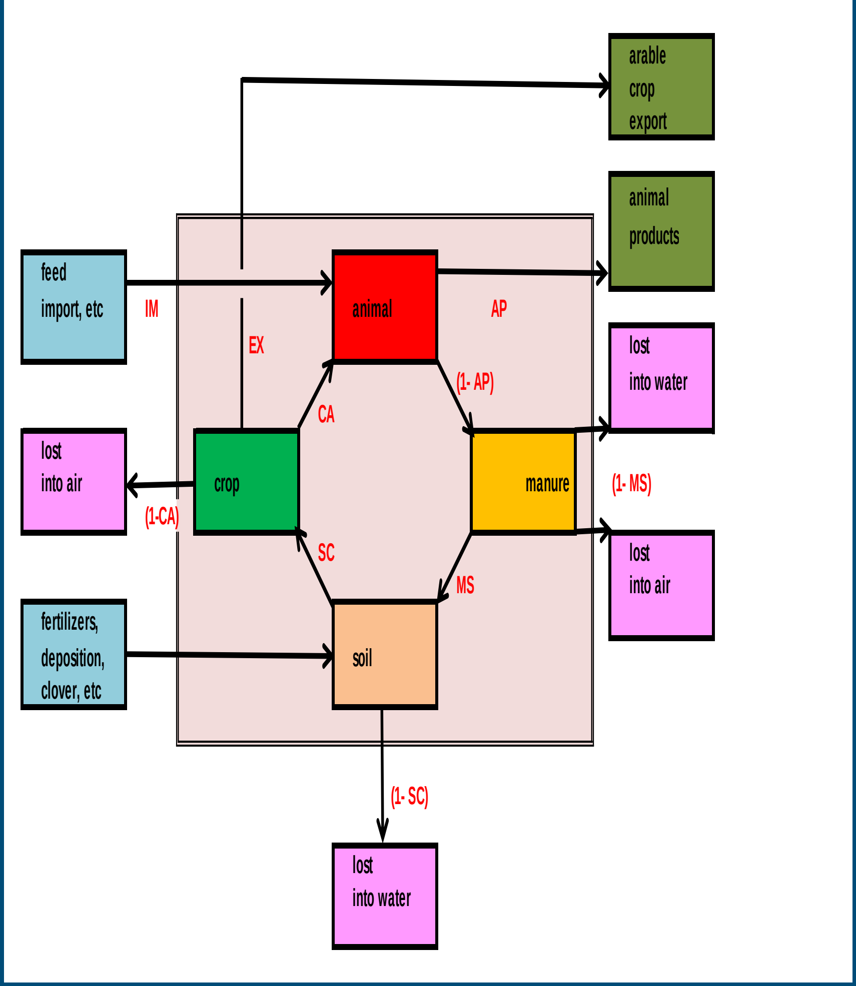
Conversion coefficients underlying O/I (1)



Conversion coefficients underlying O/I (2)



- O/I = p/q
- *p* = (AP + (EX*(1-IM)/(CA*(1-EX))))
- *q* =(IM+(p-AP)/(EX*SC)-((1-AP)*MS))
- Lost N:
  - Per unit area: input x (1-p/q)
  - Per unit output: q/p - 1
- Check: Schröder *et al*., 2003

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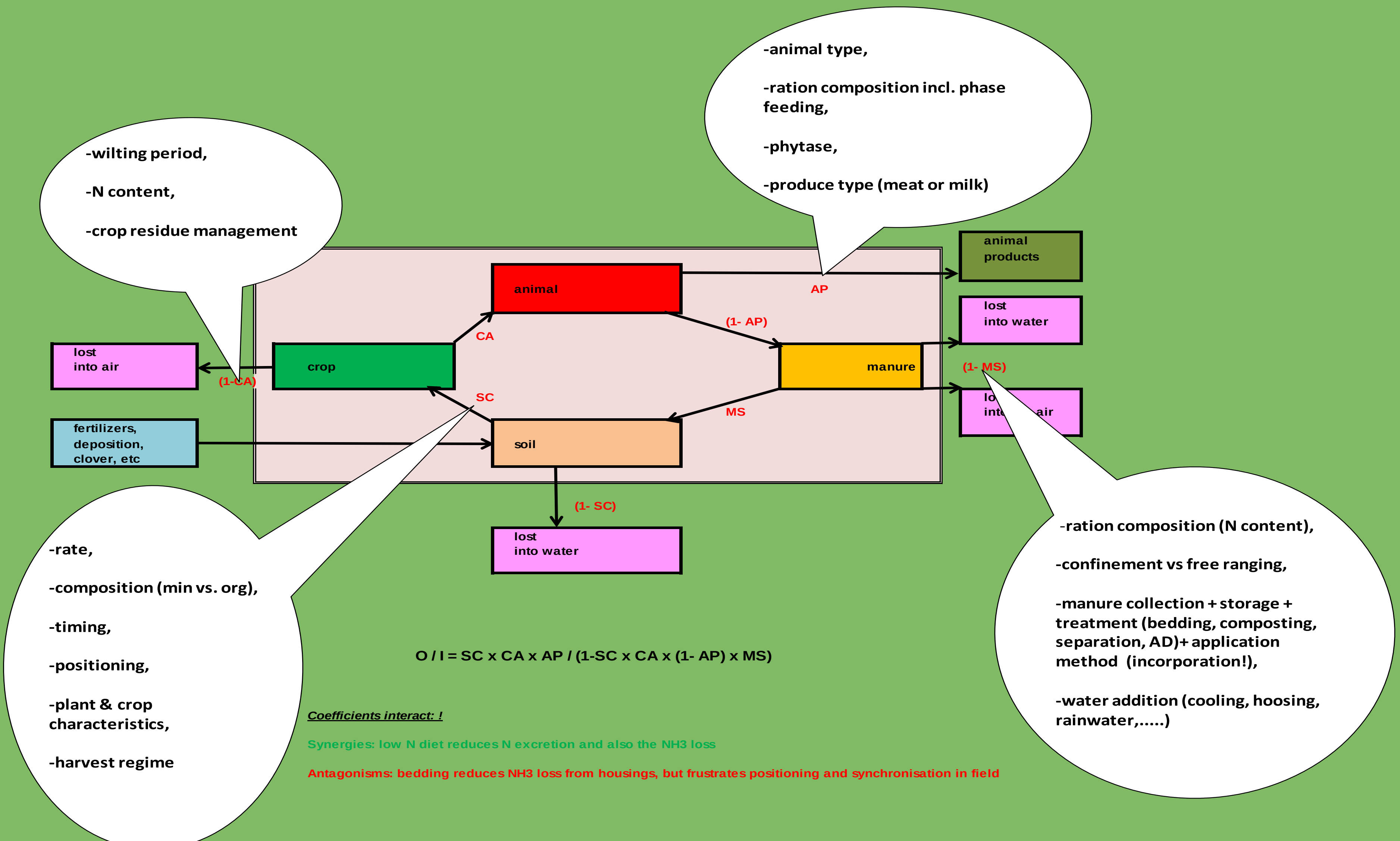
Typical conversion coefficients: beef<dairy<chicken

	N	P
AP: from feed to milk & meat	10-45 %	15-50 %
(1- AP: from feed to manure)	(55-90 %)	(50-85 %)
MS: from manure to soil	50-90 %	90-100 %
SC: from soil to crop	40-80 %	50-100 %
CA: from crop to animals	80-90 %	80-100 %
Whole farm, livestock	10-40 %	20-100 %

Knobs and handles to improve the efficiency



O / I = SC x CA x AP / (1-SC x CA x (1- AP) x MS)

Coefficients interact: !

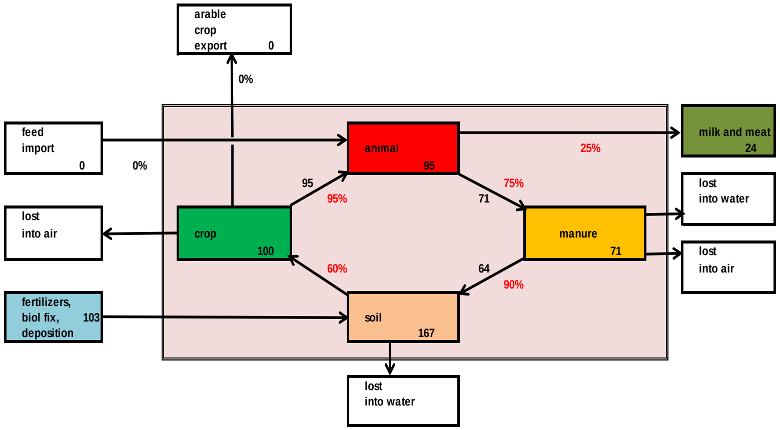
Synergies: low N diet reduces N excretion and also the NH3 loss

Antagonisms: bedding reduces NH3 loss from housings, but frustrates positioning and synchronisation in field

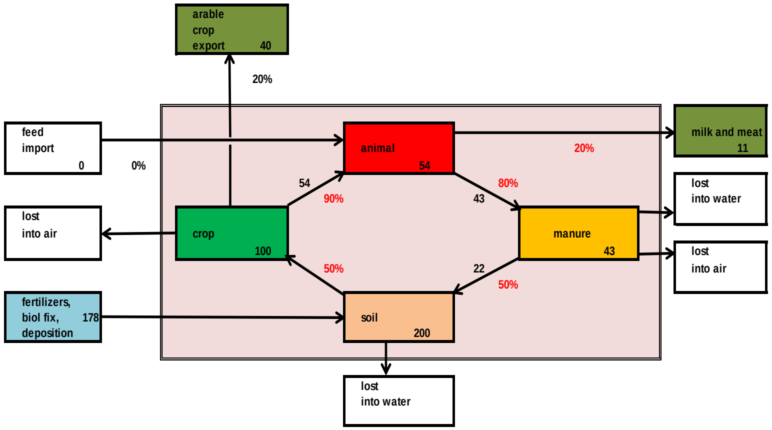
Pitfalls: Externalisation (1)

- Imagine 3 livestock farms within one village:
  - farm A: N output / N input = 23%
  - farm B: N output / N input = 25%
  - farm C: N output / N input = 28%
- Which of these 3 has the most efficient manager of N fluxes?

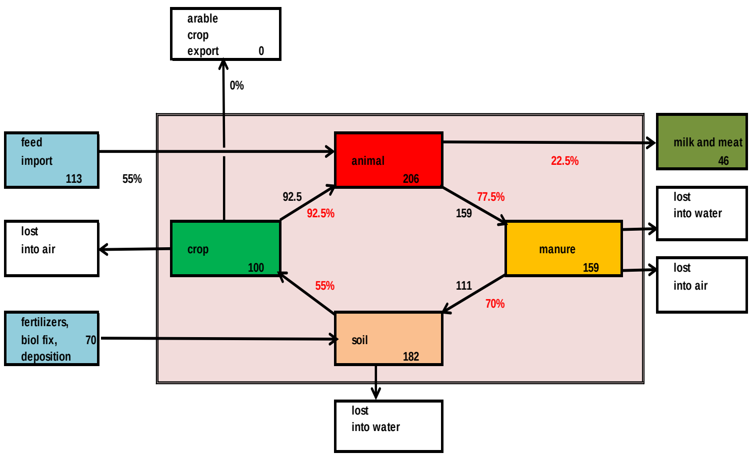
FARM A: output / input ((*kg N per ha)/(kg N per ha)*)= 24 / 103 = 23%



FARM C: output / input ((*kg N per ha)/(kg N per ha*)) = (11+40) / 178 = 28%



FARM B: output / input ((*kg N per ha)/(kg N per ha)*) = 46 / (70+113)= 25%



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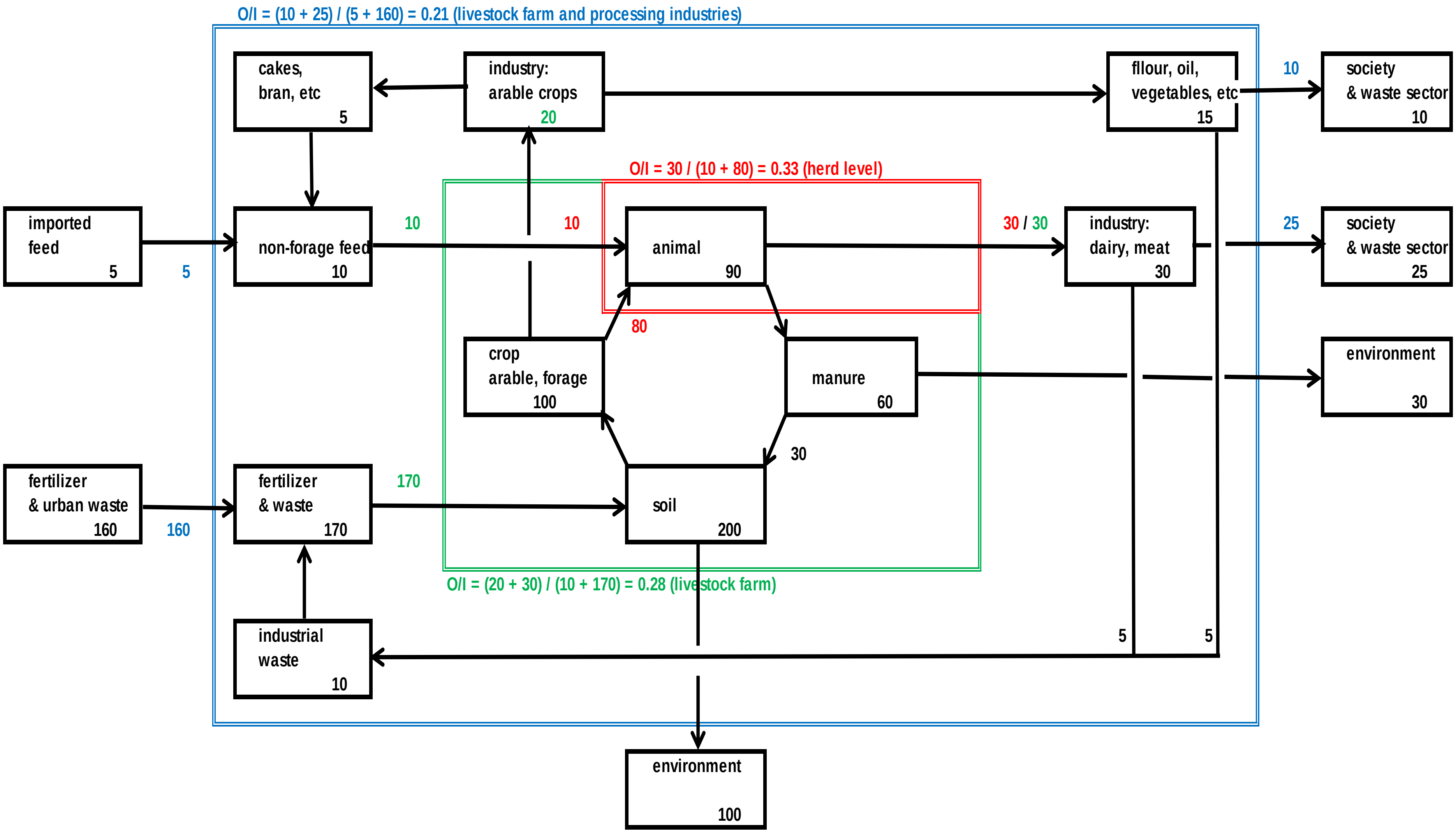
Pitfalls: Externalisation (2)

Efficiency	Farm A	Farm B	Farm C
animal N to milk & meat N: AP	0.25	0.225	0.20
manure N to soil N: MS	0.90	0.70	0.50
soil N to crop N: SC	0.60	0.55	0.50
crop N to animal N: CA	0.95	0.925	0.90
fraction of crop N *exported*	0.00	0.00	0.40
fraction of feed N *imported*	0.00	0.55	0.00
N output / N input	23%	25%	28%

- Farms differ in externalisation
- Farm with lowest output/input ratio, can still have the best N manager!
- Compare only like with like or dip into the subsystems O/I's!

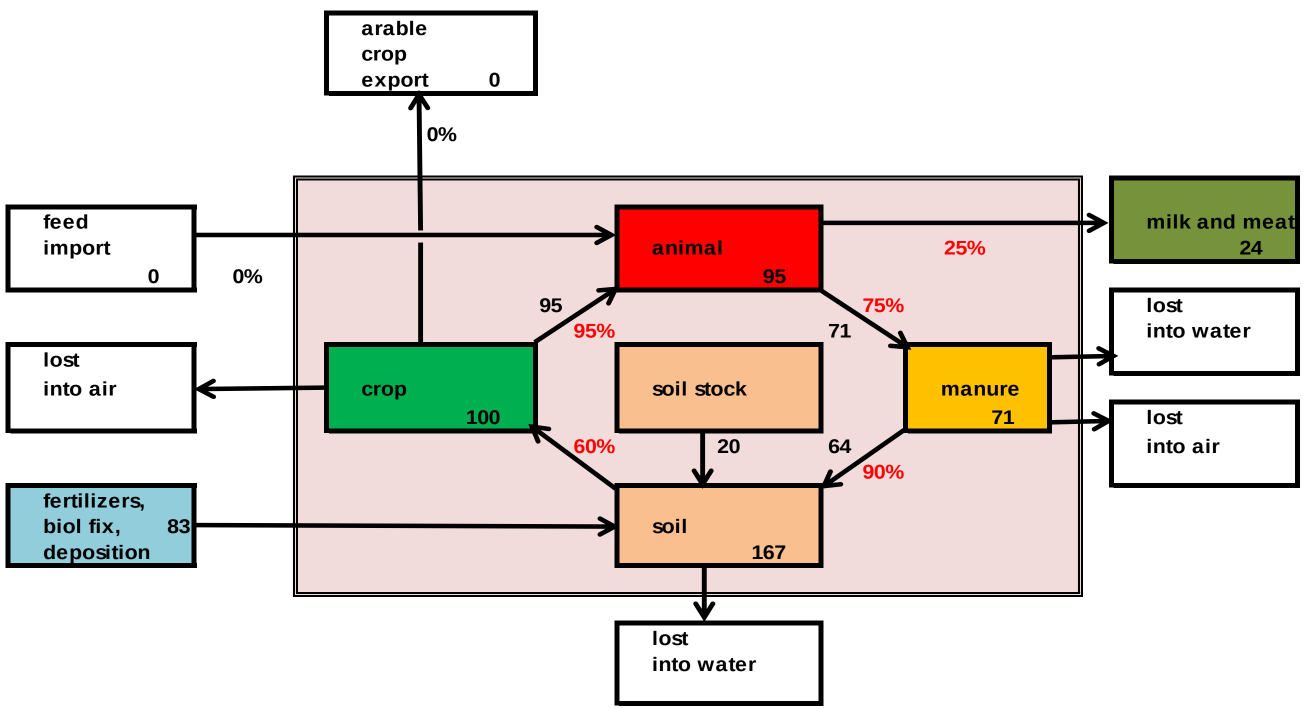
Pitfalls: The efficiency paradox: specialised system seemingly more efficient: 33% > 28% > 21%



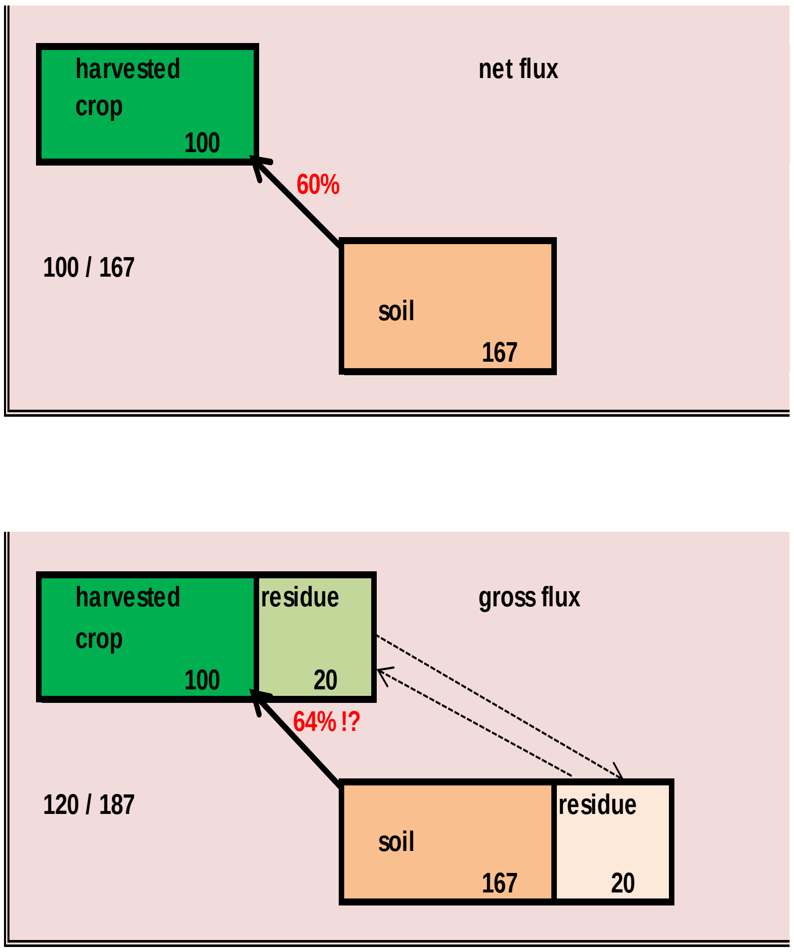
Pitfalls: Stock changes

- Depletion of soil fertility: misleading output / input ratio: Farm D 29% versus Farm A 23%

FARM D: output / input (*(kg N per ha)/(kg N per ha)*)= 24 / 83 = 29%



Pitfalls: Gross and net fluxes



- Same farm, differently defined subsystem output / input ratio's !
- Accurate definitions of the states matter !

Pros and cons of intensification

- Intensification: *more output with, ideally, a subproportional increase of inputs, i.e. improved resource use efficiency through addition of technology & information*

- Pros
  - Potential savings on land, energy, water and NP inputs per unit output
  - Intensification pays, so higher farm income
- Cons
  - Potential loss of local environmental quality, as surplus = *input* x (1 – O/I)
  - Loss of small-scale mosaics due to upscaling
  - Specialisation frustrates proper recycling
  - Rural unemployment
  - Stronger reliance on external capital, information & fossil resources
  - Lost proximity: transport costs, alienation of urban public

Conclusions

- NP surpluses (≈ emissions) per unit area and per unit output are both relevant indicators
- NP use efficiencies will not improve automatically
- Measures are needed, but try to target them by analysis:
  - define system boundaries and states
  - compare like with like only !
  - *subsystem* analysis shows where leaks occur and where to focus efforts
- In general: prioritize manure-soil-crop part (MS, SC) over feed conversion (CA, AP) part of the cycle

Thank you for your attention !

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