Learning methodologies and aspects of RA in adult education

Farm gate nutrient use efficiency in different farming systems

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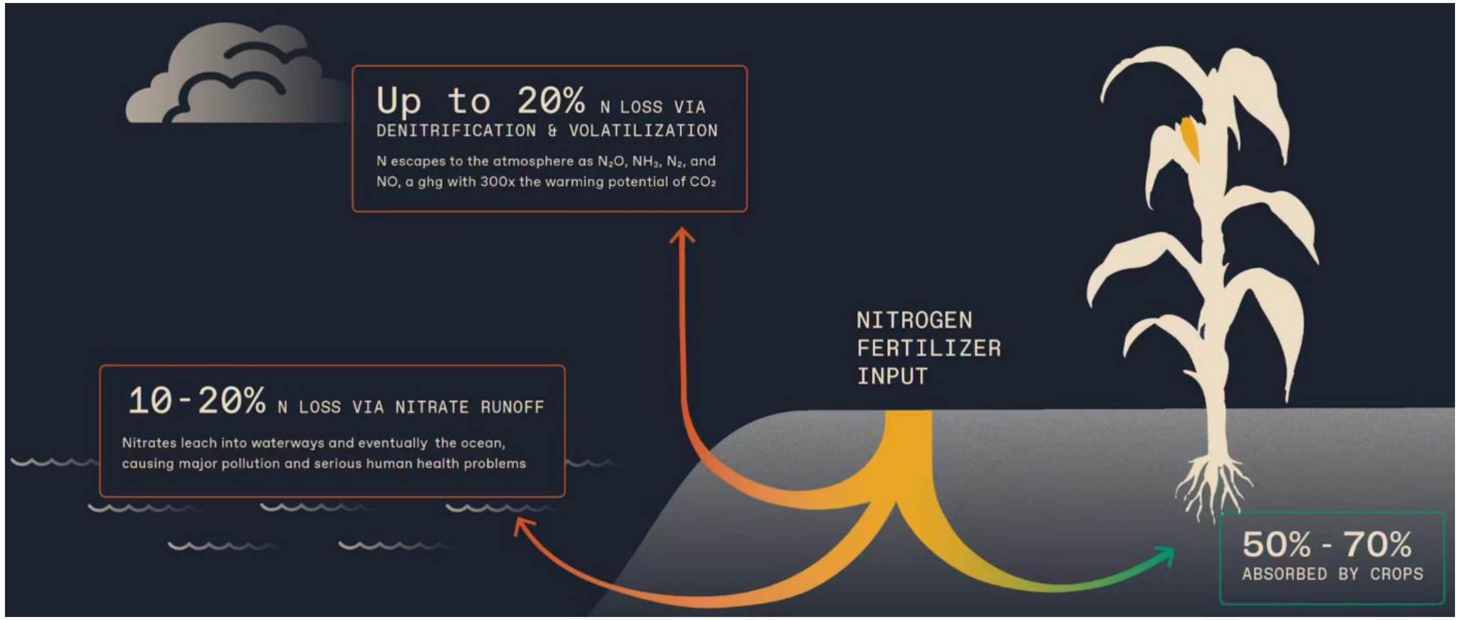
Nitrogen use efficiency – why it is a key aspect of any regenerative practice?

- Nitrogen (N) is essential for life and plays a key role in food production. It is the most important crop-yield limiting factor in the world, together with water. That is why farmers apply animal manures, compost and mineral N fertilizers to cropland. They grow also N fixing crops, such as beans, peas, and clover, and/or N-fixing trees in agroforestry systems.

- With increasing N input, there is an increase in the risk of surplus N application and losses to groundwater, surface water and the atmosphere, which are harmful to biodiversity, the functioning of ecosystems and potentially to human health. Further, N may accumulate in leafy crops and soils to toxic levels. The management of N is therefore important, also because synthetically fixed N is costly. Nitrogen management aims at achieving agronomic objectives (farm income, high crop and animal productivity) and environmental objectives (minimal N losses) simultaneously. However, N management is not easy, because the N cycle is complex and N is easily lost from the farm to the environment.

Nutrient use efficiency NUE

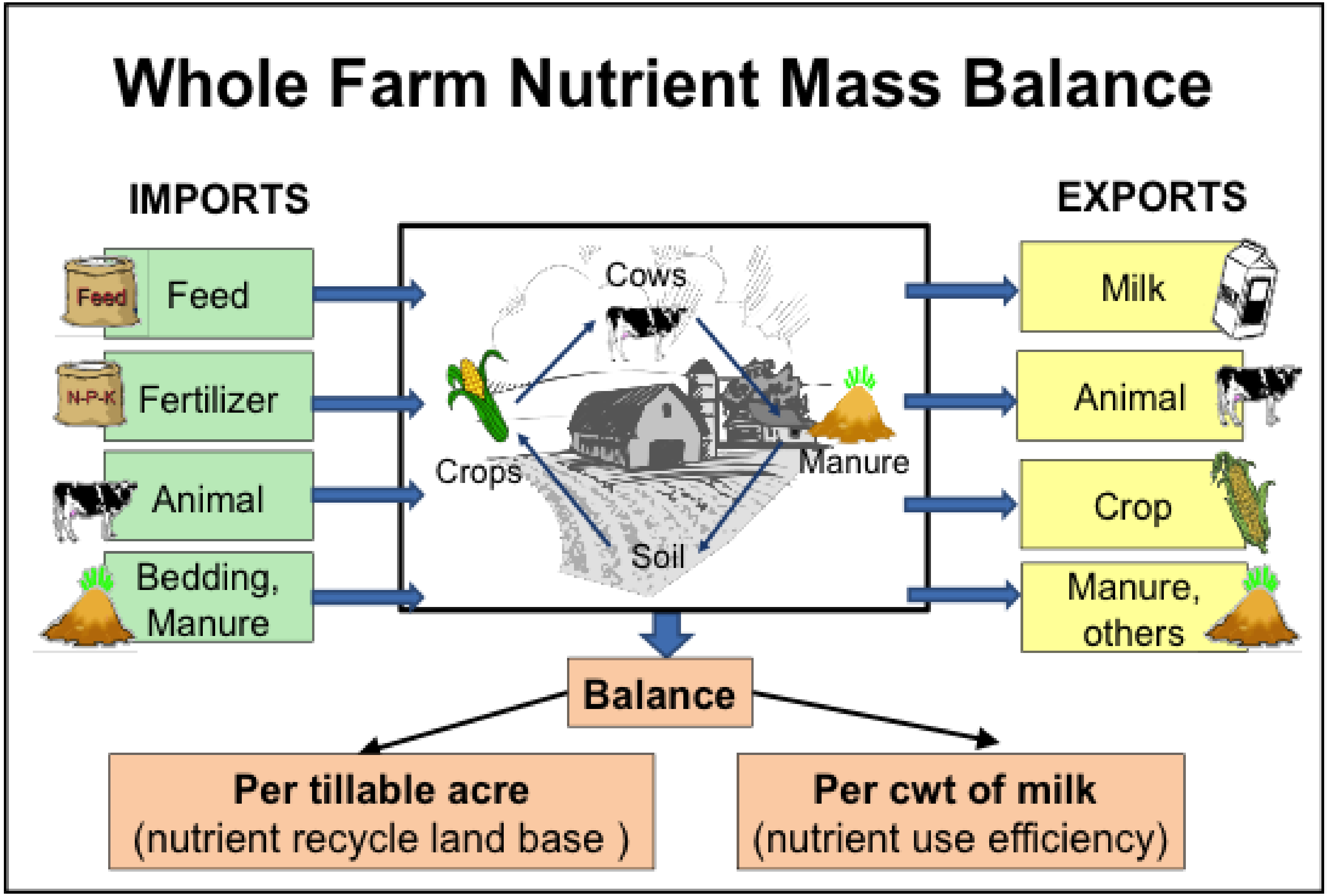
Farm nutrient use efficiency NUE (%) is defined as the ratio of total nutrient input and total nutrient output in products of a farm:



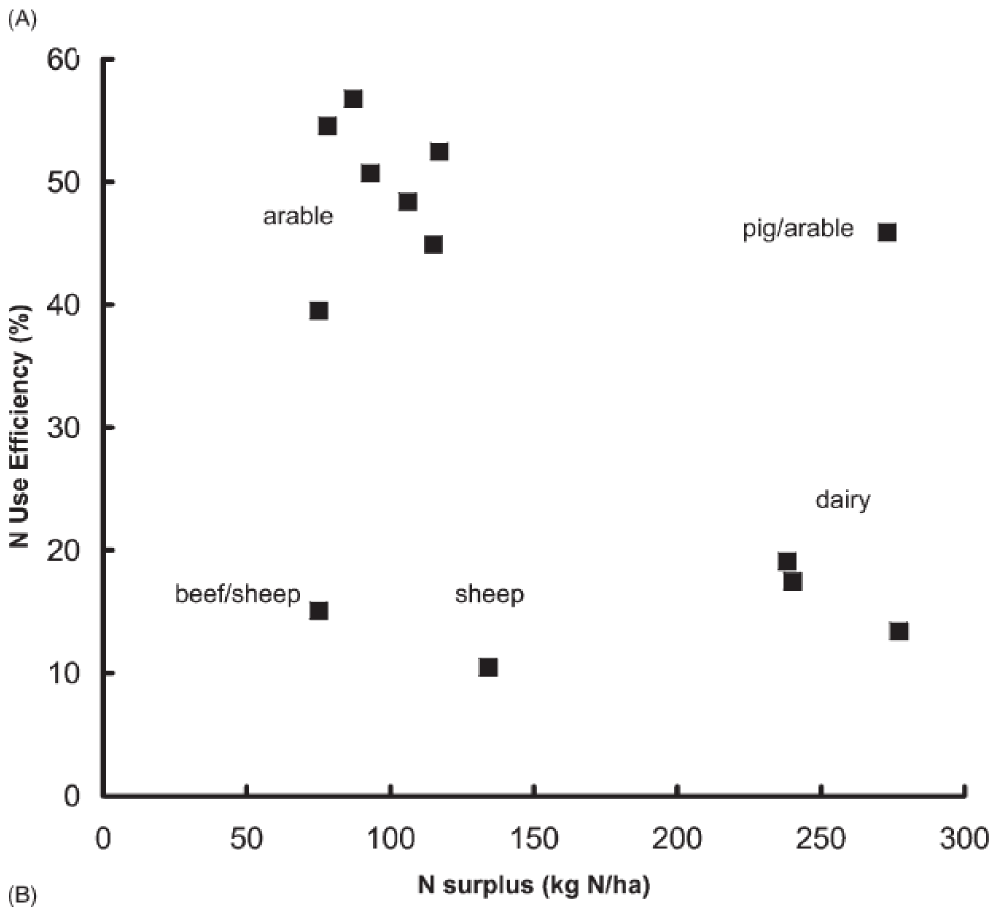
EU Nitrogen Expert Panel (2016) Nitrogen Use Efficiency (NUE) – Guidance document for assessing NUE at farm level. Wageningen University, Alterra, PO Box 47, NL-6700

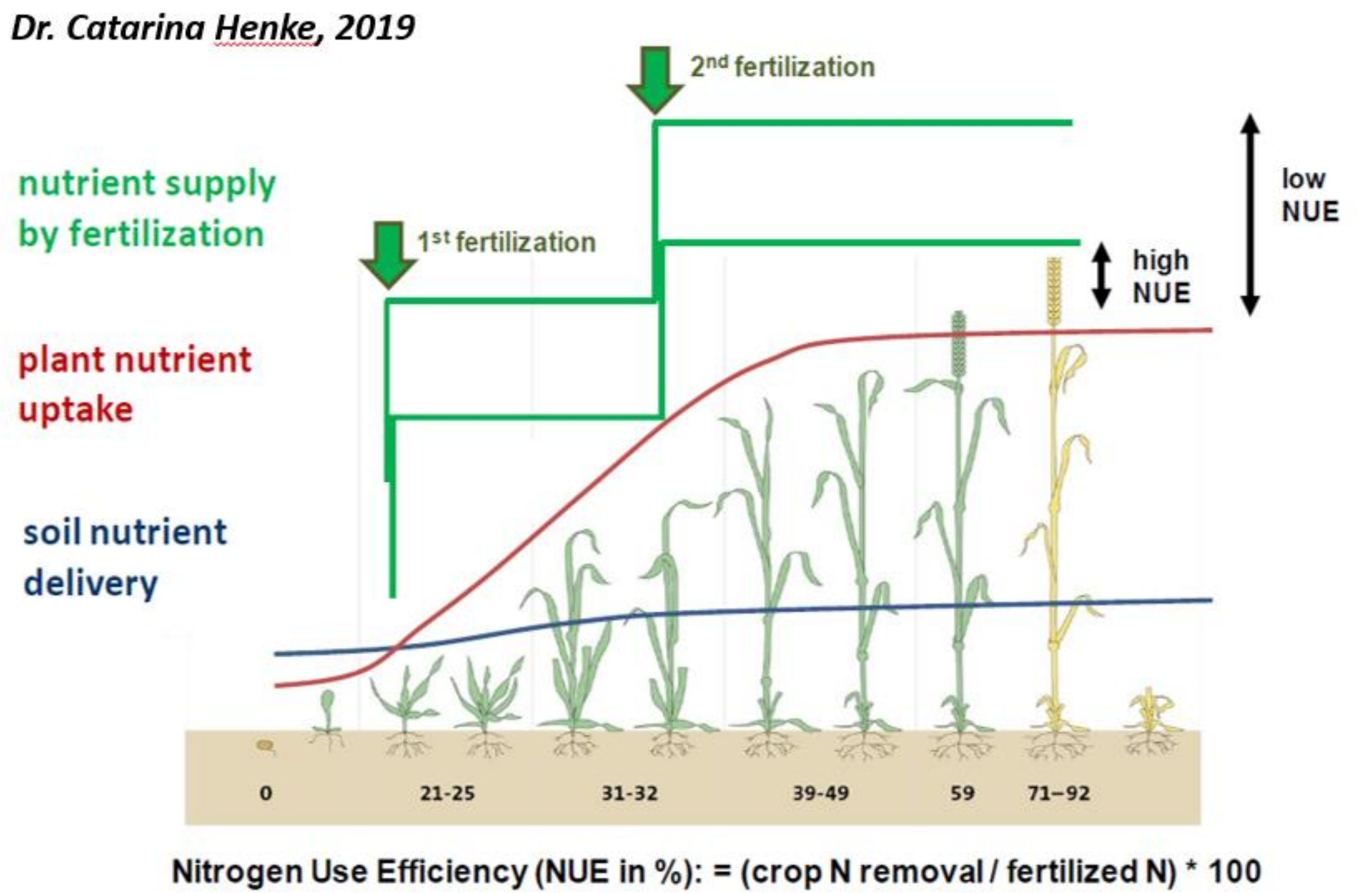
NUE = [Σ(N output) / Σ(N input)] * 100

- N output = nutrient in produce exported from farm (kg nutrient / farmed area (ha)) (kg nutrient/ha/yr)
- N input = nutrient in operating resources and feed (kg nutrient / farmed area (ha)) (kg nutrient/ha/yr)


Whole Farm Nutrient Mass Balance
IMPORTS
EXPORTS
Feed
Feed
N-P-K
Fertilizer
Animal
Bedding, Manure
Cows
Crops
Manure
Soil
Milk
Animal
Crop
Manure, others
Balance
Per tillable acre
(nutrient recycle land base)
Per cwt of milk
(nutrient use efficiency)

Nitrogen use efficiency and nitrogen surplus of various farming systems (general)




Dr. Catarina Henke, 2019
2nd fertilization
nutrient supply
by fertilization
1st fertilization
low
NUE
high
NUE
plant nutrient
uptake
soil nutrient
delivery
0
21-25
31-32
39-49
59
71–92
Nitrogen Use Efficiency (NUE in %): = (crop N removal / fertilized N) * 100

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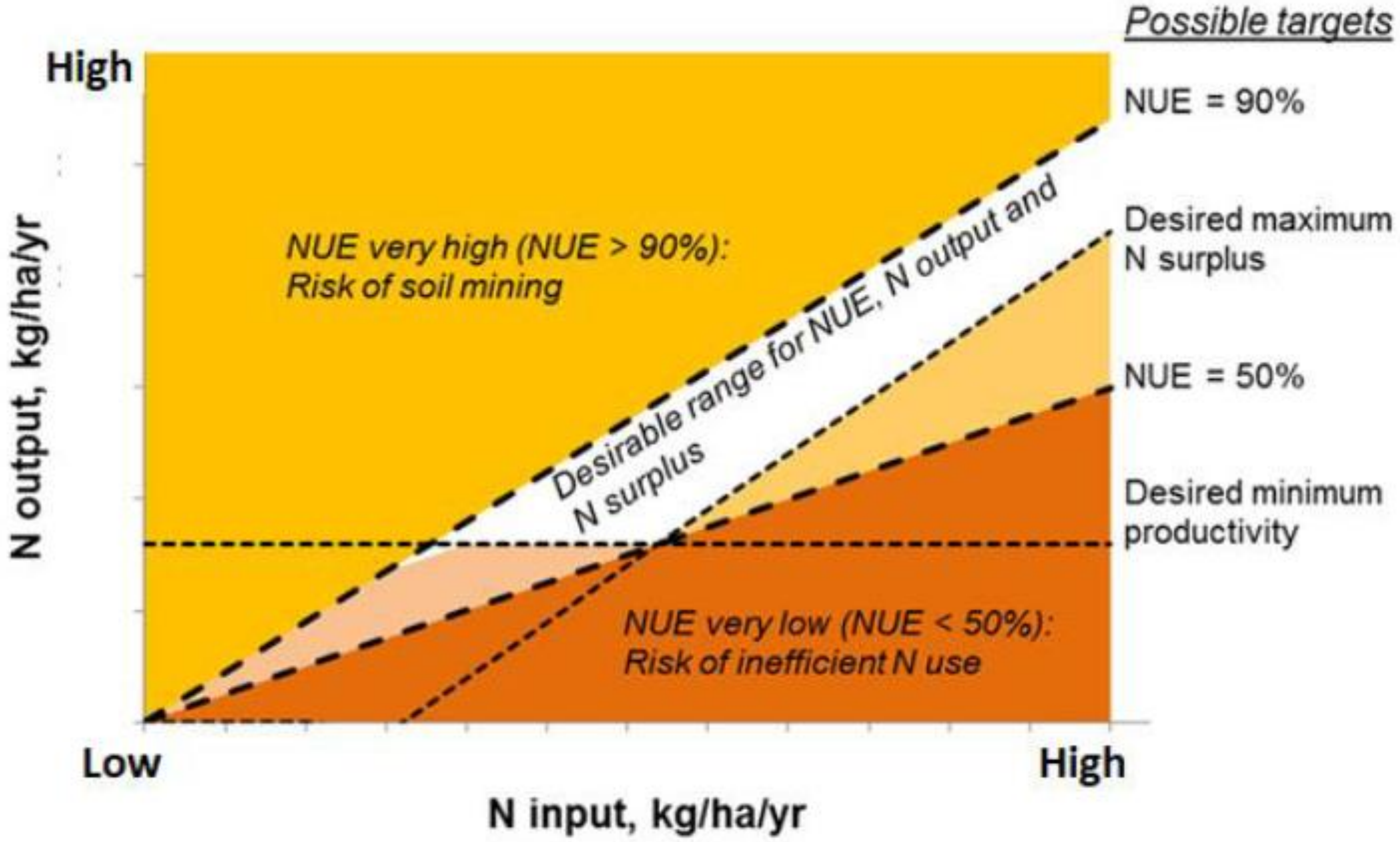
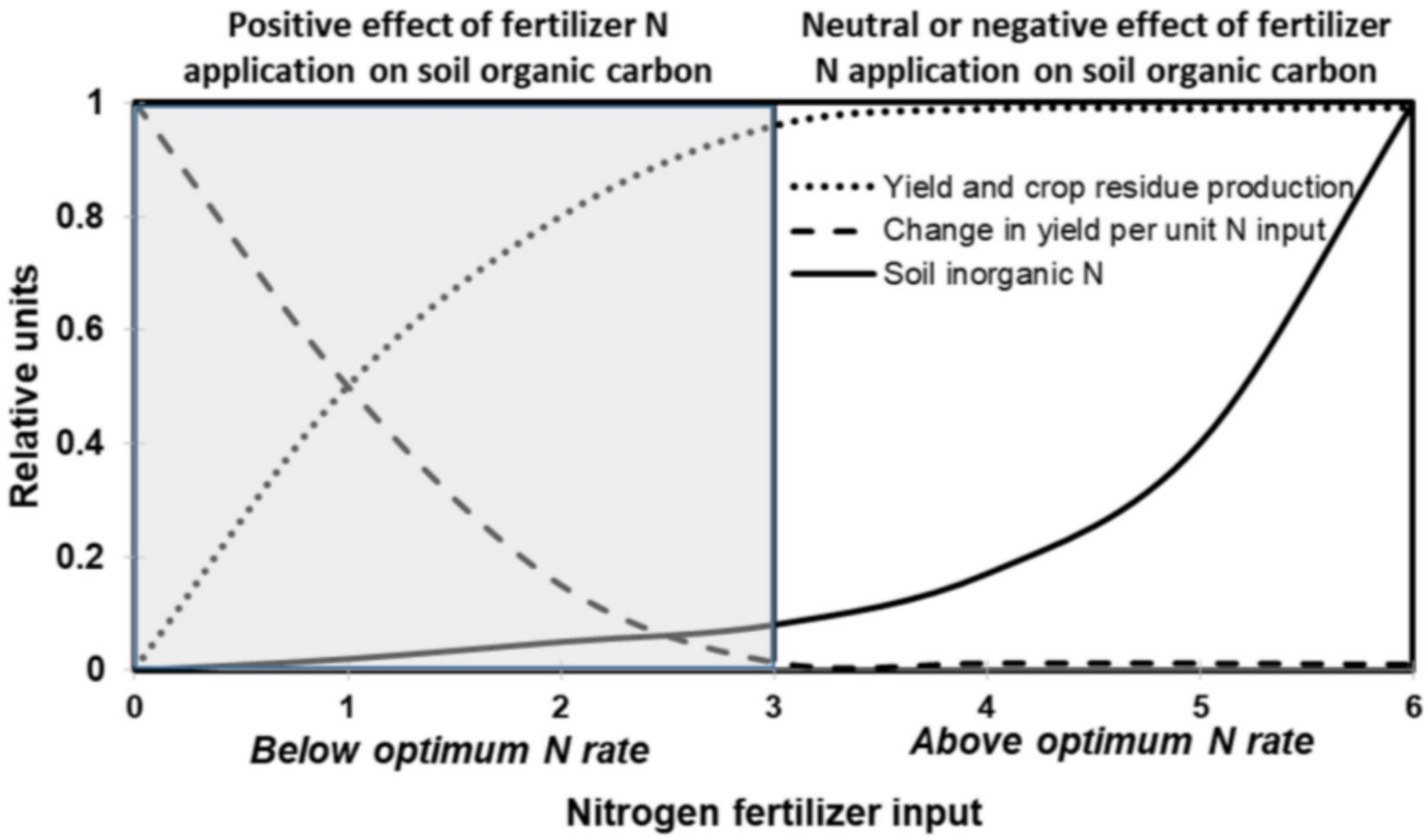
The numbers shown are illustrative of an example system and will vary according to context (soil, climate, crop, farming system).



- The area within the diagonal wedge represents a range of desired NUE between 50% and 90%:
- lower values exacerbate N pollution and higher values risk mining of soil N stocks by soil carbon depletion.
- The horizontal line indicates a desired minimum level of productivity for cropping system.
- The additional diagonal (short dashes) represents a limit related to maximum N surplus to avoid substantial pollution by N losses.
- The combined criteria serve to identify the most desirable range of outcomes (area in white).

Model of optimal N fertilization



Interpretation of NUE for different cropping systems

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Interpretation	Nitrogen Use Efficiency (NUE) (%)		
	Cropping systems	Mixed crop-livestock systems, 1 LSU/ha	Mixed crop-livestock systems, 2 LSU/ha
Soil N mining	>100	>80	>60
Risk of soil N mining	90-100	60-80	50-60
Balanced N fertilization	70-90	40-60	30-50
Risk of N losses	50-70	30-40	20-30
High risk of N losses	<50	<30	<20

- the lower NUE target value (>50%) approximately equal to the current average EU value in cropping systems;
- above the upper NUE target value (>90%), increases the risk of **soil N mining**, which is unsustainable in the long term.

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N excess is related to NUE

NUE = N output / (N surplus + N output) [1]

N excess = N input * (1 - NUE) [2]

Formula [2] shows that low N excess can be achieved with low Ninput and/or high NUE.

Interpretation	Nitrogen surplus (kg/ha/yr)		
	Cropping systems	Mixed crop-livestock systems, 1 LSU/ha	Mixed crop-livestock systems, 2 LSU/ha
Very high	>120	>160	>200
High	80-120	120-160	160-200
Modest	50-80	90-120	130-160
Low	20-50	60-90	100-130
Very low	<20	<60	<100

Greater losses of N in livestock-agricultural farms.

Livestock incorporate only part (20 to 40%) of ingested N in meat, milk and eggs, and excrete the rest in manure and urine. The organically bound N in manure must first be mineralized to be available to plants. Mineral N in manure is also sensitive to losses due to volatilization of NH3, especially during manure storage and immediately after surface application to the soil. N in manure excreta and urine in pastures is sensitive to leaching and denitrification.

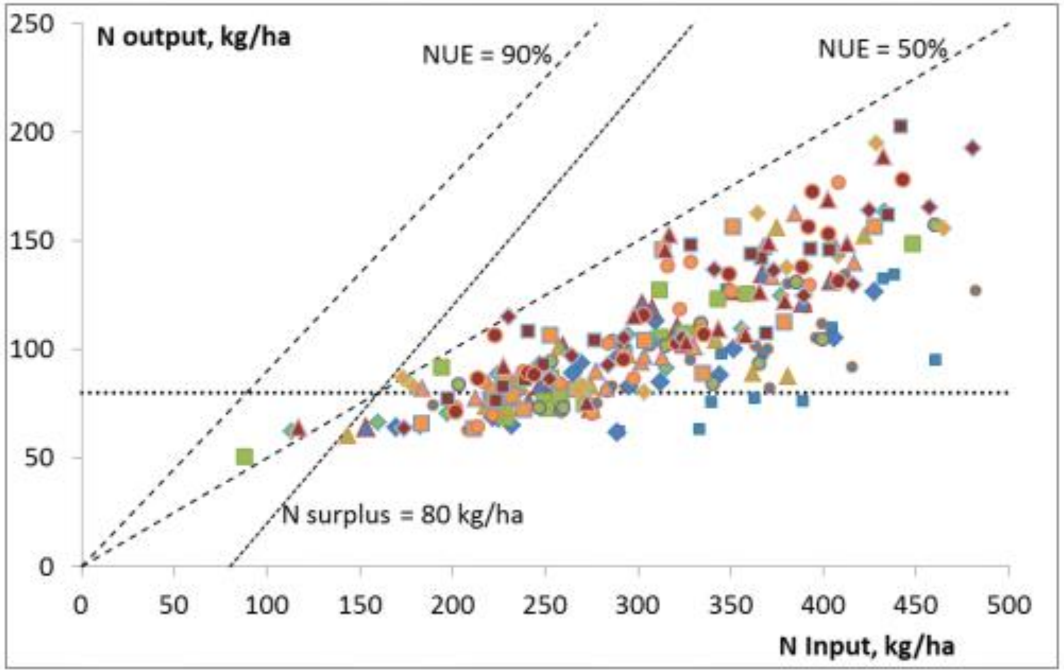
Livestock density classes (1 and 2 LSU/ha).

N surpluses inevitably increase by an average of 40 kg per each livestock unit (LSU = 500 kg livestock weight)**,**

1 LSU (in intensive farming) excretes from 100-140 kg N/a,

"inevitable" losses due to volatilization of NH_3 10-20 kg N, leaching and denitrification losses in manure and urine 10-20 kg N, 10-20 kg of organically bound N in animal manure accumulates in organic matter in the soil and becomes available to the crop only after many years, and the release is poorly coordinated with the needs of crops.

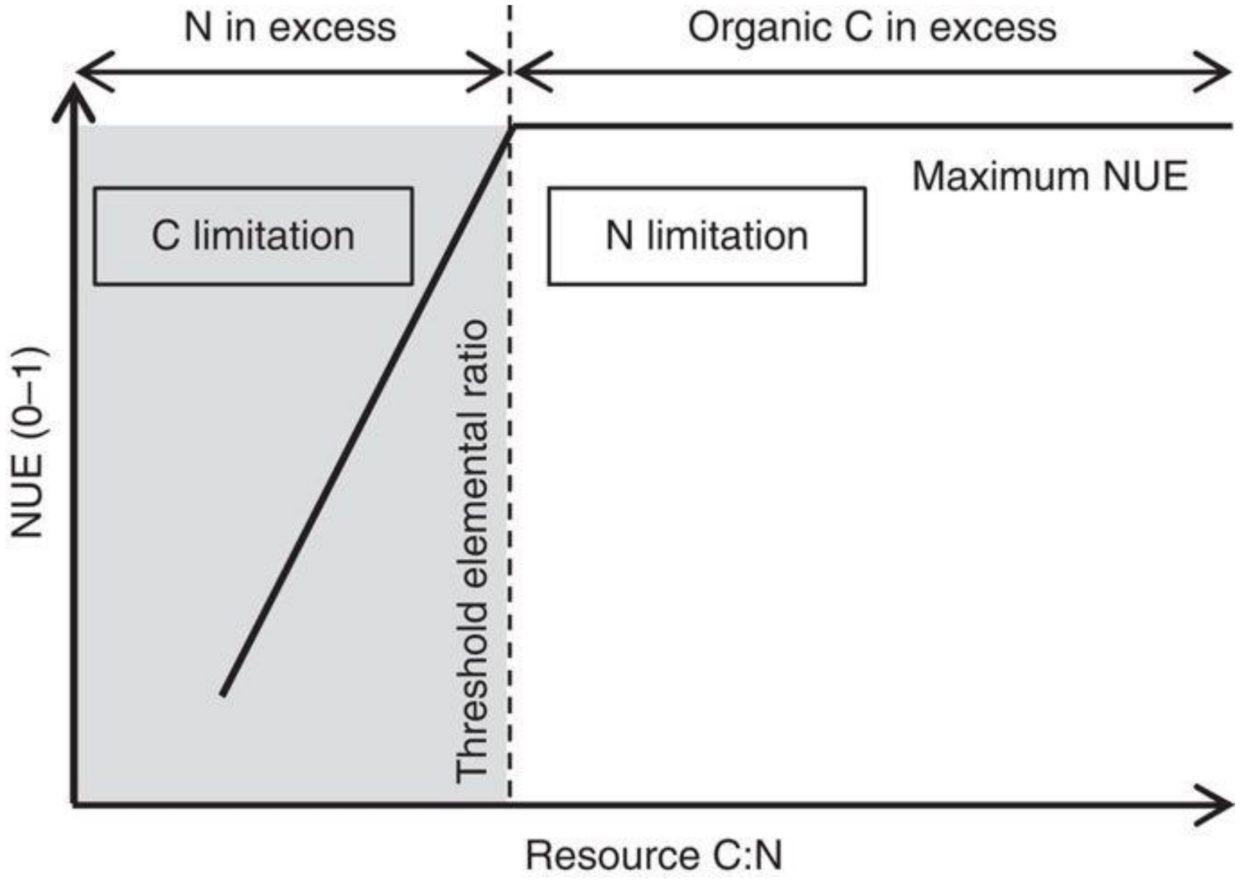
NUE on **16 specialist dairy farms in the Netherlands** (Oenema, 2013).



Excess N was from 50 to 300 kg per ha per year. Apparently, the proposed target values for NUE (50 to 90%), N output (>80 kg/ha/year) and N surplus (<80 kg/ha/year) are not achieved. This is mainly due to the relatively low conversion efficiency of plant protein to milk and to meat protein and the relatively high loss of N through ammonia volatilization, N leaching (from pasture urine patches) and denitrification **(Oenema, 2013).**

https://www.nature.com/articles/ncomms4694

NUE = nitrogen use efficiency = nitrogen utilization for growth and yield in relation to the introduction of organic fertilizers into the soil and their C:N ratio



Two equal size farms tested in Slovenia with very similar intensities - different specializations leading to very different results in NUE

Farm 1	Farm 2
Cattle - milk	Field crops – cattle (milk)
20 ha FLU (5.3 ha field)	20 ha FLU (11.6 ha field)
4.5 ha maize	5.6 ha potato, 5 ha maize
53 LU (2.7 LU/ha FLU)	48 LU (2.4 LU/ha FLU)
NPK+CAN: 8.4 t/a	NPK+CAN: 16 t/a
Imported feed: 44 t/a	Imported feed: 27 t/a
Milk production: 170,000 l/a	Milk production: 120,000 l/a

Nutrient balance at the farm gate

- Fertilizer and feed purchase
- Sale of produce
- Nutrients content in inputs and products
- Balance period: 1 average year

Input of nutrients to the farm

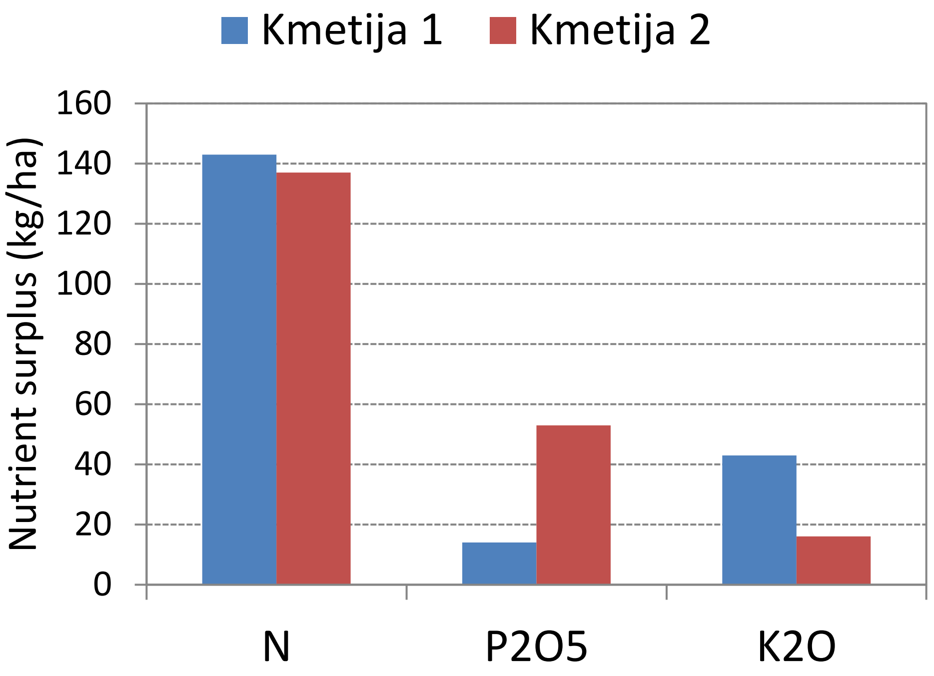
	Farm 1			Farm 2		
	N	P2O5	K2O	N	P2O5	K2O
Seed potatoes				23	9	39
Feed for chickens and pigs	12	5	5			
Feeders for calves	55	24	21			
High protein feed	1589	427	544	808	379	381
Minerals and vitamins		56			61	
Purchased feed	179	90	210	184	92	319
Nitrogen fertilizers	1772			2160		
NPK fertilizers	450	450	450	1219	1219	1219
The symbiotic fixation of N	426					
Together	**4483**	**1052**	**1230**	**4394**	**1760**	**1958**

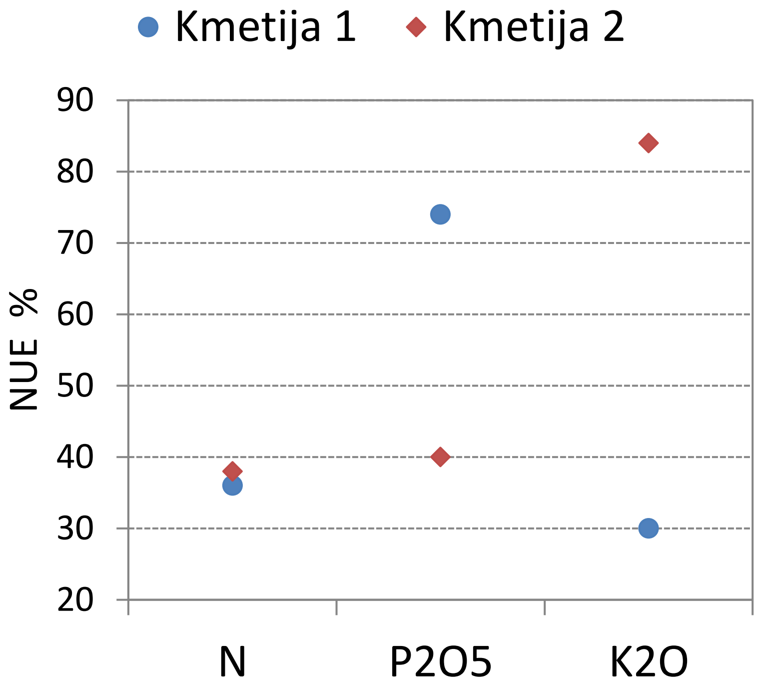
Nutrient output from the farm

	Farm 1			Farm 2		
	N	P2O5	K2O	N	P2O5	K2O
Vegetables				61	25	90
Potatoes				777	311	1332
Milk	956	403	298	635	267	198
Eliminated cows	488	273	47	178	99	17
Other bovine animals	184	104	18	10	6	1
Together	**1628**	**780**	**363**	**1661**	**708**	**1638**

Balance and utilization of nutrients on the farm

(kmetija = farm)





N surplus for these farms are in the range 130 – 160 kg N/ha, wich is moderate to high for these farms systems.

Balanced nitrogen use efficincy (%) for these two farms would be 30 – 50 %.

Low NUE for potassium in Farm 1 (low potassium export from farm with milk sold):

The opposite at Farm 2: low NUE for P and high for K due to potato produce export containg high K content.

NUE on the two farms – conclusions

- Great importance of feed and fertilizers
- Nutrients (feed) > nutrients (fertilizers)
- The product exported from the farm defines the nutrient output
- Moderately good N utilization
- Different use efficiency for P and K due to farm production orientation.