# European N budgets for farm, land and soil: N surplus, N use efficiency and N dynamics

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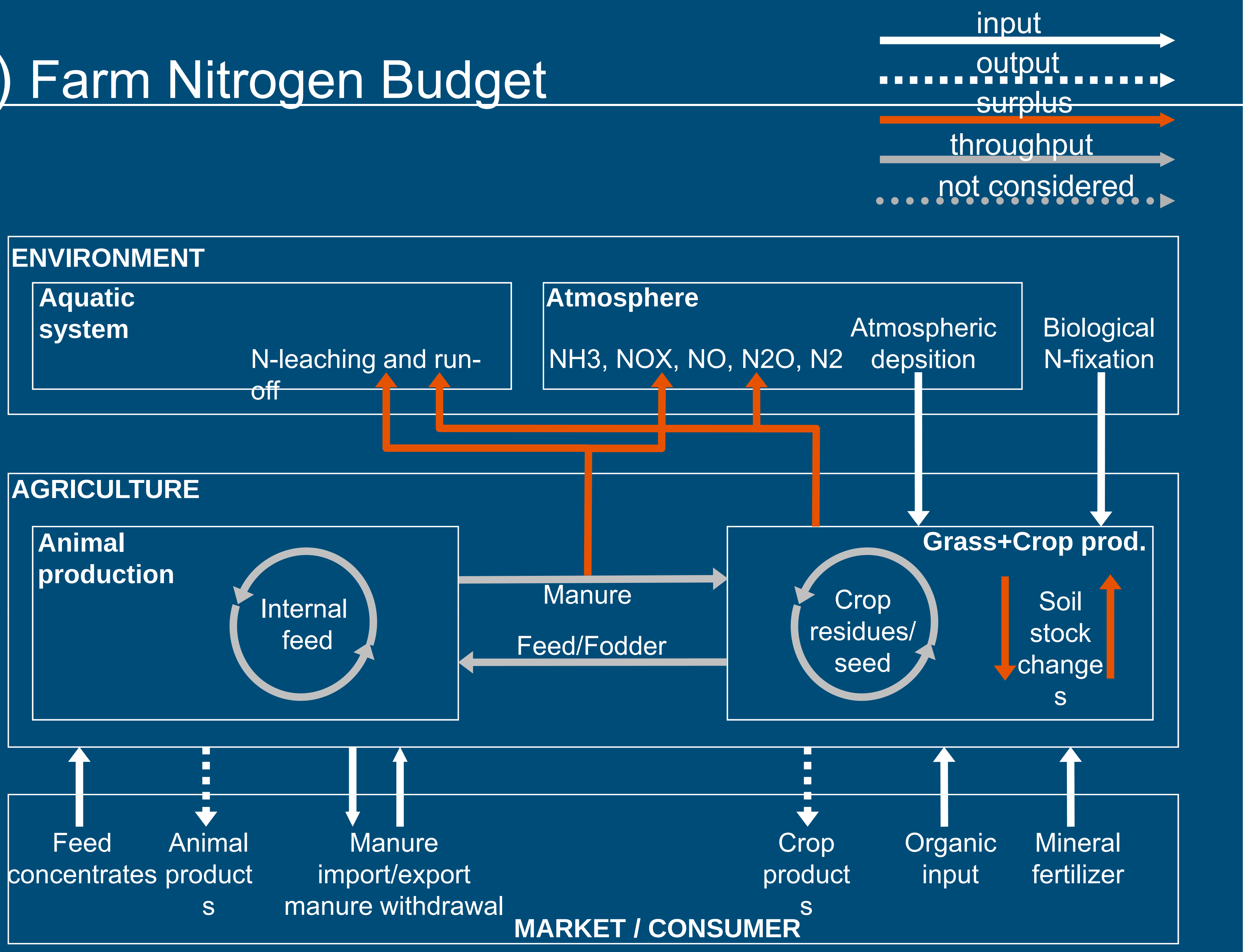
# Contents

- Farm, land and soil nitrogen budgets
- The models CAPRI and INTEGRATOR
- N surplus and N use efficiency in farm and soil budgets related to agricultural production structure
- Dynamics in land N budgets in agricultural and terrestrial systems

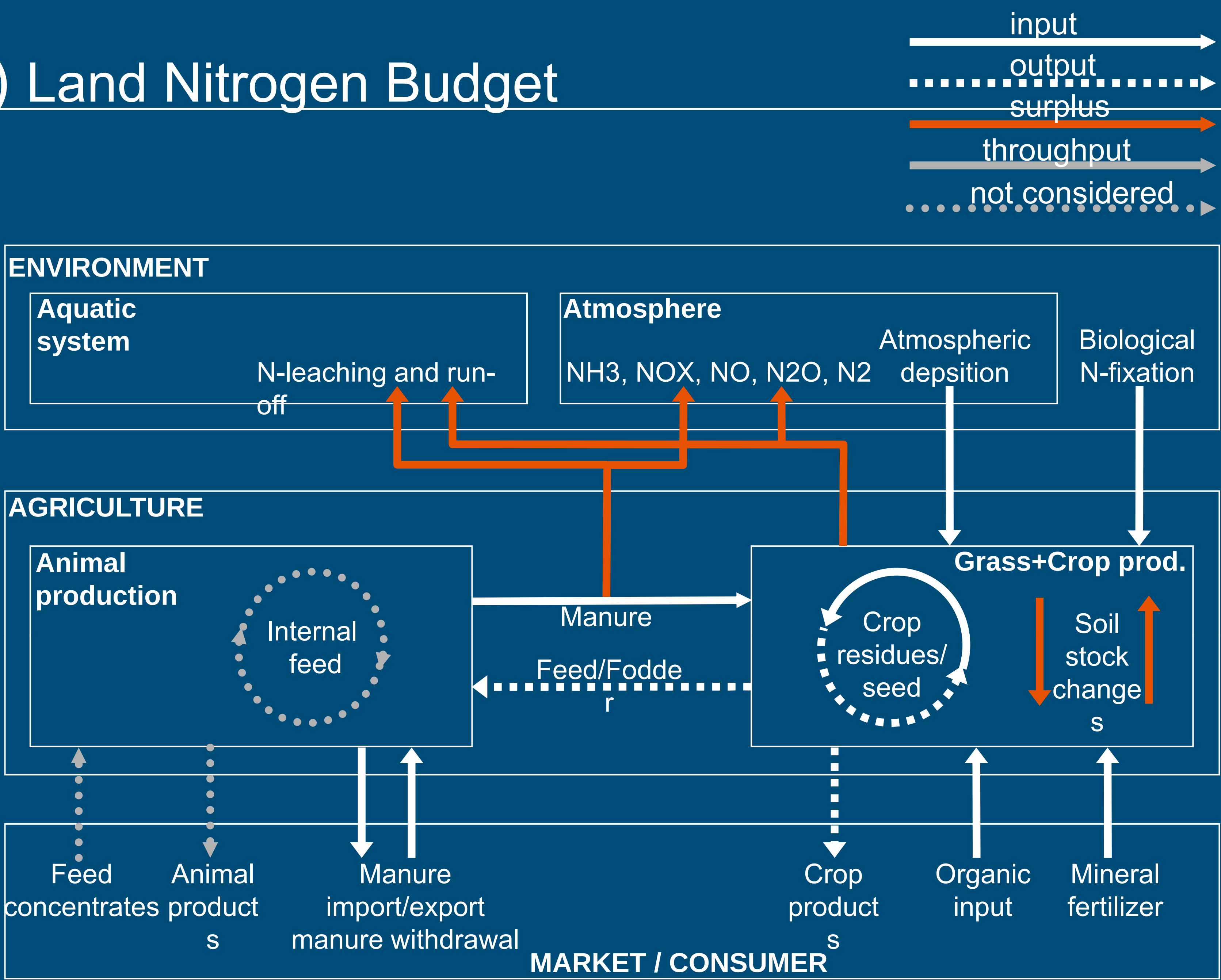
# Farm, land and soil nitrogen budgets

- Farm N budget (farm-gate budget) record N in all kinds of products that enter and leave the farm: output is crop and animal products.
- Land N budget (OECD gross N balances) record N that enters and leaves the farmland (includes housing/manure storage systems and soil): output is crop products and grass
- Soil nitrogen budgets: (soil surface budget) record N that enters and leaves the soil: output is crop products and grass.

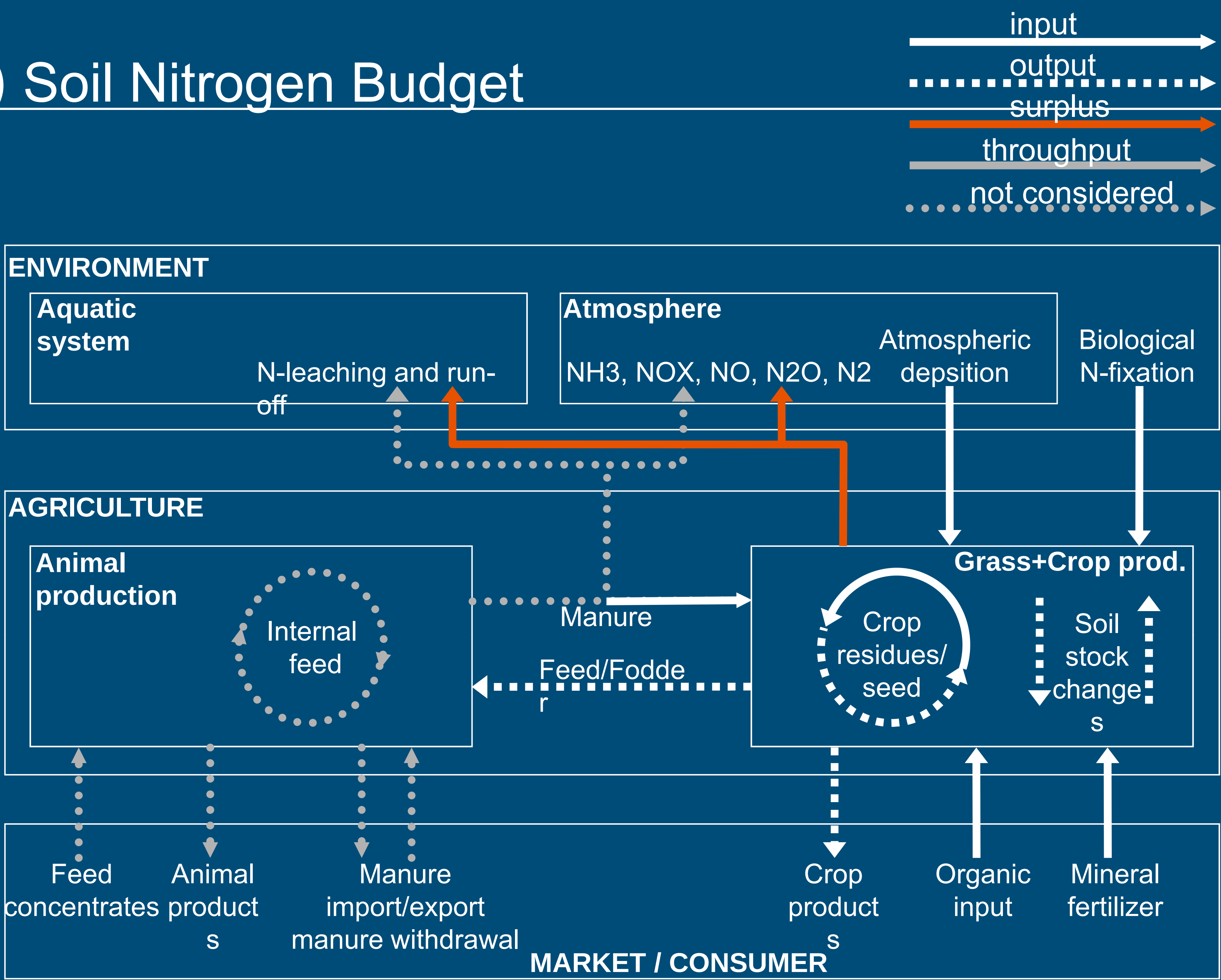
# a) Farm Nitrogen Budget



# b) Land Nitrogen Budget



# c) Soil Nitrogen Budget



# Inputs in regional farm, land and soil N budgets

| **Inputs** | **Flux-terms** | **Farm system budget** | **Land system budget** | **Soil system budget** |
|---|---|---|---|---|
| Mineral N fertilizer | $N_{minfert}$ | Fertilizer *purchase* | Fertilizer *application* | Fertilizer *application* |
| Manure N input | $N_{manure}$ | Trade of manure between farms[1] | Manure *excretion* in housing systems and by grazing animals on pasture | Manure *application* and manure excretion *by grazing animals* on pasture |
| Other forms of N fertilizer (compost, sewage sludge) | $N_{other} = N_{compost} + N_{sewage\_sludge}$ | yes, if data available | yes, if data available | yes, if data available |
| Imported products | $N_{import}$ | Feed purchases, animal and crop products | no | no |
| Biological N-fixation | $N_{biofix}$ | yes | yes | yes |
| N deposition | $N_{atmdep}$ | yes | yes | yes |

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# Outputs in regional Farm, land and soil N budgets

| Outputs | Flux-terms | Farm system budget | Land system budget | Soil system budget |
|---|---|---|---|---|
| Exported products | $N_{products}$ $N_{rem}$ $N_{residue}$ | Sold animal (meat, milk etc.) and crop products[2]. | Plant products in arable systems and the net removal of grass in livestock systems[2]. | Plant products in arable systems and the net removal of grass in livestock systems[3]. |
| N pool changes | $N_{pool}$ | No | Usually not. estimated in some models, e.g. CAPRI and INTEGRATOR | Yes |
| Emissions of N to air ($NH_3$, $N_2O$, NOx, $N_2$) | $N_{housing}$ $N_{mms}$ $N_{soil}$ | Losses from housing/ manure management systems and soil | Losses from housing/ manure management systems and soil | Losses from soil |
| Leaching and runoff of N to ground- and surface water | $N_{leaching}$ $N_{runoff}$ | Losses from housing/ manure management systems and soil | Losses from housing/ manure management systems and soil | Losses from soil |

# Use of the CAPRI and INTEGRATOR model

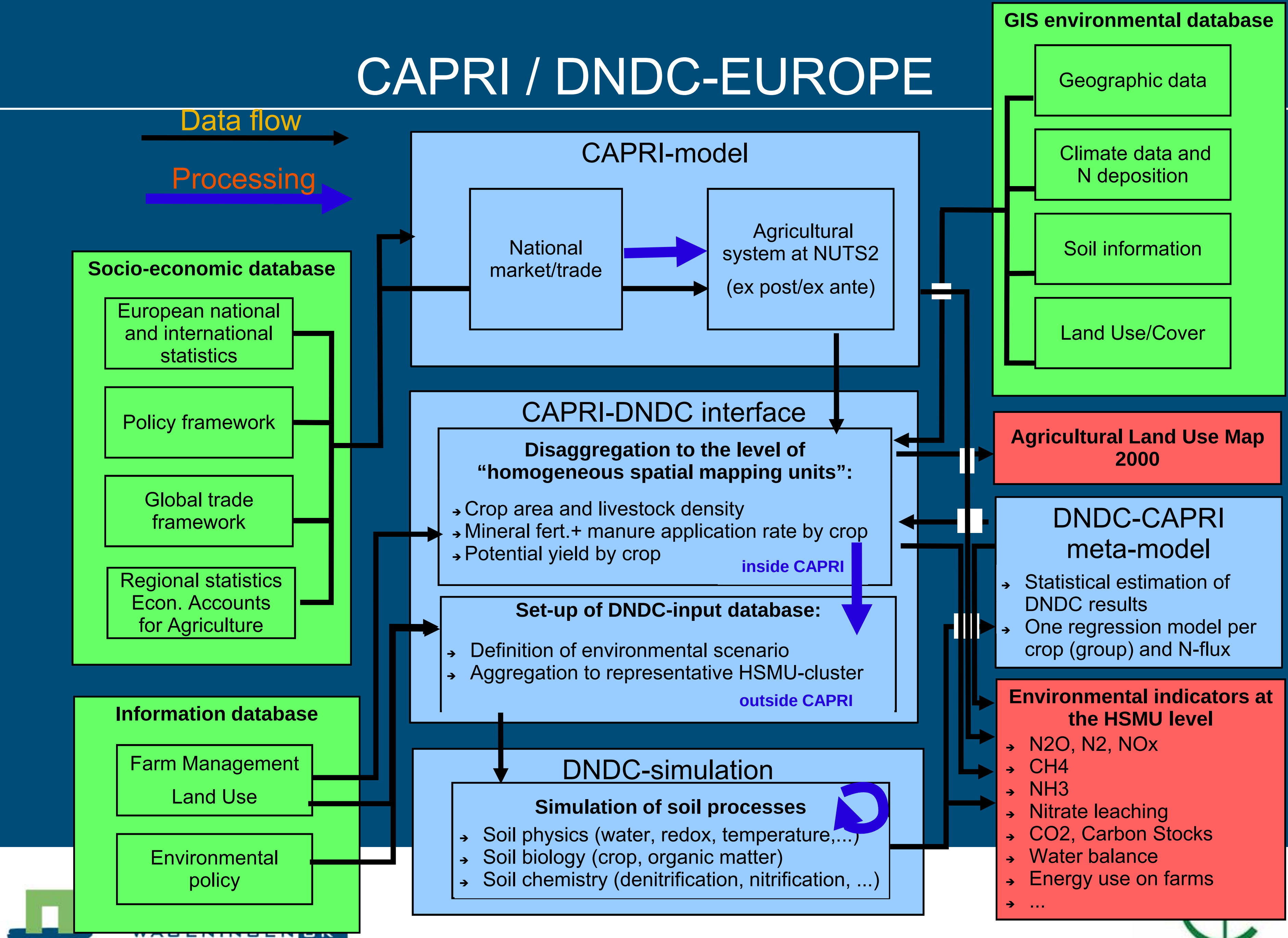
- CAPRI was used to illustrate N surplus and NUE relations in farm, land and soil budgets in agro–ecosystems as it can estimate all N budgets
- INTEGRATOR was used to assess dynamics in land (and soil) N budgets in both agro–ecosystems and other terrestrial systems

# Characteristics of CAPRI and INTEGRATOR

Overview of available models approaches

| Model approach | Method | Sectors considered | Area involved | Geographic resolution | Time |
|---|---|---|---|---|---|
| **CAPRI** | Economic model for agriculture, linked to mechanistic model to simulate soil N budget | Agriculture | EU 27 | HSMU | 2002 |
| **INTEGRATOR** | Adapted MITERRA approach for agricultural systems. Statistical model for terrestrial systems | Agriculture, terrestrial systems | EU27+3 | NCU | 1970-2030 |

# CAPRI / DNDC-EUROPE




Leip et al, 2008, Biogeosciences

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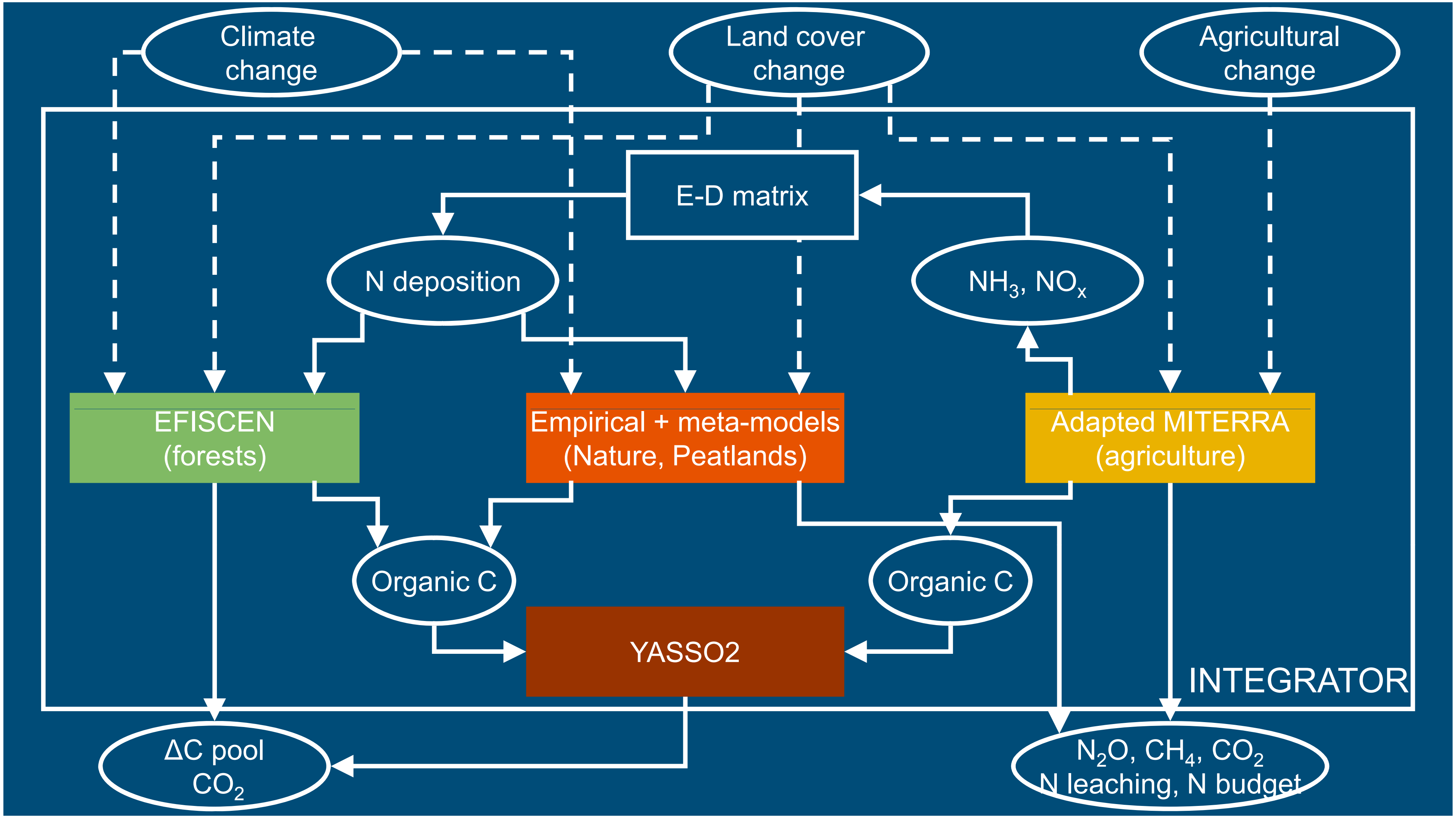
# Integrator model

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# Data sets to estimate N inputs and outputs

| Model inputs | CAPRI | INTEGRATOR |
|---|---|---|
| Land cover | EUROSTAT production statistics | CLUE model outcome, based on CORINE 2000. |
| Land use (crops) | LUCAS crop database | CAPRI data. |
| Animal livestock numbers | EUROSTAT production statistics. | FAO database |
| Nitrogen fertilizer application | FAO/ IFA/ IFDC data | FAO/ IFA/ IFDC data |
| N excretion factors | Calculated as N input (feed, fodder) minus N output (products sold). | N excretion model scaled to GAINS data in 2000 |
| N deposition levels | EMEP model estimates | EMEP model estimates |

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# Data sets to estimate N inputs and outputs

| Model inputs | CAPRI | INTEGRATOR |
|---|---|---|
| Biological N Fixation rates | Fixed fraction of aboveground nitrogen uptake<br>0.05 for fodder on arable land.<br>0.75 for pulses and legumes | 2 kg N $ha^{-1}$ for arable land<br>5 kg N $ha^{-1}$ and grassland<br>1.2-1.3 times the harvested N amount for pulses/ legumes |
| Crop yields | EUROSTAT production statistics | FAO database |
| Nitrogen contents in crops | Constant values | N contents varying with N input |
| Nitrogen-emission fractions | $NH_3$ emission factors: GAINS.<br>$N_2O$ emission factors: IPCC | $NH_3$ emission factors: GAINS $N_2O$ emission factors: function of N source, application technique, soil type, pH, land use, precipitation |

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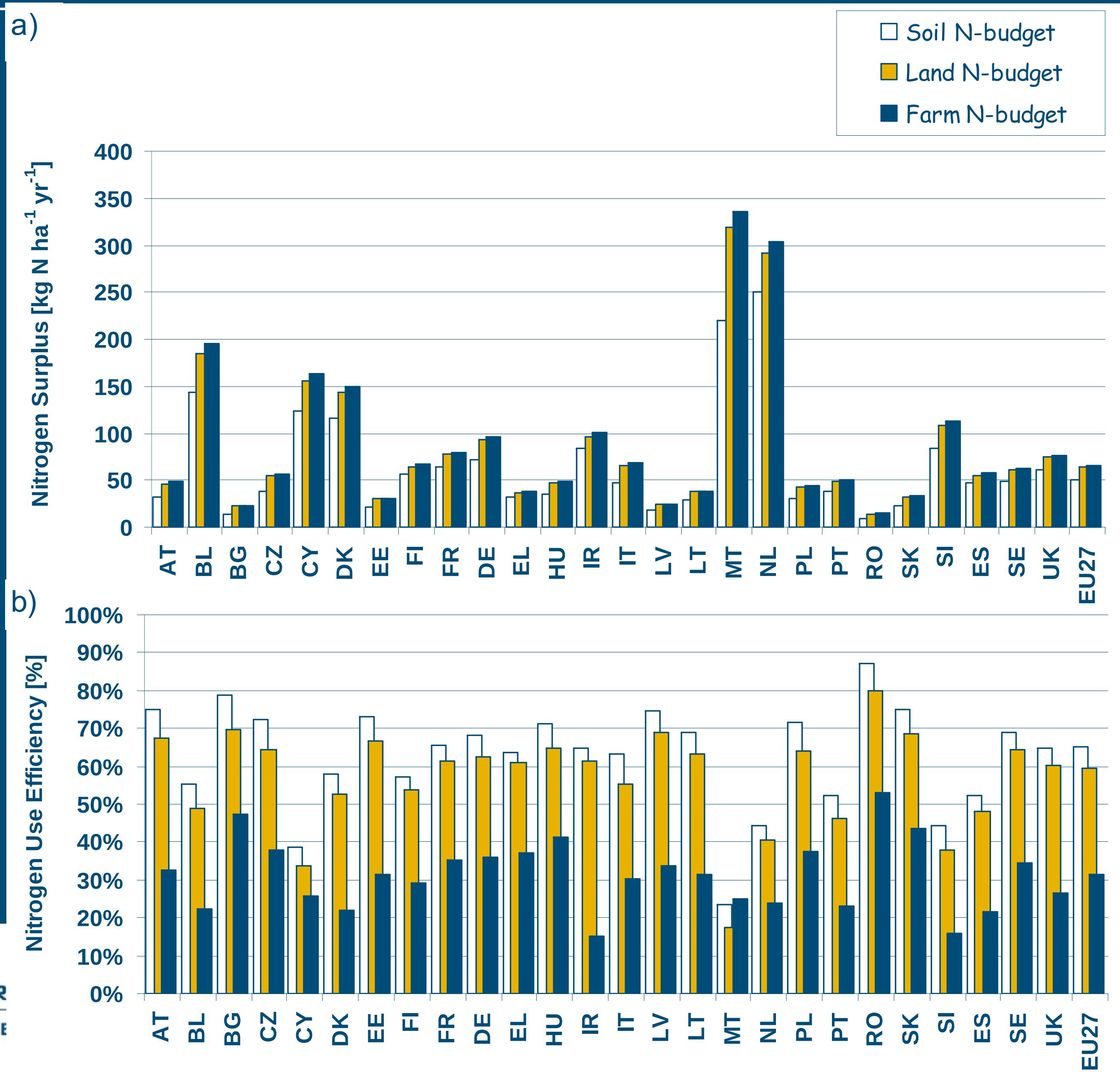
# N surplus and NUE in different N budgets

- $N_{surplus} = N_{in} - N_{removal}$ (1)
  - farm: removal output is crop and animal products.
  - Land and soil: output is crop products and grass (feed and fodder)
- $NUE = N_{removal} / N_{in}$ (2)

Combination of 1 and 2 gives:

- $NUE = 1 - (N_{surplus}/N_{in})$ (3)

# NS and NUE for farm, land and soil N-budgets

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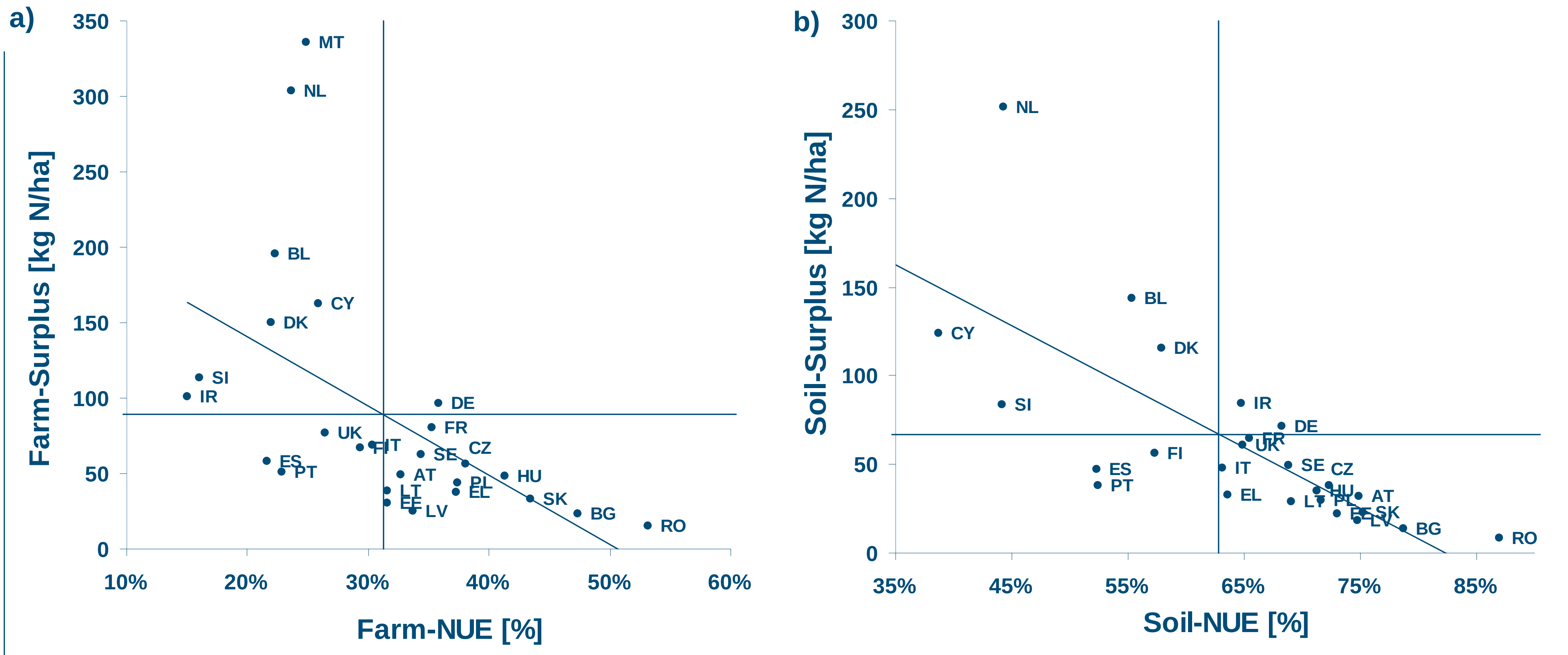
# Relation N surplus and NUE in farm and soil budgets

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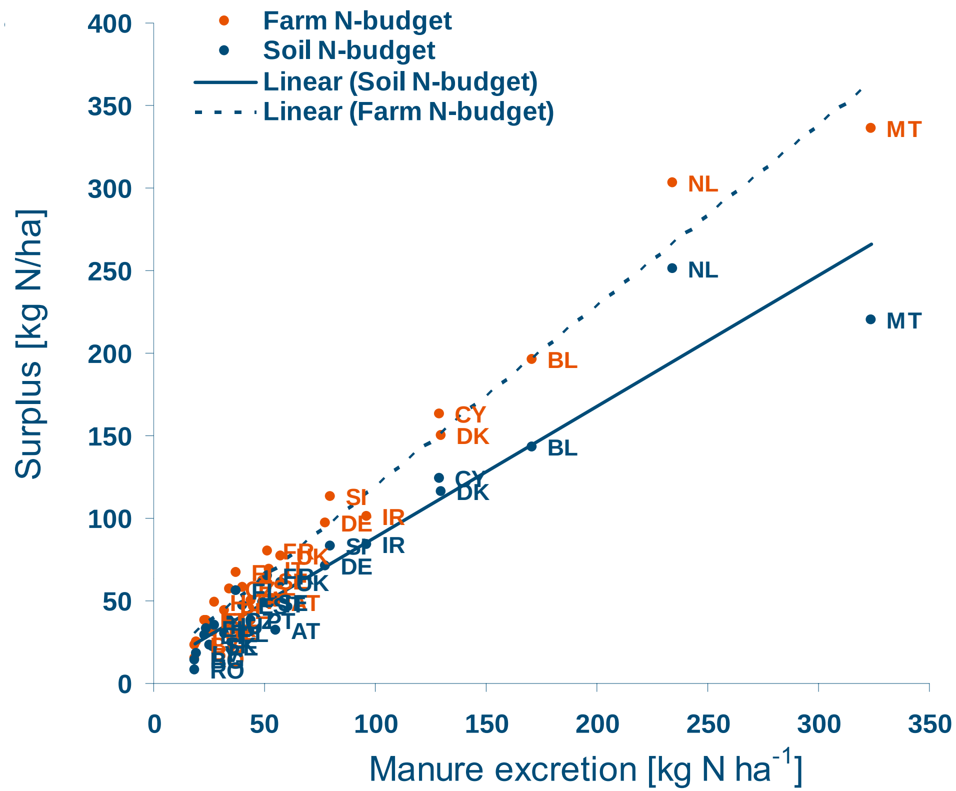
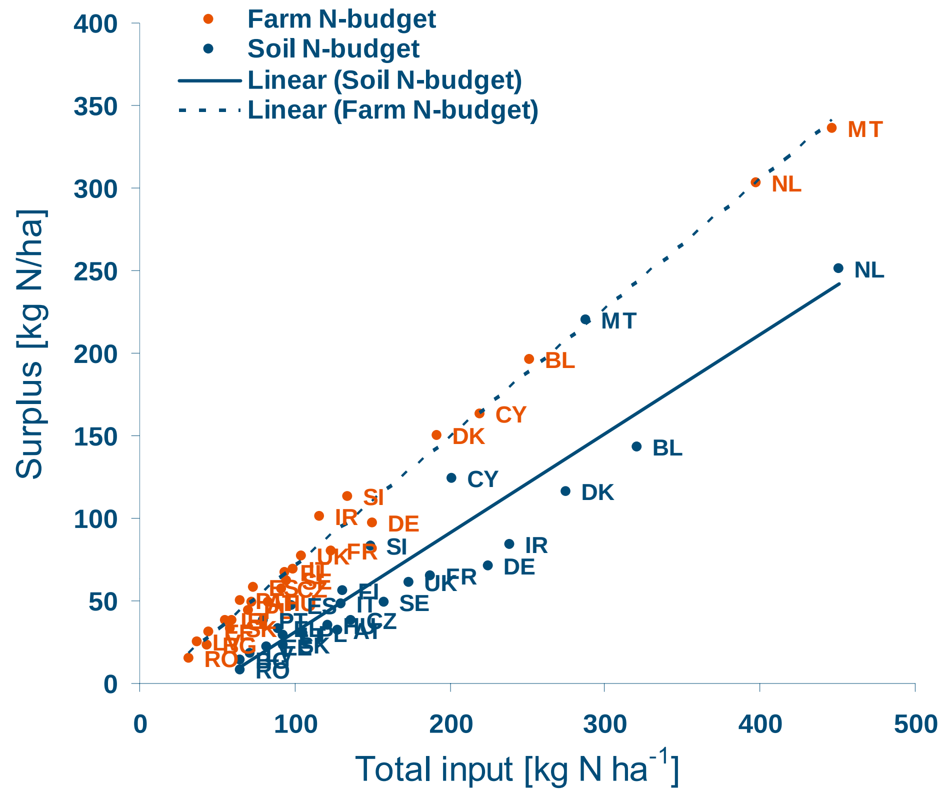
# Relation N surplus in farm/soil budget and N inputs

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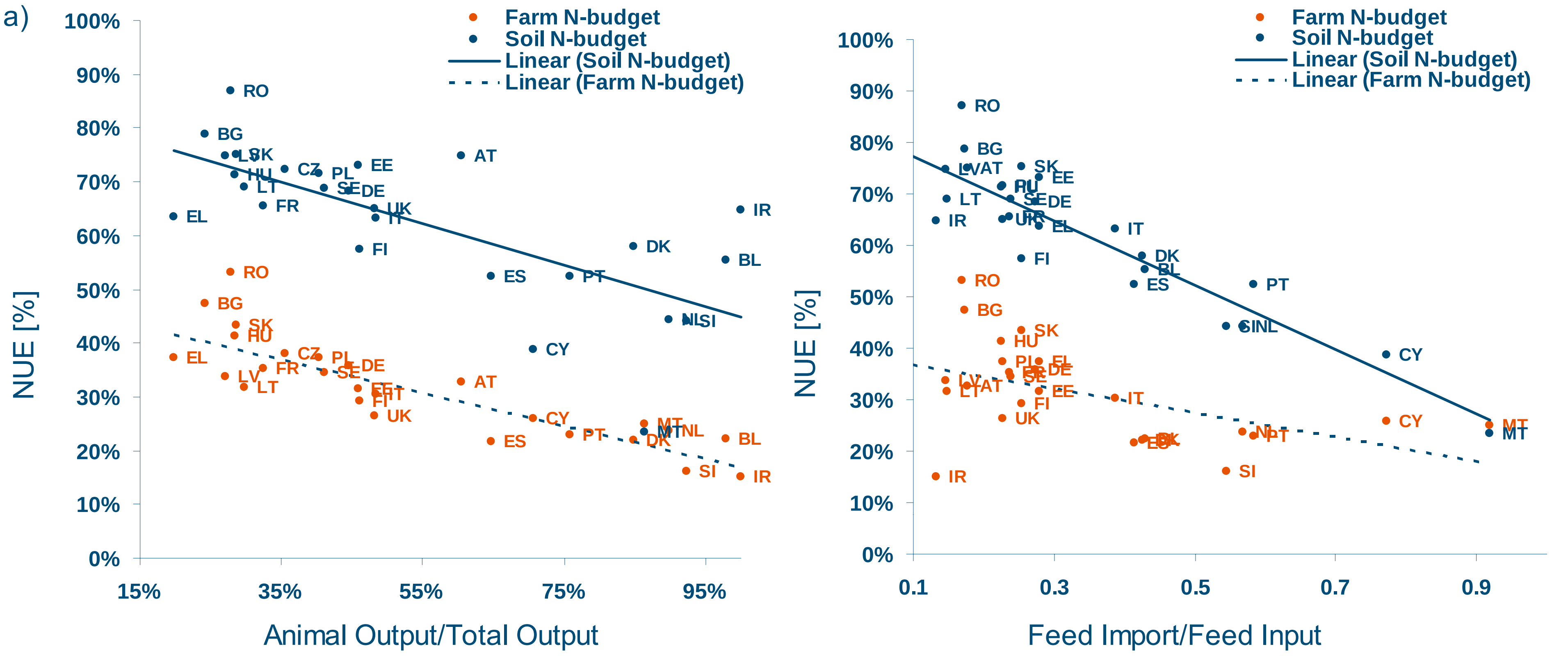
# Relation NUE and agricultural characteristics

a)

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# Correlation NUE and agricultural characteristics

| Characteristic | Farm NUE | Soil NUE |
|---|---|---|
| **a) Output composition** | | |
| Animal output / Total output | -0.86 | -0.71 |
| Crop output / Total soil output | 0.83 | 0.42 |
| Fodder output / Total soil output | -0.81 | -0.59 |
| Crop residues / Total soil output | 0.39 | 0.54 |
| **b) Input composition** | | |
| Mineral fertilizer / Total farm input | 0.40 | 0.68 |
| Feed import / Total farm input | -0.54 | -0.90 |
| Feed import / Total feed | -0.52 | -0.91 |
| Atmospheric deposition / Total farm input | 0.61 | 0.78 |
| Manure excretion / Total soil input | -0.62 | -0.87 |
| **c) Intensity measures** | | |
| Feed import [kg N $ha^{-1}$] | -0.37 | -0.81 |
| Manure excretion [kg N $ha^{-1}$] | -0.50 | -0.79 |
| Manure application / Mineral fertilizer | -0.29 | -0.68 |

# Conclusion farm, land and soil N budgets

- While there is a high correlation between soil, land, and farm N-surplus, there is more scatter for the NUE indicators calculated by the three approaches.
- NUE is 32% for the farm budget, 60% for the land budget and 65% for the soil budget.
- Total N input and the specialization to animal production (manure excretion, high share of feed import or fodder output) are found to be the main drivers for a high NS and low NUE

# Assessment N dynamics in terrestrial ecosystems

- N fertilizer use, animal numbers, milk and meat production and crop yields from FAO database and IMAGE predictions.

- N excretion rates scaled to RAINS/GAINS data for 2000, based on a simple N excretion model, using milk production for dairy cattle and meat production for all other cattle.

- N deposition history based on historical $NO_x$ emissions by EMEP, agricultural $NH_3$ emissions by INTEGRATOR and non agricultural sources by IMAGE and using an emission-deposition matrix based on the EMEP model

# Assessment N dynamics in terrestrial ecosystems

- Constant N fixation rates, but using FAO data and IMAGE predictions on trends in the area of dry pulses and soy beans
- Scaled N contents in crops, based on a change in N availability (this is automatically calculated in INTEGRATOR).
- Trends in $NH_3$ emission factors in view of changes in housing systems and manure application techniques. For 2000, GAINS data are used.
- N pool changes related to the dynamics in C sequestration, assuming a fixed C/N ratio.

# N budgets for different land uses in EU 27 in 2000

| Source | N budget (Mton N.$yr^{-1}$) | | |
|---|---|---|---|
| | Agriculture | Forests | Semi-natural vegetations |
| **Inputs** | | | |
| Synthetic fertiliser | 11.5 | - | - |
| Manure input (grazing) | 10.3 | - | 1.00 |
| Deposition | 2.7 | 1.37 | 0.35 |
| Biological N fixation | 1.3 | 0.27 | 0.21 |
| Total | 25.7 | 1.64 | 1.56 |
| **Outputs** | | | |
| Net uptake | 15.43 | 0.30 | 0.78 |
| N accumulation | -3.3 | 0.73 | -0.026 |
| Emissions of | | | |
| $NH_3$ | 2.9 | 0.021 | 0.22 |
| $N_2O$ | 0.4 | 0.045 | 0.037 |
| $NO_x$ | 0.21 | 0.013 | 0.018 |
| $N_2$ | 7.0 | 0.26 | 0.43 |
| N leaching + runoff | 3.1 | 0.27 | 0.11 |
| Total | 25.7 | 1.64 | 1.57 |

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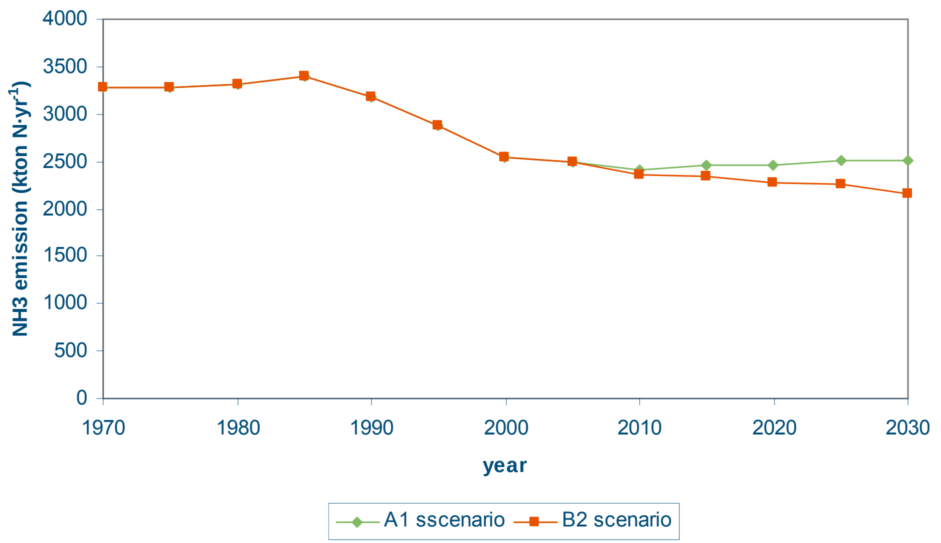
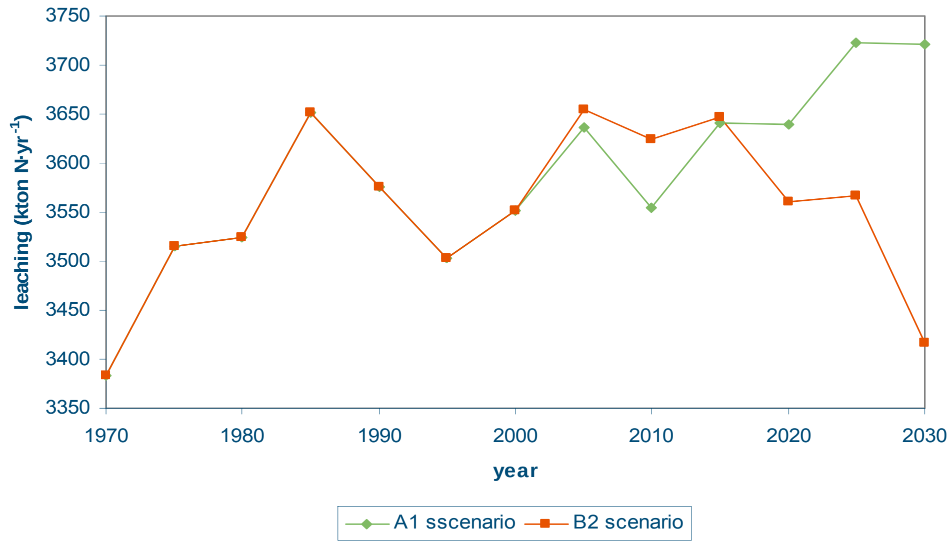
# Dynamics $NH_3$ fluxes and N leaching in 1970-2030

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# Conclusion/discussion N dynamics

- N outputs follow changes in N inputs. For past: data are know on fertilizer use, animal numbers, crop areas and yields
- Uncertainties in N excretion, N crop contents and N emission factors in time as a function of agricultural management
- Large uncertainties in N pool changes and $N_2$ emissions, both at present and in time: requires more attention.

# Questions?



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