Assessing land nitrogen budgets for Danish agriculture

Wim de Vries

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Contents

- The Model INTEGRATOR
- Methods and data sources for spatially explicit agricultural N budgets
- Disaggregated agricultural N budget for Denmark
- Impacts of measures to mitigate N losses: Example of INTEGRATOR results

The model INITEGRATOR

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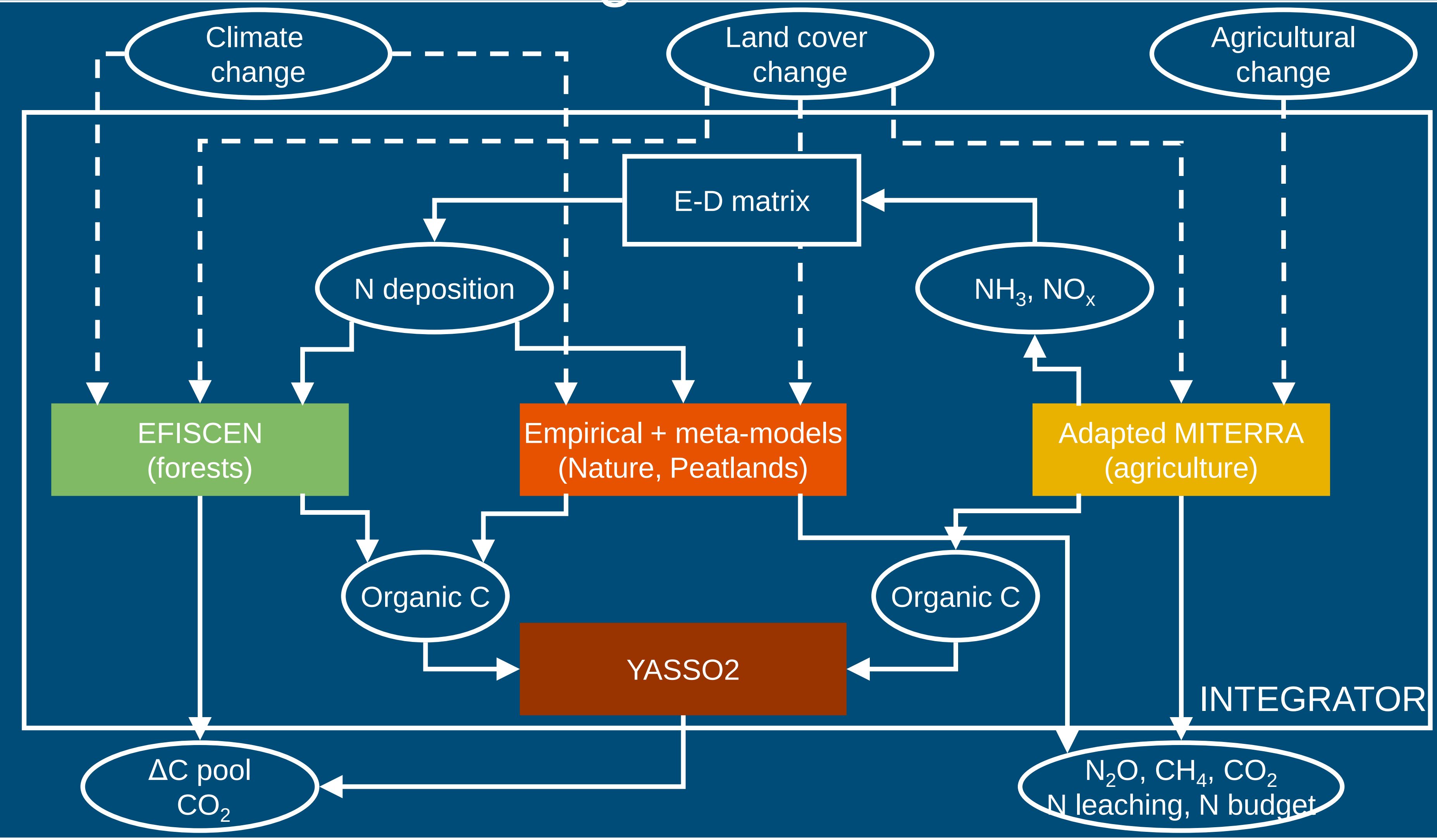
Integrator model



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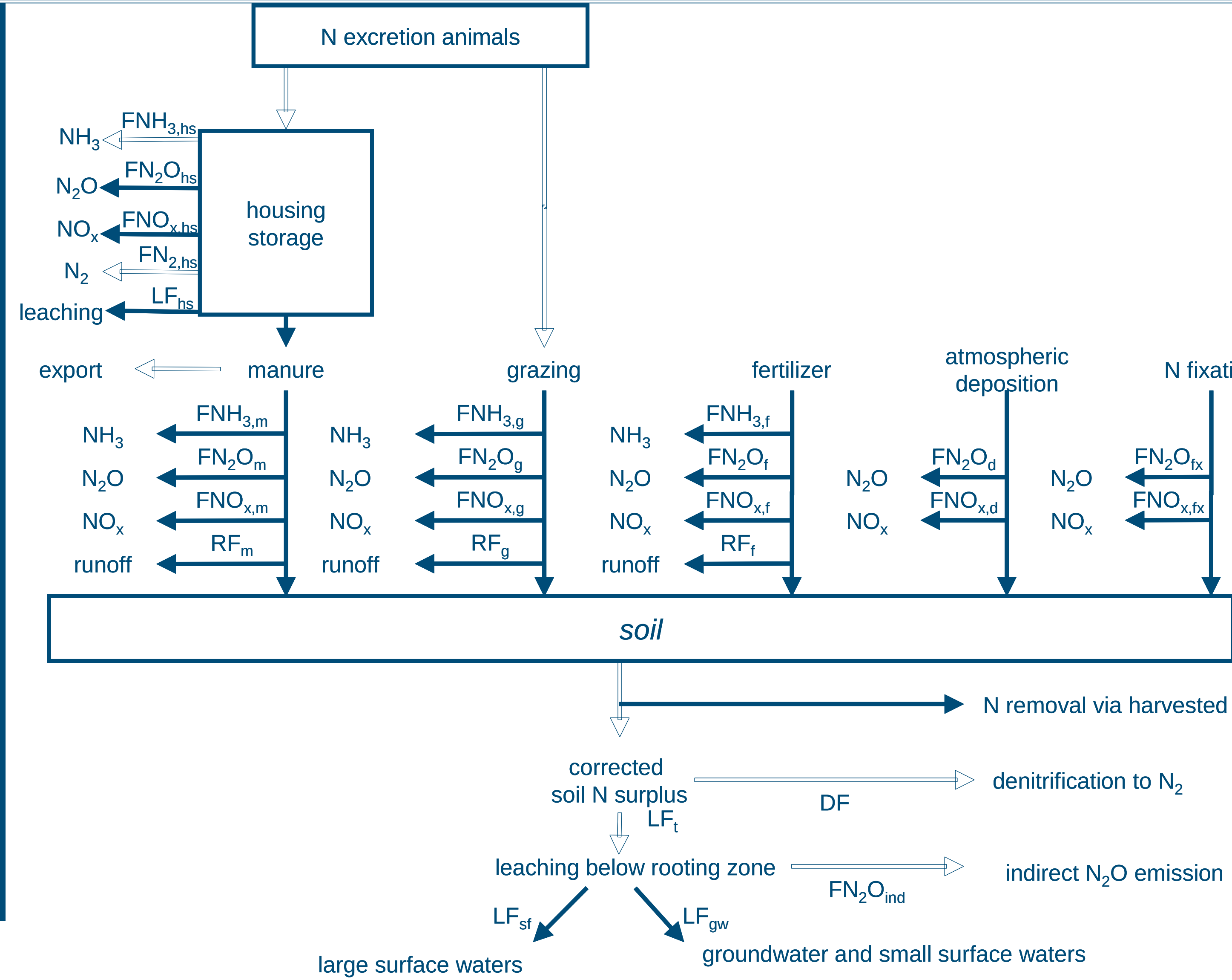
The MITERRA model: Schematic overview



F emission fraction, L leaching fraction, D denitrification fraction, R runoff fraction.

Adaptations MITERRA in INTEGRATOR

Aspect	MITERRA	MITERRA in INTEGRATOR
Tool	Stand alone policy tool (DG ENV)	Research model
Scale	NUTS 2	NCUs
Time aspect	Steady state model	Build in a dynamic environment
N manure input	Manure distribution model	Adapted from MITERRA-EUROPE
Ammonia emission	From RAINS	From MITERRA-EUROPE
N leaching	MITERRA leaching model	From MITERRA-EUROPE
Nitrous oxide emission	From GAINS	Emission factors as a function of manure type, land use, soil type etc. In future including interactions N and C.

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Parameterization of N_2O emissions in INTEGRATOR

N source	Type	Application technique	Soil type	Land use	Precip	pH	temp
Fertilizer	nitrate fertilizer ammonium fertilizer urea		sand/ clay/ peat	grassland/ arable land	3 groups	2 groups	3 groups
Manure	pig slurry	surface/ incorporation					
	pig solid manure cattle slurry						
	cattle soilid manure	surface/ incorporation					
	poultry manure grazing other manure						
Soil organic N	nett mineralization						
Biological N fixation							
Atmospheric deposition							
Crop residues	cereals vegetables arable crops						

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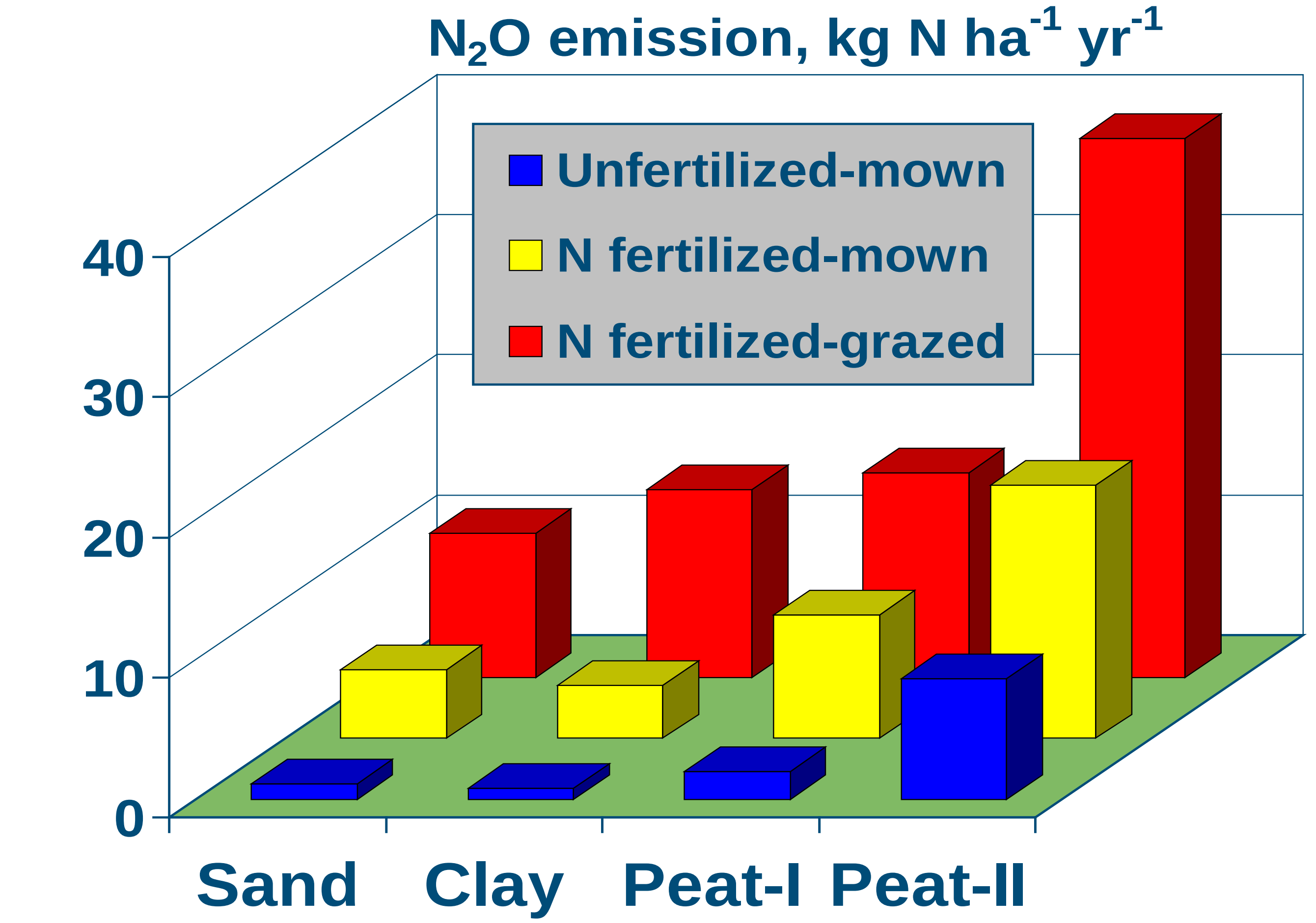
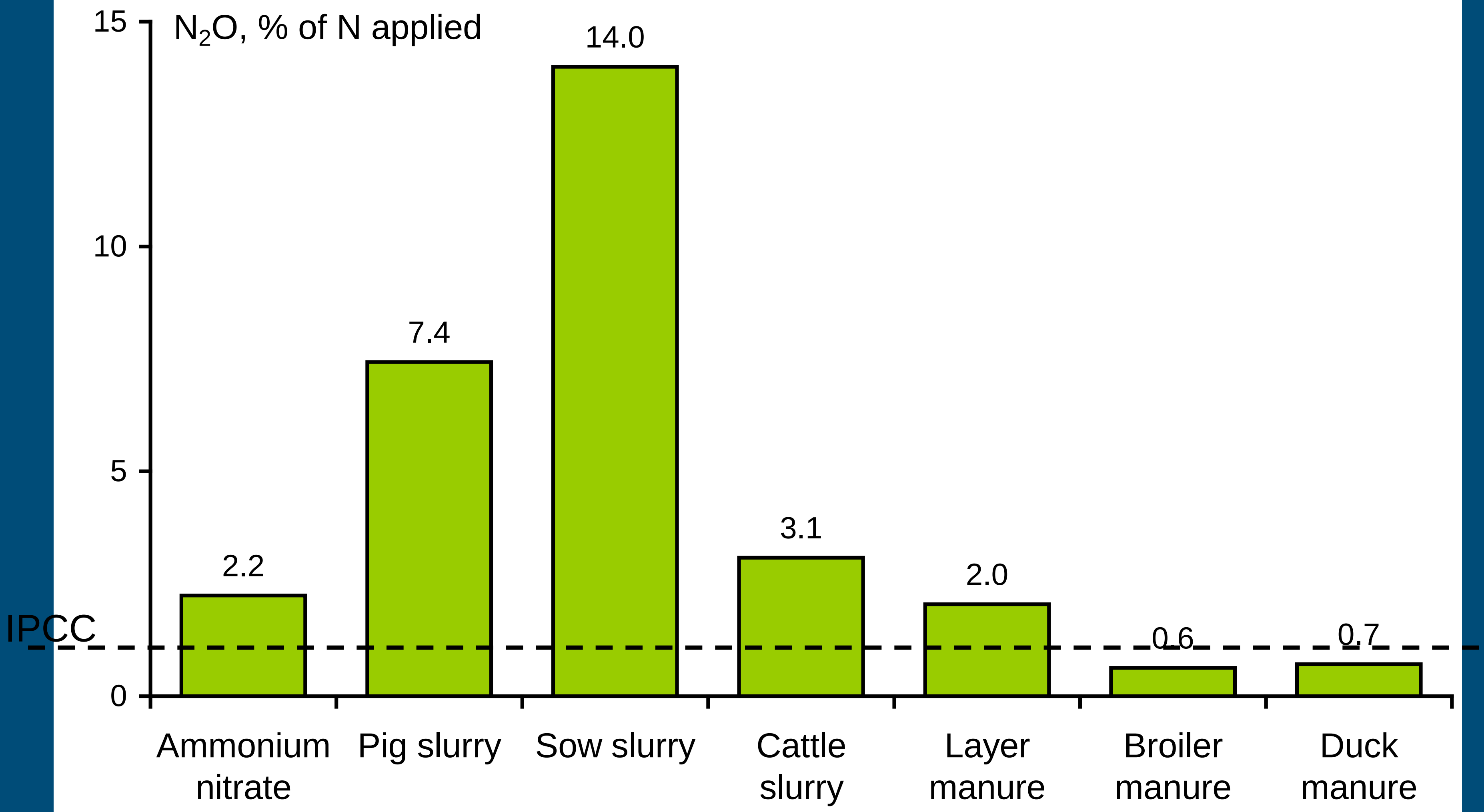
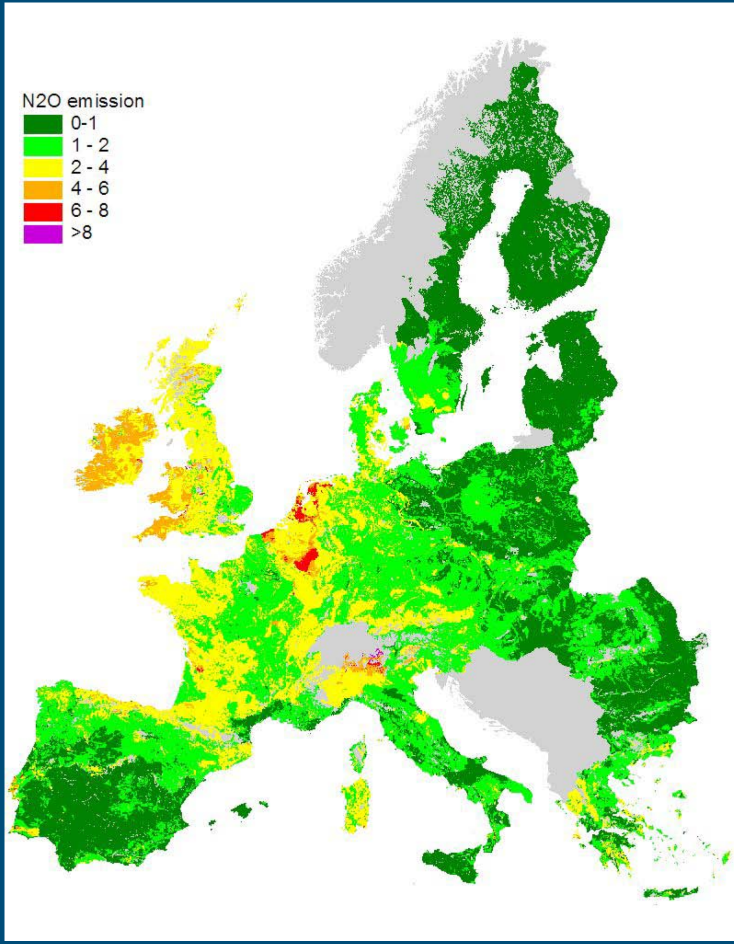
Effect of soil type and management

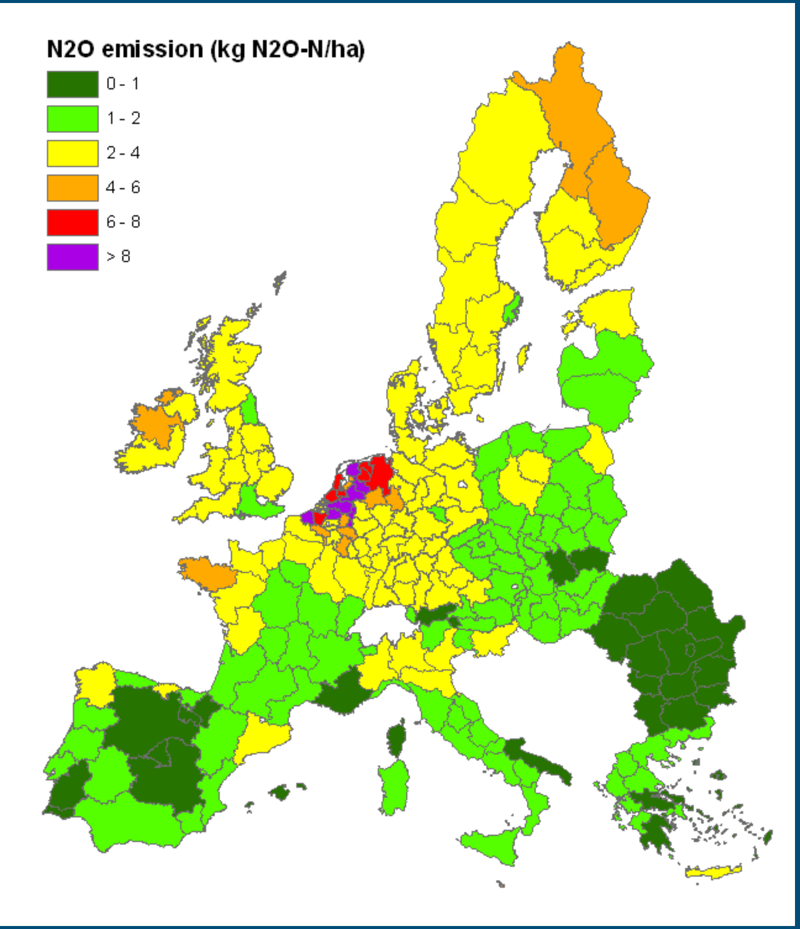


Effect of fertilizer and manure type



European wide N_2O emissions





Integrator

Miterra

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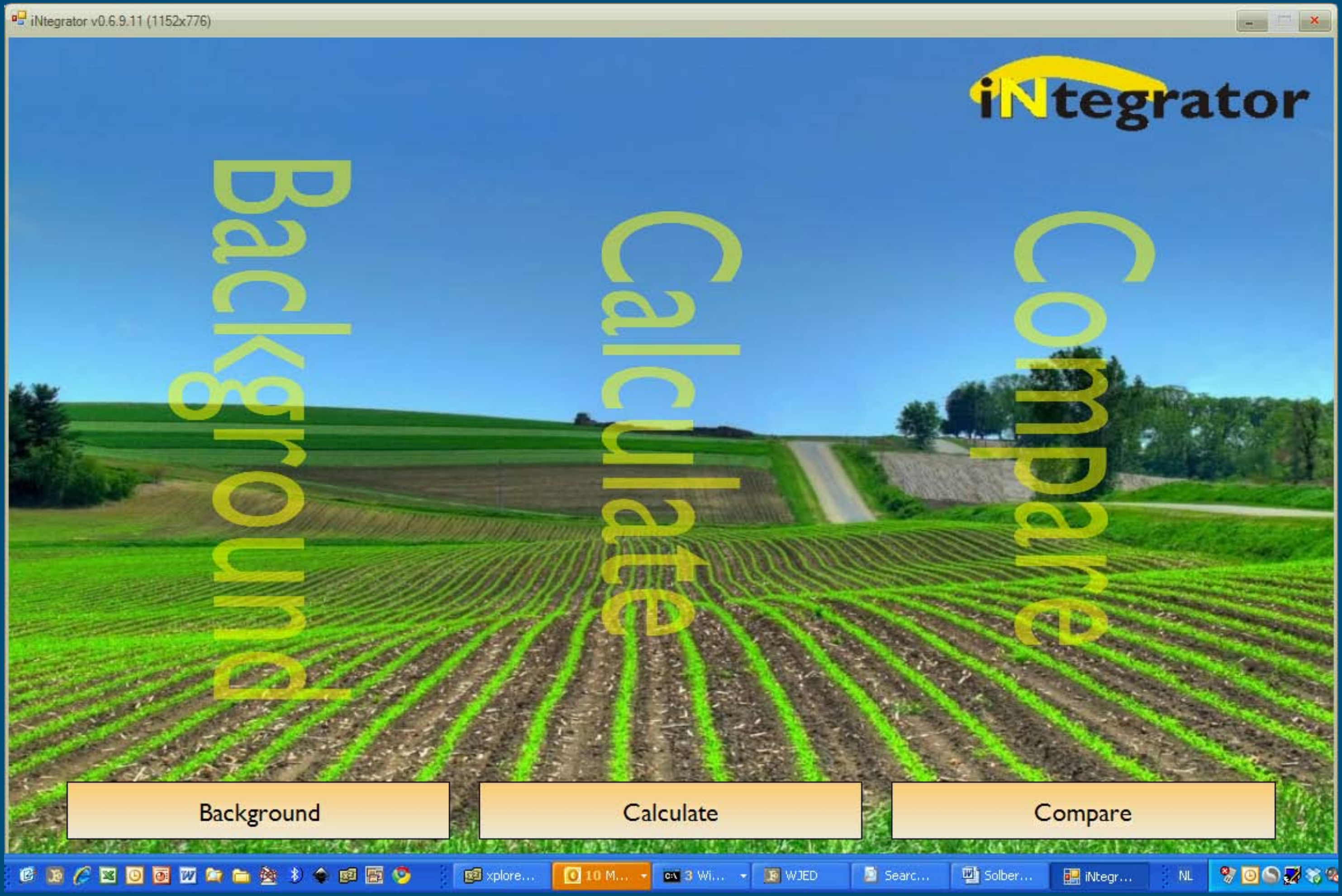
Startup



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iNtegrator
Background
Calculate
Compare
Background
Calculate
Compare
xplore...
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3 Wi...
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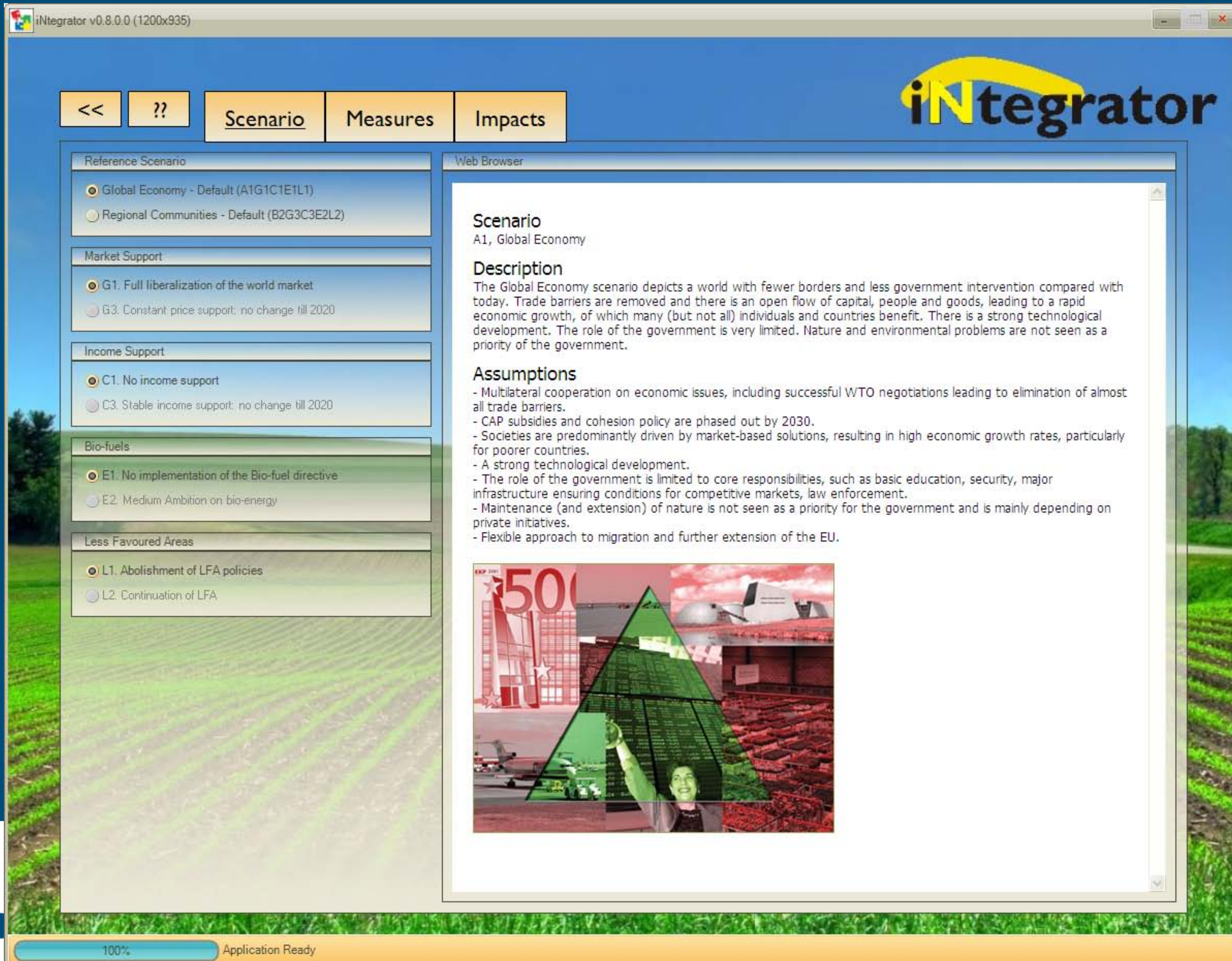
Scenarios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Scenario
Measures
Impacts
iNtegrator
Reference Scenario
Global Economy - Default (A1G1C1E1L1)
Regional Communities - Default (B2G3C3E2L2)
Market Support
G1. Full liberalization of the world market
G3. Constant price support: no change till 2020
Income Support
C1. No income support
C3. Stable income support: no change till 2020
Bio-fuels
E1. No implementation of the Bio-fuel directive
E2. Medium Ambition on bio-energy
Less Favoured Areas
L1. Abolishment of LFA policies
L2. Continuation of LFA
Web Browser
Scenario
A1, Global Economy
Description
The Global Economy scenario depicts a world with fewer borders and less government intervention compared with today. Trade barriers are removed and there is an open flow of capital, people and goods, leading to a rapid economic growth, of which many (but not all) individuals and countries benefit. There is a strong technological development. The role of the government is very limited. Nature and environmental problems are not seen as a priority of the government.
Assumptions
- Multilateral cooperation on economic issues, including successful WTO negotiations leading to elimination of almost all trade barriers.
- CAP subsidies and cohesion policy are phased out by 2030.
- Societies are predominantly driven by market-based solutions, resulting in high economic growth rates, particularly for poorer countries.
- A strong technological development.
- The role of the government is limited to core responsibilities, such as basic education, security, major infrastructure ensuring conditions for competitive markets, law enforcement.
- Maintenance (and extension) of nature is not seen as a priority for the government and is mainly depending on private initiatives.
- Flexible approach to migration and further extension of the EU.
100%
Application Ready

Measures


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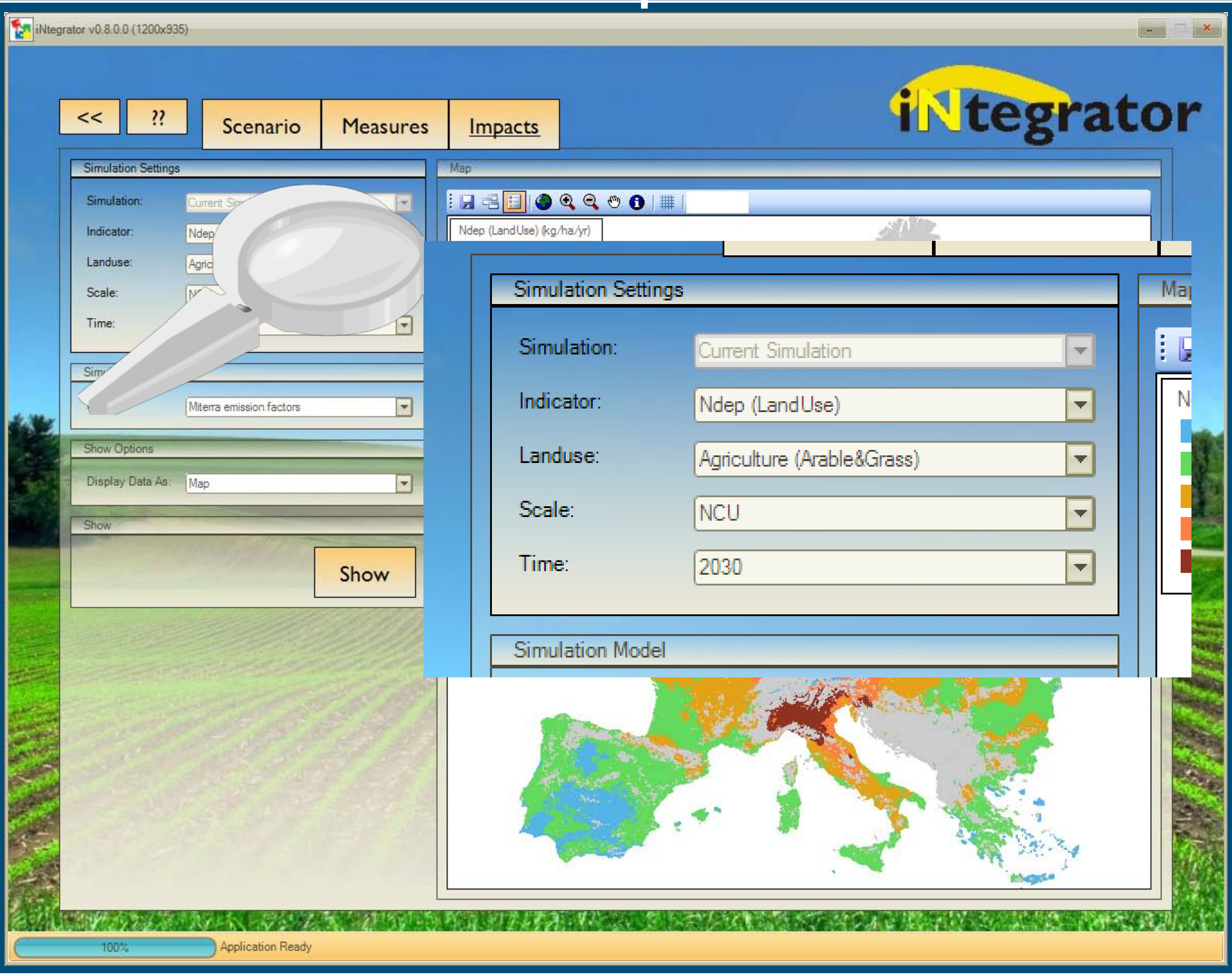
Scenario
Measures
Impacts
iNtegrator
Measures
Crop Production
Adding legumes
Balanced Fertilisation
Catch crops
Change fertilizer type
Crop Rotation
Fertilizer free zones/riparian zones
Fertilizer Placement
Fertilizer/manure timing
Manure incorporation
Maximum amount of animal manure of 170 kg N / ha
Nitrification inhibitors
Reduced residue removal
Reduced tillage
Restoration of Histosols
Zero Tillage
Livestock
Livestock grazing period/intensity
Low ammonia emission housing and storage
Low leaching housing and storage
Reduced protein content of feed
Treatment/incineration of manure
Measure Information
Measure
Low ammonia emission housing and storage.
Description
Housing adaptation by improved design and construction. Lower NH_3 emission fractions from stables and manure storages by improved de-sign and construction. For the effect of this measure we assume a redaction of 50% for dairy cattle, 25% for other cattle, 40% for pigs, 65% for lay hens and 40% for other poultry
Effect
Resulting in lower NH_3 emissions

Impacts


iNtegrator v0.8.0.0 (1200x935)
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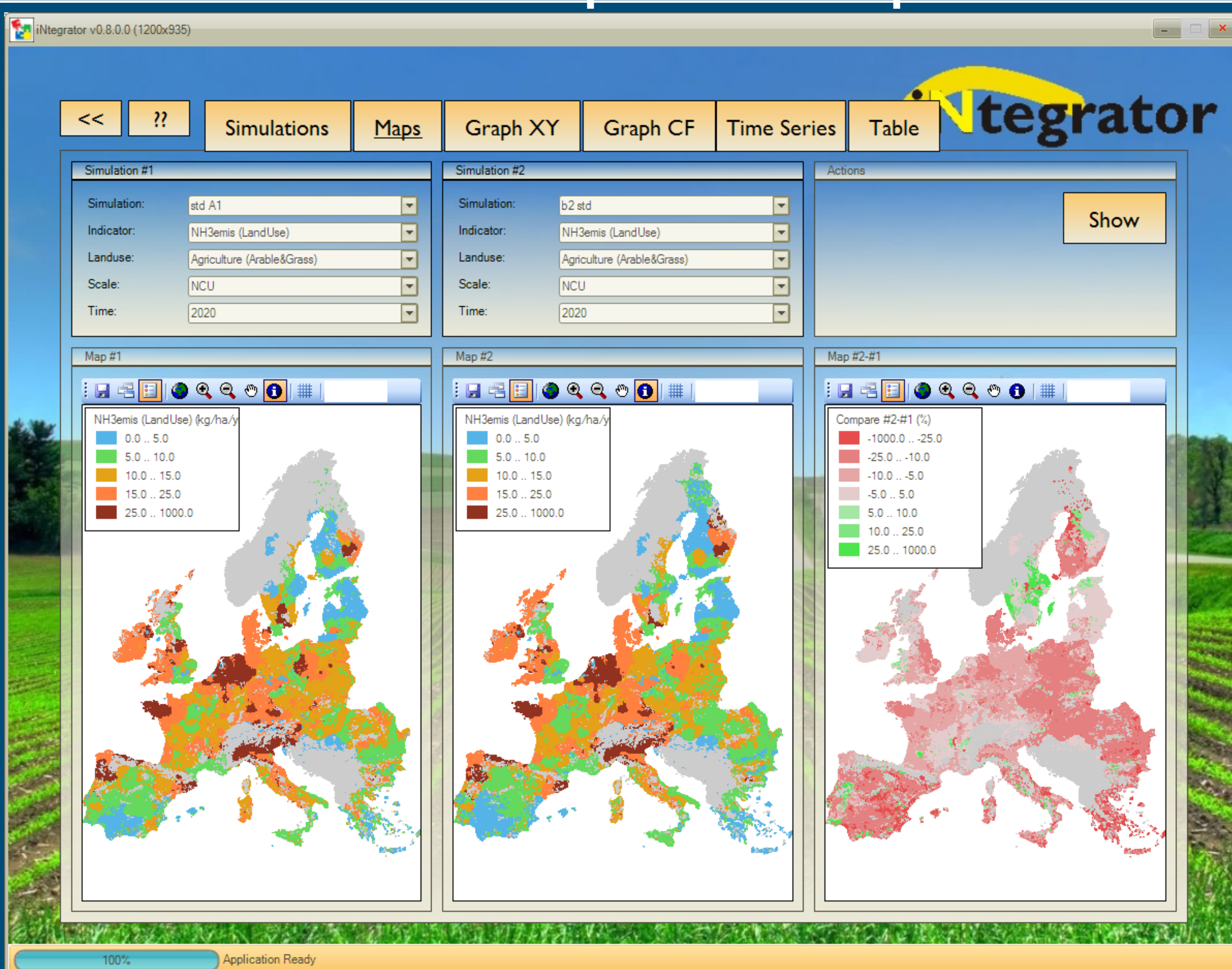
Scenario
Measures
Impacts
iNtegrator
Simulation Settings
Simulation:
Indicator:
Landuse:
Scale:
Time:
Miterra emission factors
Show Options
Display Data As:
Map
Show
Show
Map
Ndep (LandUse) (kg/ha/yr)
Simulation Settings
Simulation:
Current Simulation
Indicator:
Ndep (LandUse)
Landuse:
Agriculture (Arable&Grass)
Scale:
NCU
Time:
2030
Simulation Model
100%
Application Ready

Compare: maps



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Methods and data sources for spatially explicit agricultural N budgets

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Schematization

- Use of NitroEurope Classification Units (NCUs): polygons of clusters of 1 km x 1 km pixels. NCU is unique combination of
  - administrative unit (Nomenclature of Territorial Units NUTS2 and NUTS3)
  - soil mapping units (SMU; Soil Geographic Database SGDB classification)
  - slope class (Catchment Characterisation and Modelling Digital Elevation Model, CCM 250 DEM)

Schematization

- Each soil mapping unit (SMU), consists of a number of soil types (STU) with a known aerial fraction but unknown location within the SMU: we now use the dominant STU per polygon.

- Approximately 40 000 NCU’s for whole of Europe and 142 in Denmark

Geographic data on land cover and land use

- Land cover
  - CLUE model outcome, based on CORINE 2000.
  - Includes arable, grass, rough grazing, forests, wetlands
- Land use
  - crops: CAPRI-DNDC data for arable land.
  - Tree species: EFISCEN database for forest land

Geographic data on livestock and soil properties

- Livestock
  - FAO database at country level and CAPRI data for distribution at NUTS 2/3 level. 4 in Denmark
  - Downscaled to NCUs: ca. 140. Just simple area weighted approach; more elaborated approach in execution.

- Soil properties
  - Based on upscaled SPADE/WISE database
  - Includes texture class, C content and C/N ratio

Approaches to estimate nitrogen inputs

Data for N inputs	Derivation
N fertilizer application	FAO/ IFA/ IFDC data
N manure excretion	N excretion factor model scaled to GAINS data in 2000 multiplied by livestock numbers (FAO data at country level; CAPRI data at NUTS 2/ 3 level: downscaled to NCUs)
N deposition levels	EMEP model estimates
N Fixation rates	2 kg N ha^{-1} for arable land 5 kg N ha^{-1} and grassland 1.2-1.3 times the harvested N amount for pulses/ legumes

Approaches to estimate nitrogen outputs

Data for N outputs	Derivation
Crop yields	FAO database; applied for 31 CAPRI crops
Nitrogen contents in crops	N contents varying with N input
N emission fractions to air	NH_3 emission: country specific data from GAINS model N_2O emission: function of N source, application technique, soil type, pH, land use, precipitation
N loss fractions to water	N leaching: function of N surplus, soil, land use, organic matter content, precipitation surplus, temperature and rooting depth after MITERRA N surface runoff: function of N manure and N fertilizer input, slope, land use, precipitation, soil type and depth to rock after MITERRA N subsurface runoff: function of slope, effective porosity and ground water level after Keuskamp et al (2012)

Disaggregated agricultural N budget for Denmark

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Farm, land and soil nitrogen budgets

Gate	Budget		N Inputs	N Outputs	N Surplus[1]
	Simple	Detailed			
Farm	*Farm N budget*	*Agricultural system budget*	Fertilizer, feed (concentrates), external organic N sources, biological N fixation and deposition	Sold animal (meat, milk etc.) and crop products.	N (NH_3, N_2O, NO_x, N_2) emissions and N leaching/ runoff from housing and manure storage systems and soil
Land	***Gross N budget (OECD approach)***	***Land system budget***	**Fertilizer, manure excretion, organic sources, N fixation, N deposition, net N manure import/ export/ withdrawals**	**Harvest of crop products or above ground grass removal**	**N (NH_3, N_2O, NO_x, N_2) emissions and N leaching/ runoff from housing and manure storage systems and soil**
Soil	*Soil N budget*	*Soil system budget*	fertilizer, manure application, grazing inputs, organic sources, N fixation and N deposition	Removal of crop products or above ground grass removal	N (NH_3, N_2O, NO_x and N_2) emissions and N leaching/ runoff from soil

[1] N surplus is specified in the detailed N-budgets

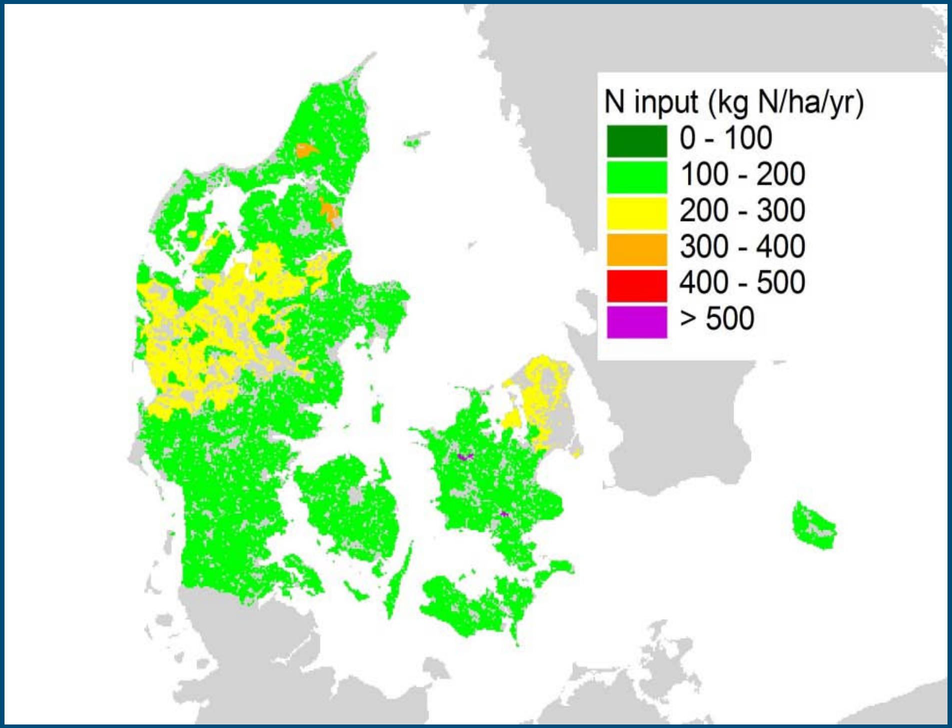
Calculated range in N inputs for arable - and grassland

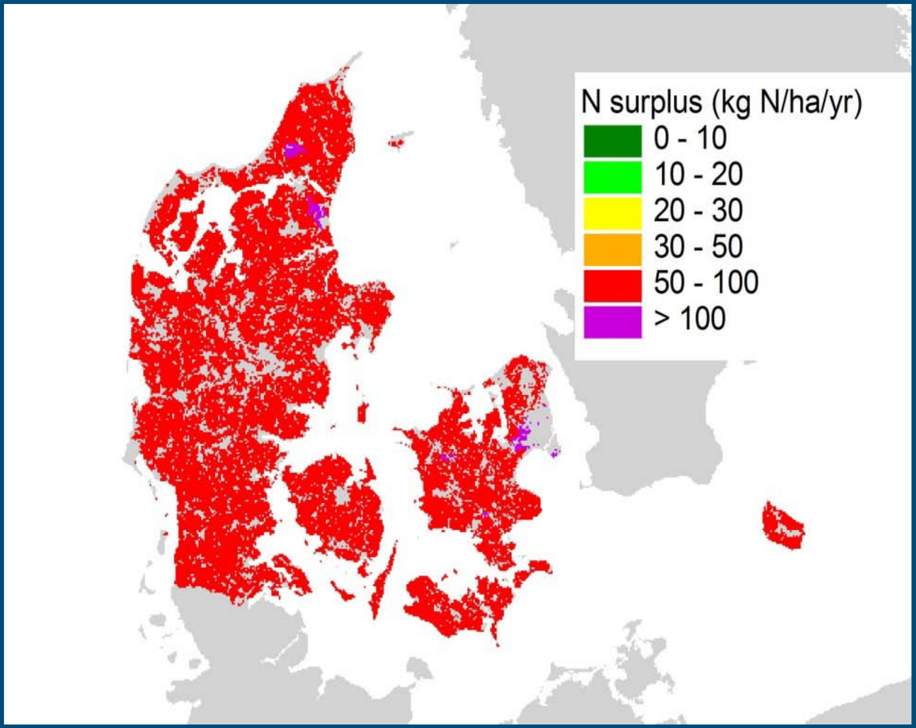
N input (kg N ha^{-1})	arable			grass		
	5%	50%	95%	5%	50%	95%
Biological fixation	5	5	5	5	5	5
Manure excretion	62	67	72	140	162	264
Synthetic fertiliser	74	82	85	0	71	84
Atmospheric deposition	9	12	13	9	12	13
Mineralisation	21	23	41	-3	-3	-2
Total	187	192	202	236	249	327

Calculated range in N budgets for arable and grassland

N flux	arable			grass		
(kg N ha^{-1})	5%	50%	95%	5%	50%	95%
Total input	187	192	202	236	249	327
Plant removal	118	120	129	137	144	189
N surplus	68	71	78	99	106	133
Emissions of						
NH_3	18	19	20	26	28	39
N_2O	1	2	2	2	3	5
NO and NO_2	1	1	1	1	1	3
N_2	21	22	28	51	56	77
N leaching+ runoff	20	27	29	15	20	24

Total N input en N surplus in arable land





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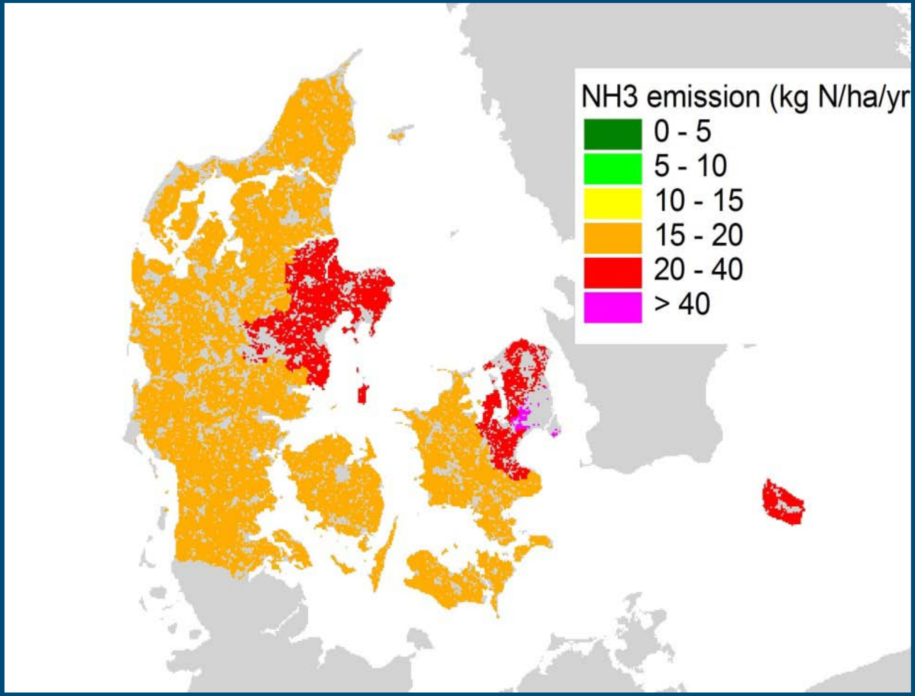
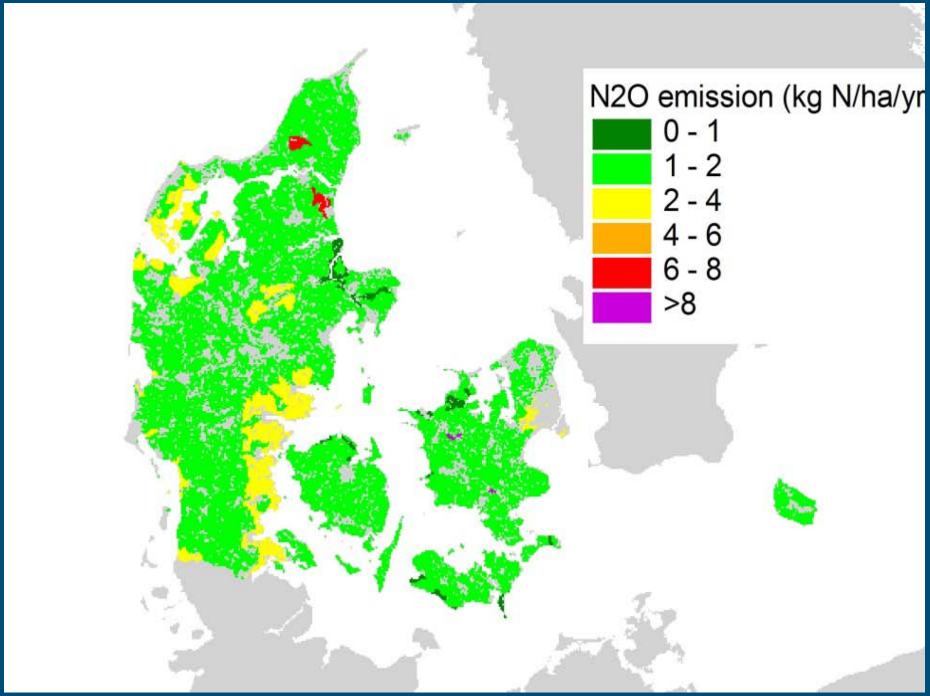
NH_3 and N_2O emissions from arable land





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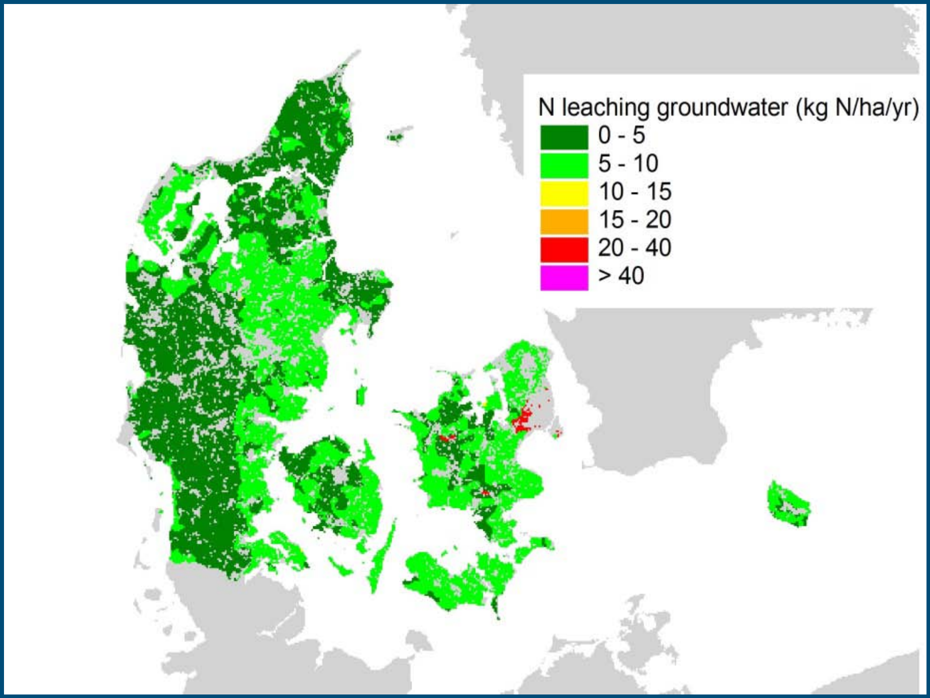
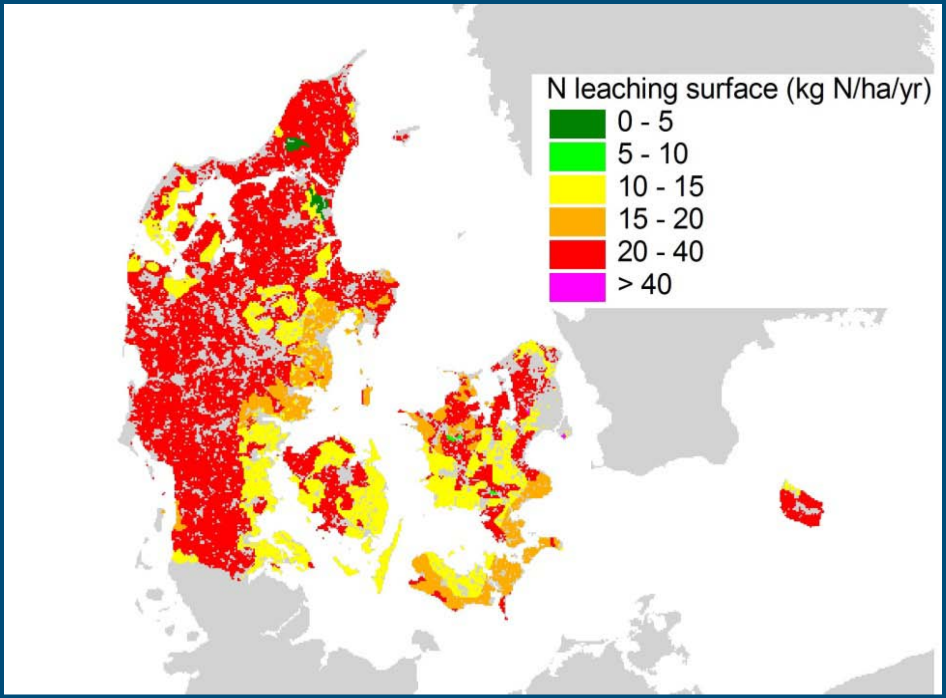
N leaching to ground water and surface water from arable land





Conclusions DNMARK application

- A maximum N application rate by animal manure of 170 kg N/ha/yr is only exceeded on grassland. DNMARK has a derogation up to 230 kg N/ha/yr, which is exceeded in few areas.

- The estimated variation in N inputs is far too limited and needs update: first use of downscaled 1 km x 1km animal number data followed by N fertilizer and livestock data from Danish municipalities.

Mitigation analysis with INTEGRATOR

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Aim mitigation study

- Assess effectiveness of ammonia mitigation options for nitrous oxide emissions (co-benefits versus pollution swapping)
  - A. Livestock management, housing and manure storage
  - B. Soil nutrient management
  - C. Water management

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Livestock management, Housing and manure storage

- 1. Reduced protein content of feed
  - Reduction in N excretion:
    - 15% for cattle
    - 20% for pigs
    - 20% for laying hens and 10% for other poultry
  - → Lower N input
- 2. Low ammonia emission housing and storage
  - Reduction in NH_3 emission
  - Lower N deposition → Lower indirect emission
  - Higher N content in manure → Higher N input → Pollution swapping

Nutrient management: soil

- 3. Balanced fertilization
  - → Lower N input
- 4. Maximum manure application rate
  - → Lower N input
  - May be compensated by fertilizer
- 5. Manure incorporation
  - → Lower NH_3 emissions
  - → Higher N_2O emission
- 6. Urea substitution by NO_3 fertilizers
  - → Lower NH_3 emissions
  - → Higher N_2O emission

Water management

- 7. Restoration histosols
  - Mean summer groundwater level → 10 cm
  - No fertilizer application
  - → Lower C and N mineralisation
  - → Lower N input

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Response to various mitigation measures

Relative changes in N_2O emission (%) for EU27

Measure	Housing and storage	Manure and fertilizer application	Other N inputs[1)]	Total
1. Reduced protein content	-1.4	-0.5	0.0	-1.9
2. Low $NH_{3\ em}$ housing, storage	0.0	0.0	0.0	0.0
3. Balanced fertilization	0.0	-8.8	-2.7	-11.5
4. Max manure application rate	0.0	-7.1	0.1	-7.0
5. Manure incorporation	0.0	0.2	0.0	0.2
6. Urea substitution	0.0	-0.3	0.0	-0.3
7. Restoration histosols	0.0	-0.8	-0.2	-1.0
All measures	-1.4	-17.4	-2.7	-21.5

1) Includes emission through soil inputs by deposition, mineralization, fixation and crop residues

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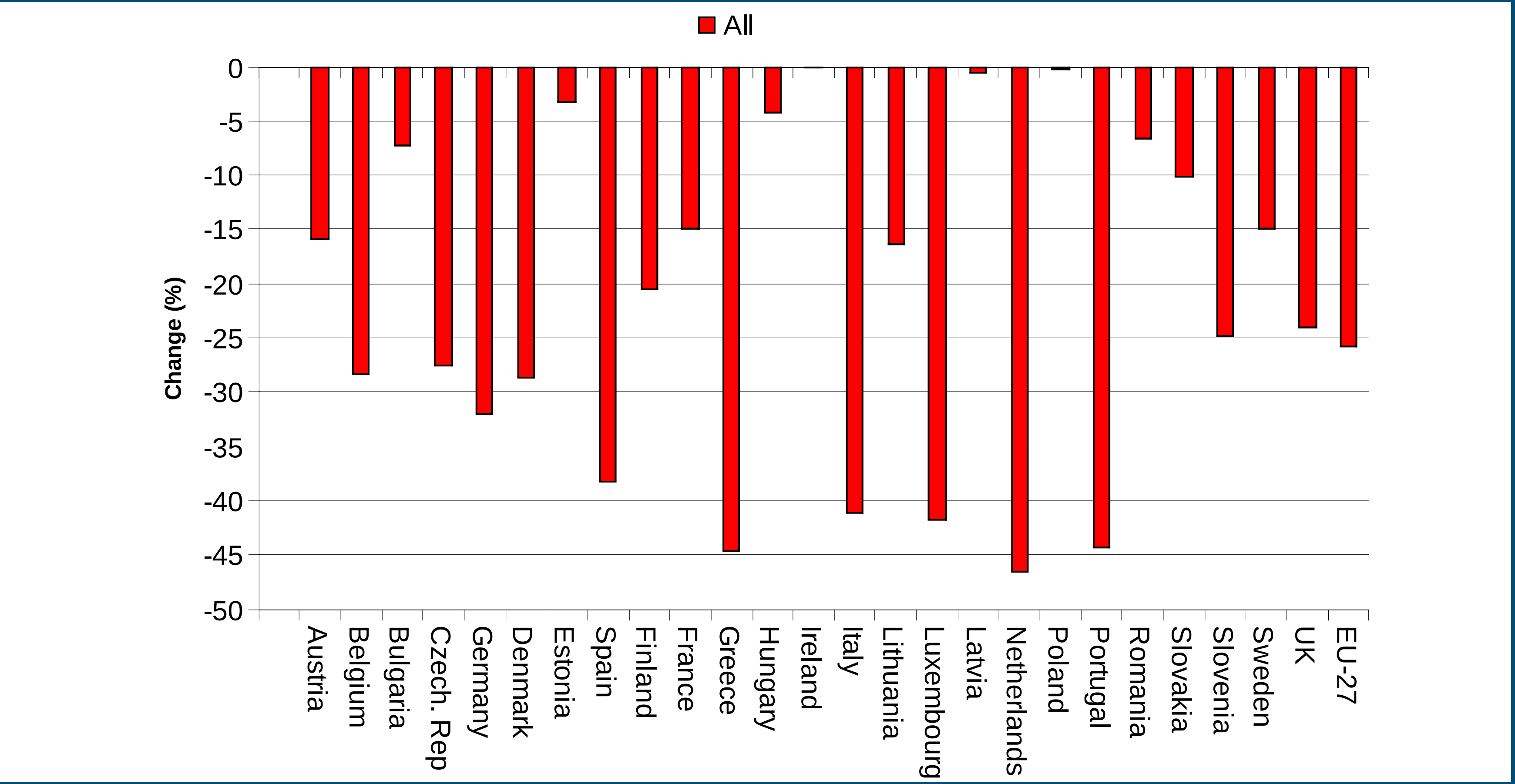
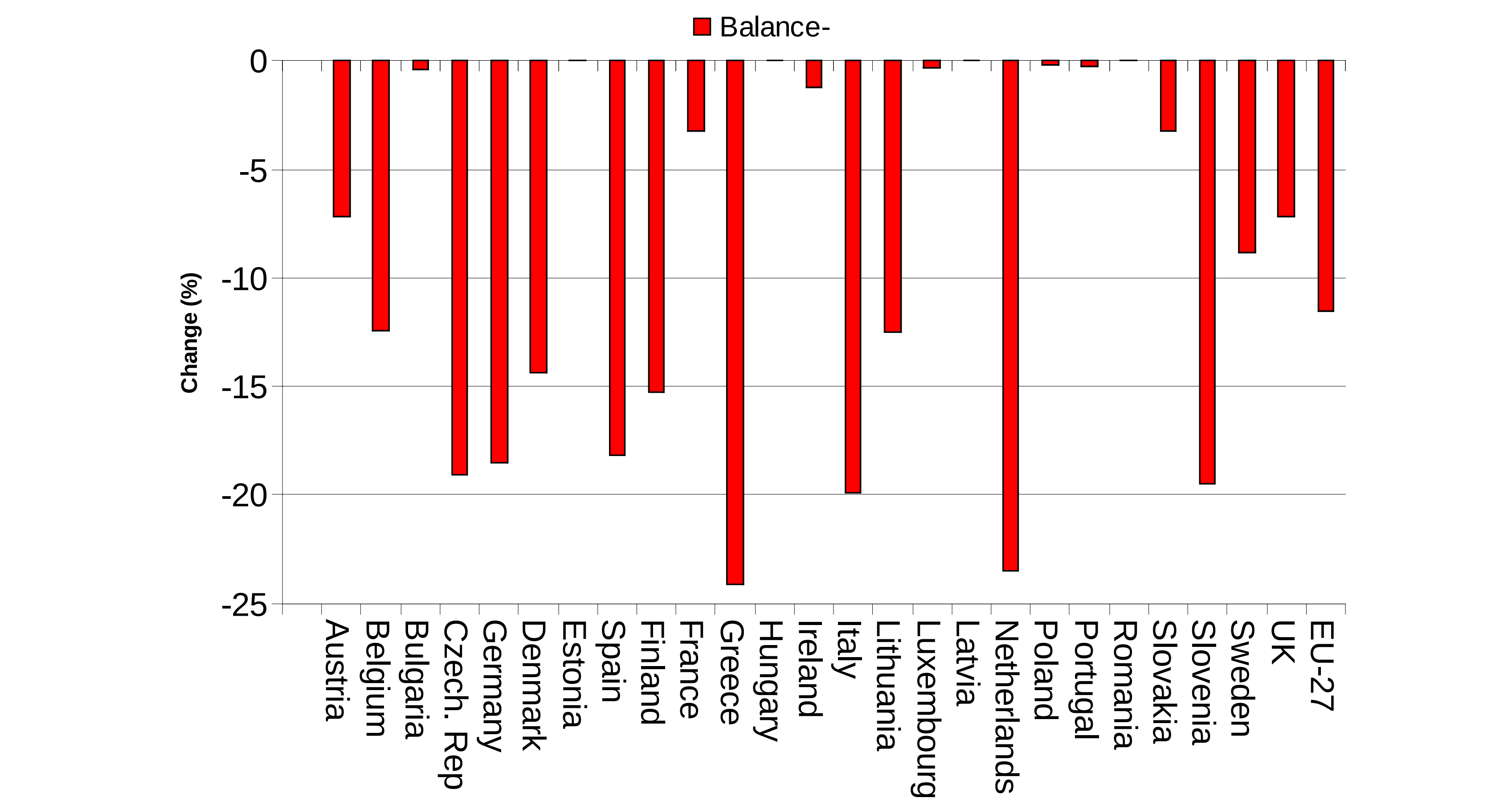
Effect of all measures per country



Effect of Balanced fertilization



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Concluding remarks

- INTEGRATOR can contribute to national N budget for the period 1990-2010 for agricultural land, forest land, semi-natural areas, ground water and surface waters.
- The regionalized N budget will be updated by making use of: (i) 1 km x 1km livestock data for Europe (more differentiation in N manure input in NCUs) and (ii) data for the 95 municipalities in Denmark.
- INTEGRATOR can contribute to scenario assessments: predictions up to 2030 available for A1 and B2 scenarios.

Questions?

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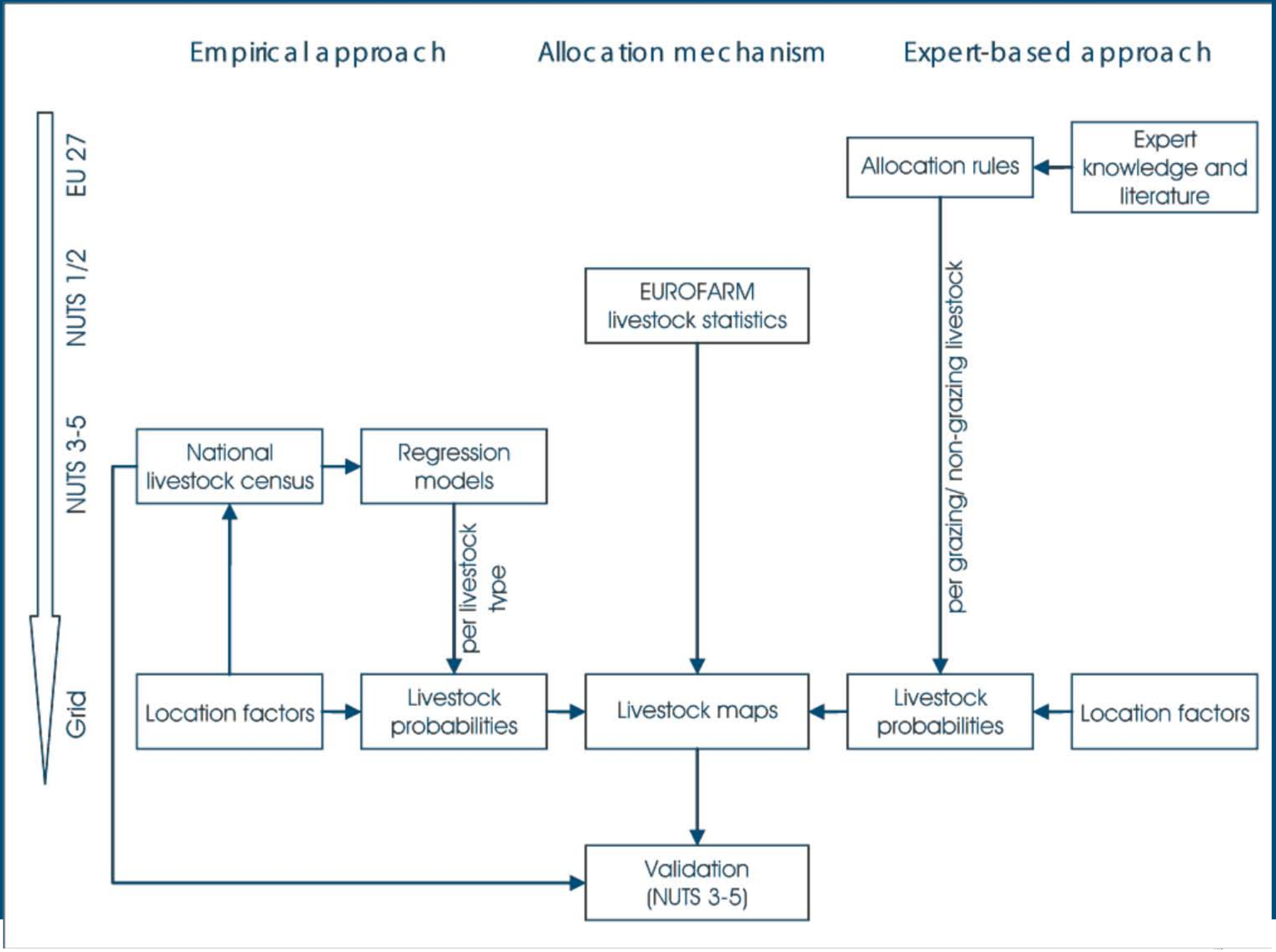
Assessment of 1 km x 1km livestock distributions in Europe

- Expert-based approach: specification of land-related suitability rules based on case study evidence and system understanding for the whole of Europe
- Empirical approach: assessment of statistical relationships between observed livestock numbers and independent variables (soil types, climate, geomorphology, and population distribution) for a selection of countries
- Patterns retrieved by both methods were validated by comparing with spatially detailed national census data and a random distribution model

Downscaling methodology



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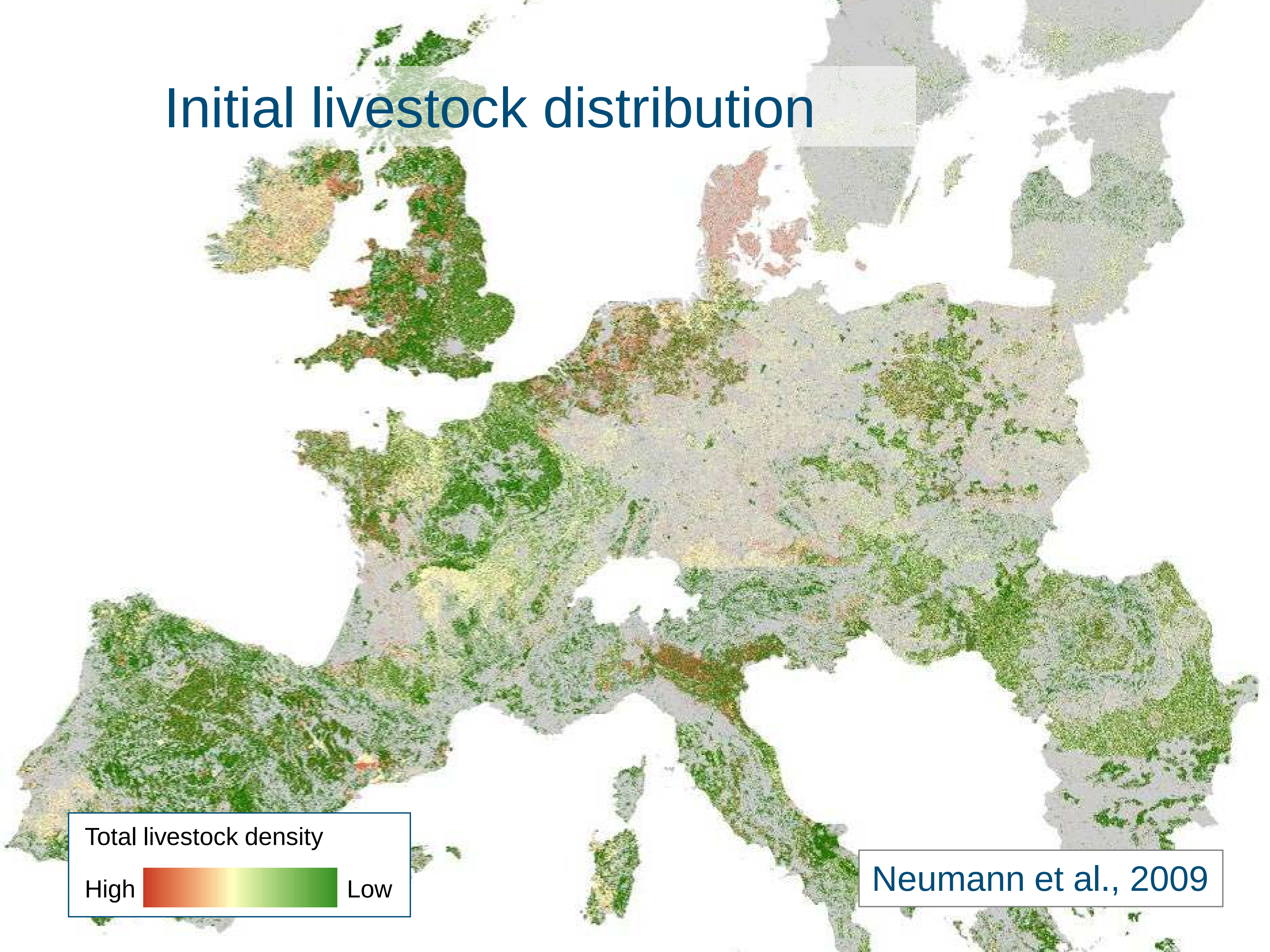
Model validation

Correspondence (r^2) between national census data and livestock maps applying a downscaling procedure *(d)* and a random distribution model *(r)*

Country	**Spatial detail of EUROFARM data**	**Spatial detail of national census data**	**Year of national census data**	**Dairy cattle**		**Pigs**	
				d	*r*	*d*	*r*
Denmark	NUTS 1 (n=1)	NUTS 5 (n-277)	2000	.47	.59	.63	.54
Finland	NUTS 2 (n=4)	NUTS 3 (n=20)	2002	.77	.10	.81	.27
Germany	NUTS 1 (n=14)	NUTS 3 (n=439)	2001	.86	.54	.38	.38
Hungary	NUTS 2 (n=7)	NUTS 3 (n=20)	2003	.61	.57	.77	.73
Netherlands	NUTS 2 (n=4)	NUTS 4 (n=488)	2003	.74	.47	.25	.39
Romania*	NUTS 2 (n=8)	NUTS 3 (n=42)	2002	-	-	.46	.22
Spain	NUTS 2 (n=17	NUTS 3 (n=50)	2001	.69	.71	-	-
Sweden	NUTS 2 (n=8)	NUTS 3 (n=21)	2003	.92	.86	.91	.83

Initial livestock distribution



Neumann et al., 2009