REPUBLIC OF SLOVENIA
MINISTRY OF THE ENVIRONMENT AND SPATIAL PLANNING

SLOVENIAN ENVIRONMENT AGENCY

Modelling and Management of nitrate inputs into groundwater and surface water in Slovenia

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2nd International Interdisciplinary Conference on Land Use and Water Quality,
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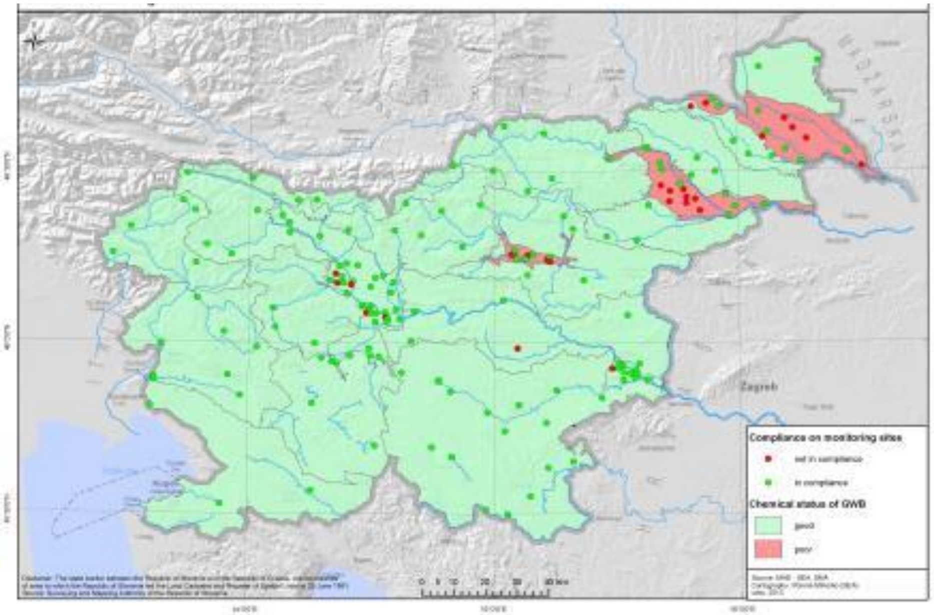
Introduction to Slovenia

Chemical status of groundwater bodies in 2012

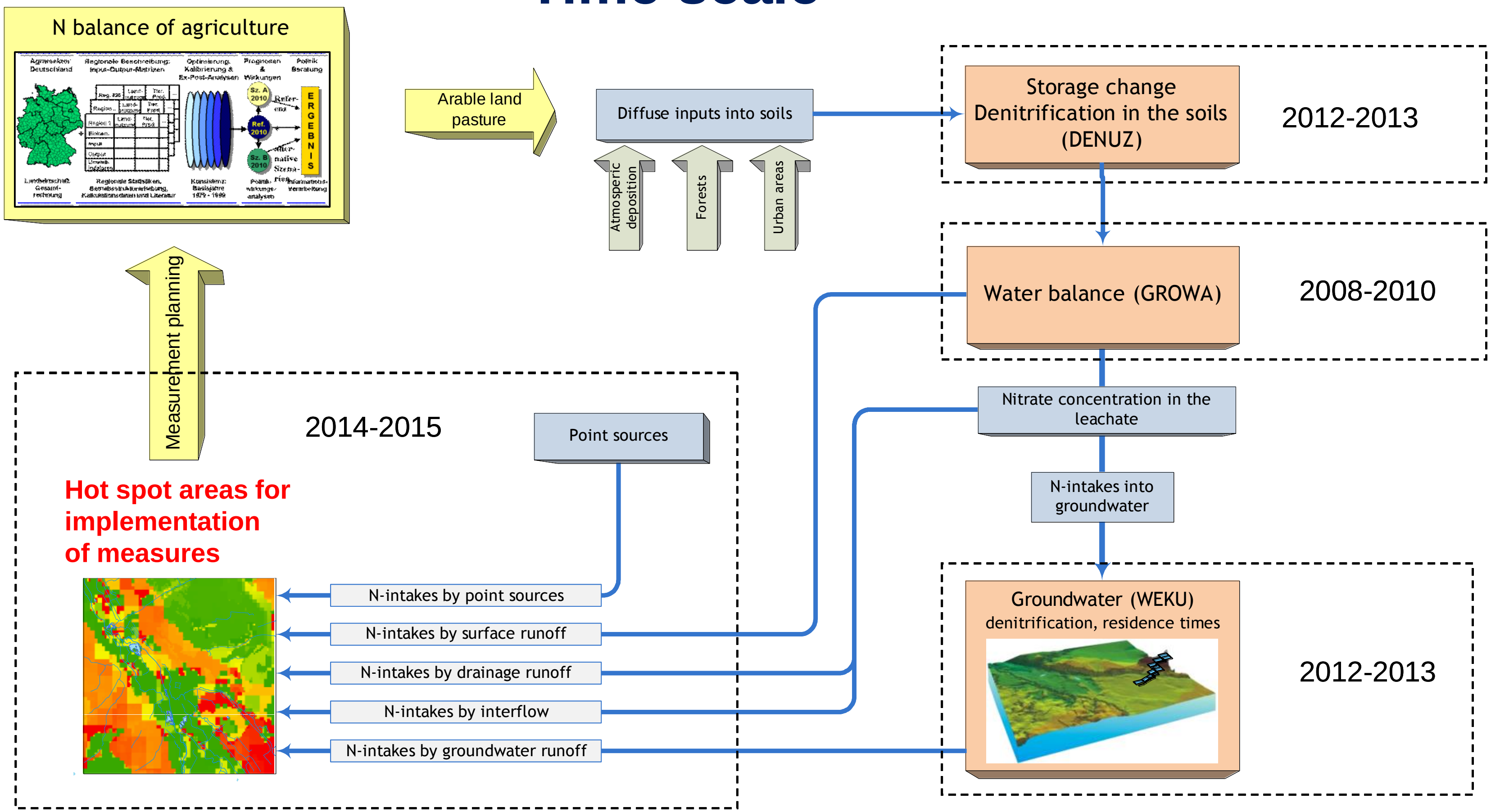


Size: 20,273 km^2
Groundwater main source of drinking water
Groundwater bodies: 21
Poor cemical status: 3 GWB
70 % of consolidated rock aquifers
44 % of the area Karst
58 % of the area is covered by forests
33 % of the area is used agriculturally
55 % waste water is treated

Water resources management targets in Slovenia

- **Identify the relevant sources, the regional dominant input pathways and the hot spot areas for action**
- **support the future design of programs of measures to reduce nutrient pollution of water resources**
- **reach good status of water resources (in the long run)**

Modeling diffuse nitrogen fluxes with GROWA-DENUZ-WEKU (interdisciplinary model network) - Time scale



All model analyses have been performed:

- ***Area – covering for the whole territory of Slovenia***
- ***highly spatially resoluted (grids 100 m X 100 m)***

R&D Cooperation of ARSO and FZJ since 2008

Gross nitrogen balance (GNB)

(Agricultural Institute of Slovenia, Department for Agroecology and Natural Resources)

- Methodology: OECD and EUROSTAT (may, 2013)

N input :

N from mineral fertilizers

(Statistical office of the RS, 2011)

N from animal fertilizers

(Agency for agricultural markets and rural devel., 2012; Agricultural institute of Slo, 2012)

Biological fixation of N

(Comparable values from other EU members, 2012)

N from seeds

(Sowing rates in Slovenia, 2011)

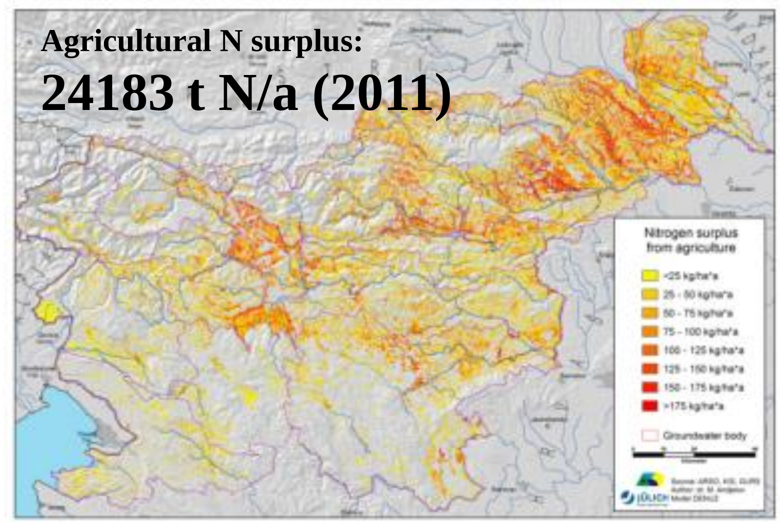
Deposition of N from atm

(Slovenian envirenmental agency - EMEP, 2010)

N output

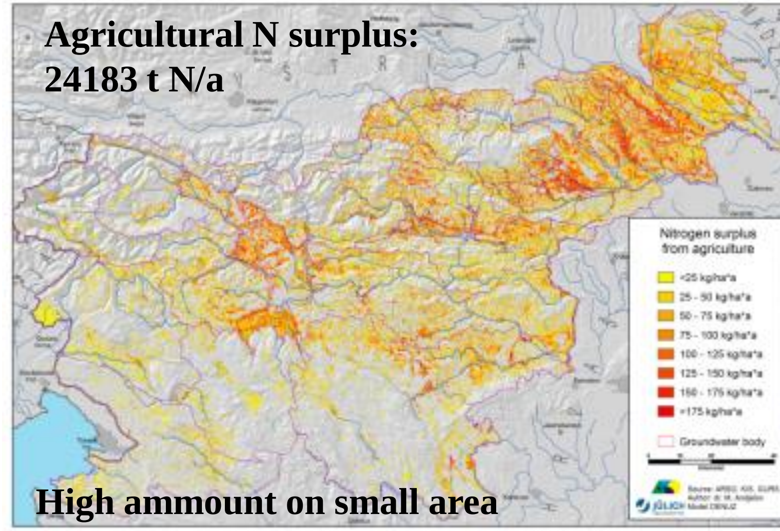
Uptake of N by crop

Statistical office of the RS, 2011)

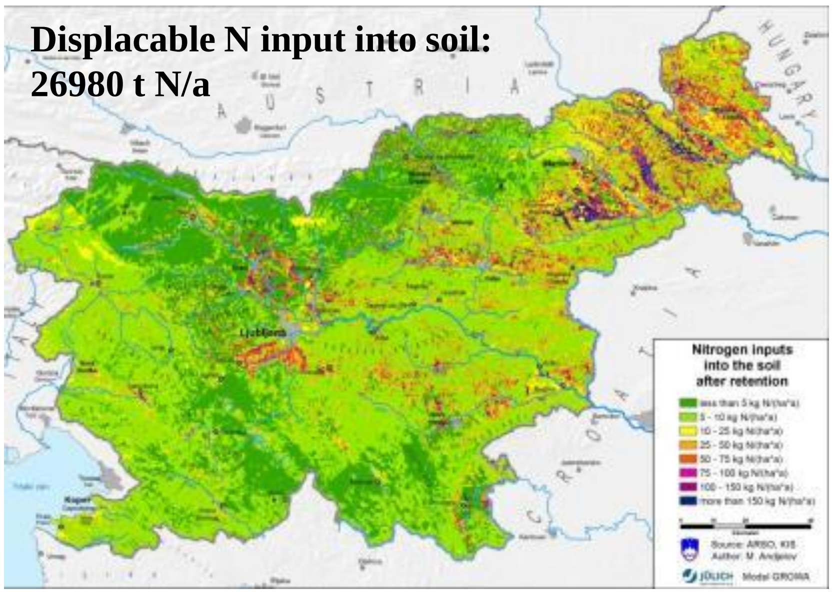


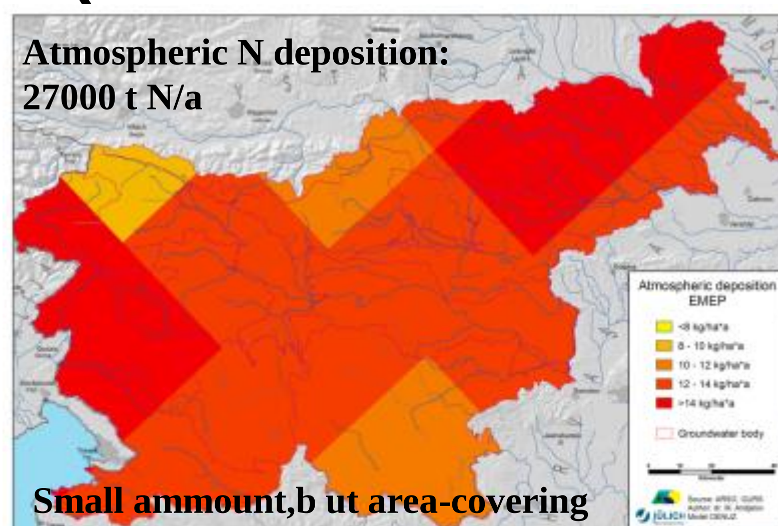
N balance (kg N/ha) = N inputs – N uptake

Displacable N-input into soil



- Distribution
- N immobilisation in soil (forest, pasture) 23750 t N/a





Source: Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)

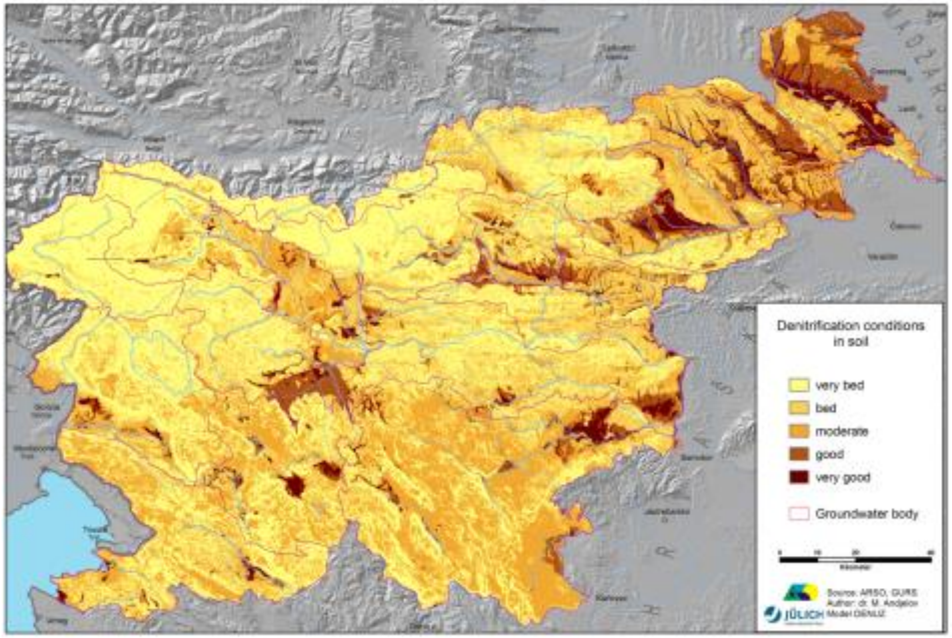
Modelling denitrification in the soil

(DENUZ – model, Kunkel & Wendland, 2004)

- Quantitative assessment of denitrification in soil using a Michaelis-Menten kinetics:

$$\frac{dN(t)}{dt} + D_{\max} \cdot \frac{N(t)}{k + N(t)} = 0$$

- Dependencies:
  - N-surpluses $N(t_0)$
  - Denitrification conditions in the soil (D_{max}, k)
  - Residence time of leachate in the soil (t)

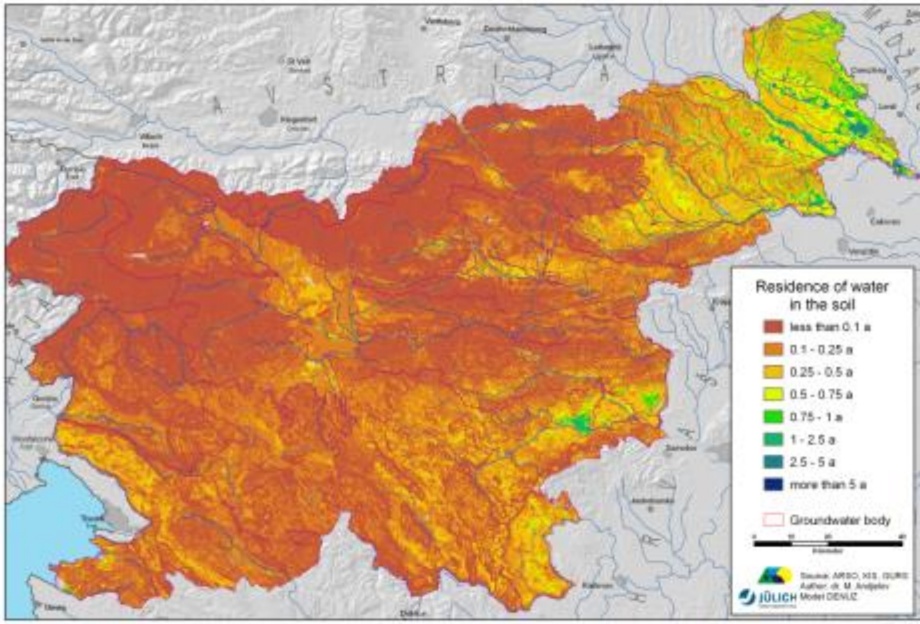


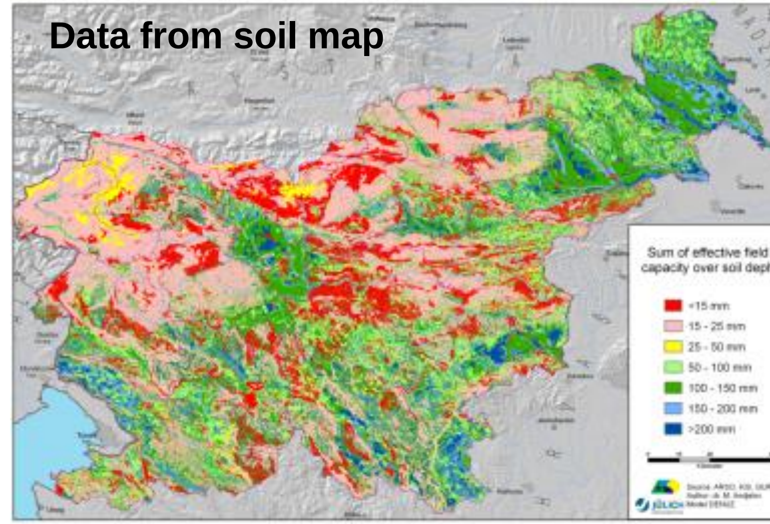
Maximum yearly denitrification rate:

Very low:	10 kg/ha a (e.g. pozol)
Low:	20 kg/ha a (e.g. luvisol)
Moderate:	40 kg/ha a (e.g. pseudogley)
High:	60 kg/ha a (e.g. gley)
very high:	100 kg/ha a (e.g. marsh soil)

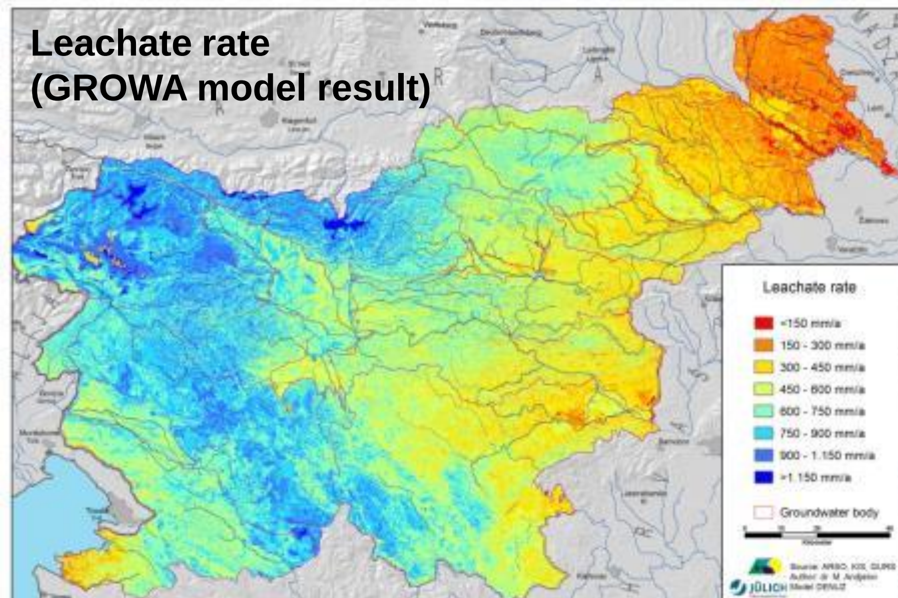
- High denitrification rates can only be expected in soils displaying high organic carbon content and high water saturation

Residence times of leachte in the root zone (ts)

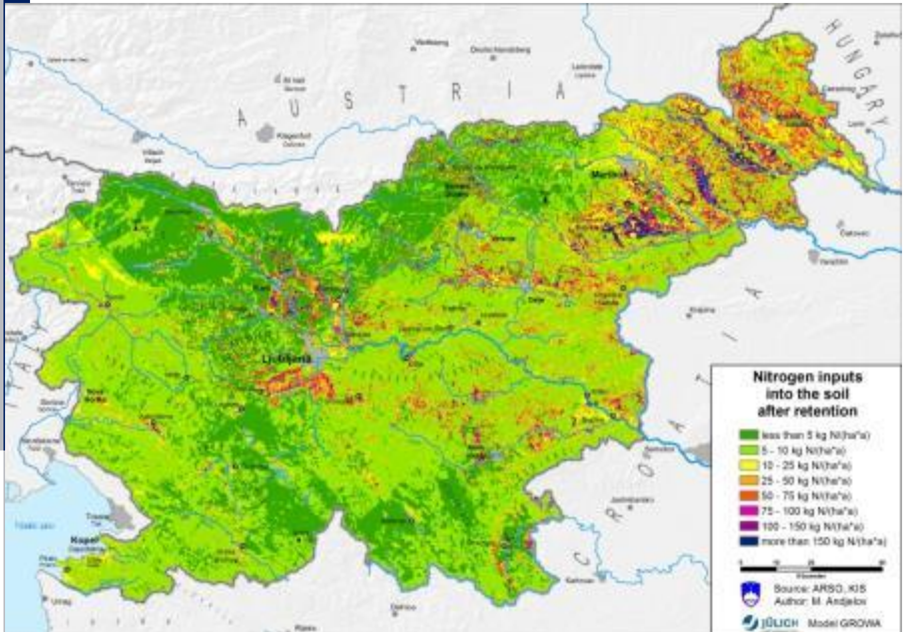




$$ts = \frac{\text{Effective field capacity of root zone (Fki * di)}}{\text{Residence times of leachte in the root zone(ph)}}$$

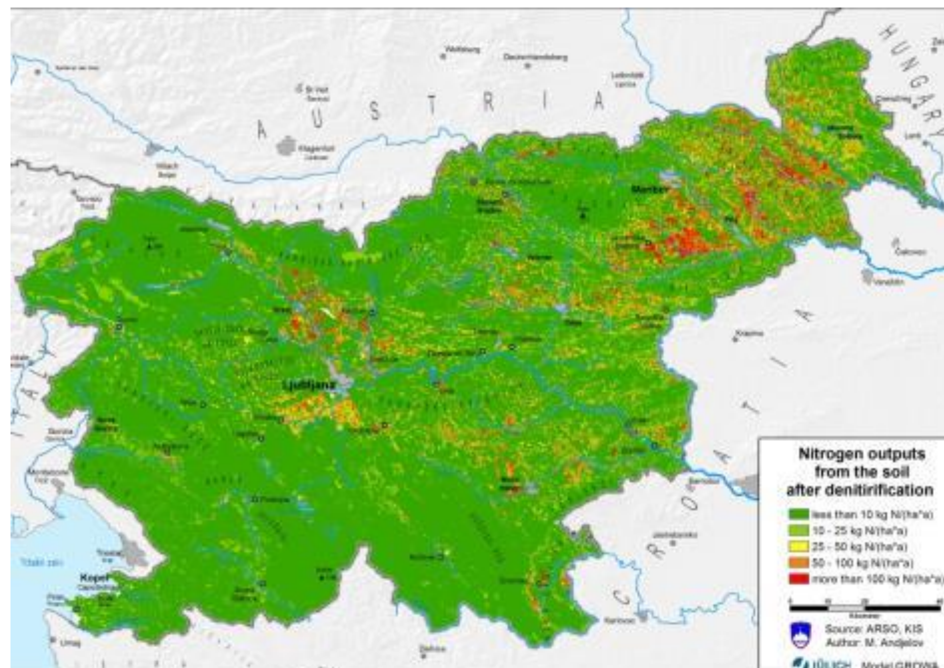


- Residence times in soil very low in general (<3 monhts) and eachate rate very high, hence dentrification rates low



Displacable N input into soil: 26980 t N/a

N output from soil: 20940 t N/a



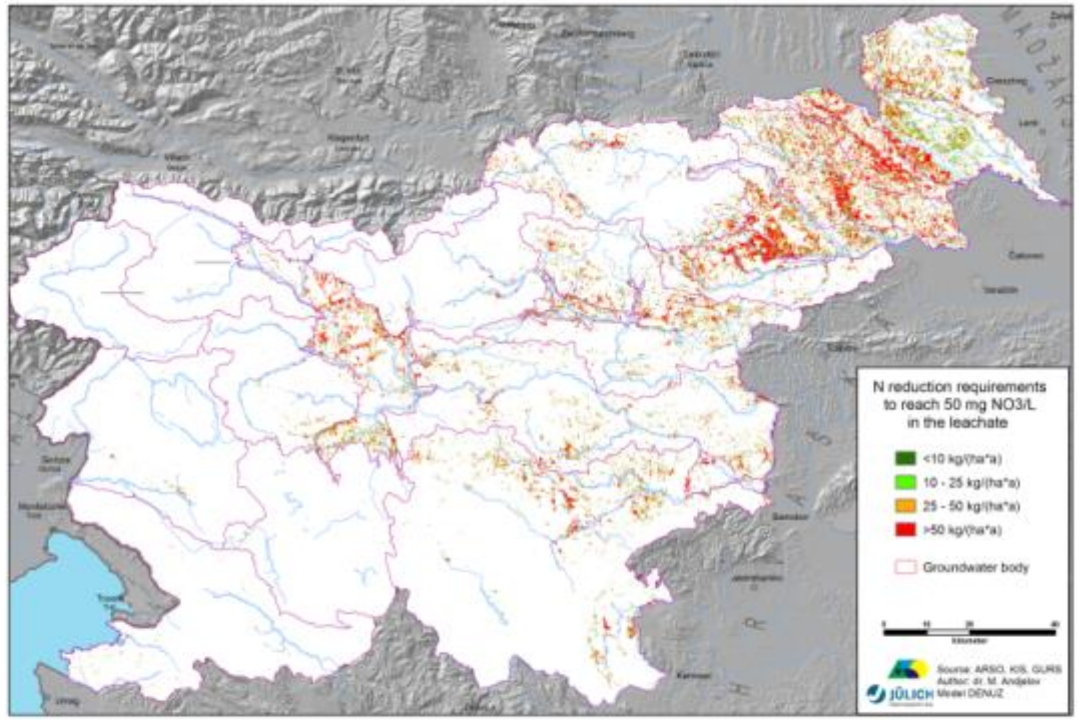
Dentrification in soil:

only of importance in basin areas; in total only ca. 6050 t N/a

N-reduction needed to guarantee 50 mg/l in the leachate

Backward calculation with (DENUZ model)

Assessment of necessary N reduction for the individual grids to reach target of 50 mg NO_3/l in the leachate



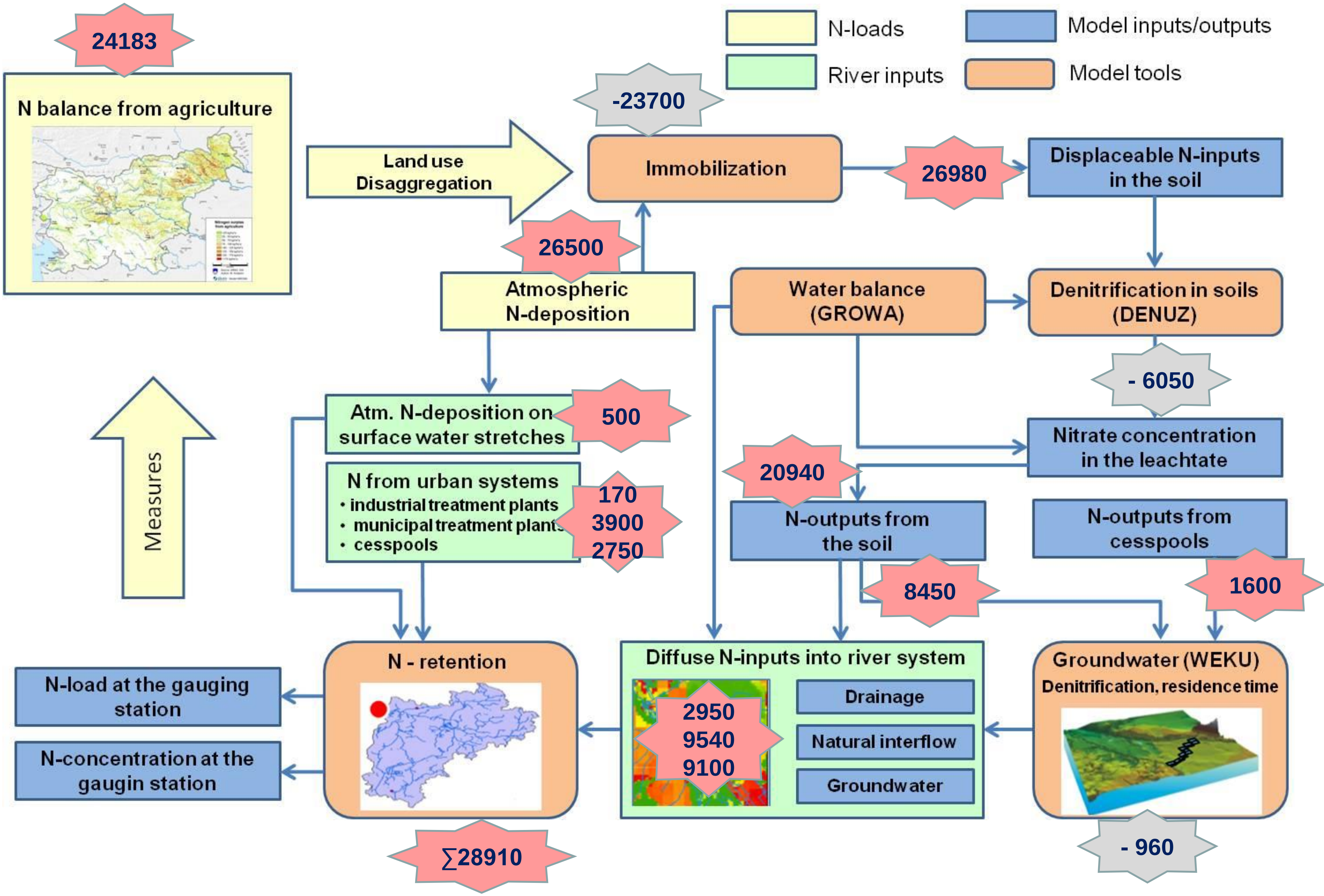
Reduction need: for ca. 939km2 (ca. 7373 t/a)

For most areas of Slovenia N reduction is not needed to guarantee 50 mg/l in the leachate

Higher N reduction only needed in certain intensive agricultural areas.

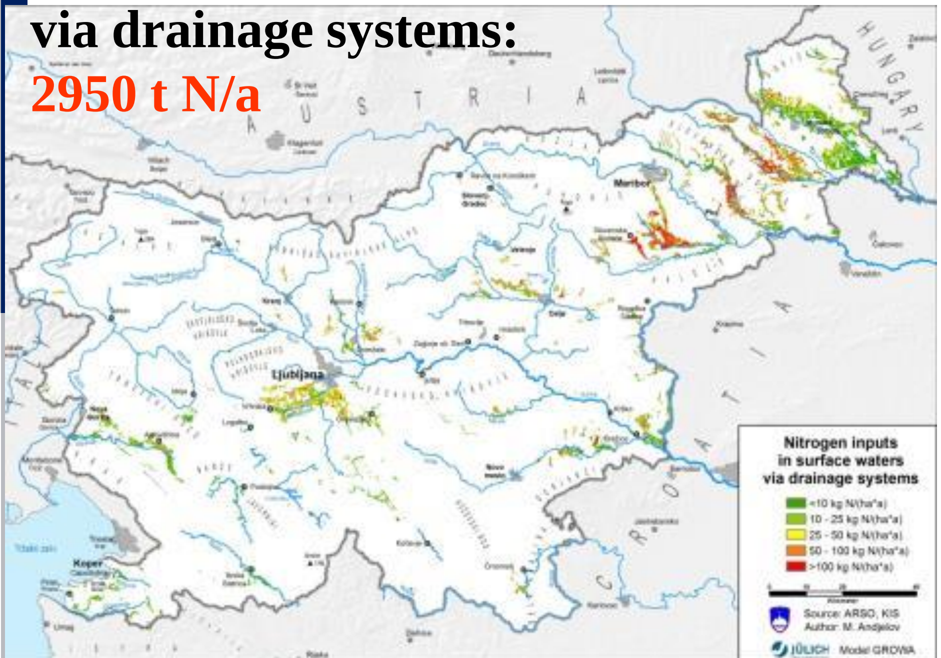
Implementation of measures can be directed to these “hot spots areas"*!!!!*

Summary of nitrogen flux analyses with GROWA-DENUZ-WEKU in t N/a (2011)

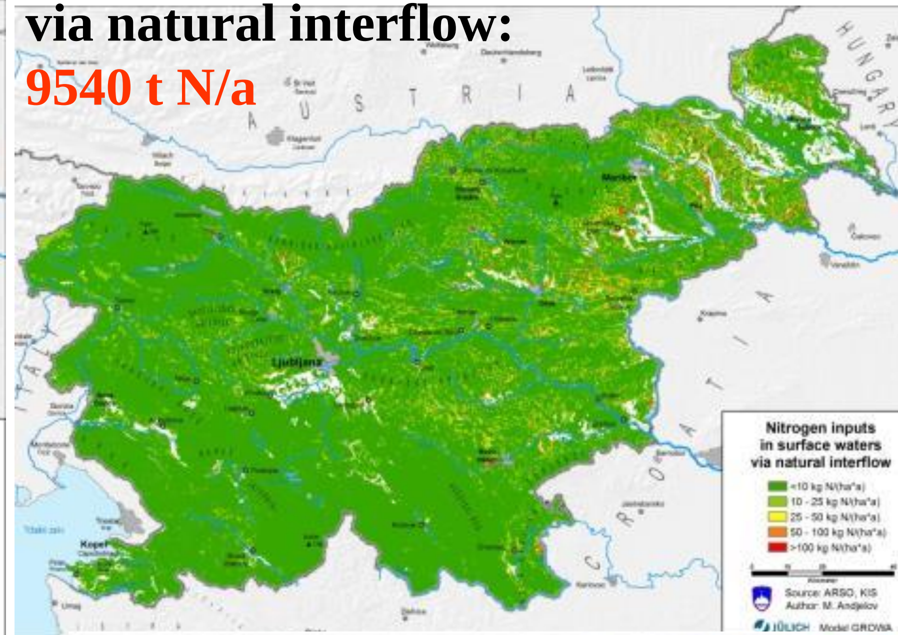


Diffuse N N input into into surface waters according to pathways

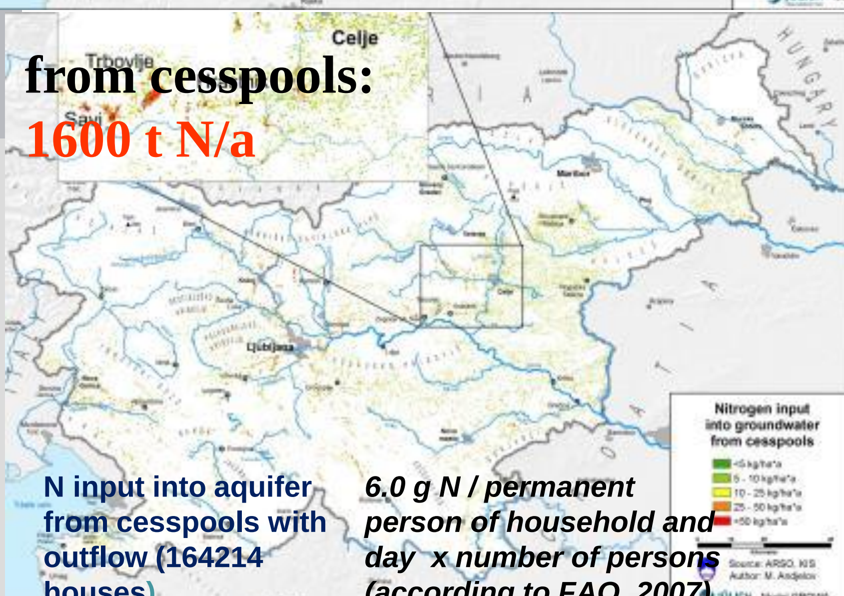
via drainage systems:
2950 t N/a



via natural interflow:
9540 t N/a



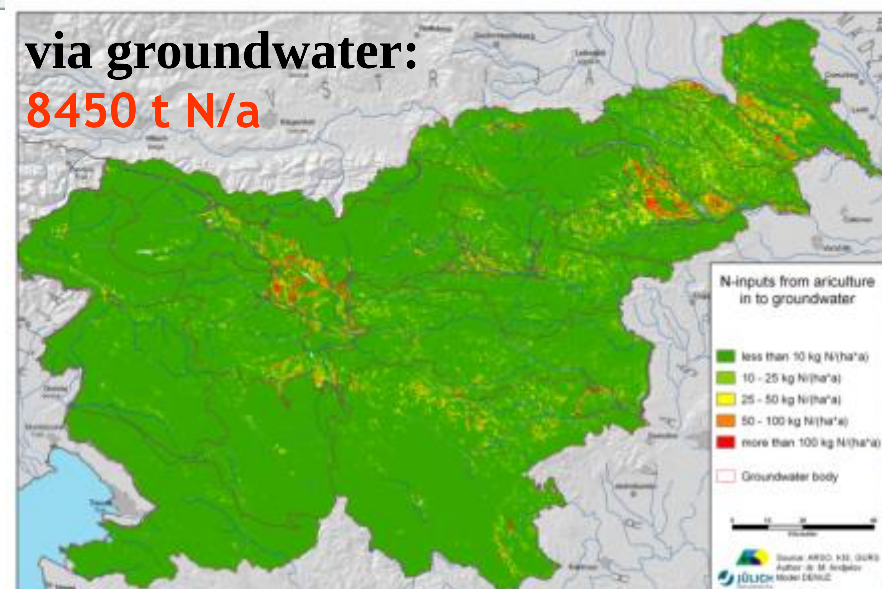
from cesspools:
1600 t N/a



N input into aquifer from cesspools with outflow (164214 houses)

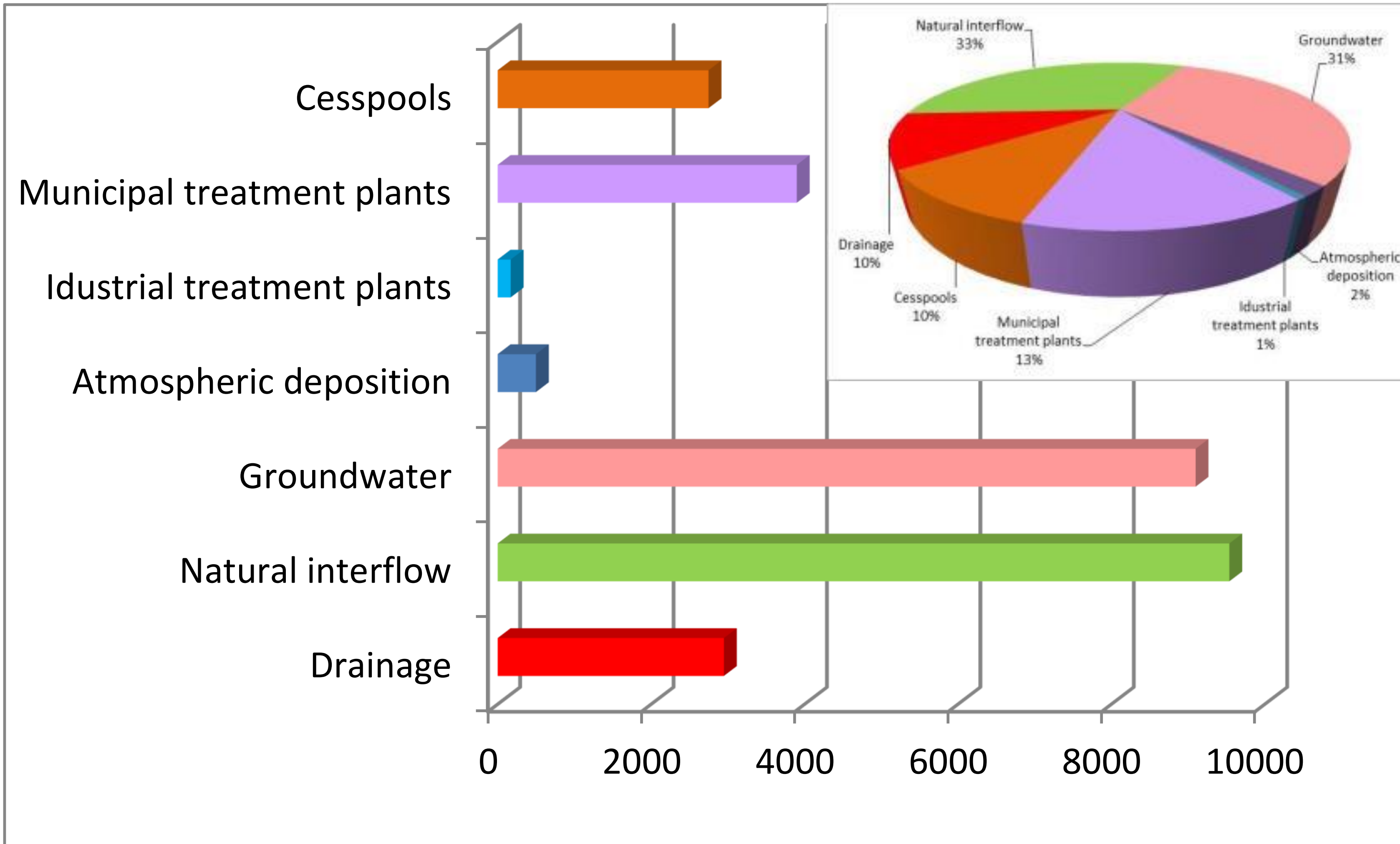
6.0 g N / permanent person of household and day x number of persons (according to FAO, 2007)

via groundwater:
8450 t N/a

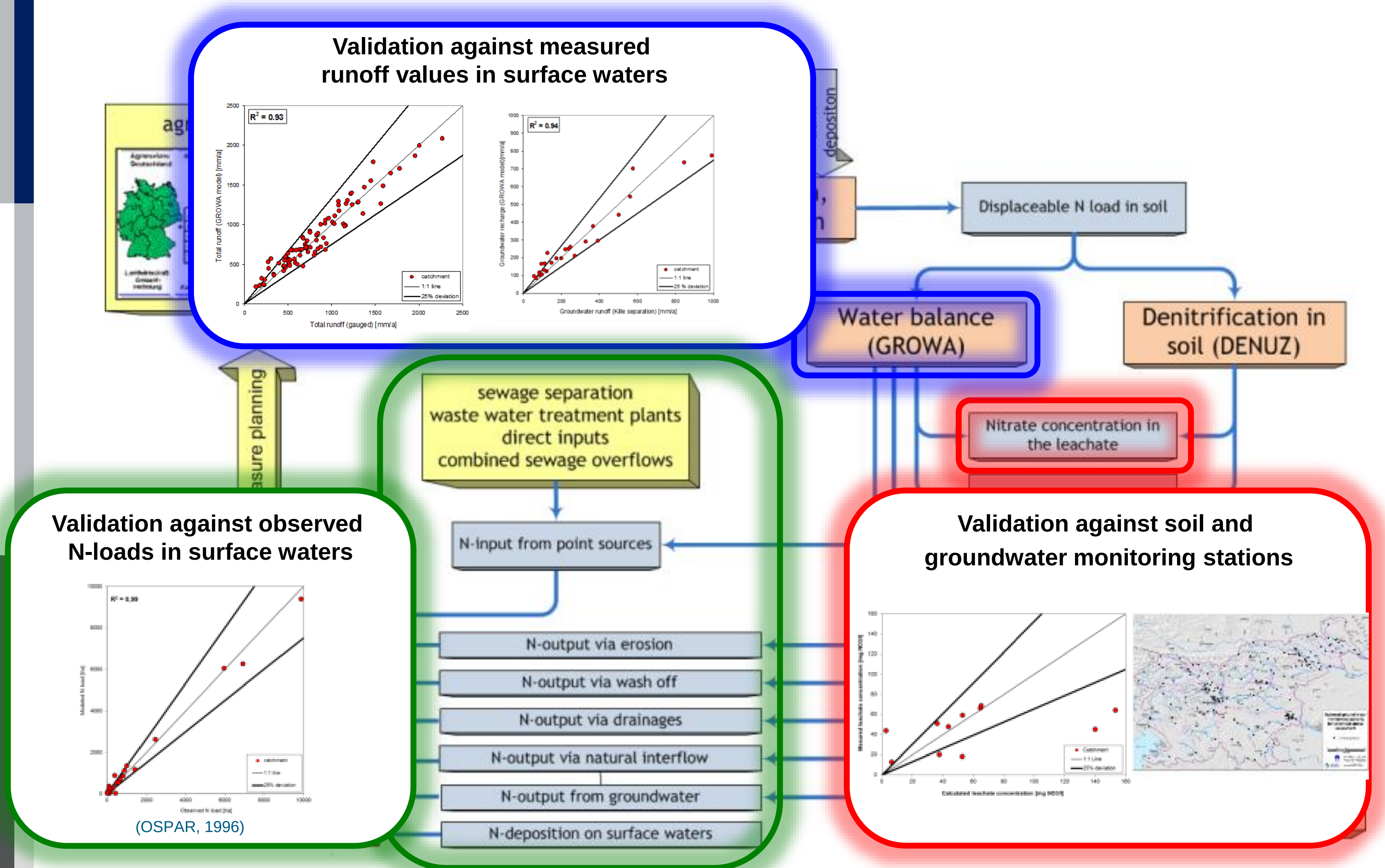


Total N input into surface waters from all sources in t N/a (2011)

Portion of diffuse inputs: ca. 74%



Validation of the model results



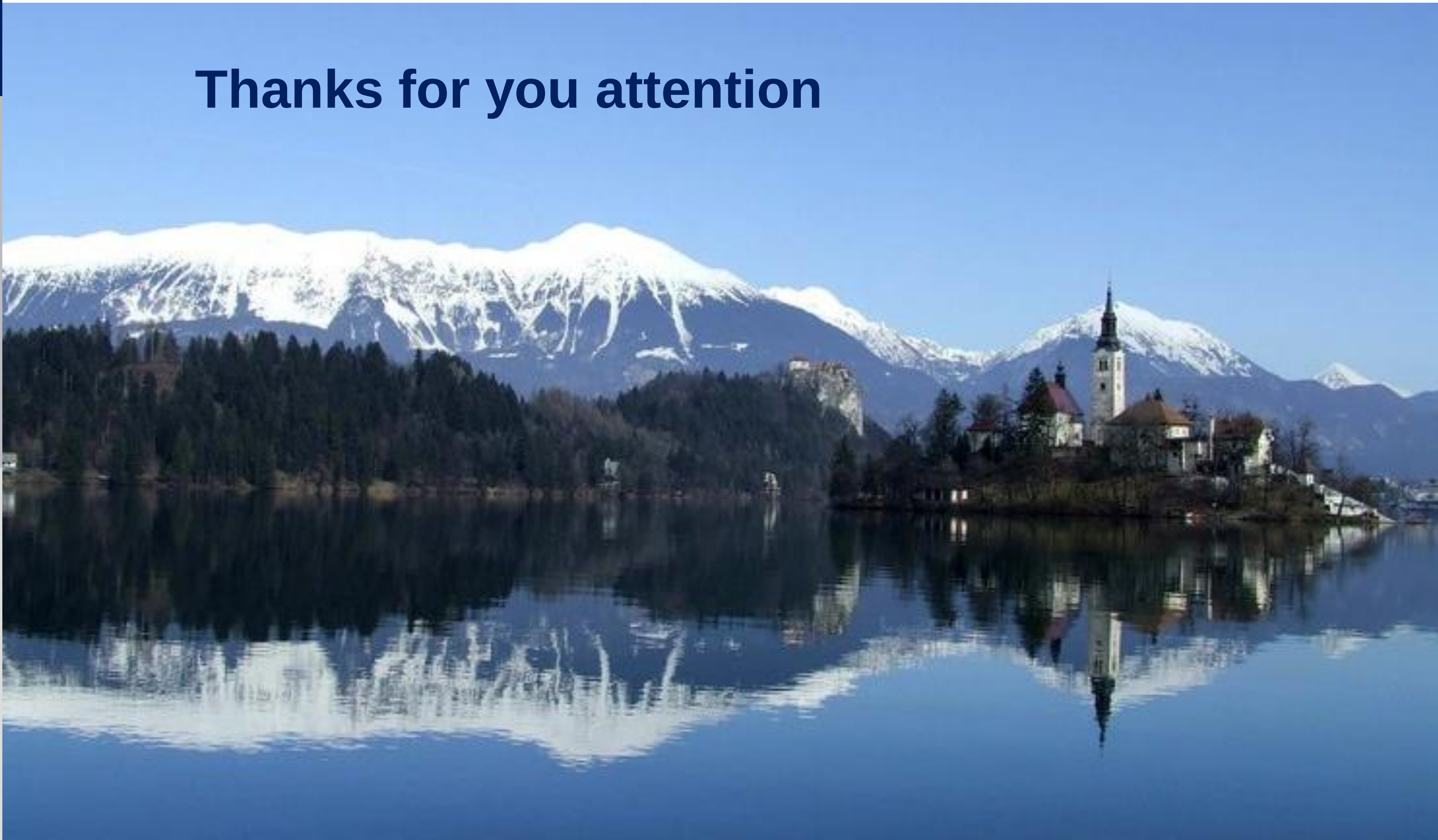
Summary

- GROWA/DENUZ/WEKU model concept as a part of an integrative N–management strategy for Slovenia:
  - Assessment of the actual N outputs from the soils and the nitrate concentration in percolation water
  - Identification of hot spot areas for action
  - Dimensioning of N reduction needs to reach 50 mg/l in percolation water was estimated by ”inverse” calculation
  - Assessment of the actual N loads into surface waters from the individual diffuse input pathways (drainage systems, interflow, groundwater)

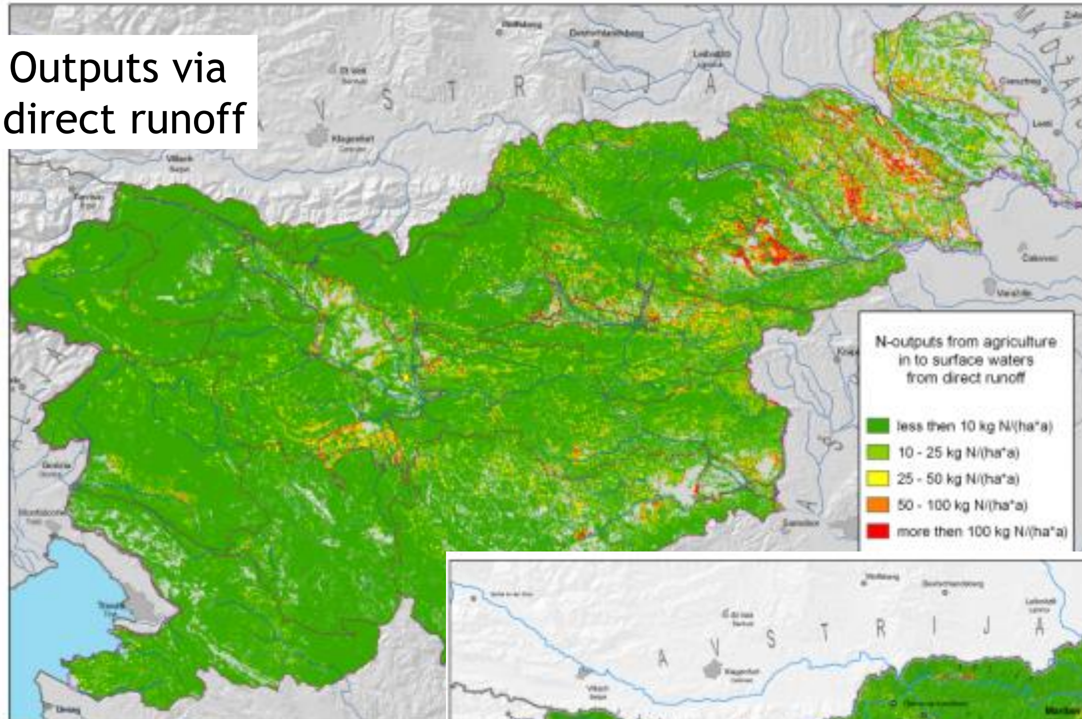
Outlook:

- Analyses of regional feasibility and impact of individual and combined agro-environmental N reduction measures (e.g. catch crops, ecological farming, fertilizer management, improved manure technics, …)
- Closing of data gaps (atmospheric deposition) and integration of additional pathways (erosion, wash-off)

Thanks for you attention

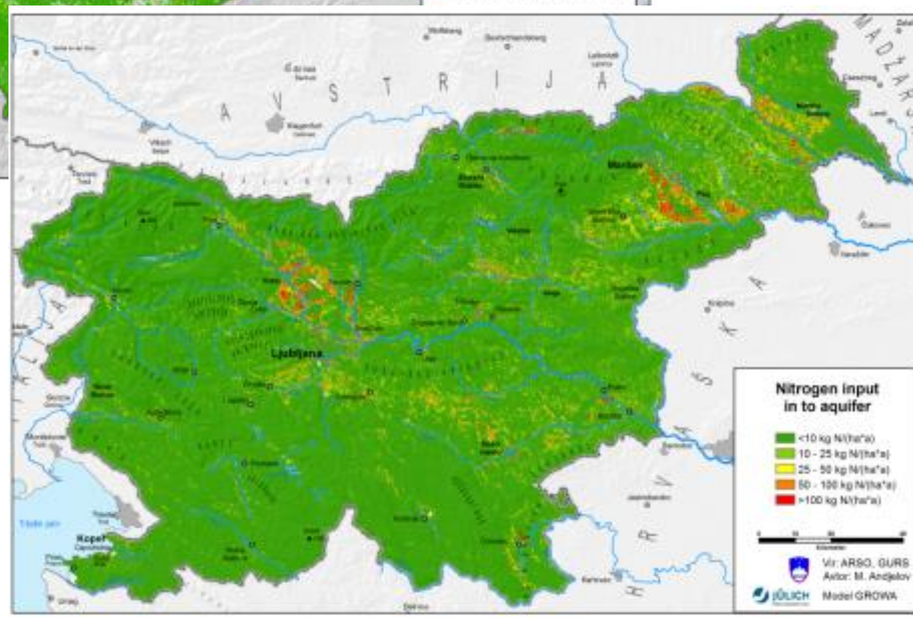


Diffuse N pathways into groundwater and surface waters according to runoff portions



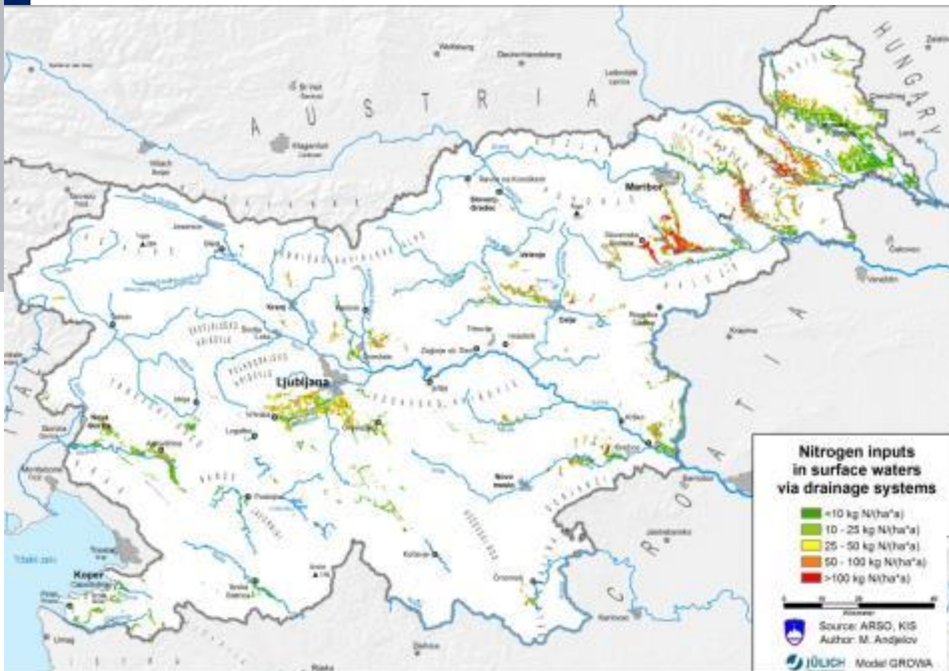
Output coupled to direct runoff reaches surface waters after days - weeks

It is assumed that the nitrate in the leachate is transported to surface waters and groundwater according to the runoff portions.



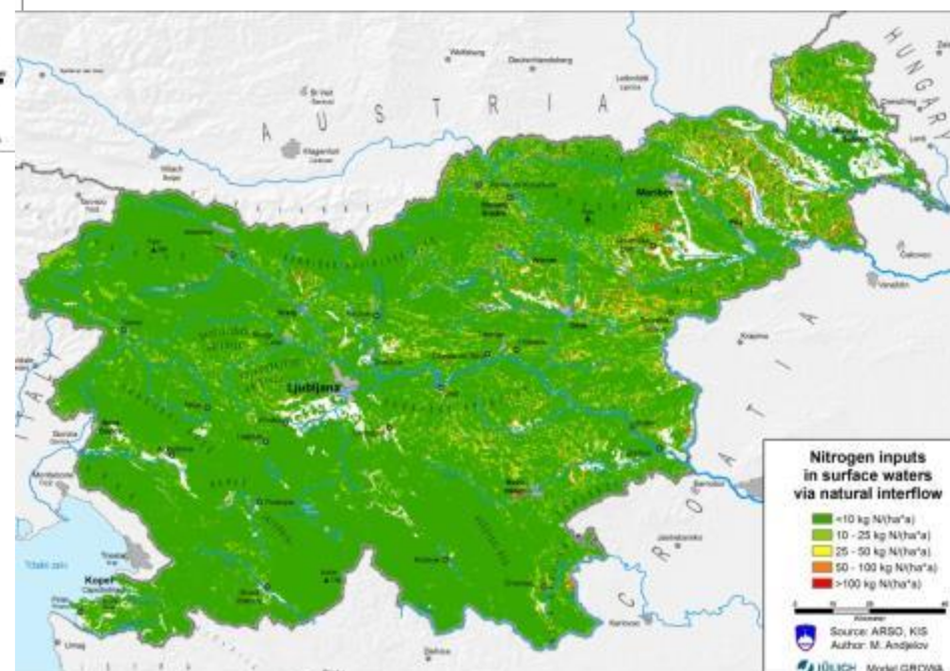
Output coupled to groundwater runoff reaches surface waters after years and decades

Diffuse N input into surface waters via direct runoff components (drainage systems, natural interflow)



N input into into surface waters via drainage systems: 2950 t N/a

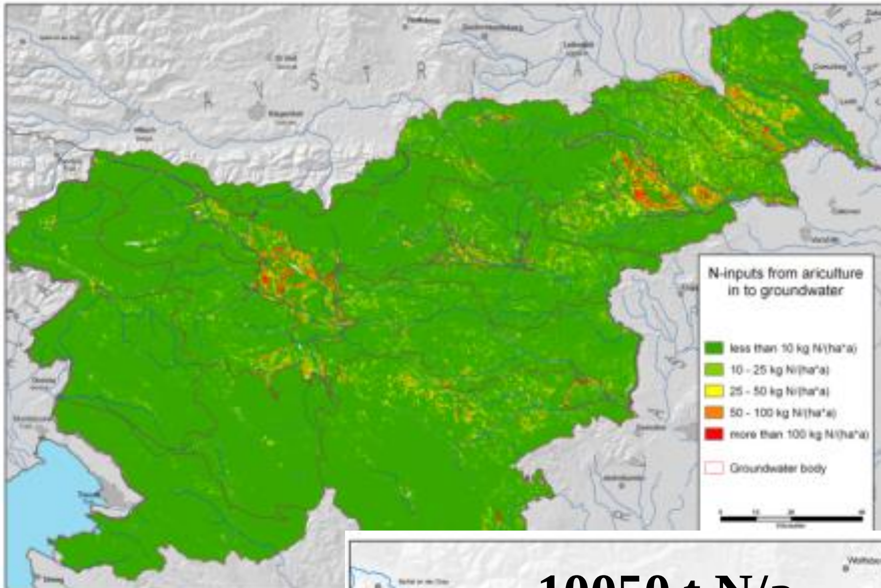
N input into into surface waters via natural interflow: 9540 t N/a



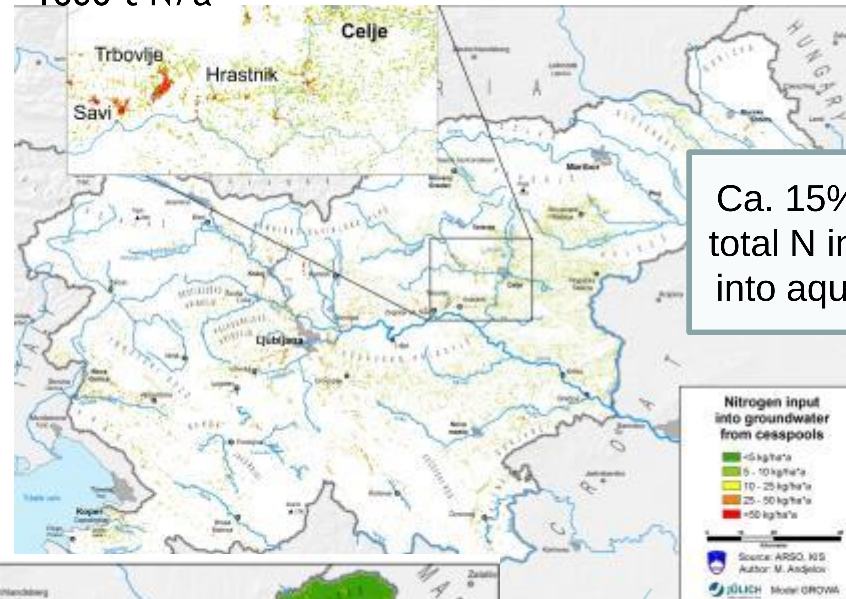
Total N input via natural interflow 3x as much as input via drainage systems, but output per hectar much higher in drained areas (31 kg / ha a compared to 4 kg / ha a from interflow)

Total N input into groundwater

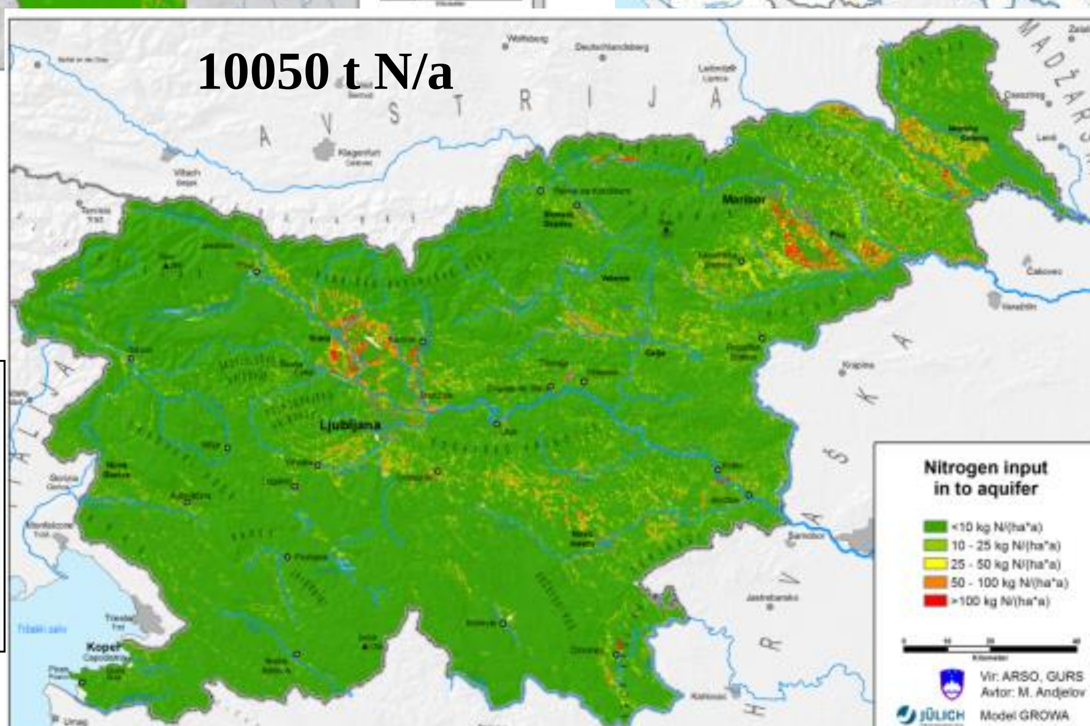
Diffuse N input into groundwater: 8450 t N/a



Point N input into groundwater from cesspools: 1600 t N/a



Ca. 15% of total N input into aquifer



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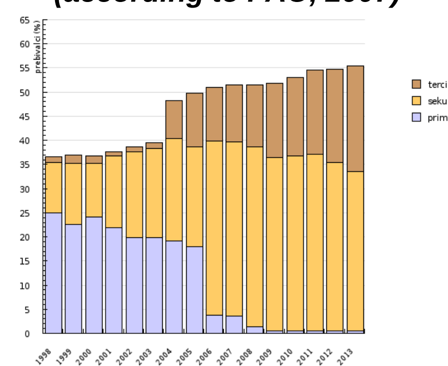


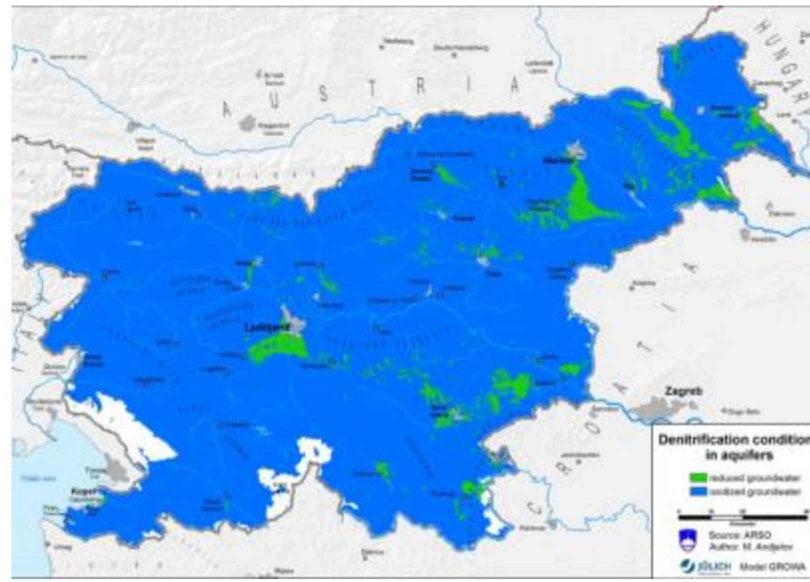
Take into account: Denitrification in some aquifers!!!

WEKU: modelling residence times and denitrification in groundwater

- Modeling as 1st order kinetics:

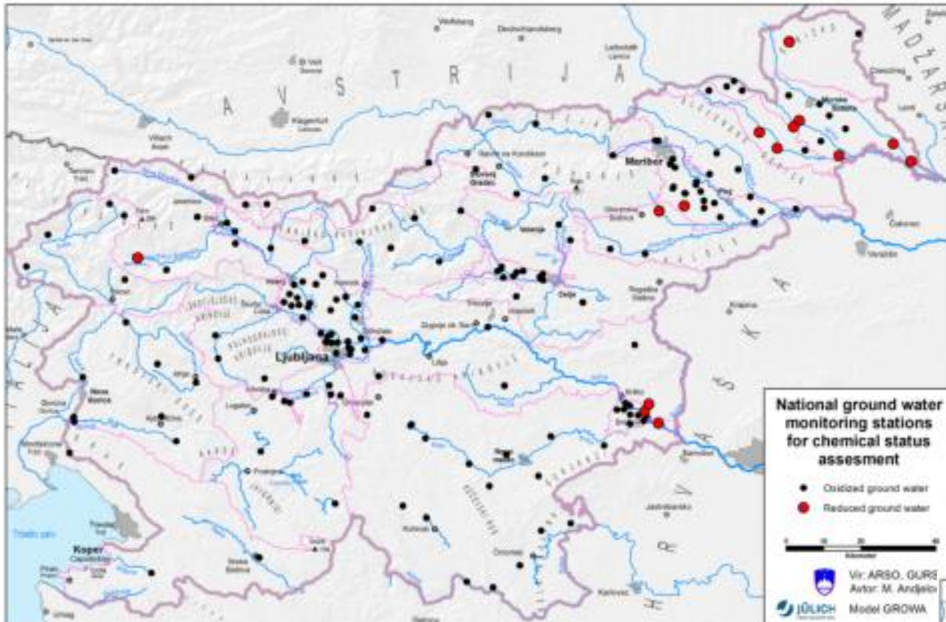
$$\frac{\partial N(t)}{\partial t} + k_n \cdot N(t) = 0 \quad \Rightarrow \quad N(t) = N_0 \cdot e^{-kn \cdot t}$$

- Denitrification depends on:
  - Nitrate concentration in recharged groundwater
  - Denitrification rate (kn)
  - Groundwater residence time (t)
- Half life time: 1.4 – 3.6 a
- Denitrification conditions derived from groundwater samples analysis



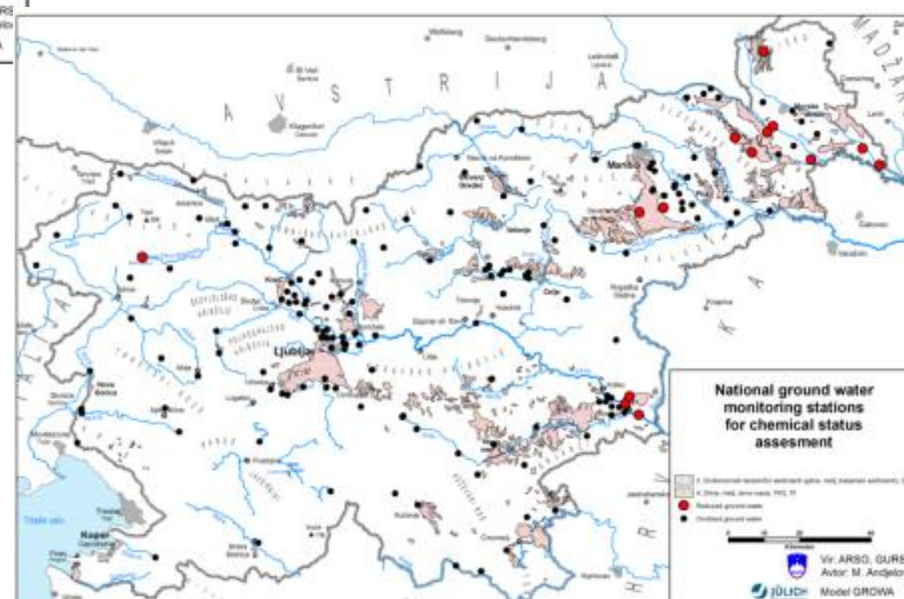
Parameter	nitrate degrading conditions
Nitrate	< 1 mg NO_3/l
Iron (II)	> 0,2 mg/ Fe (II)/l
Manganese (II)	> 0,05 mg Mn (II)/l
Oxygen	< 2 mg O_2/l

Identification of aquifers with denitrification



Available data base: National groundwater monitoring stations for chemical status assessment (187 stations).

- Only 14monitoring stations showed reduced aquifer conditions

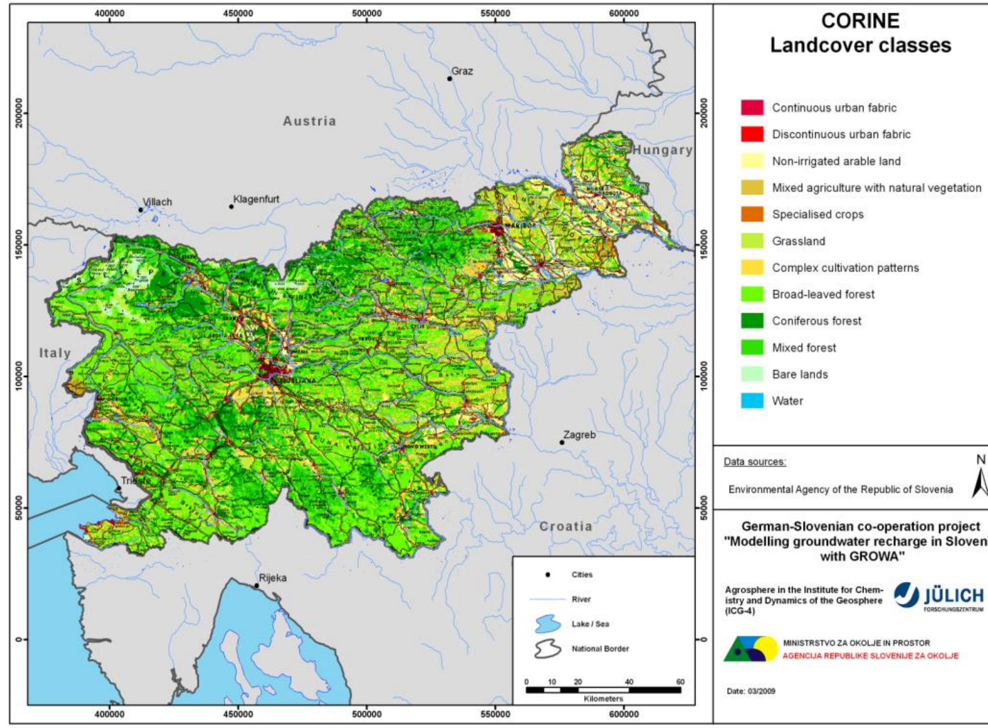


From this evaluation it can be concluded that only 3 aquifer typologies display denitrifying conditions:

- Coarse-grained non-lithified terrestrial sediments (Sand and gravel)
- Fine-grained terrestrial sediments (clay, silt, marsh deposits)
- Gravel, sand and silt

Introduction to Slovenia

- Size: 20,273 km^2
- Population: 2 Mio.
- Member of the EU since 2004
- Maximum precipitation 2600 mm/a
- Mean temperatures 8-10 ° C
- 30 % of the area is used agriculturally
- 65 % of the area is covered by forests
- 70 % of the aquifers are build up from consolidated rocks (Alps, Karst)



Transposition of the Nitrate Directive – Action Programme

Slovenia applies the action programme to the whole territory

Concerns all agricultural holdings that carry out fertilisation and agricultural holdings that produce livestock manure

Restrictions, conditions, measures:

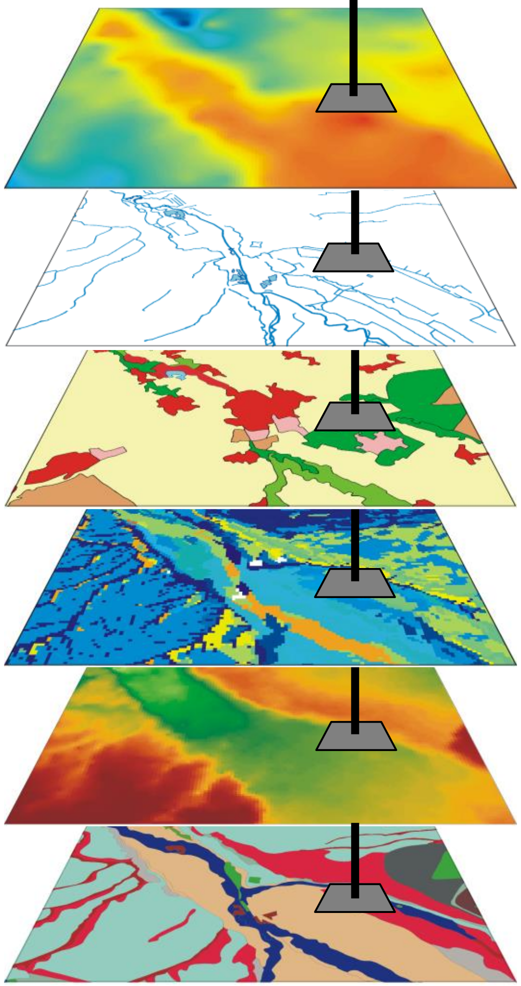
Limit of use to 170 kg N/h a/year for livestock manure

- Periods when the land application of certain types of fertilisers is prohibited
- The rules for fertilisation on steeply sloping ground
- The rules for fertilisation on water-saturated, flooded, frozen or snow-covered ground
- The rules for fertilisation in the vicinity of watercourses
- The smallest permitted capacities of facilities for the storage of livestock manure
- Measures to prevent the pollution of waters from the storage of solid manure
- Fertilisation procedures, including the doses and homogeneity of consumption of mineral fertilisers and livestock manure
- Inspection
- Fines
- Reporting obligations

GROWA model

(Kunkel & Wendland, 1998; 2002)

Parameter set for one raster cell



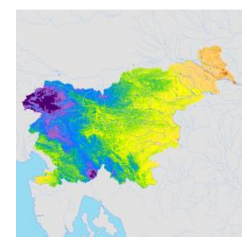
GROWA

Calculation of total runoff depending on landuse ℓ

$$Q_{tot}(\ell) = P_y - h_{relief}\left[a_\ell \cdot P_{wi} + b_\ell \cdot P_{su} + c_\ell \cdot \log(W_{pl}) + d_\ell \cdot ET_{pot} + e_\ell\right]$$

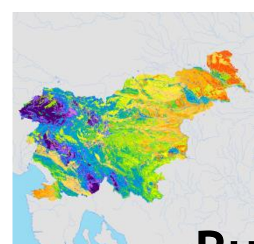
Separation into runoff components

$$\mathrm{Q}_{\mathrm{tot}} = \mathrm{Q}_{\mathrm{groundwater}} + \mathrm{Q}_{\mathrm{direct}} = \mathrm{r}_{\mathrm{b}} \cdot \mathrm{Q}_{\mathrm{tot}} + (1 - \mathrm{r}_{\mathrm{b}}) \cdot \mathrm{Q}_{\mathrm{tot}}$$

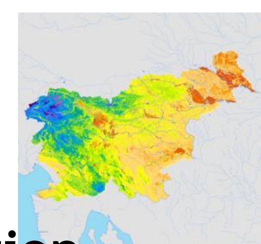


$\mathbf{Q_{tot}}$

$\mathbf{Q_{groundwater}}$



$\mathbf{Q_{direct}}$

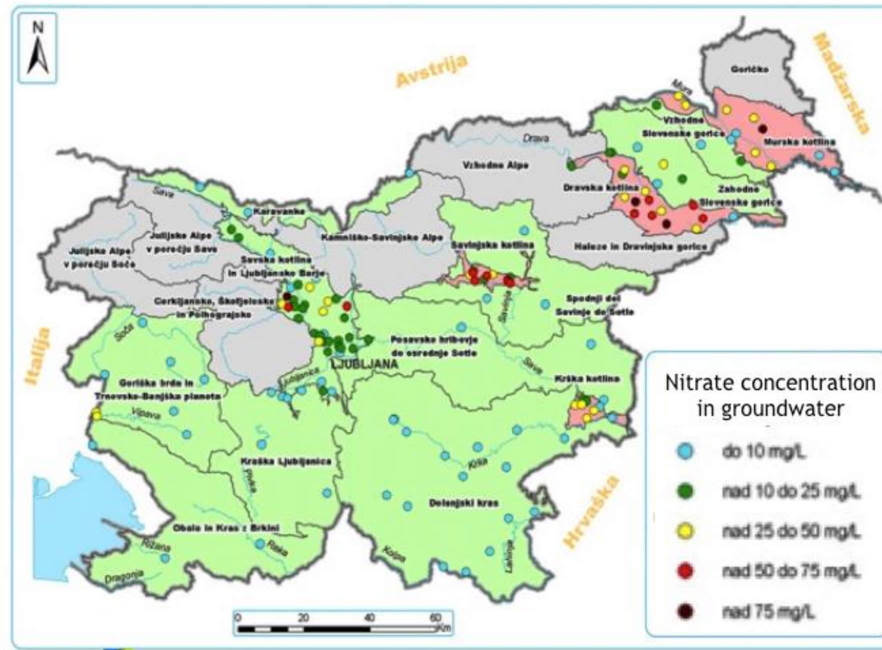


Runoff separation

Water resources management targets in Slovenia

Integrated N-management strategies include the imple-mentation of an N-model on the country level to:

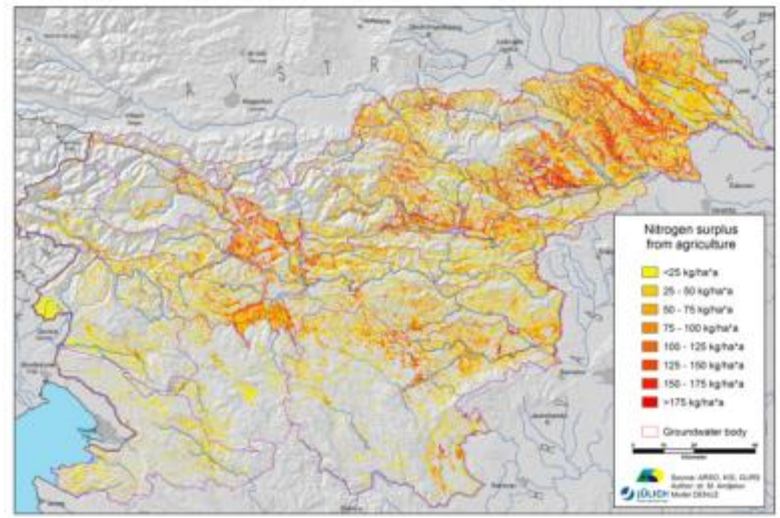
- Identify the relevant sources, the regional dominant input pathways and the hot spot areas for action
- support the future design of programs of measures to reduce nutrient pollution of water resources
- reach good status of water resources (in the long run)



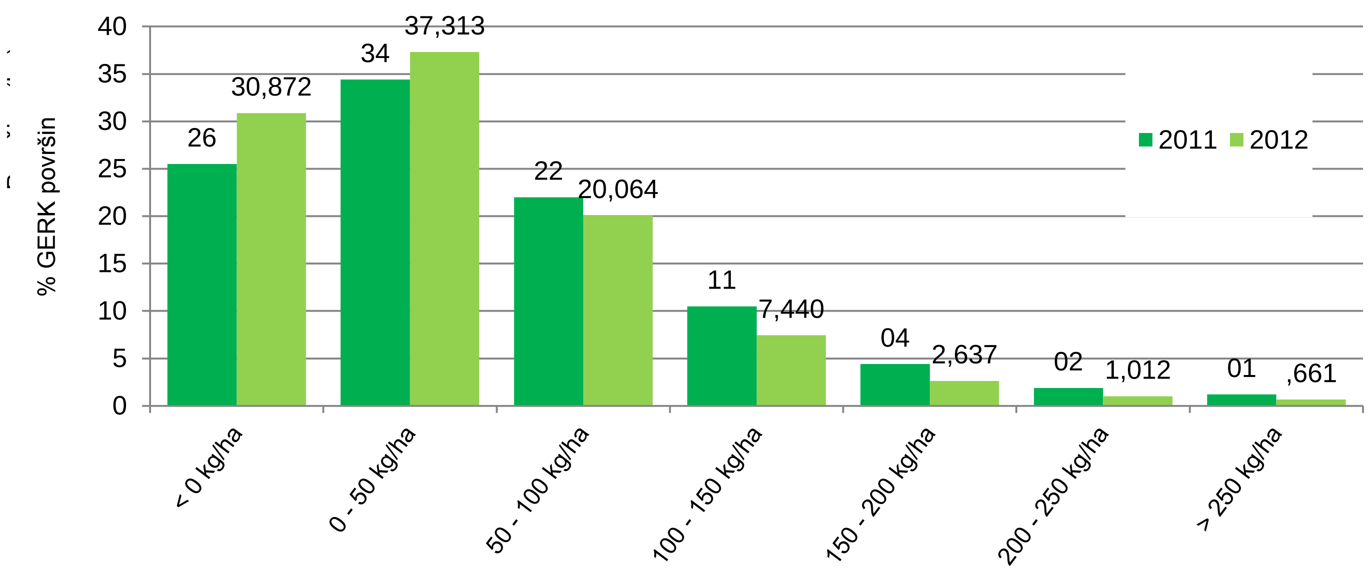
R&D Cooperation of ARSO and FZJ since 2008

Interpretation of the results

- Evaluated 456.314 ha of agricultural area (69 % of all agricultural area)..
- The comparison with 2011 shows the:
    - increase of areas with balance of N bellow 50 kg/ha.
    - decrease of areas with balance above 50 kg/ha.



N-balance of agriculture- 2012 - 2011



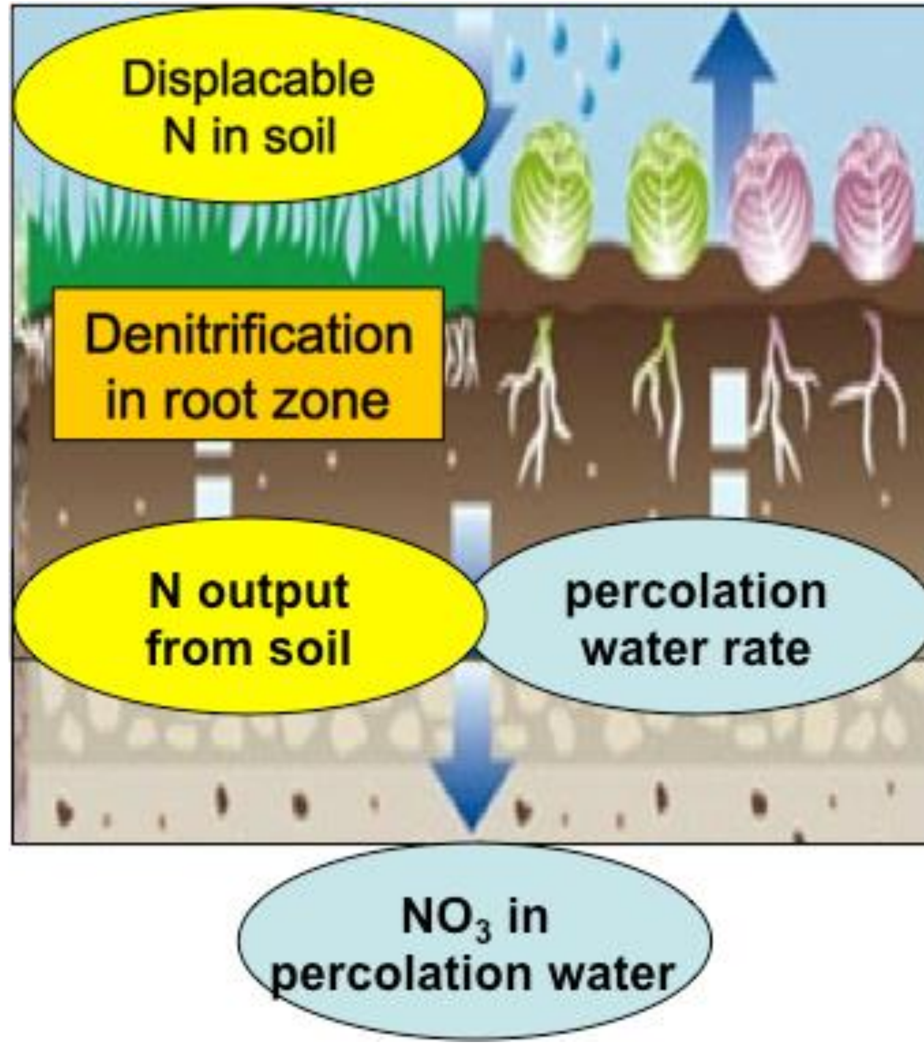
Nitrate concentration in the leachate

EU groundwater directive:

- 50 mg NO_3/L in groundwater
- **not accessible by large-scale models**

Environmental target:

- nitrate concentration in the leachate ≤ 50 mg NO_3/L
- (long-term) achievement of the nitrate quality target for groundwater is guaranteed
- Accessible by large-scale models



Conclusions

- Combined model system GROWA/DENUZ/WEKU was used to analyze current pressures by N-surpluses in the Weser basin to
  - Groundwater
  - Surface waters (not presented here)
- For groundwater
  - An environmental target for groundwater protection measures was defined as 50 mg NO3/L in the leachate
  - The reduction demand of N-surpluses from agriculture was estimated by ”inverse” calculation
- Representation and validation of status quo
- Impact of EU Common Agricultural Policy of the EU until 2021
- Identification of priority areas and additional N reduction level necessary in order to meet groundwater quality targets
- Estimation of extent and costs of additional N reduction measures