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Measured and modelled nitrogen fluxes at the ICP IM site Zöbelboden, Austria

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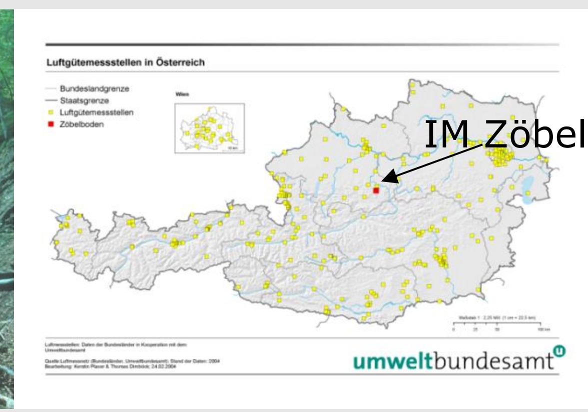
LTER Zöbelboden - overview

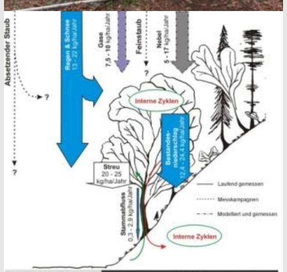
- Established in the year 1992 as the Austrian's contribution to **ICP Integrated Monitoring** (UN-ECE) of air pollution effects in Europe
- Forested, **90 ha Karst catchment** (550 - 950 m a.s.l) in the Northern Limestone Alps
- Combines high quality air measurements (EMEP) with integrated ecosystem monitoring
- Today LTER Zöbelboden serves as an ecosystem monitoring and research site for the **effects of air pollution and climate change including biodiversity**
- Part of LTER Europe, EU ALTER-Net (FP6), EU EXPEER (FP7), LTER Austria and LTSER Eisenwurzen



Background & research questions

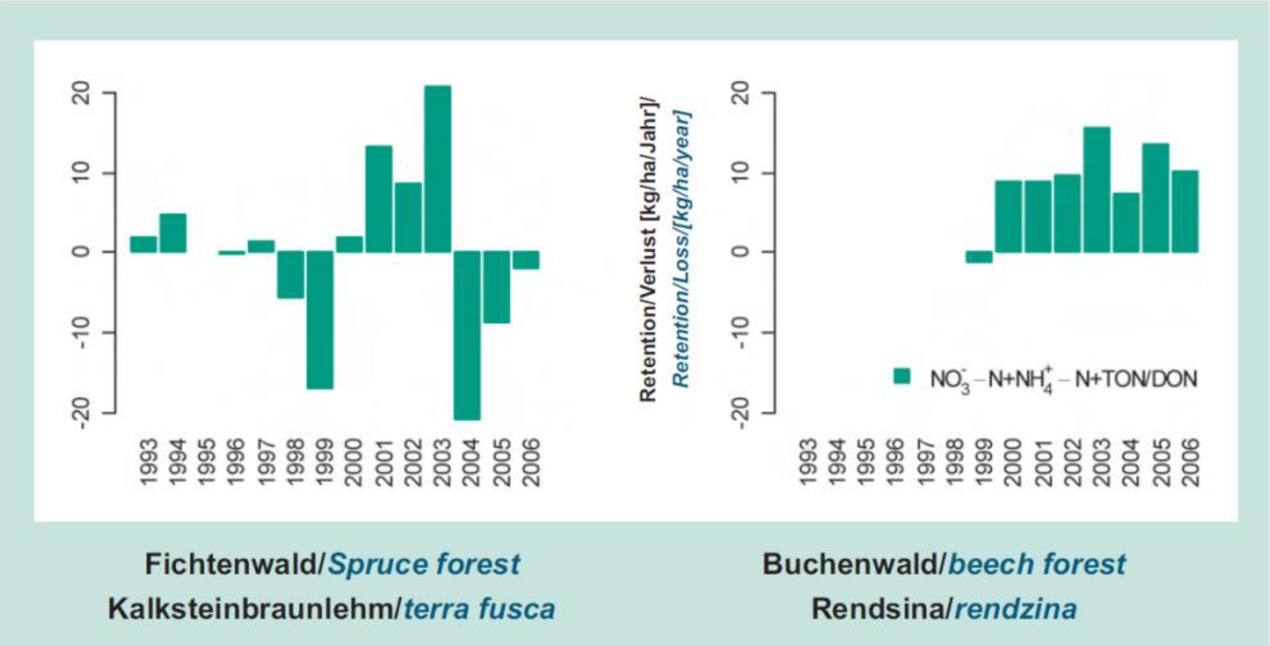
- **Karst areas provide 50% of the Austrian drinking water**
- Owing to a **very fast runoff dynamic** the **water quality is highly vulnerable to forest disturbances** from management but also from climate change
- **How can forestry minimize negative effects of climate change on water quantity and quality?**
- We **focused on nitrate** because high nitrogen pollution occurs in many Karst areas in Austria

Excess N deposition at Zöbelboden



- **Pre-industrial: 3-5 kg/ha/year**
- **Critical load** for eutrophication: **10 – 20 kg/ha/year**
- **Measured exceedance**
  - Throughfall + stemflow **21 (beech forest) – 27 (spruce forest) kg/ha/year**
  - **Total** deposition (including modelled dry and fog deposition) **sums up to 30-40 kg/ha/year**

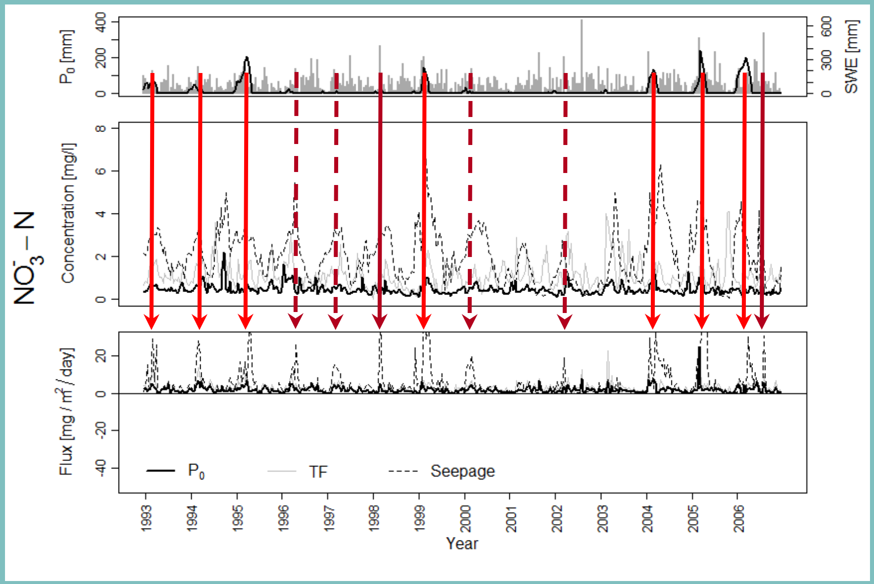
Annual N balances at two forest sites



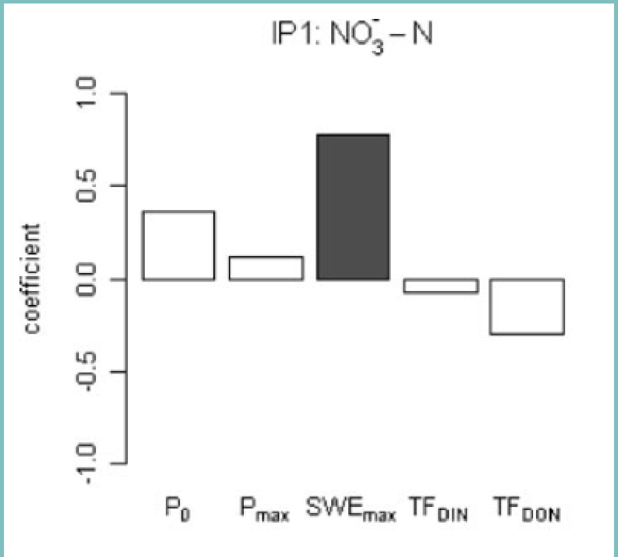
- Very **high variation in Norway spruce forest** with peaks up to 34 kg Nitrat-N/ha/yr
  - This is in the range of polluted or disturbed sites but there are **no other signs of N saturation**
  - **Strong throughflow events, are typical for Karst areas**, even when sites are N limited (… may hide saturation effects)
- European **beech forest accumulates N**

Jost, G., Dirnböck, T., Grabner, M.-T. & Mirtl, M. 2010. Nitrogen leaching of two forest ecosystems in a Karst watershed. *Water Air and Soil Pollution*

What controls nitrate leaching at the forest stand scale?



Spruce forest, Cambisols



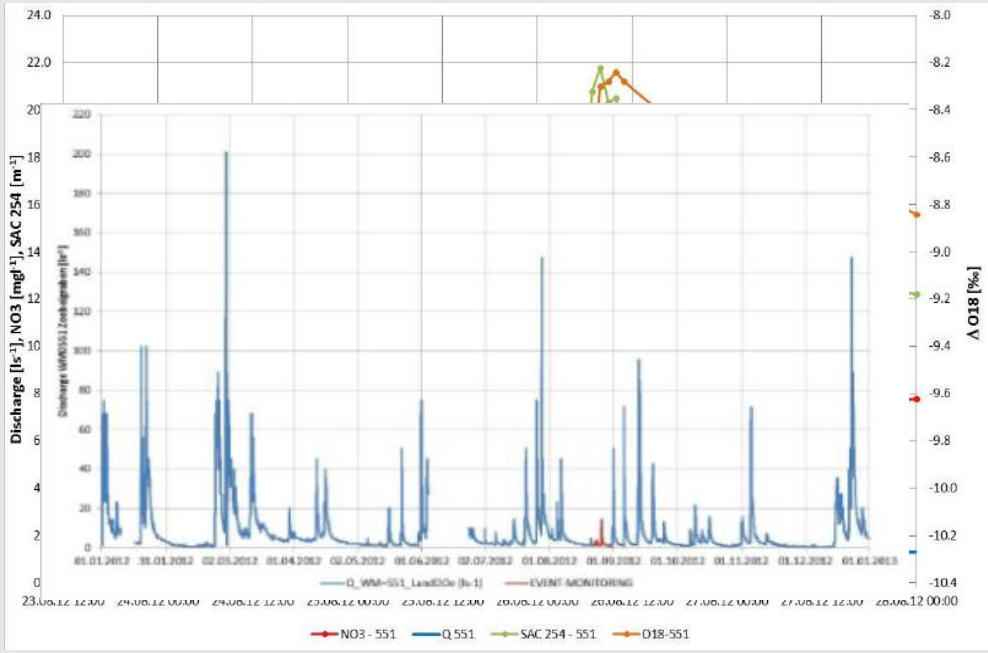
P: Precipitation; SWE: Snow water; TF: Throughfall (Conz.)

- Nitrate leaching is predominately **controlled by snow melt and heavy rain events**
- **Climate events** play an important role (drought year 2003, wind throw – bark beetle)

Jost, G., Dirnböck, T., Grabner, M.-T. & Mirtl, M. 2010. Nitrogen leaching of two forest ecosystems in a Karst watershed. *Water Air and Soil Pollution*

Catchment scale Nitrate runoff dynamic during hydrological events

- Two **unexceptional (not strong!) summer rain events** (36 mm precipitation during 7 days)
- **Rapid increase in nitrate concentrations** after a short dillution phase



Stadler, H. 2013. unpublished report

Nitrate loss from soils after small scale forest disturbance

2001
Undisturbed

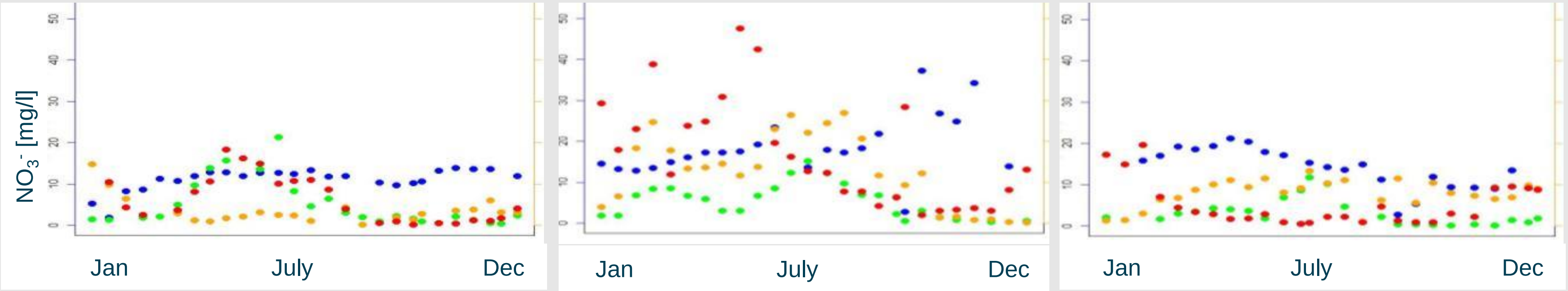
2004
gap disturbance at about 20% area

2007
tree regeneration

→ Nitrate < 20mg/l

→ Nitrate up to ~50 mg/l

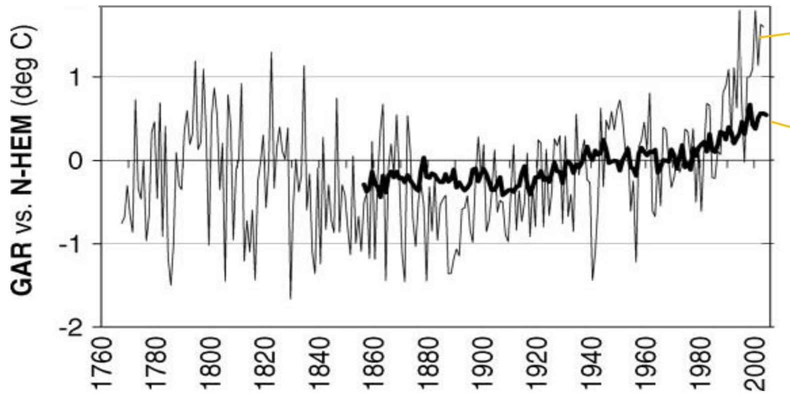
→ Nitrate elevated but again < 20 mg/l



Norway Spruce forest on Cambisols/Leptosols; windthrow + bark beetle

Climate change

Auer et al. (2007)

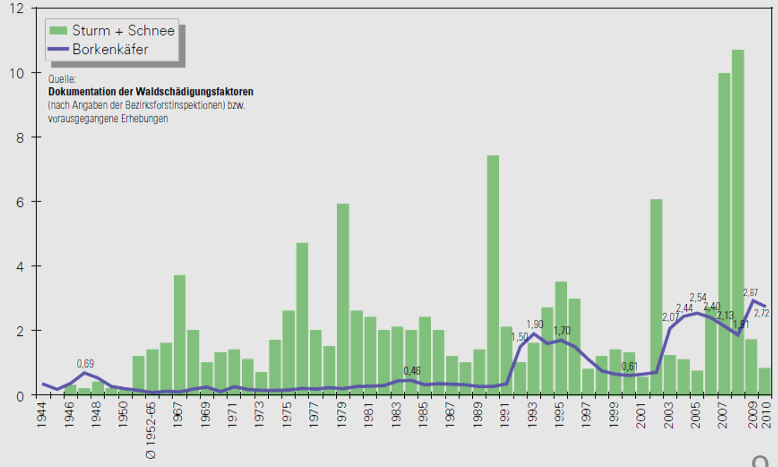


European Alps

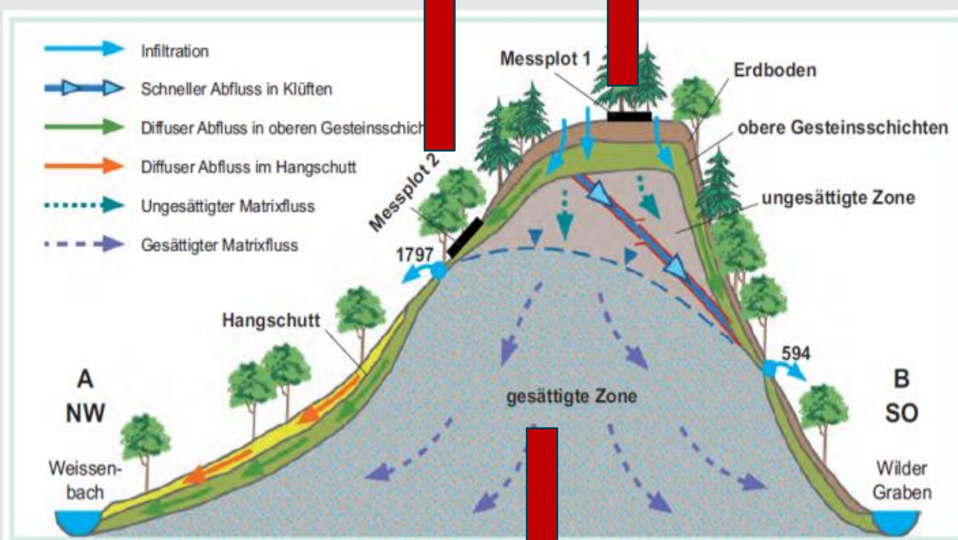
Northern Hemisphere

- … and indirect effects to forests

Tomiczek et al. (2011)



DNDC at forest stand level together with the hydrological catchment model VarKarst



Landscape-DNDC
Ecosystem Model

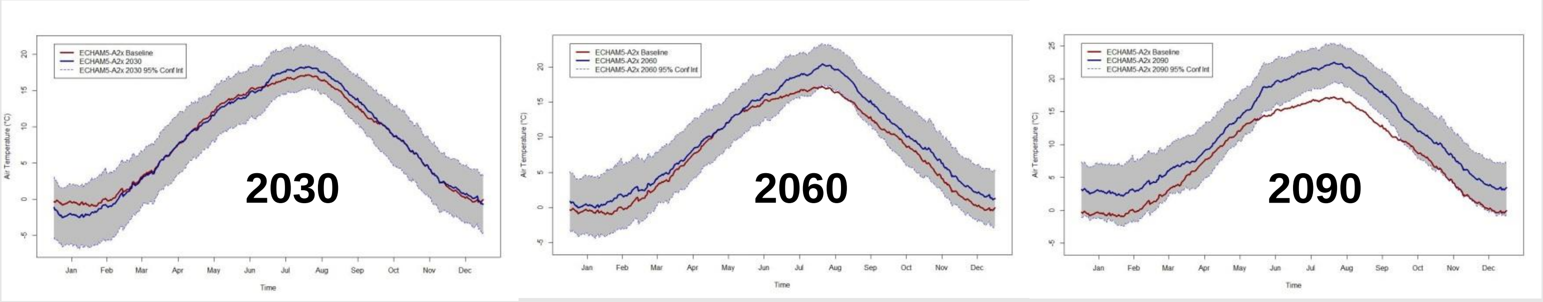
VarKarst
Hydrochemical
Catchment Model

Climate and management scenarios

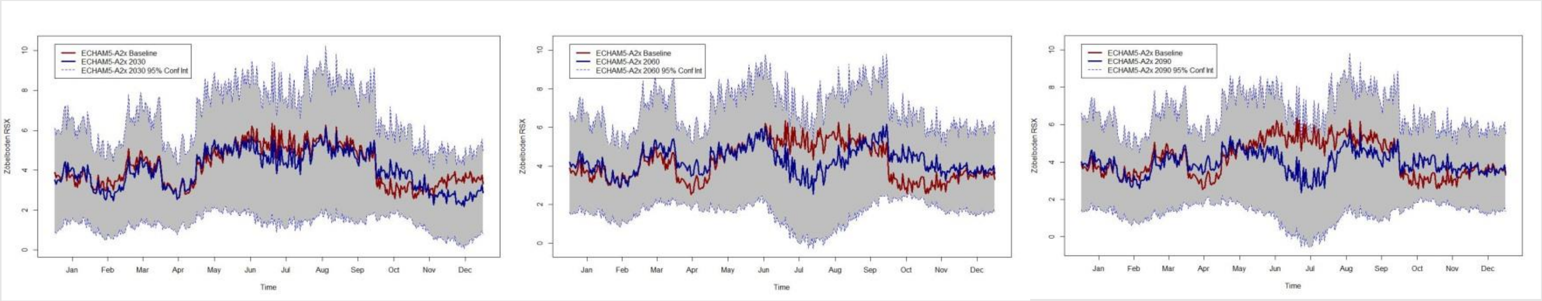
- Climate
  - **Daily values** for temperature, precipitation, global radiation, humidity, and wind speed
  - Synthesized from several **downscaling Scenarios** (A1B, B1 & A2); resolution 10 km
  - … and **two GCM models**: ECHAM5/MPI-OM, HadCM3
  - … using a **weather generator (ClimGen)** which is calibrated with the long-term measured data
- Forest management
  - **Low-intervention** forest management (spruce-beech forest with single tree harvest)
  - **Medium-intervention** shelterwood Norway spruce management
  - **High-intervention** clearcut Norway spruce management

Climate Scenarios

- Increasing temperature; **strongest temperature increase will occur in summer**
- **Decreasing precipitation in summer, increase in winter** (**BUT** high GCM specific variation!)



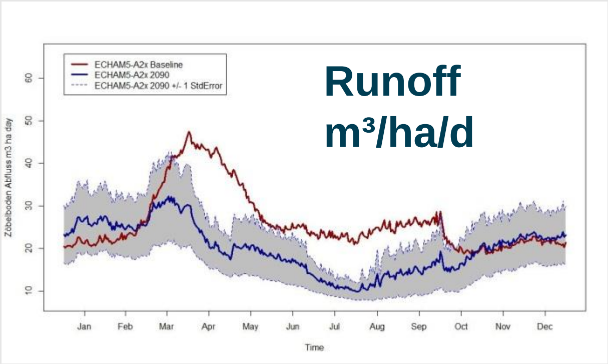
Temperature scenarios (ECHAM5-A2) for Zöbelboden showing mean (bold line) and variation (95% confidence interval in grey shade) of a 150 years time series. Baseline refers to the years 1990 to 2010 (bold red line).

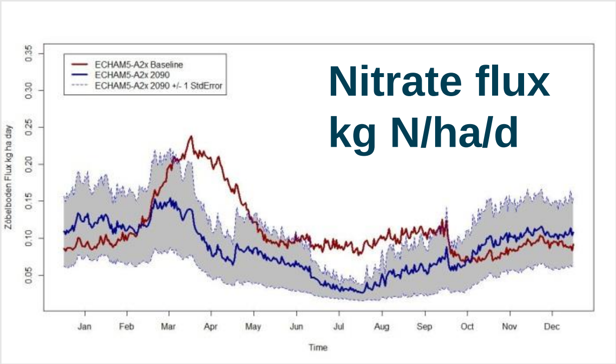


Precipitation scenarios (ECHAM5-A2) for Zöbelboden showing mean (bold line) and variation (95% confidence interval in grey shade) of a 150 years time series. Baseline refers to the years 1990 to 2010 (bold red line).

CC Effects to catchment runoff and water quality

- Climate change will **decrease water runoff in the summer** months
- During the coming **1-3 decades runoff in winter/spring will increase** due to more precipitation, less snow and higher snowmelt in early spring, **later on runoff decreases** throughout the year
- Direct **climate change effects rather decrease nitrate leaching**
  - **Higher nitrate leaching** may occur in winter/spring **during the next 1-3 decades**





Baseline (1990-2010)

ECHAM-A2, 2080-2100

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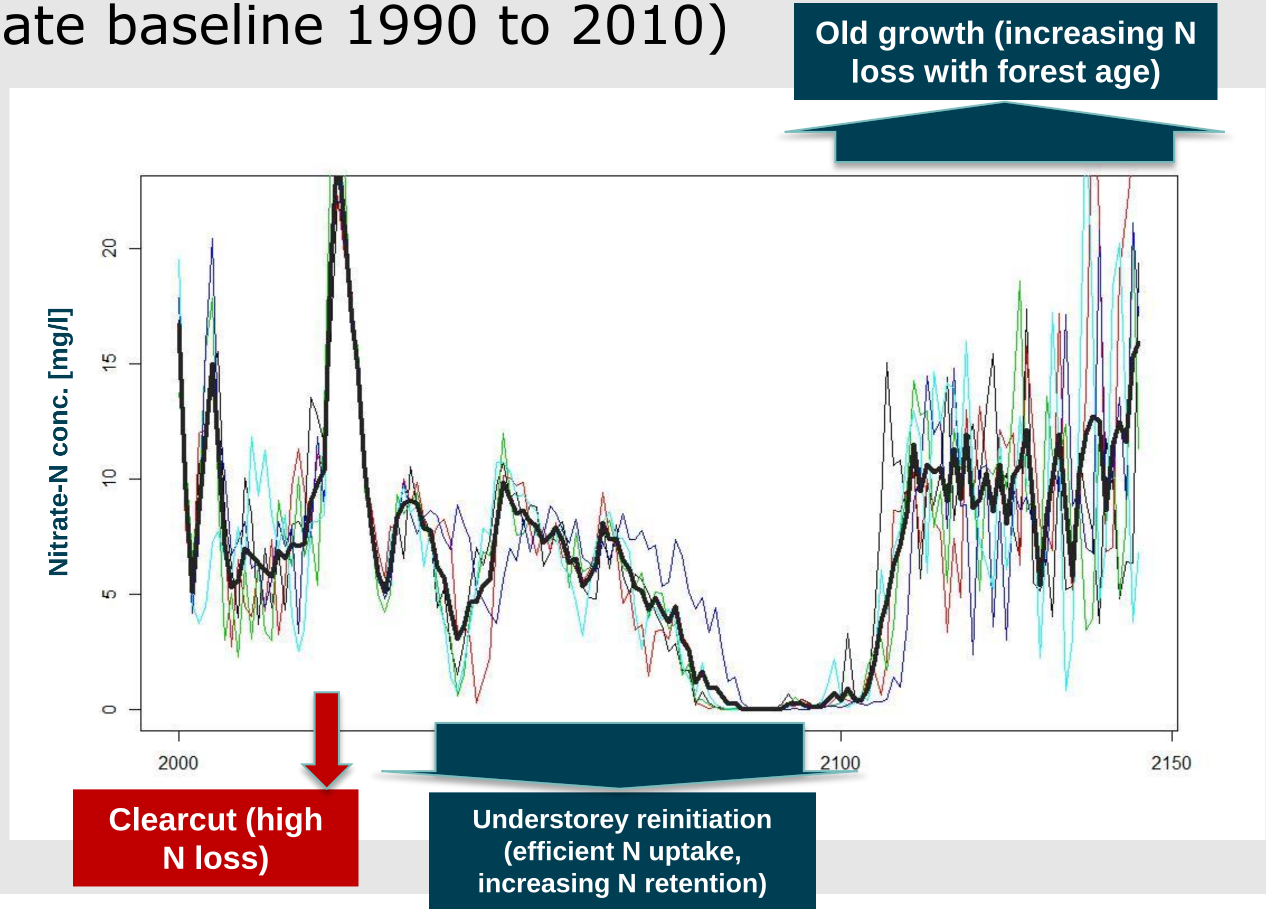
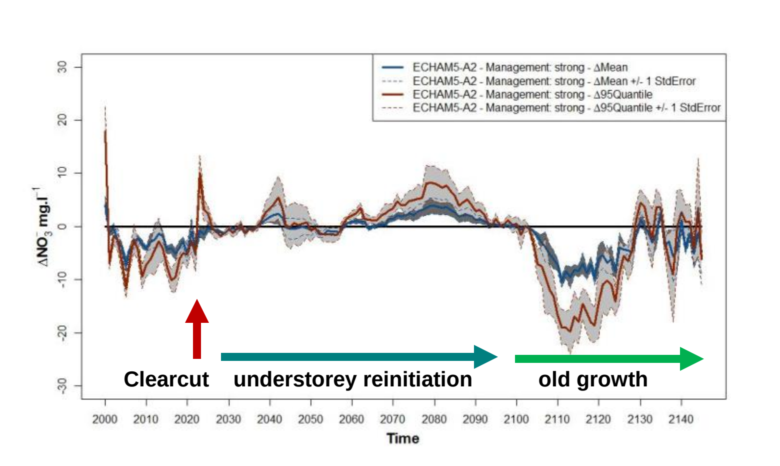
Management effect upon nitrate leaching (Clearcut Norway Spruce Management)

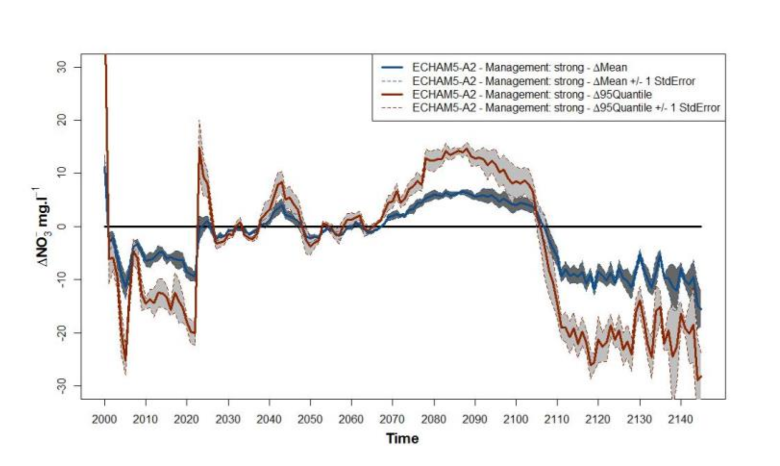
- L-DNDC Nitrate seepage flux during a ~120 yr rotation time (Climate baseline 1990 to 2010)



Management x Climate effects to nitrate leaching

2060 ECHAM5-A2 **2090**





- **Summer drought** causes retarded tree regeneration
- **Less N-uptake** and **more water percolation in winter** causes **higher seepage Nitrate concentrations during understorey reinitiation**
- **Mature forests have a higher growth rate under climate change** and therefore **retain Nitrate more efficiently**

Conclusions

- **High N deposition cause high Nitrate loss** in leaky karst catchments
  - … even if the forests are not N saturated
- **Climate change** will **decrease water runoff in summer months**
  - … so that drinking water shortage may become an issue in some regions
- During the coming **1-3 decades runoff in winter/spring will increase** due to more precipitation, less snow and higher snowmelt in early spring
- **Direct climate change effects to water quality are lower than impacts of forest management practices, however**
  - **During understorey reinitiation in clearcut management** the risk of high Nitrate concentrations in the runoff increases due to retardation in tree growth
  - Since the reverse happens in the old growth stage **total nitrate export might be levelled out at the catchment scale**
- **Indirect climate change effects** (bark beetle, windthrow) might be **more severe for drinking water quality**!
  - **Adaptation** towards stable mixed conifer-decideous forests are recommended
  - **Continuous forest management** lowers the risk of karst water pollution

Contact & Information

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