Effects of land use and climate change on biosphere-atmosphere exchange of GHG in terrestrial ecosystems

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Increase of atmospheric GHGs

- Carbon dioxide
- Methane
- Nitrous oxide

Increase of atmospheric GHGs

- anthropogenic
- biogenic

Land use change

- Rice paddies, wetlands, ruminants
- arable, grassland- and forest soils
Biosphere as sink and source for atmospheric GHGs

- **Photosynthesis**
  - CO₂ (30%)
- **Respiration**
  - N₂O (60-70%)
  - CH₄ (60-70%)
- **Nitrification**
- **Denitrification**
- **Mineralisation**
- **CH₄-Oxidation**
- **Methanogenesis**

**GWP**
- GWP 1
- GWP 310
- GWP 21

**Climate Change**
- Land use change

**Biosphere**
- is a significant source and sink for environmentally important atmospheric trace gases
- is in continuous exchange with the atmosphere; altered by climate and land use change
- thus, has an important effect on the chemical composition of the atmosphere
Impacts of climate and land use change on C/N in terrestrial ecosystems of Baikal Area

Preliminary ideas:

- ecosystems at increasing elevations using natural temperature gradient for climate change study and/or manipulation experiments with effects on permafrost and active layer
- ecosystems with contrasting land uses
- .......

Why Baikal region?
Global importance of the biome type Taiga

Estimated carbon stock in terrestrial system

Giga tonnes of carbon

IPCC, 2001
In anaerobic soil conditions, methane is produced through methanogenesis, which involves the reaction:

\[ CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \]

In aerobic soil conditions, methane is oxidized to carbon dioxide, which is part of the respiratory process:

\[ CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \]
In anaerobic soil conditions, methane oxidation is not possible. Methane can be produced through methanogenesis (\(-\text{O}_2\)) and be oxidized in respiration (\(\text{O}_2\)).
Integrated interdisciplinary research concept at IMK-IFU

**Regionale Skale**
- Vegetation
- Soil properties
- Climate
- GIS
  - forest growth
  - water demand
  - root respiration
  - water uptake by roots
  - water stress
  - photosynthesis
  - biomass
  - leaf-N content
  - plant respiration
  - leaves
  - wood
  - root N-demand
  - CO₂
  - N-uptake by roots

**Prozess-Skale**
- NO₃

**Parameterisation**

**Process based model**

**plot scale**

**parameterisation**

**calibration/testing**

**regional/global scale**

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Integrated interdisciplinary research concept at IMK-IFU

**process scale**

**GIS**

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Institut für Meteorologie and Klimaforschung IMK-IFU (Garmisch-Partenkirchen)
IMK-IFU research sites / measuring techniques for GHG exchange

- Burkina Faso
- Germany
- Inner Mongolia
- S-China
- Kenya
- Philippines
- Australia
- Finland

Institut für Meteorologie and Klimaforschung IMK-IFU (Garmisch-Partenkirchen)
CH$_4$ fluxes in a steppe ecosystem in Inner Mongolia / China

still significant uptake in wintertime with temperatures as low as -20°C
**N₂O fluxes in a steppe ecosystem in Inner Mongolia / China**

Wintertime N₂O fluxes driven by frost thaw cycles dominate annual N₂O emissions.
Long term measurements at a German temperate spruce forest

N$_2$O emission [µg N m$^{-2}$ h$^{-1}$]

- Spruce control
- Selective cutting
- Clearcut

Cutting
Full GHG balance over a 80 years rotation period

-35 %
-24 %
Process based biogeochemical Modell DNDC

ecological drivers:
- mean daily temperature
- daily evapotranspiration
- LAI depending albedo
- soil temperature profile

climate:
- daily evapotranspiration

soil climate:
- evaporation
- transpiration
- infiltration

soil:
- mineralisation
  - very labile
  - labile
  - resistant
  - degradable organic matter
  - very labile
  - resistant
  - degradable microbial matter
  - very labile
  - resistant
  - degradable humines
  - non-degradable organic matter

vegetation:
- forest-growth module (PnET-N-DNDC)
- crop module (DNDC)

human impact:
- predicted soil environmental forces
  - anaerobic balloon

substrate (C, N):
- denitrification
  - NO
  - NO₂
  - N₂O

nitrification:
- N₂O-denitifier
- N₂O-denitifier

methanogenesis:
- diffusion
- soil temperature
- soil moisture
- NH₄⁺

predicted gas fluxes:
- emission of NO, N₂O, N₂ and NO₃⁻

oxidation of CH₄
Model application – nitrate leaching at regional scale / Germany

Projected changes in NO3 leaching

- Yearly average: -18.6%
- Autumn: -4.6%
- Summer: -7.1%
- Spring: -39.4%
- Winter: +4.0%
Tank you for your attention