Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

Integrated experiment – May-August 2010

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Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

Objective
Understand ecosystem fluxes and measure their impact on:

1) Environmental sustainability
2) Ecosystem service provision
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What environmental sustainability?
Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

Objective
Understand ecosystem fluxes and measure their impact on:

1) Environmental sustainability
2) Ecosystem service provision

What environmental sustainability?

⇒ Estimate and model the contribution of agricultural fields to the export of nutrients in the Soyang Lake reservoir

Atmospheric / Soil-plant CO₂ exchanges

N deposition, leaching and emissions
Objective
Understand ecosystem fluxes and measure their impact on:

1) Environmental sustainability
2) Ecosystem service provision

What ecosystem services?

Agricultural Production
Biological Pest control
Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

Objective
Understand ecosystem fluxes and measure their impact on:

1) Environmental sustainability
2) Ecosystem service provision

What ecosystem services?

- Estimate optimal gains in ecosystem services of agricultural production, vs. limited impacts on water quality and nutrient balances

Testing the impact of different fertilizer levels on agricultural production and nutrient balances
Main assumption
Ecosystem processes & fluxes both impact functioning and *interact with each other*

- Separate measurements of each process cannot account for such interactions
- In order to fully apprehend the set of parameters that influence production and sustainability, an *interdisciplinary approach* is necessary

**Integrated approach to the measurement of ecosystem processes**

Use of an identical field setup with coordinated measurements by multiple disciplines
Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

What are we measuring?

1. N balances
   - \( \text{N}_2\text{O} \) emissions
   - Atm. N deposition
   - Soil retention
   - N leaching and seepage
   - Plant nutrient uptake

2. Carbon dioxide fluxes & plant production
   - Soil & Plant respiration
   - \( \text{CO}_2 \) fixation
   - Biomass production
   - Nutrient allocation

3. Herbivory & biological pest control
   - Crop plant: Radish
Flux Regulation, N Balances and Production in Agroecosystems of Haean Catchment

I. Experimental setup

II. Nutrient cycling: N fluxes and N balances J. Kettering, S. Berger

III. CO$_2$ fluxes and plant production S. Lindner, B. Lee

IV. Herbivory and pest control E. Martin
I. Experimental setup
I. Experimental setup

Radish field
No slope
X ha
I. Experimental setup

- **Radish field**

- 4 concentrations of N
- \(^{15}\text{N}\) labelled plots

- Furrow establishment
- Parking and supply area
- Drainage ditch
- Roadway
I. Experimental setup

- 16 plots = 4 * 4 fertilizer levels → 50 - 150 - 250 - 350 kg N/ha
- Harvest of subplots after 25, 50 and 75 days
- Fertilizer application: reproduce as closely as possible the practices of local farmers
- Liquid or granulate mineral fertilizer in 2 applications (1st: everywhere, 2nd: only interrow), done manually

Recommendation of Korean Agricultural Center: up to 400 kg N/ha
Usual amount in Germany: 50-150 kg N/ha

15N + biomass
CO₂ exchange
N emissions
Herbivory + monitoring
II. NUTRIENT CYCLING: N fluxes and N balances J. Kettering, S. Berger
II. NUTRIENT CYCLING – N fluxes and N balances

Input:
- Synthetic Fertilizer
- Atmospheric deposition

Output:
- Emissions
- Seepage
- Crop uptake
- Retention in soil

Understand cycling of Nitrogen in agroecosystems
II. NUTRIENT CYCLING – Research Questions

- How is N uptake by plants and N allocation affected by different N application rates? Does N use efficiency change?

- How differs the biomass in response to different N application rates?

- Which ones are the main N loss pathways and how do they differ in response to different N application rates?

- How are the nitrous oxide emissions and leaching to the groundwater affected by different levels of N applied?

- When do the biggest losses occur?

- How soon after fertilizer application are huge amounts of the fertilizer already degassed as nitrous oxide?

- How are nitrous oxide emissions influenced by the black cover?

Understand shifting of the cycle in response to different fertilizer levels
II. NUTRIENT CYCLING

1. Synthetic Fertilizer – NPK (~20% N)
   - Rates: 50, 150, 250, 350 kg N/ha
   - Tracer application (K$^{15}$NO$_3$)

2. Atmospheric N deposition
   - Key parameter in the cycle and should be taken into account for N fertilizer recommendations
   - Measurements conducted from May to August/September 2010
   - 3 representative locations in the catchment (4 replicates)
   - Principles of method:
     - Accumulative deposition over the growing season
     - ITNI system based on $^{15}$N isotope dilution method

Layout:
- 3 field sites à 4 replicates

Measurements:
- Installation of devices at the beginning of the growing season
- Collecting the exchange resins and quartz sand at the end of the vegetation period

Method:
- ITNI: Calculate the losses of N during the growing season
- Resins: exchange and store NO$_3$, NH$_4$, and DON in rainwater

Analyses:
- $N_{tot}$, $^{15}$N, $^{13}$N, NH$_4$, DON

Results:
- Accumulative N deposition over the growing season
- No cycling necessary

Cation exchange
- Resin nylon bag
- Glass wool

Anion exchange
- Resin nylon bag
- Glass wool

Activated carbon
- Nylon bag

Rainwater drainage
- Tube with 3 exchange resins
- Micro mesh for protection
- Micro mesh
- No plants
- No cycling necessary
- No water collection

Nylon bag
- 15N labeled quartz sand
- Micro mesh for protection
- Rainwater drainage
- Tube with 3 exchange resins
- Micro mesh for protection
- Micro mesh
- No plants
II. NUTRIENT CYCLING – OUTPUT

1. Retention in soil
2. Crop uptake
3. Seepage
4. Emissions

Frequency of measurements:

- 3 harvest times
  - Soil (15N abundance)
  - Biomass
  - N uptake by plants (15N)
  - Seepage (15N)

- Additionally
  - Nmin
  - Atmospheric deposition
  - Seepage after heavy rain events (15N)

Soil sampling for soil nutrient status
- Retention rate: percentage of applied 15N fertilizer recovered in the top 60 cm of the soil profile

Harvest for N uptake
- Recovery rate: percentage of applied 15N fertilizer taken up by the aboveground plant parts
- Root to shoot ratio with growth at differing fertilizer levels
- N use efficiency
- Biomass at different fertilizer levels
II. NUTRIENT CYCLING – SEEPAGE

Method:

-Suction lysimeter controlled by Tensiometers and FDR sensors for recording soil water content

-Disadvantage: don’t capture preferential flow, non-continuous sampling, undefined soil volume

-Advantage: easy to install and measure

-3 suction lysimeter and tensiometer in each 75 days plot

-Different depths and locations

-4 sampling times plus after heavy rain events

Results:

-Modeled seepage over the course of a season

-N loss in seepage water

-Soil water content
II. NUTRIENT CYCLING – N$_2$O emission measurements

**Method:** Closed Chamber in conjunction with Infrared Photoacoustic Trace Gas Analyzer
II. NUTRIENT CYCLING – N$_2$O emission measurements

**Design:** On each of the plots three chambers will be installed:
- on a radish plant
- on black cover
- on path between rows

It will take one day to measure the N$_2$O emissions of all plots.

**Measurement frequency:**
Every day……..Reducing measurement days……Every day…Reducing..Every day…
(measurements once a week)

**Results:**
- Nitrous oxide fluxes between soil and atmosphere
- Cumulative nitrous oxide emissions
III. Carbon dioxide fluxes and plant production S. Lindner, B. Lee
III. Carbon dioxide fluxes and plant production

**Main objectives**

1. Understand the impact of different input levels on CO₂ fluxes and plant production

   → In terms of LA, biomass, C/N content, carboxylation capacity & light use efficiency

2. Up scaling of CO₂ fluxes up to landscape level

**TERRECO-02:** Spatial assessment of atmosphere-ecosystem exchanges via micrometeorological measurements, footprint modelling and mesoscale simulations

   Peng Zhao, Johannes Lüers, Thomas Foken, Chong Bum Lee

3. Validation of the Pixgro model

**TERRECO-15:** Comparisons of net ecosystem CO₂ exchange, carbon gain, growth and water use efficiency of agricultural crops in small catchments in Korea

   Bora Lee, John Tenhunen, Sinkyu Kang
III. Carbon dioxide fluxes and plant production

- **Crop biomass** data from crop sampling
- **Gas exchange** data from chamber measurement and eddy system
- **Land cover map** from field survey and remote sensing
- **Meteorological data** from AWS
- **Crop management** data from fertilizer measurement
- **PIXGRO** for Haean cahtchemmnt
III. Carbon dioxide fluxes and plant production

Introduction:

Dark chamber:

Soil respiration $R_{soil}$ = CO$_2$ release from the bare soil
Ecosystem respiration $R_{eco}$ = CO$_2$ release from the soil ($R_{soil}$) + plant ($R_{plant}$)

Light chamber:

Net ecosystem exchange NEE = GPP + Reco

Gross primary production (GPP): rate at which an ecosystem's producers capture and store a given amount of chemical energy as biomass in a given length of time.
III. Carbon dioxide fluxes and plant production

Methods: Portable closed chamber system

- Daily courses
- At least 5 times/growing season and fertilizer level
- Intensified measurements on the Radish field with different fertilizer treatments
- NEE, Reco, Rsoil
- Microclimate
- Biomass leaves/ stem/ roots
- C/N content

- Detailed information of plant reaction to environmental factors in small scale (1-2 plants enclosed)
III. Carbon dioxide fluxes and plant production

Methods: \( \text{CO}_2/\text{H}_2\text{O} \) porometer CQP-130, Fa. WALZ, Effeltrich, Germany

- Measuring leaf gas exchange (photosynthesis or respiration of the leaf can be measured)
- In relation to microclimate
III. Carbon dioxide fluxes and plant production

**Methods:** Pressure Chamber & Ech2o logger

- Plant water relations will be accessed using the Scholander pressure chamber

- Soil moisture content and soil temperature
- Automatic Weather Station for continuous recording of climate parameters (air temperature, relative humidity, solar radiation, wind speed and direction, rainfall)
III. Carbon dioxide fluxes and plant production

Results from 2009:

DOY 196 mid of July

Reco = Rsoil + Rplant

NEE = GPP + Reco

Daily course of NEE from a radish field
III. Carbon dioxide fluxes and plant production

Results:

Seasonal course of CO$_2$ fluxes from radish
Hyperbolic light response model
(Michaelis-Menten type model)

- Used Michaelis-Menten/rectangular hyperbola model to estimate model parameters for ecosystem/leaf level gas exchange

\[
NEE = - \frac{\alpha \cdot \beta \cdot \text{PAR}}{\alpha \cdot \text{PAR}} + \beta + \gamma
\]

Physiological parameters:

\(\alpha\) is the initial slope of the light response curve and an approximation of the canopy light utilization efficiency
\(\beta\) is the maximum NEE of the canopy
\(\gamma\) is an estimate of the average ecosystem respiration (Reco) occurring during the observation period

Gilmanov et al, 2003
III. Carbon dioxide fluxes and plant production

Results:

- Estimated parameters to describe gas exchange capacity of radish
IV. Herbivory and pest control

E. Martin
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes

- **Abiotic constraints**
  - Resource limitation

- Availability of nutrients
  - Level of N fertilizer
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes

- **Abiotic constraints**
  - Resource limitation
- **Herbivore pressure**
  - Natural predator compensation
- Availability of nutrients
  - Level of N fertilizer
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes

Herbivore pressure
Natural predator compensation
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.

Insects and birds act as natural enemies of pests by regulating insect herbivore populations.

Pest mortality is induced by:
- consumption (natural predators)
- parasitism (parasitoids - wasps)
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.

Herbivore pressure

Natural predator compensation

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Biological pest control
IV. Herbivory and pest control

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Agricultural production is regulated by **bottom-up** and **top-down** processes

- Herbivore pressure
- Natural predator compensation
- Biological pest control
- Multiple trophic level interactions
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes

Herbivore pressure

Natural predator compensation

Biological pest control

Multiple trophic level interactions

Intraguild predation, Sampling effects, Additivity & Synergisms

Duffy et al., Ecology Letters 2007
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.

- **Herbivore pressure**
- **Natural predator compensation**
- **Biological pest control**
- **Multiple trophic level interactions**
  - Intraguild predation, Sampling effects, Additivity & Synergisms
  - Different impacts on the efficiency of pest control

Duffy et al., Ecology Letters 2007
IV. Herbivory and pest control

Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.

**Abiotic constraints**
- Resource limitation

**Herbivore pressure**
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**Availability of nutrients**
- Level of N fertilizer

**Biological pest control**
- Multiple trophic level interactions
Introduction

Agricultural production is regulated by **bottom-up** and **top-down** processes.

**Abiotic constraints**
- Resource limitation

**Herbivore pressure**
- Natural predator compensation

**Availability of nutrients**
- Level of N fertilizer

**Crop production**

**Biological pest control**
- Multiple trophic level interactions
IV. Herbivory and pest control

Research questions

• How does the level of N fertilizer impact
  a) herbivore abundance
  b) the efficiency of pest control
  c) interactions between trophic levels and between guilds of natural predators
IV. Herbivory and pest control

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• How does the level of N fertilizer impact
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• How does the degree of herbivore pressure and natural predator compensation impact nutrient uptake and biomass production?
IV. Herbivory and pest control

**Research questions**

- How does the level of N fertilizer impact
  - a) herbivore abundance
  - b) the efficiency of pest control
  - c) interactions between trophic levels and between guilds of natural predators

- How does the degree of herbivore pressure and natural predator compensation impact nutrient uptake and biomass production?

- What is the relative contribution of top-down control on agricultural production, vs. bottom-up regulation?
IV. Herbivory and pest control

Methods

4 exclusion treatments + 1 open in each plot – 4 plants per treatment

- No predators
- Parasitoids
- Parasitoids
- Birds
- Birds

- B + P + GD excluded
- B + GD excluded
- B excluded
- GD excluded
- No exclusion
IV. Herbivory and pest control

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4 exclusion treatments + 1 open in each plot – 4 plants per treatment

- No predators
- Parasitoids
- Parasitoids Ground dwellers
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- Birds Parasitoids
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→ Monitoring: herbivory + abundance herbivores + predators + weed cover
IV. Herbivory and pest control

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→ Monitoring: herbivory + abundance herbivores + predators + weed cover

→ Harvest 75 days: total fresh biomass + crop fresh biomass + sellable crop fresh biomass + final weed cover + total weed biomass + C/N protocol
IV. Herbivory and pest control

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→ Monitoring: herbivory + abundance herbivores + predators + weed cover

→ Harvest 75 days: total fresh biomass + crop fresh biomass + sellable crop fresh biomass + final weed cover + total weed biomass + C/N protocol

→ Comparison of temperature / humidity between treatments (avoid microclimatic effects)
On behalf of all the students...

THANK YOU!