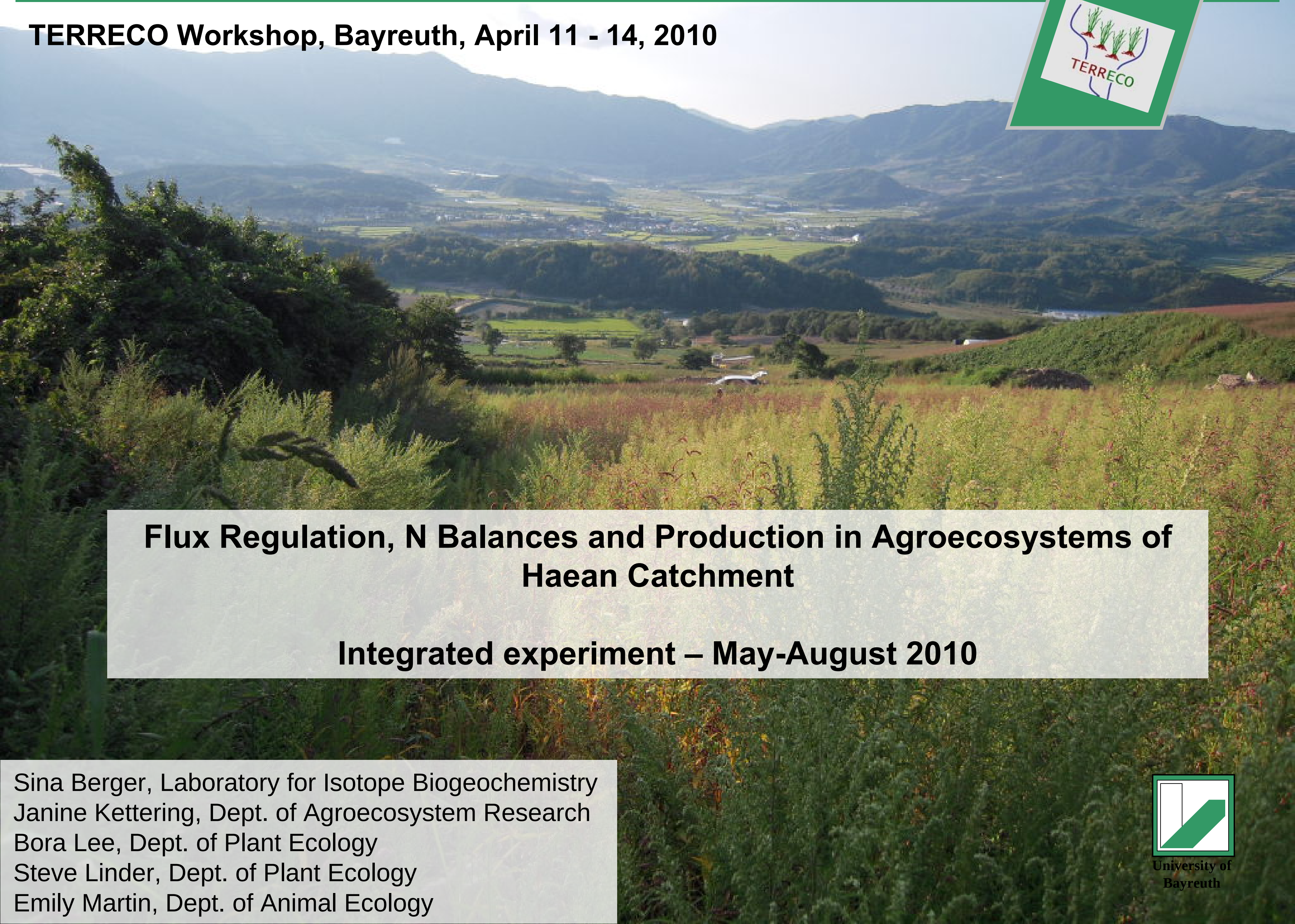

TERRECO Workshop, Bayreuth, April 11 - 14, 2010

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

Integrated experiment – May-August 2010

Sina Berger, Laboratory for Isotope Biogeochemistry
Janine Kettering, Dept. of Agroecosystem Research
Bora Lee, Dept. of Plant Ecology
Steve Linder, Dept. of Plant Ecology
Emily Martin, Dept. of Animal Ecology

University of Bayreuth

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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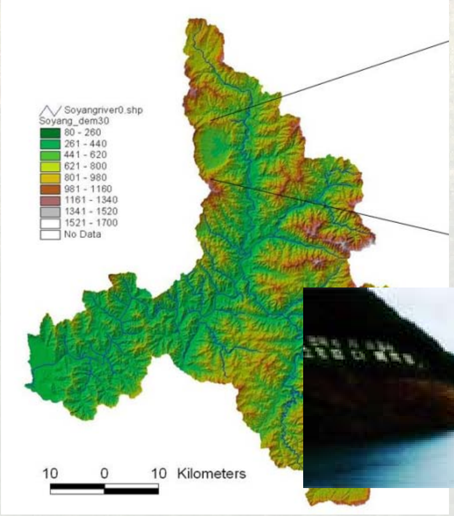
What environmental sustainability?

Atmospheric / Soil-plant **CO_2** exchanges

N deposition, leaching and emissions



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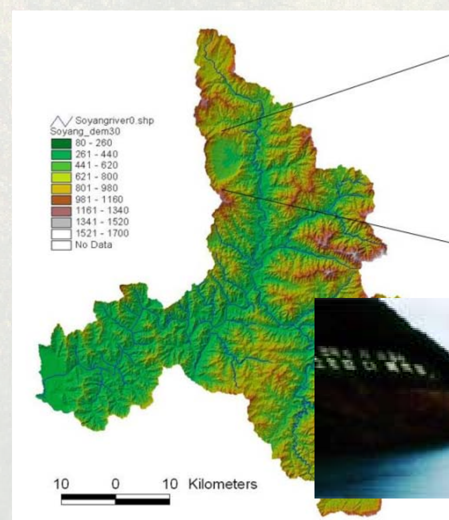
Atmospheric / Soil-plant **CO_2** exchanges

N deposition, leaching and emissions

What environmental sustainability?

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



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

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Agricultural **Production**

Biological **Pest control**

What ecosystem services?

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

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Understand ecosystem fluxes and measure their impact on:

1) Environmental sustainability

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Agricultural **Production**

Biological **Pest control**

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***

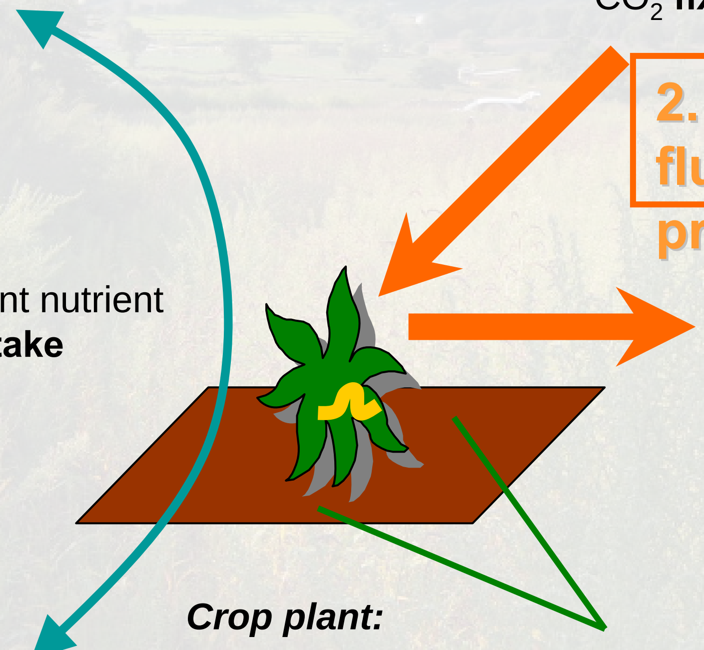
- ➔ Separate measurements of each process cannot account for such interactions
- ➔ In order to fully apprehend the set of parameters that influence production and sustainability, an interdisciplinary approach is necessary

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?



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

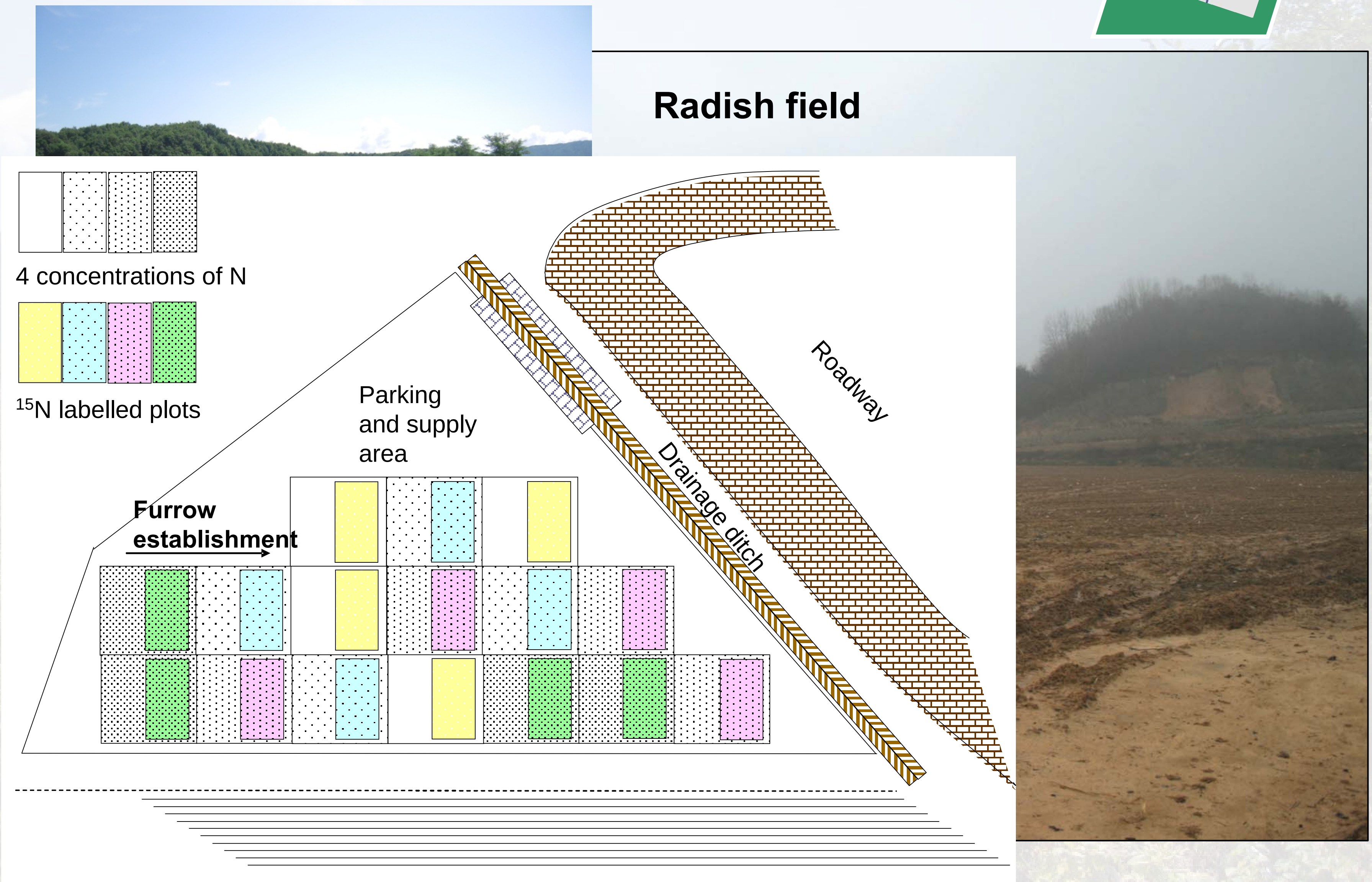
I. Experimental setup

Radish field

No slope

X ha

I. Experimental setup

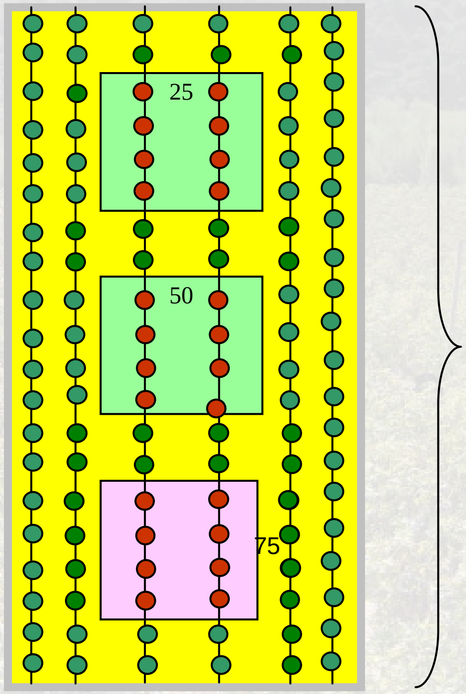


I. Experimental setup

- 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



^{15}N + biomass

CO_2 exchange

N emissions

Herbivory + monitoring

1st fertilizer application

Ploughing
Disking

Ridges
Black cover

Planting (seeds)

Harvest 25

Harvest 50

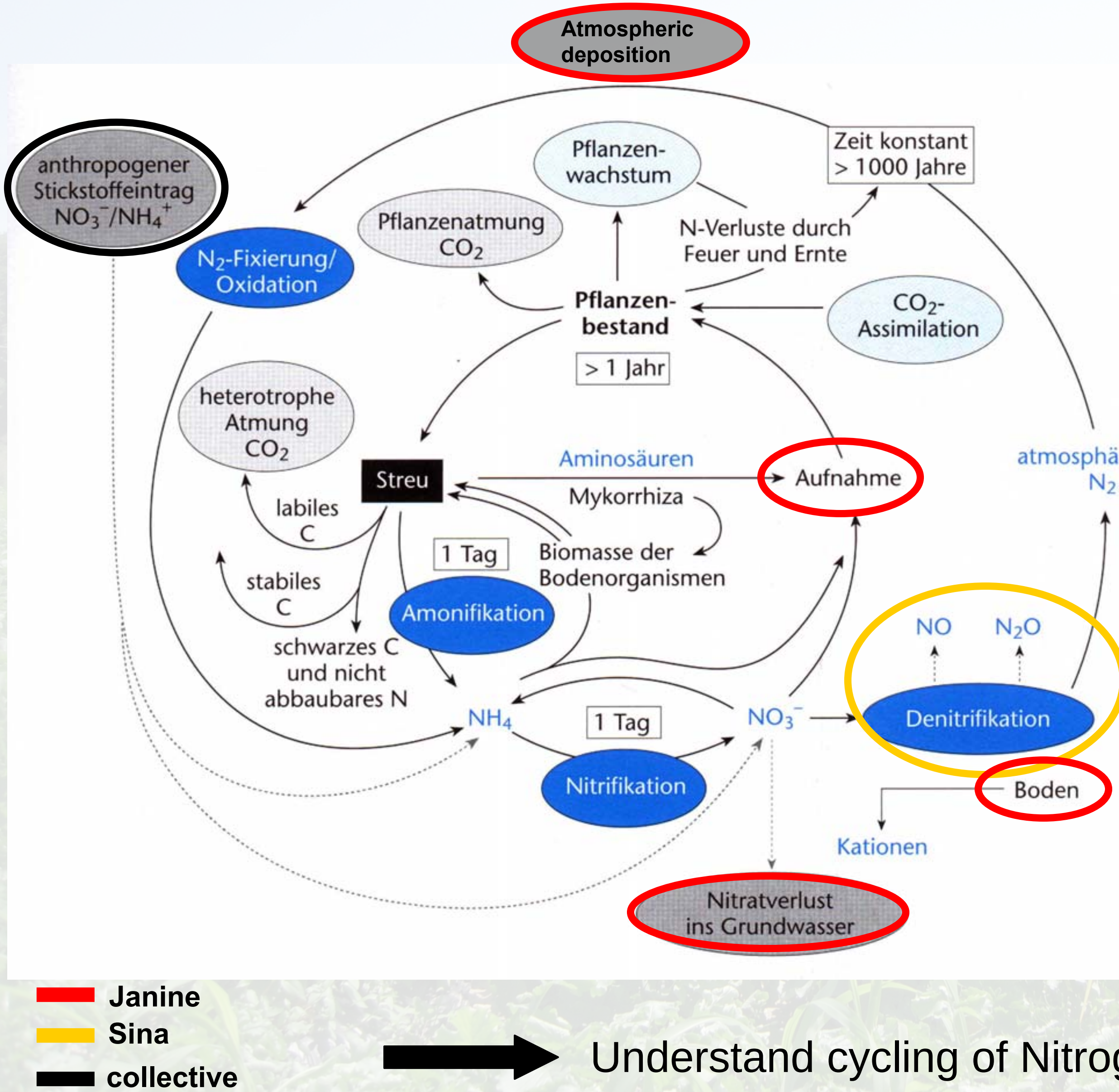
2nd fertilizer application

Harvest 75

May | June | July | August

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 – Atmospheric deposition

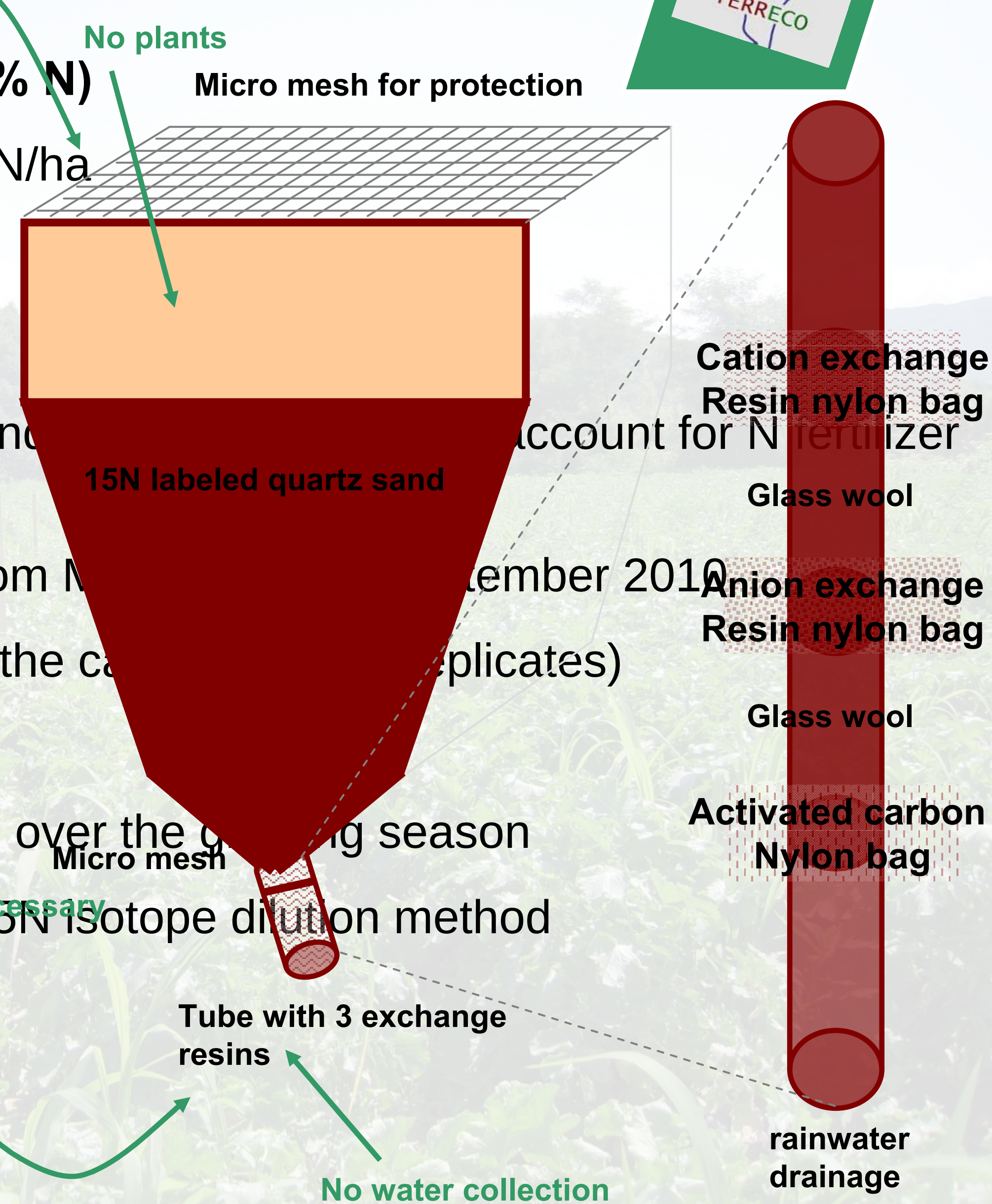
Layout:
- 3 field sites à 4 replicates

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 experiment
- **Resins:** exchange and store NO_3, NH_4 and DON in rain water

Analyses:
- N_{tot}, ^{15}N, NO_3, NH_4, DON

Results:
- Accumulative N deposition over the growing season



II. NUTRIENT CYCLING – INPUT

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 … account for N fertilizer recommendations
   - Measurements conducted from M… ember 2010
   - 3 representative locations in the ca… eplicates)
   - Principles of method:
     - Accumulative deposition over the g… g season
     - ITNI system based on 15N isotope dilution method
     - Ion exchange resins

II. NUTRIENT CYCLING – OUTPUT

Soil sampling
Atmospheric deposition
Harvest
Seepage

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

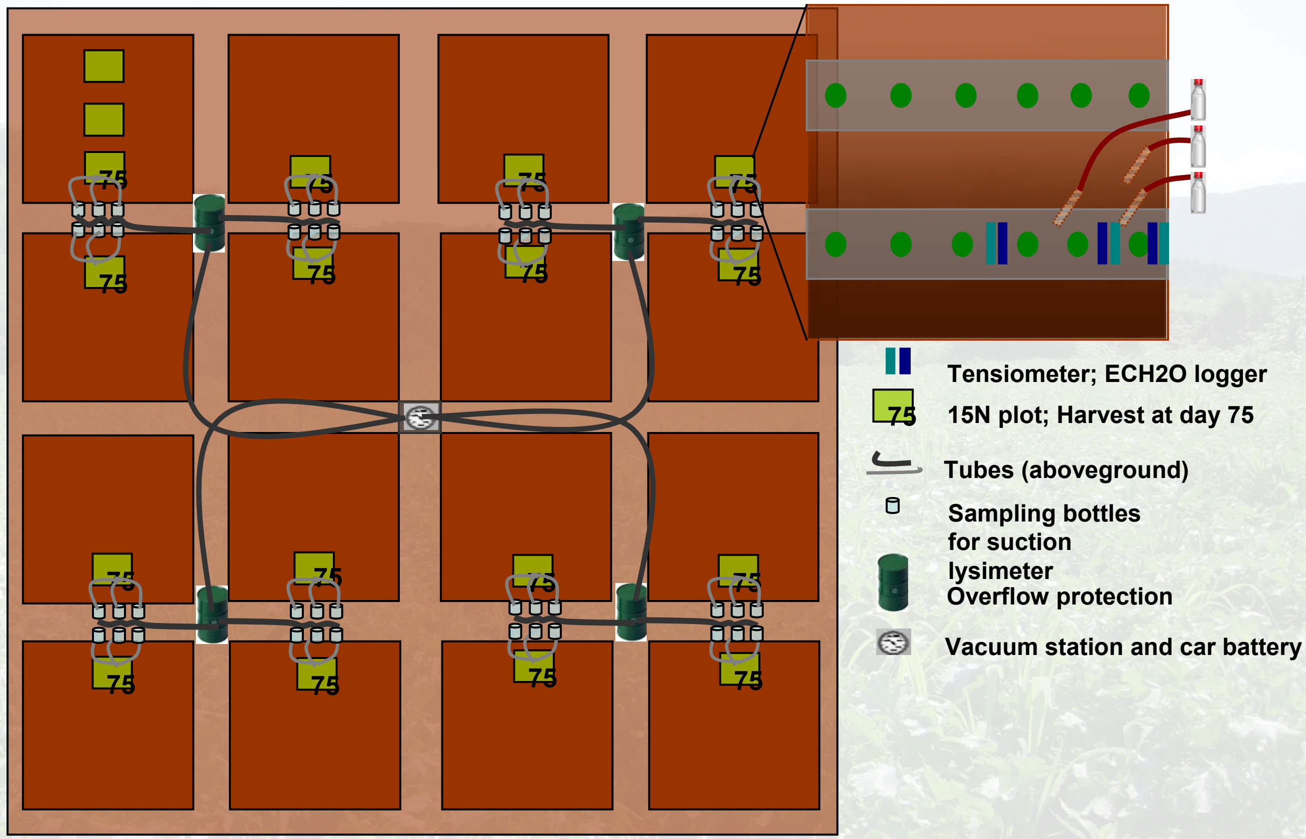
-Disadvantage: don't capture preferential flow, non-continuous sampling, undefined soil volume

-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:

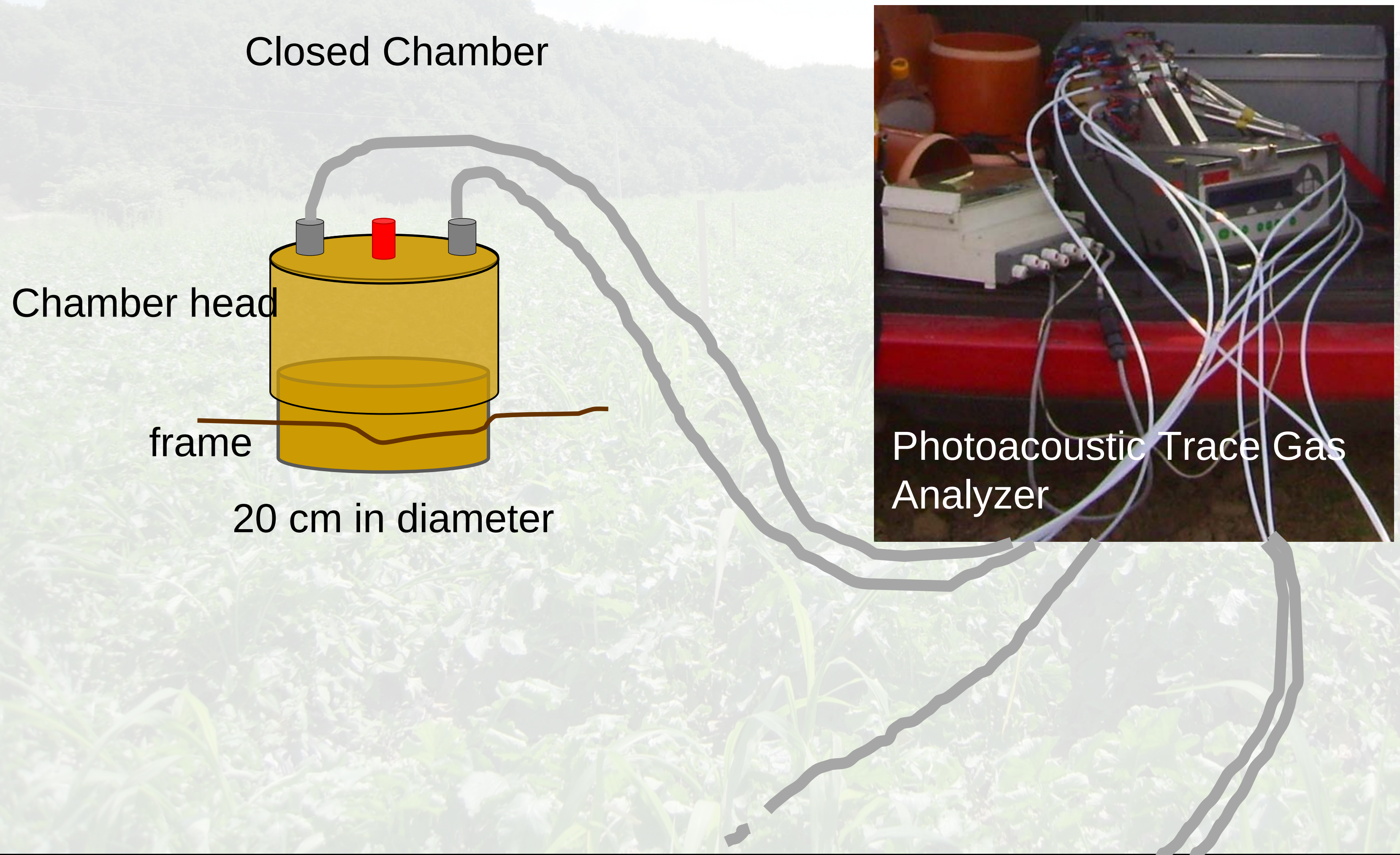
-Modeled seepage over the course of a season

-N loss in seepage water

-Soil water content

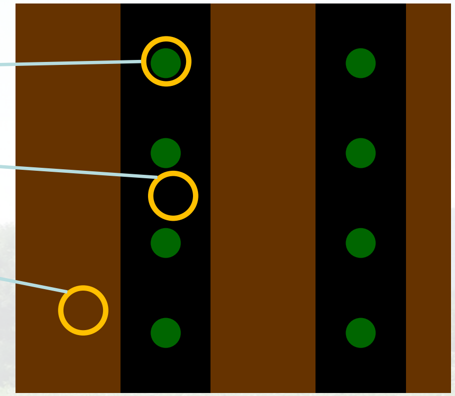
II. NUTRIENT CYCLING – N_2O emission measurements

Method: Closed Chamber in conjunction with Infrared Photoacoustic Trace Gas Analyzer



II. NUTRIENT CYCLING – N_2O 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_2O emissions of all plots.

Measurement frequency:

Every day……..Reducing measurement days……Every day…Reducing..Every day….
(measurements once a week)

Results:
- Nitrous oxide fluxes beetween 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 CO_2 fluxes and plant production

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

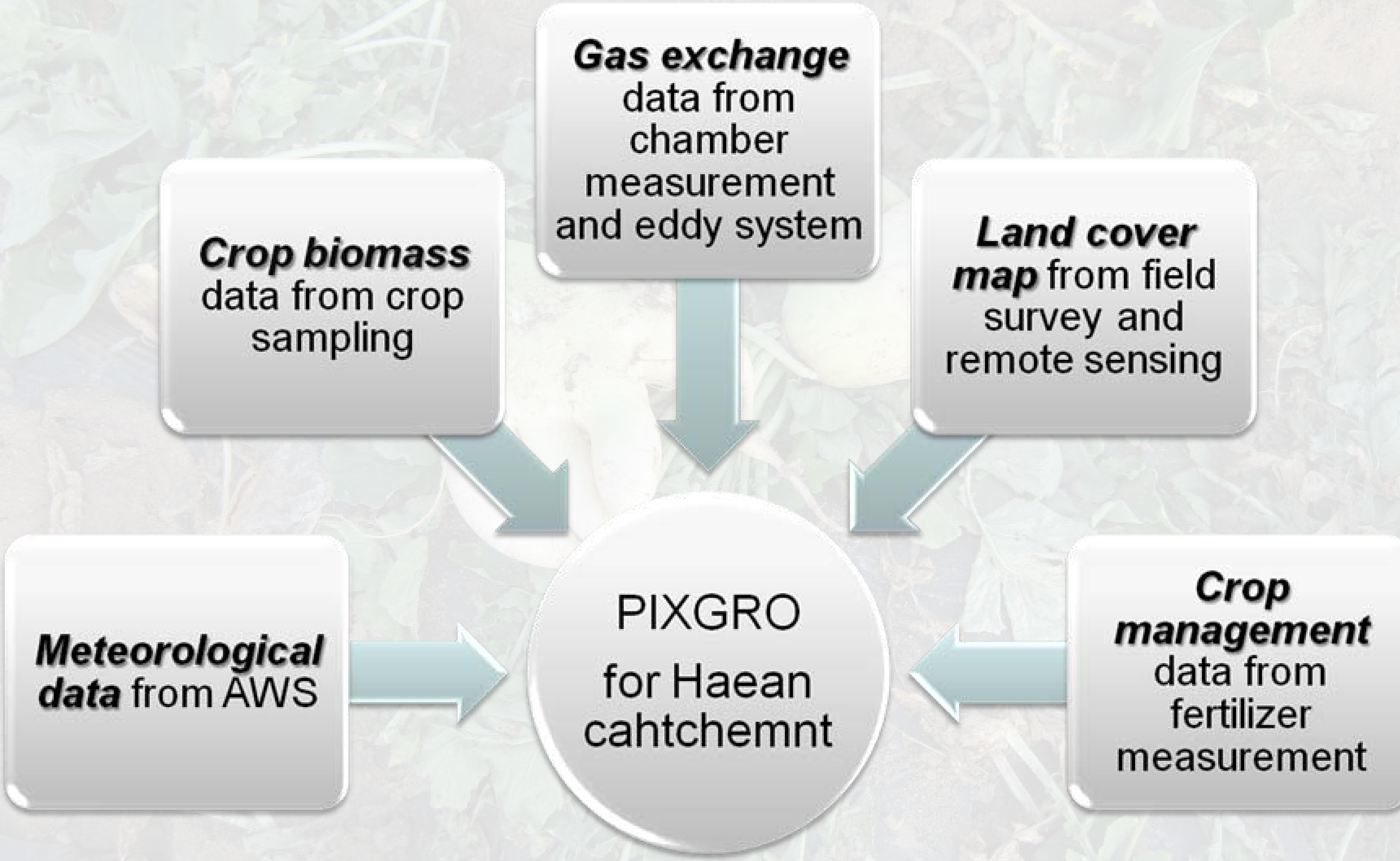
2. Up scaling of CO_2 fluxes up to landscape level

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 CO_2 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



III. Carbon dioxide fluxes and plant production

Introduction:

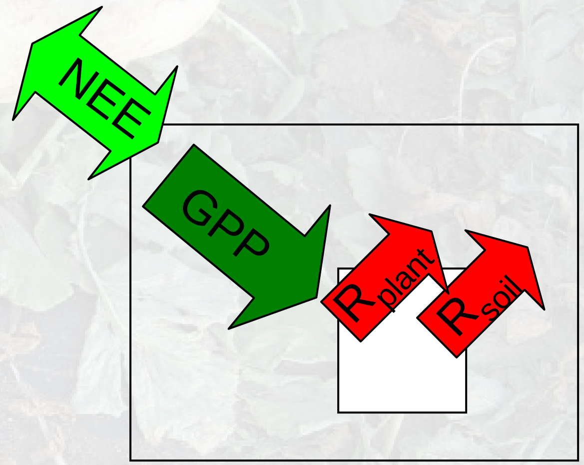
Dark chamber:

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

Figure 1: Applied light and dark gas exchange chambers for measuring the NEE and R_{eco}

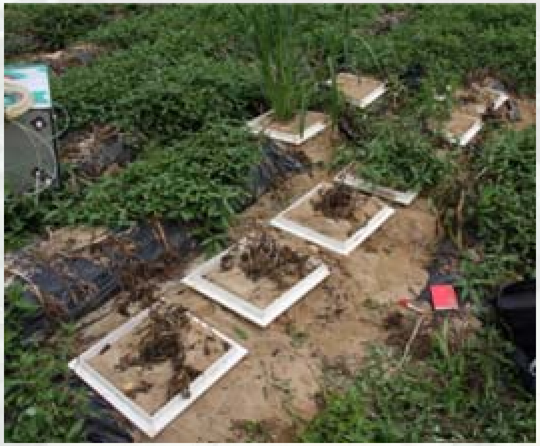


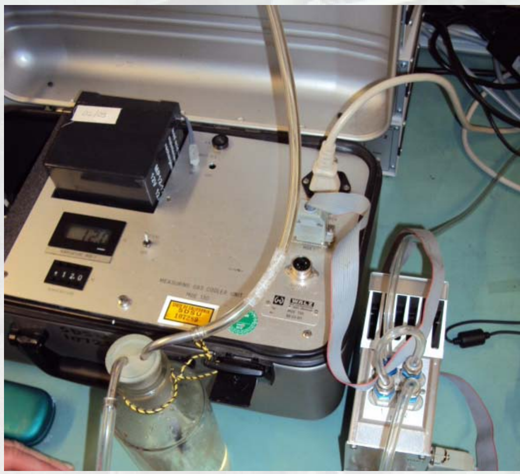
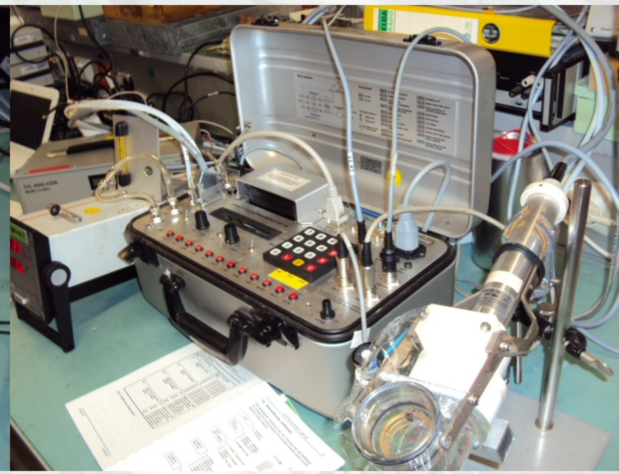
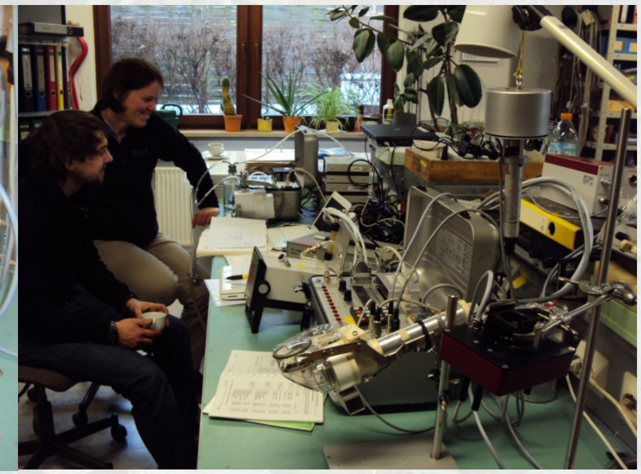
Figure 2: Installed soil frames (38 x 38 cm^2) as a base for the gas exchange chambers

- 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: *CO_2/$H_2$0 porometer CQP-130*, Fa. WALZ, Effeltrich, Germany

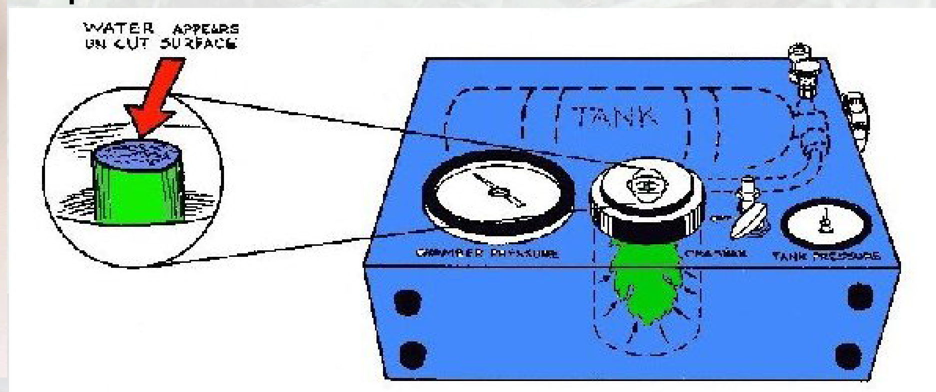




- Measuring leaf gas exchange (photosynthesis or respiration of the leaf can be measured)
- In relation to microclimate

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)

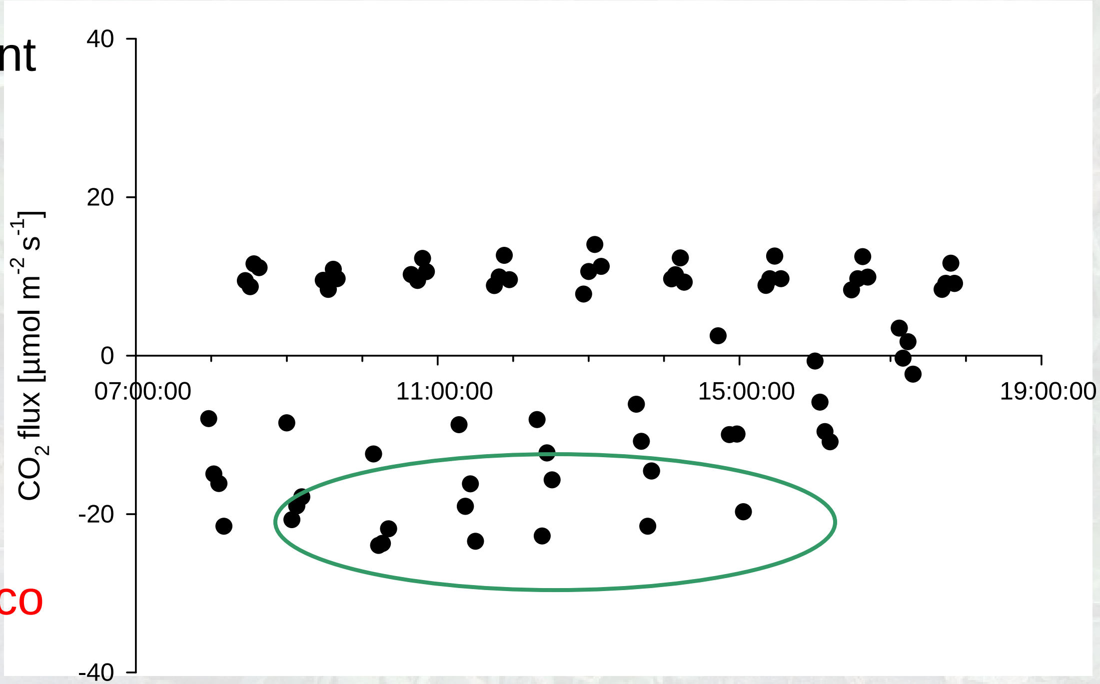
III. Carbon dioxide fluxes and plant production

Results from 2009:

Reco=Rsoil+Rplant

NEE = GPP + Reco

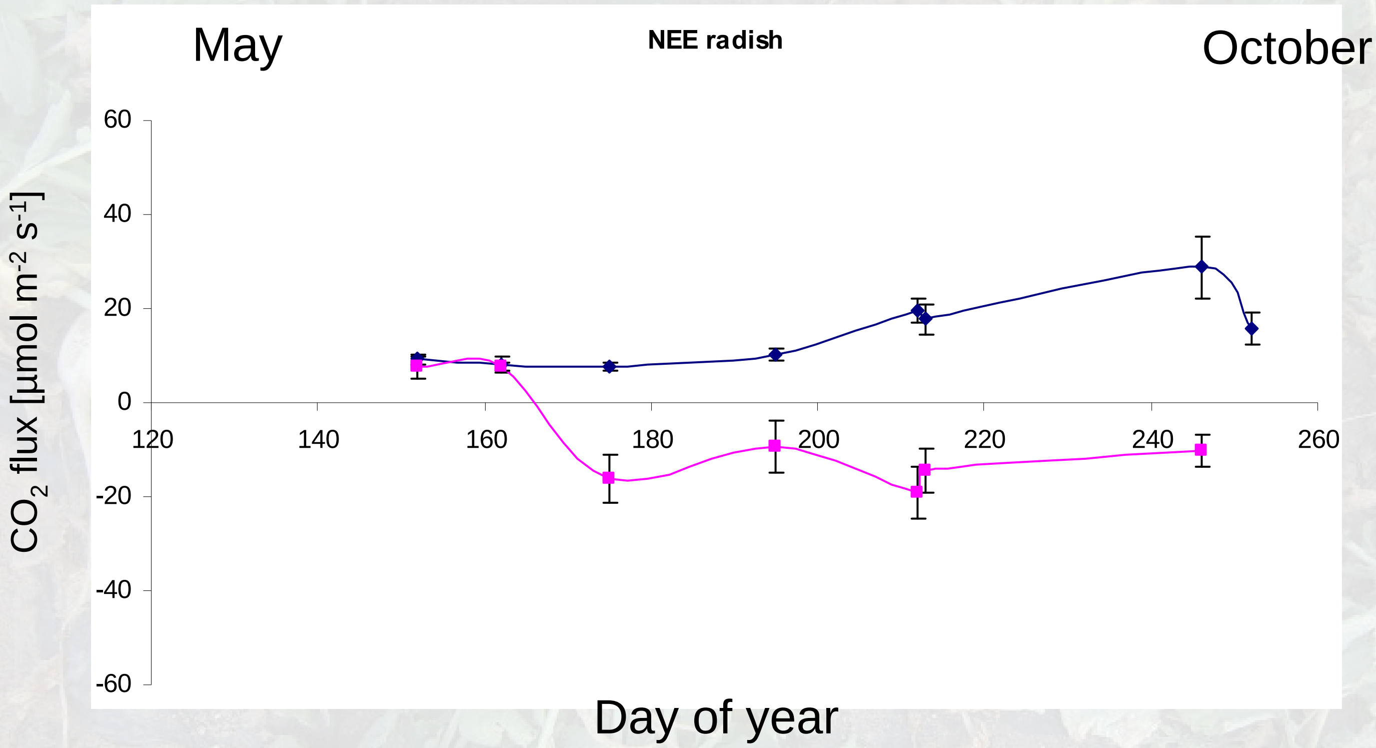
DOY 196 mid of July



Daily course of NEE from a radish field

III. Carbon dioxide fluxes and plant production

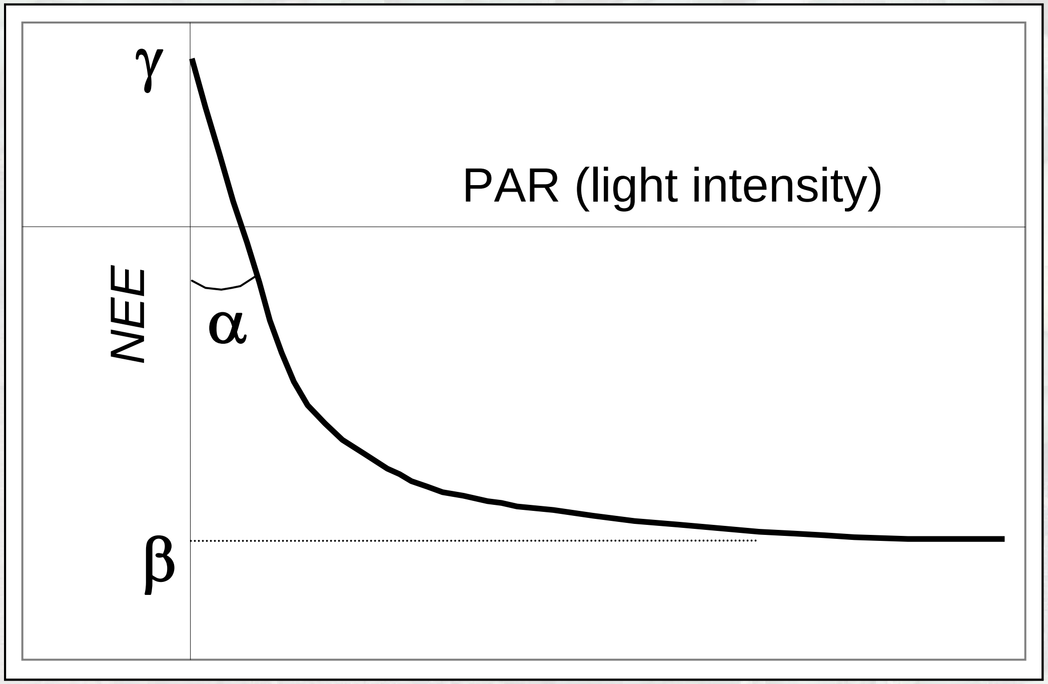
Results:



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



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

Gilmanov *et al*, 2003

Physiological parameters:

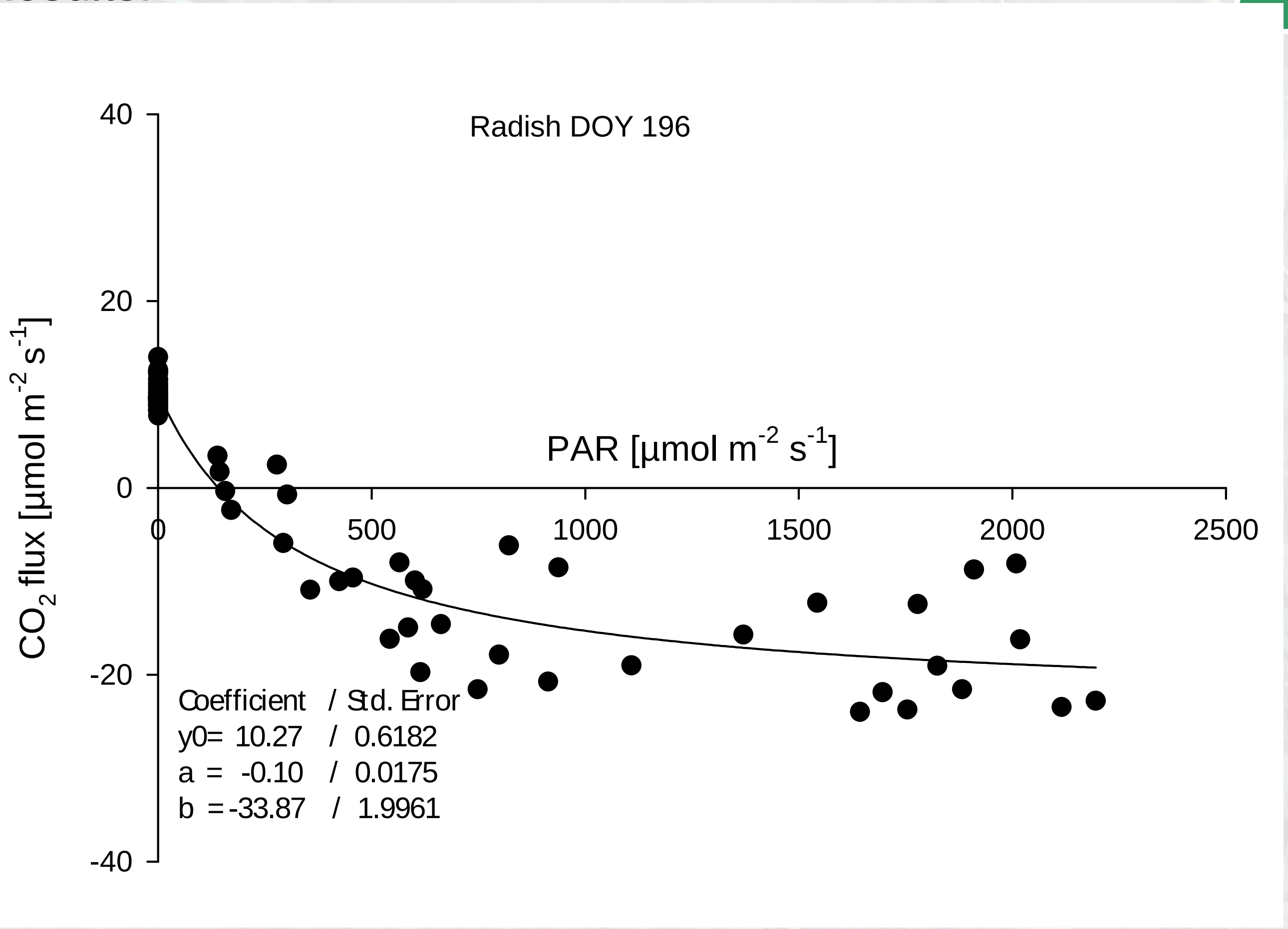
α is the initial slope of the light response curve and an approximation of the canopy light utilization efficiency

β is the maximum NEE of the canopy

γ is an estimate of the average ecosystem respiration (Reco) occurring during the observation period

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

Abiotic constraints
Resource limitation

IV. Herbivory and pest control

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Availability of nutrients

/ Level of N fertilizer

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Natural predator compensation

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)

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Biological pest control

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↓

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Natural predator compensation

Biological pest control

Multiple trophic level interactions

IV. Herbivory and pest control

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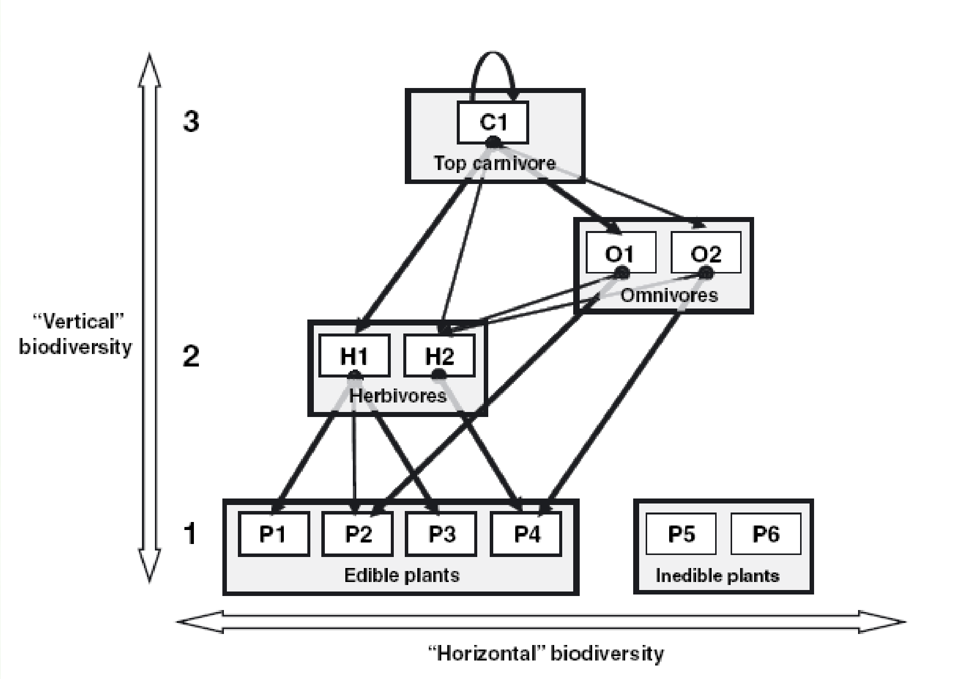

Duffy et al., Ecology Letters 2007

Herbivore pressure

Natural predator compensation

Biological pest control

Multiple trophic level interactions

Intraguild predation, Sampling effects, Additivity & Synergisms

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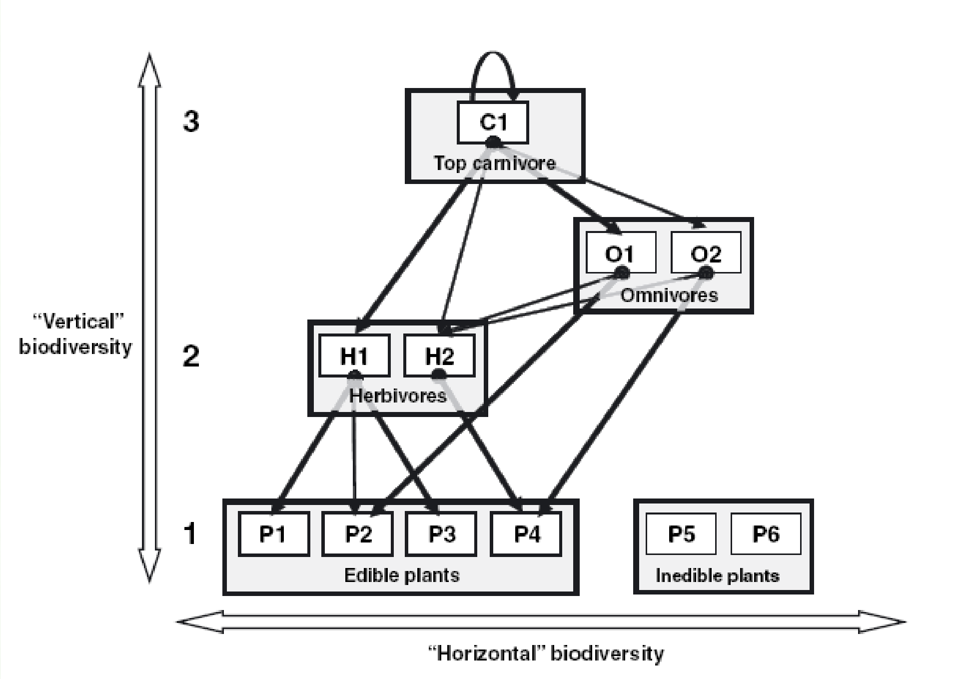

Duffy et al., Ecology Letters 2007

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

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Herbivore pressure

Natural predator compensation

Availability of nutrients

/ Level of N fertilizer

?

Biological pest control

Multiple trophic level interactions

Crop 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

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?

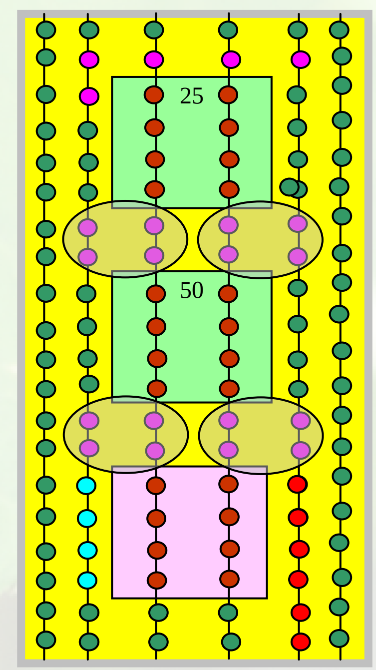
- What is the relative contribution of top-down control on agricultural production, vs. bottom-up regulation?

IV. Herbivory and pest control

Methods

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

No predators	Parasitoids	Parasitoids Ground dwellers	Birds Parasitoids	Birds Parasitoids Ground dwellers
B + P + GD excluded	B + GD excluded	B excluded	GD excluded	No exclusion



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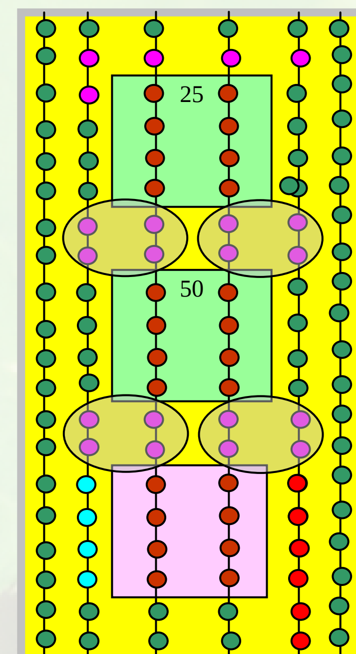
No predators	Parasitoids	Parasitoids, Ground dwellers	Birds, Parasitoids	Birds, Parasitoids, Ground dwellers
B + P + GD excluded	B + GD excluded	B excluded	GD excluded	No exclusion

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



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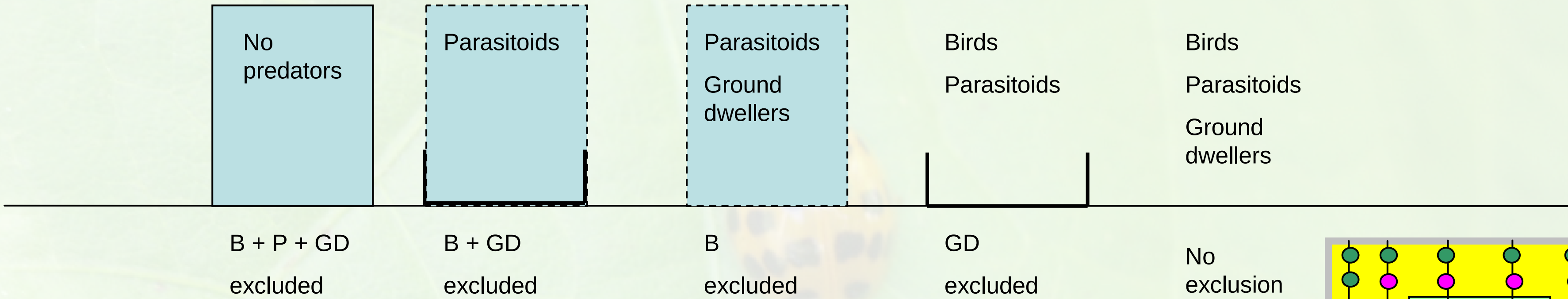
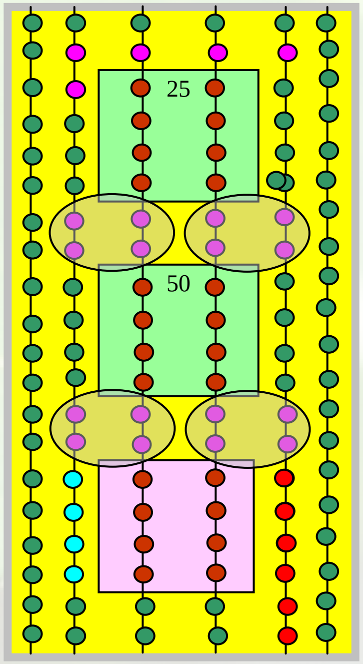


→ Monitoring: herbivory + abundance herbivores + predators + weed cover

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



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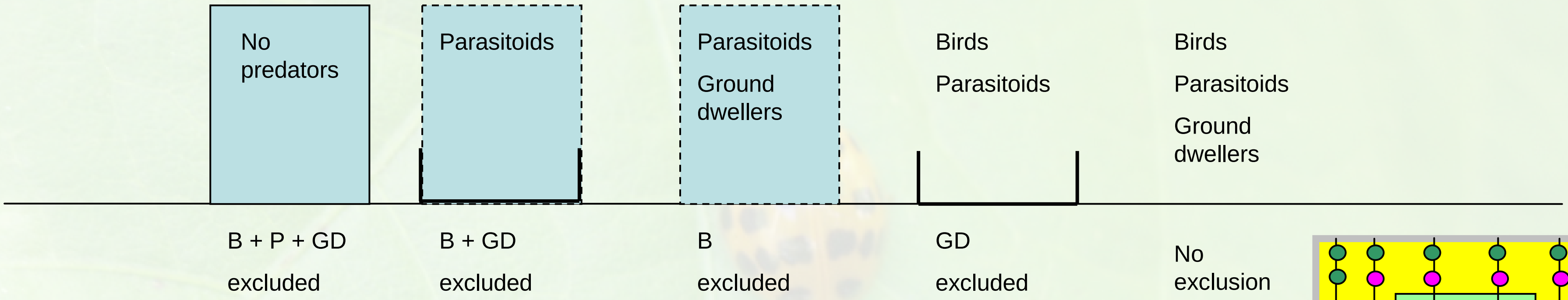
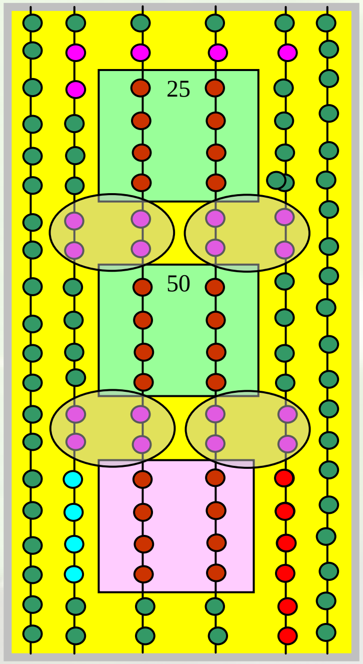


→ Monitoring: herbivory + abundance herbivores + predators + weed cover

→ 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!