Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

DAGRL
World Food System

ETH Zurich
grassland sciences

Greenhouse gas emissions from agricultural soils – a global perspective

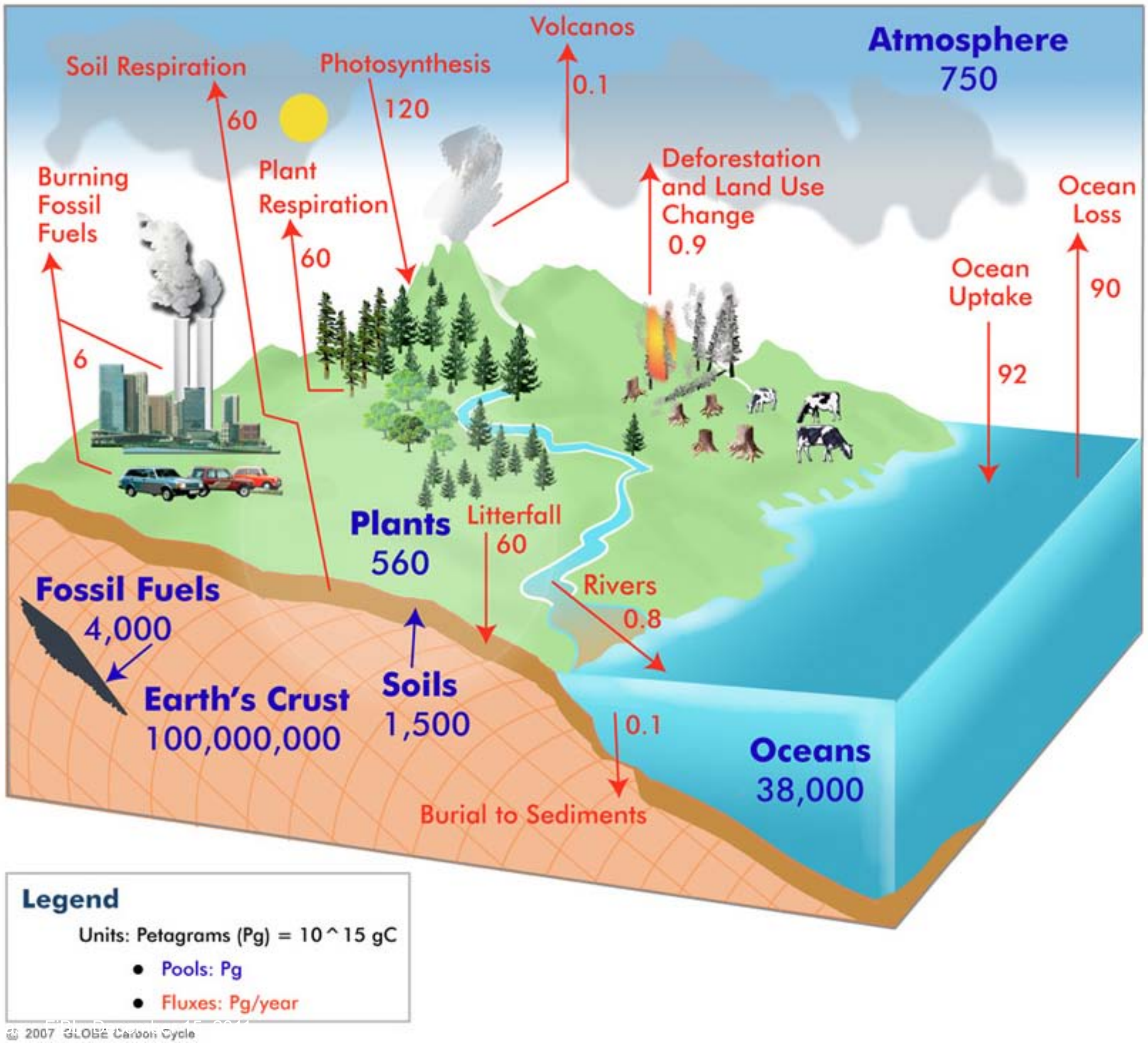
PD Dr. Werner Eugster, Prof. Nina Buchmann
Institute of Agricultural Sciences, ETH Zürich

Outline

Greenhouse gas emissions from agricultural soils

- Global C pools and fluxes
- Sectorial emissions
- Quantification of GHG emissions
- Sensitivity of GHG fluxes to changing environment and management
- Different mitigation options in the agricultural sector

Global C pools and fluxes

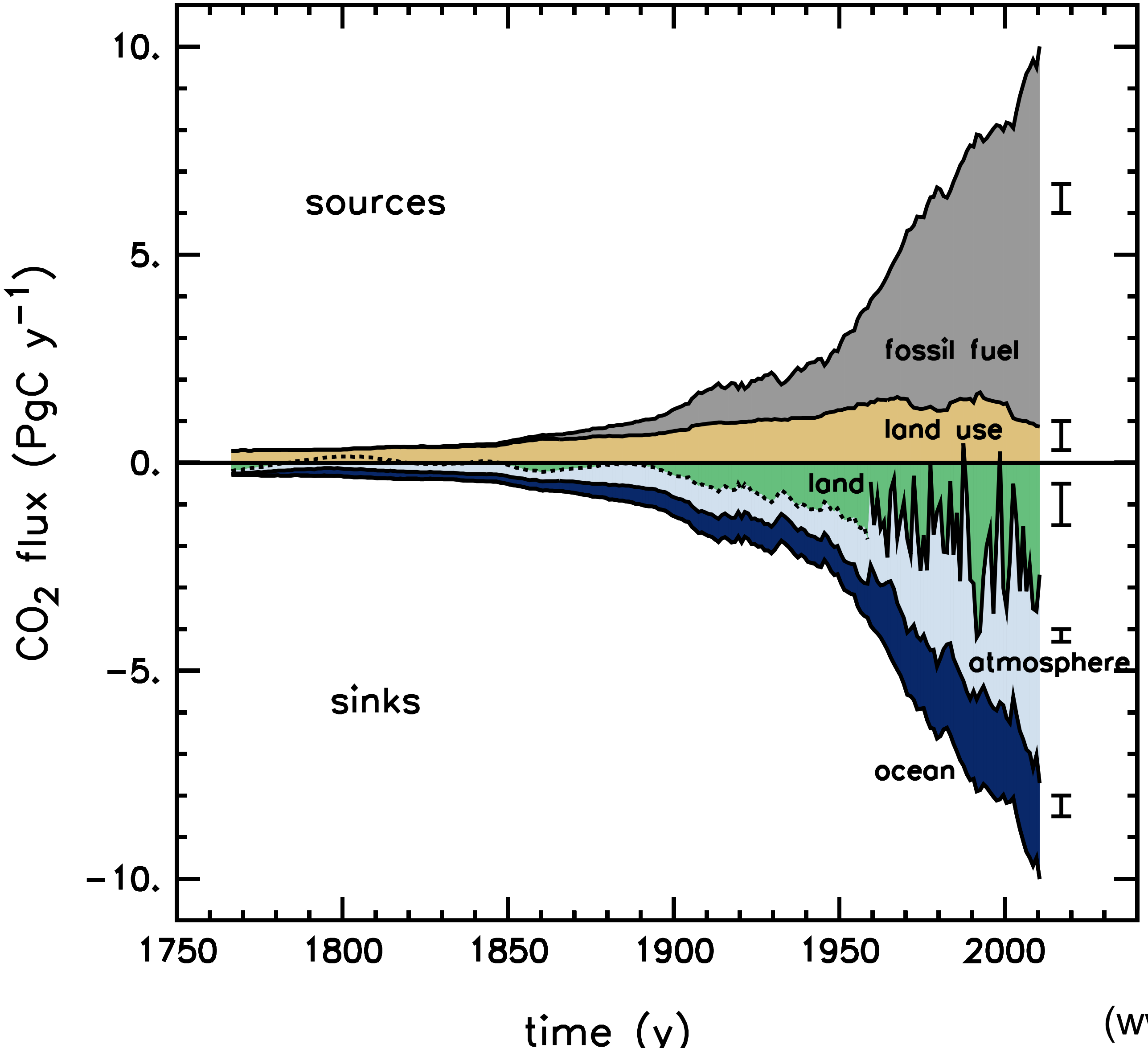


p://www.globe.gov)

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

DAGRL
World Food System

Understanding the global C balance



2000-2010

(PgC y^{-1})

7.9±0.5

1.0±0.7

2.5±1.0

(Residual)

4.1±0.2

2.3±0.5

(5 models)

(www.globalcarbonproject.org)

Update: Global C budget in 2010

0.9±0.7 PgC y^{-1}

+

9.1±0.5 PgC y^{-1}

5.0±0.2 PgC y^{-1}
50%

2.6±1.0 PgC y^{-1}
26%

As residual

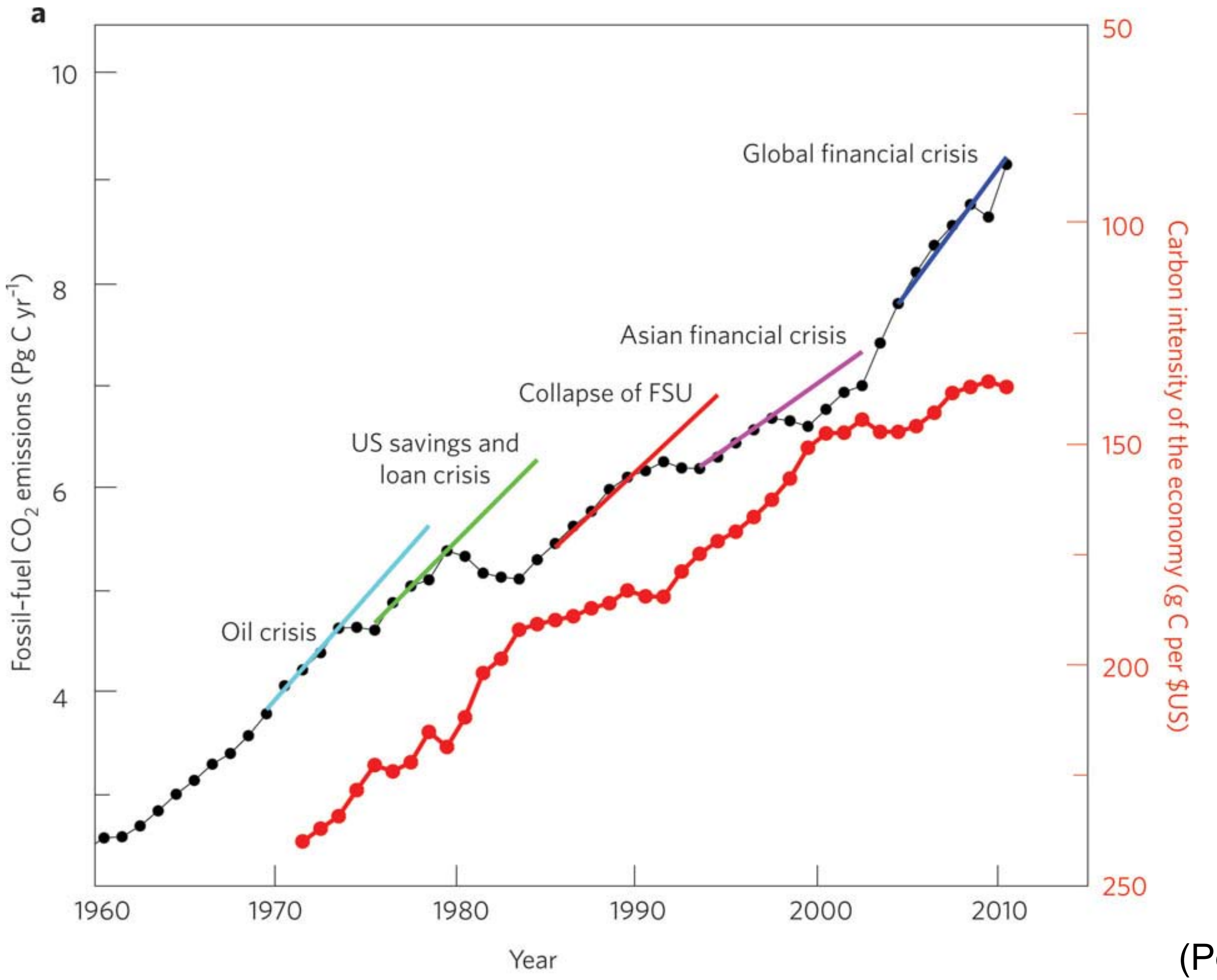
all other flux components

24%
2.4±0.5 PgC y^{-1}

Average of 5 models

(www.globalcarbonproject.org)

Fast "recovery" after last financial crisis



(Peters et al. 2011)

Sectorial GHG emissions

IN FOCUS NEWS

FOOD SECURITY

Summit urged to clean up farming

Leading scientists say that agriculture is a 'poor relation' in global-warming negotiations.

BY NATASHA GILBERT

Delegates meeting this month in Durban, South Africa, to assess international progress on tackling climate change need to look beyond smoke stacks and car exhausts to a neglected source of emissions — agriculture.

That's the message from an international group of leading agricultural and climate scientists in a report published on 16 November. They say that agriculture is the "single largest contributor to greenhouse-gas pollution on the planet", through routes such as deforestation, rice growing and animal husbandry (see 'Farming footprint'). Emissions include nitrous oxide from fertilizer and methane from livestock, as well as carbon dioxide. With global food demand projected to double by 2050, agri-

13.5% Agriculture

≈ 6.6 Gt CO_2eq/a

– OR –

31.1% Agriculture

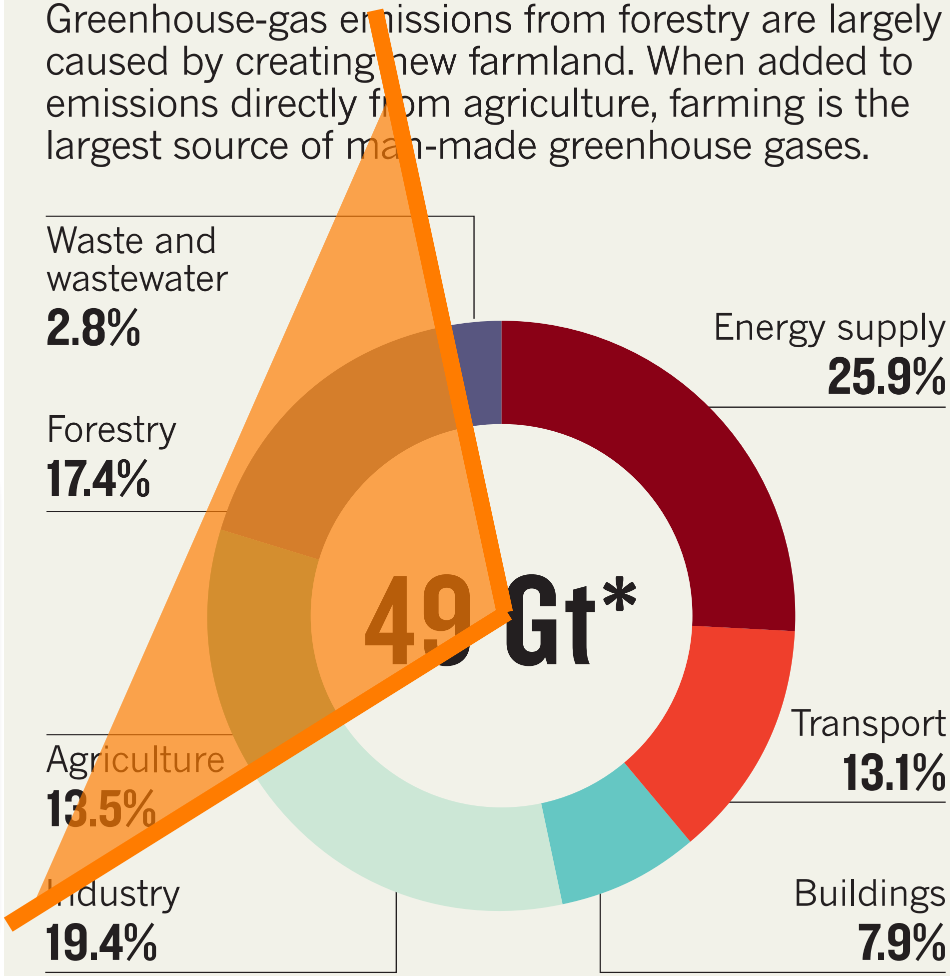
≈ 15.2 Gt CO_2eq/a

?

(data from 2004)

FARMING FOOTPRINT

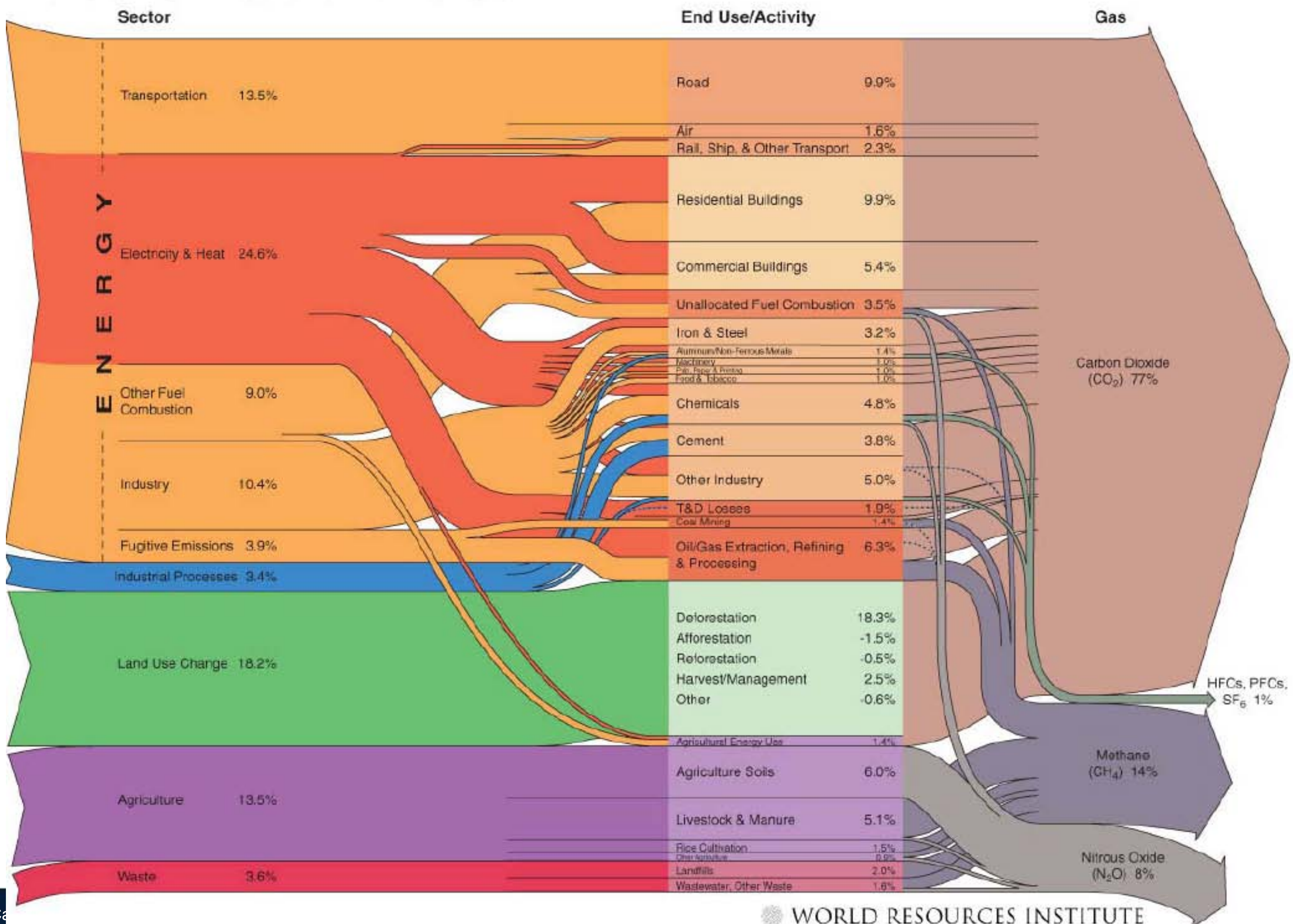
Greenhouse-gas emissions from forestry are largely caused by creating new farmland. When added to emissions directly from agriculture, farming is the largest source of man-made greenhouse gases.



*49 gigatonnes of carbon-dioxide equivalent per year; 2004 data

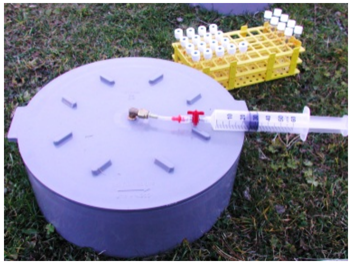
(Gilbert 2011)

Sectorial GHG emissions: Agriculture

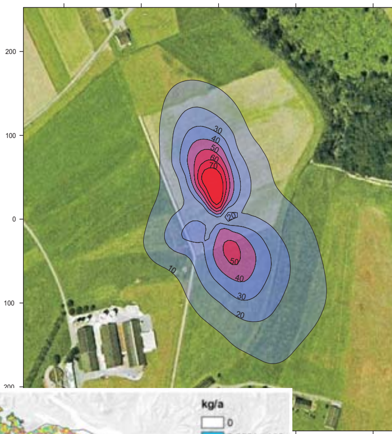


Quantification of GHG fluxes

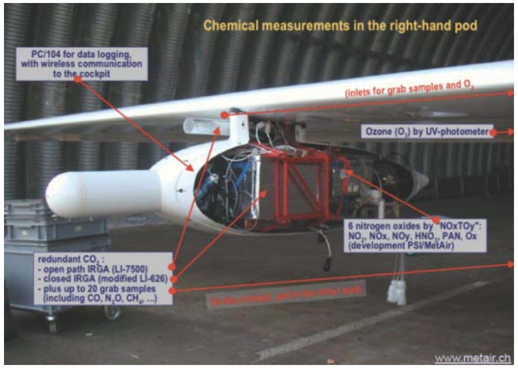
Chambers → soil or vegetation scale

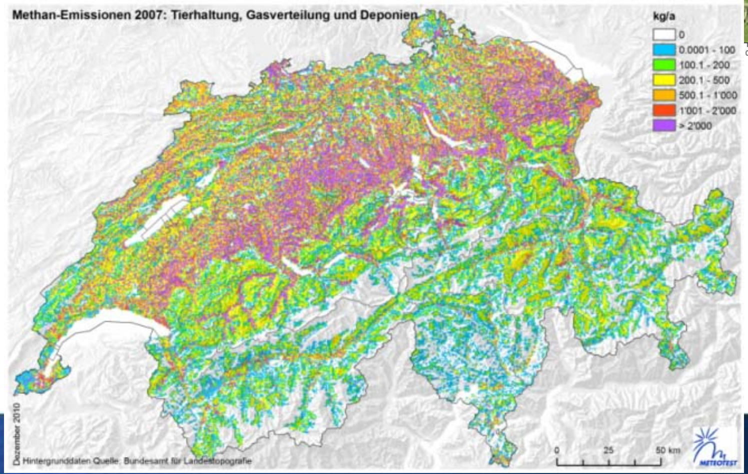
Flux towers, tall towers → ecosystem or regional scale

Aircrafts → regional to national scale

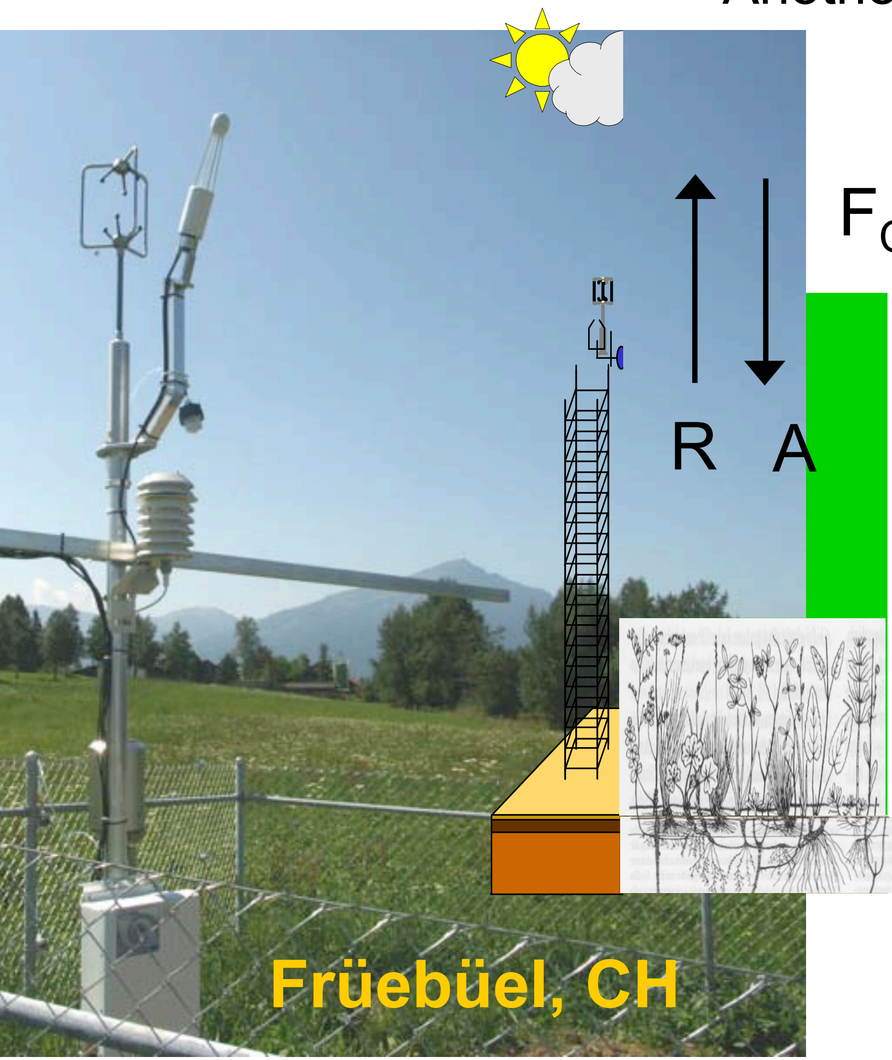


Modelling, inventories



Biosphere–atmosphere gas exchange

Another approach: Land-based measurements



F_{CO2} = Net ecosystem exchange NEE

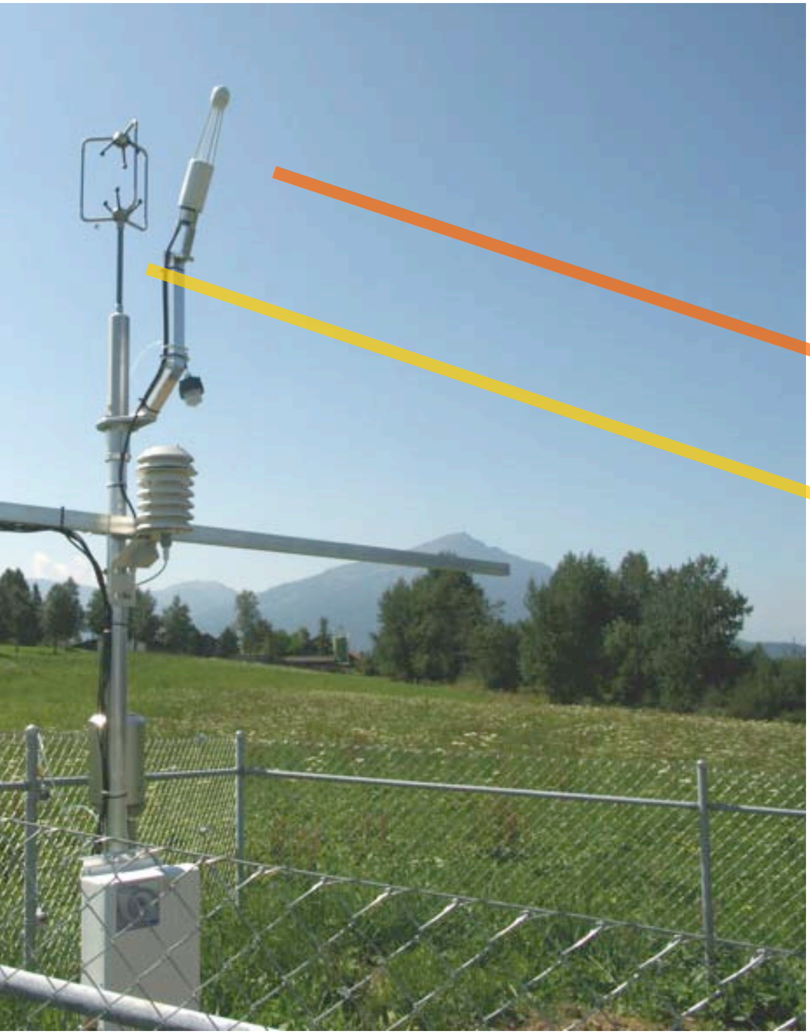
R = Respiration

A = Assimilation, photosynthesis

C sink: Assimilation >> Respiration

C source: Respiration >> Assimilation

Measurements of net CO_2 exchange



Eddy Covariance method:

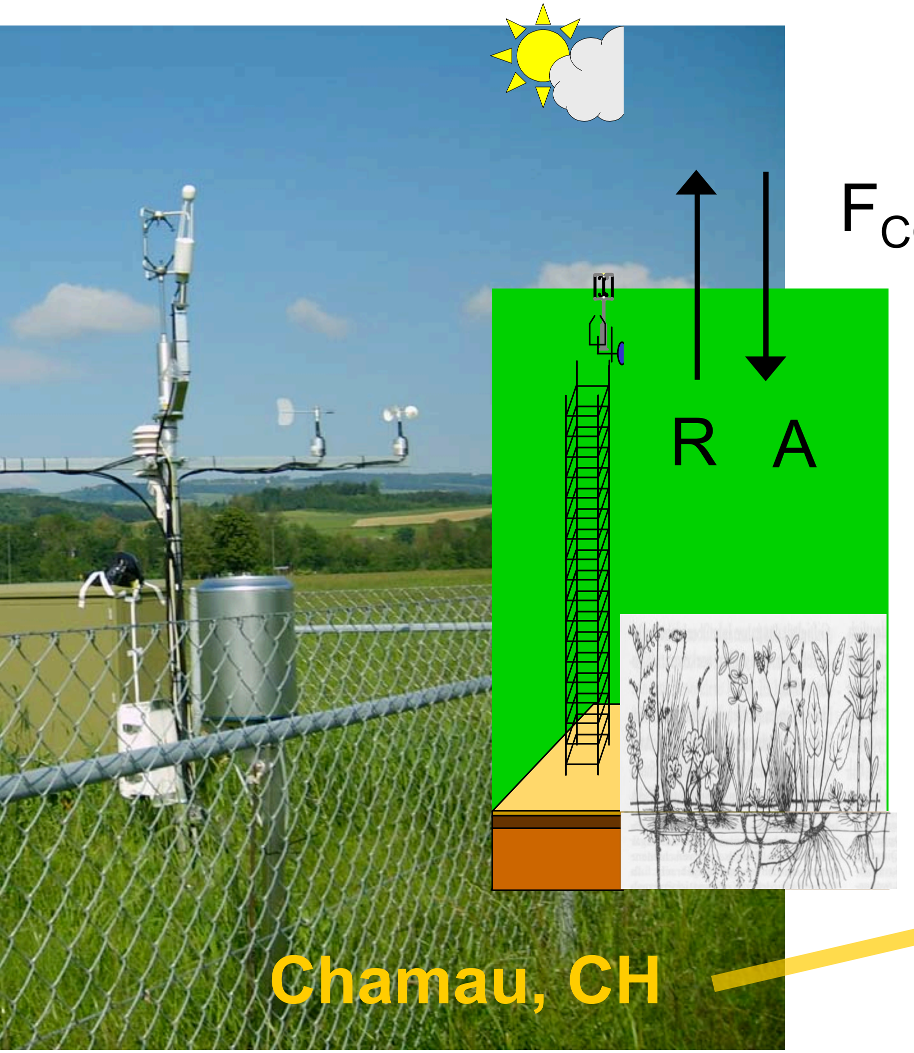
Measurements of

- Radiation,
- Temperature, humidity,
- CO_2, H_2O concentrations,
- Wind direction,
- Wind velocity,
- …

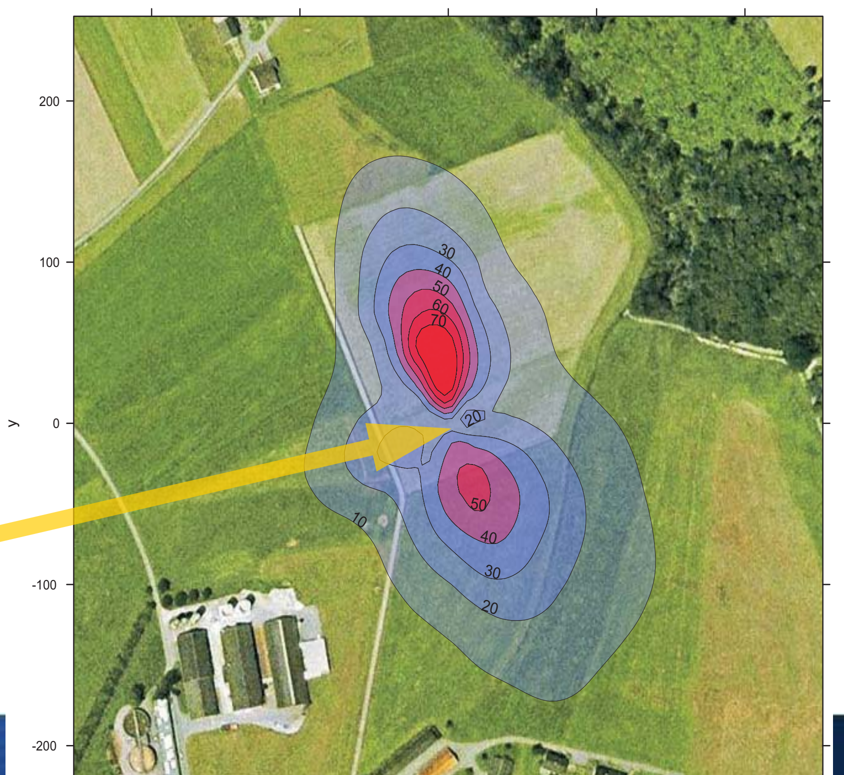
➢ Calculation of CO_2 flux:

$$F_{CO_2} = V_{mol} \overline{w'c'}$$

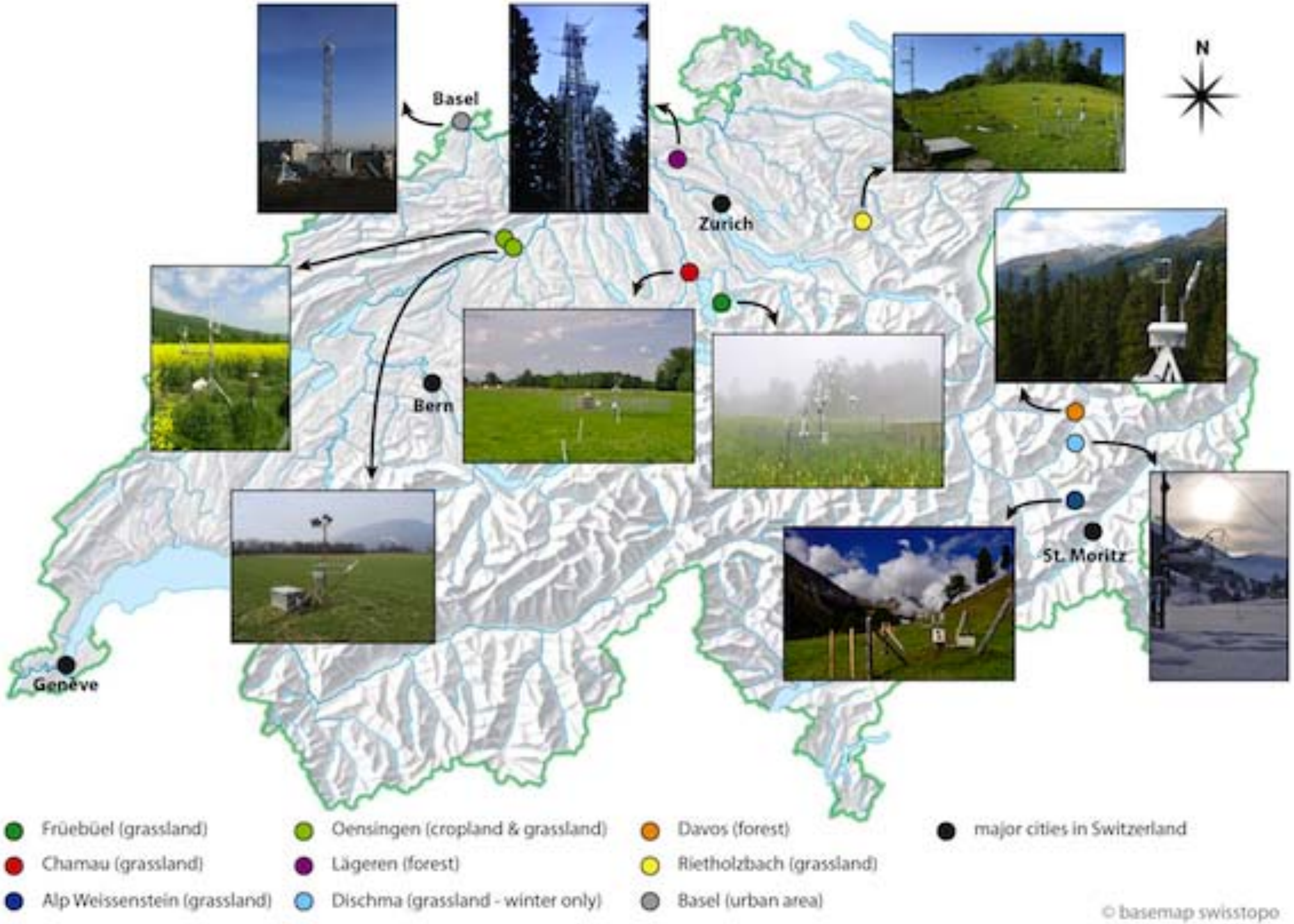
Measurements of net CO_2 exchange



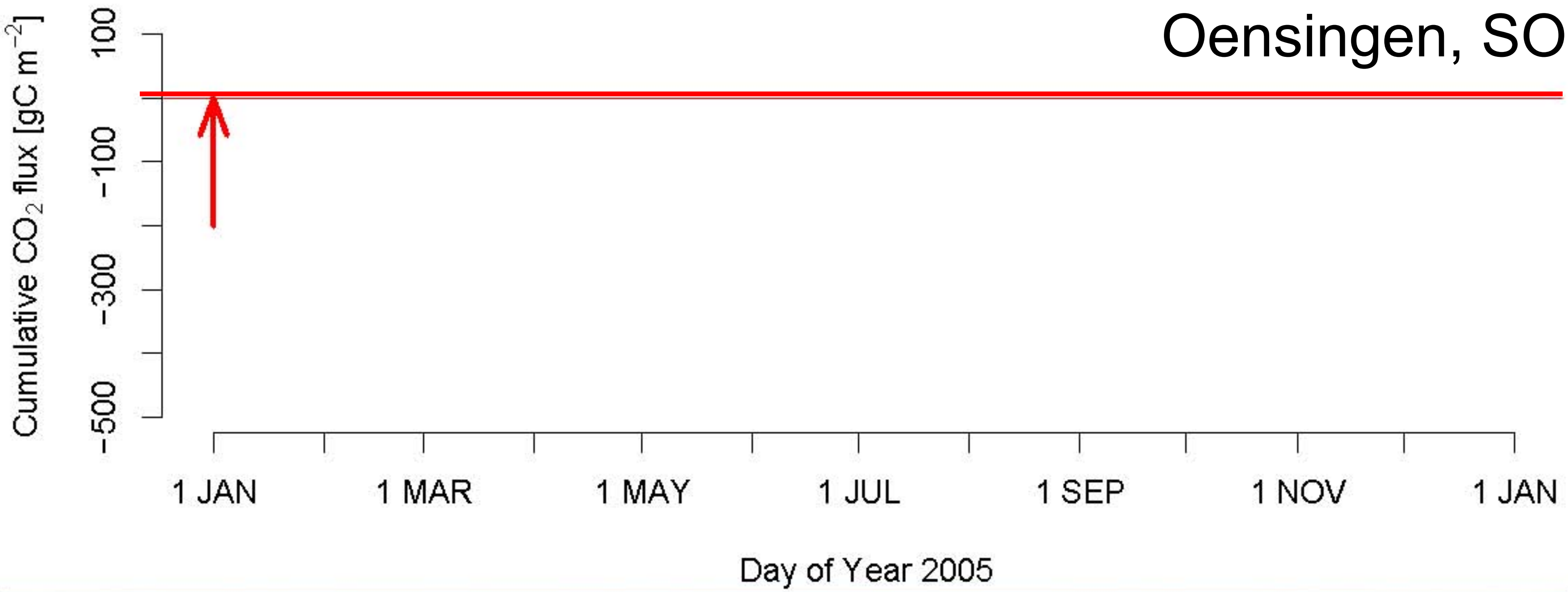
- Continuous measurements (24 h/day, 365 days/year, multiple years)
- Spatial integration

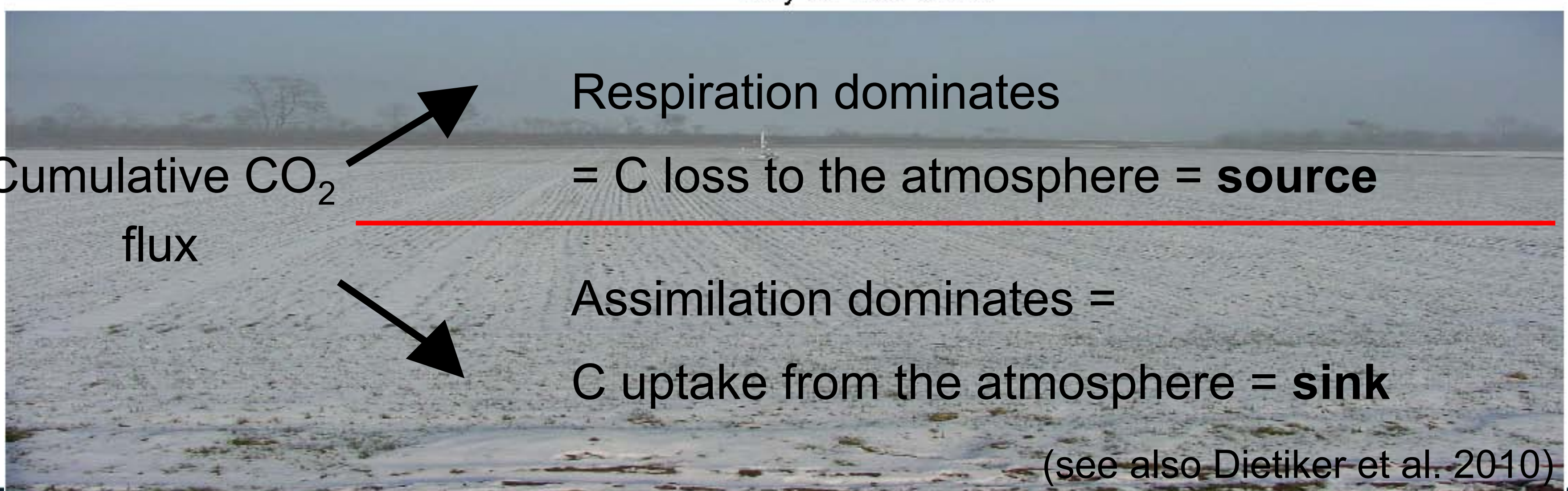


Swiss Fluxnet



Annual carbon fluxes of a cropland?





Cumulative CO_2 flux

Respiration dominates

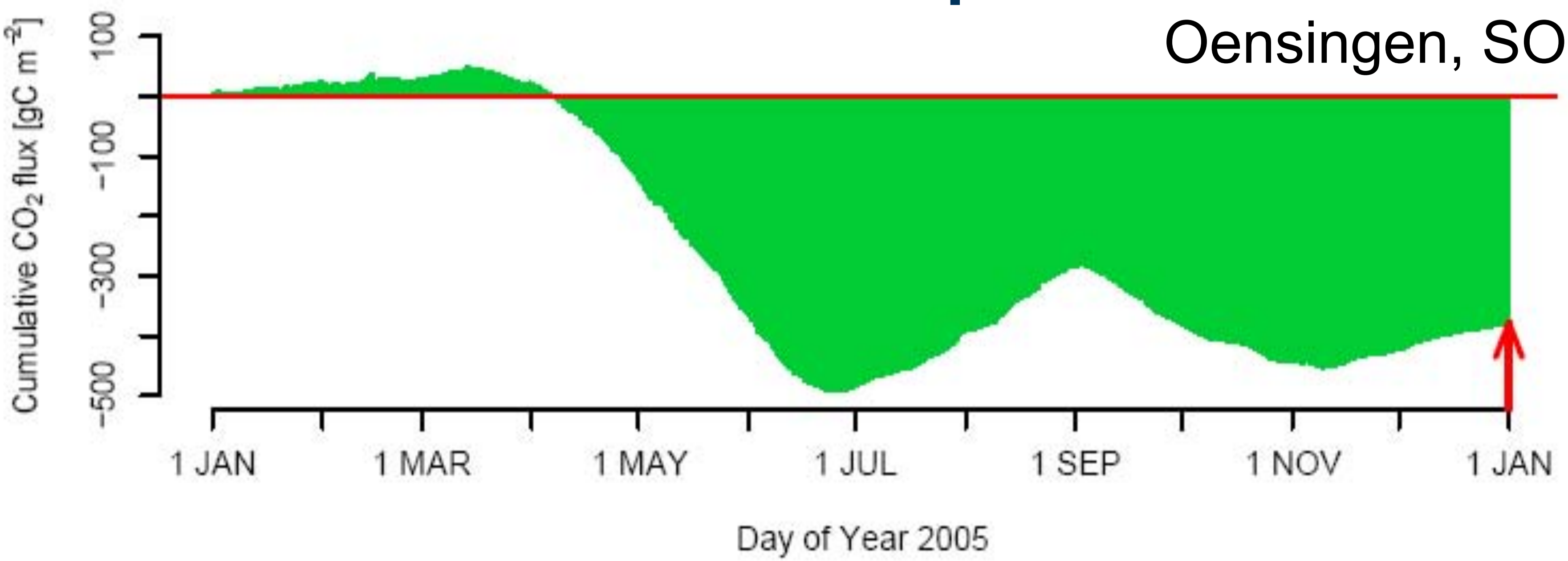
= C loss to the atmosphere = **source**

Assimilation dominates =

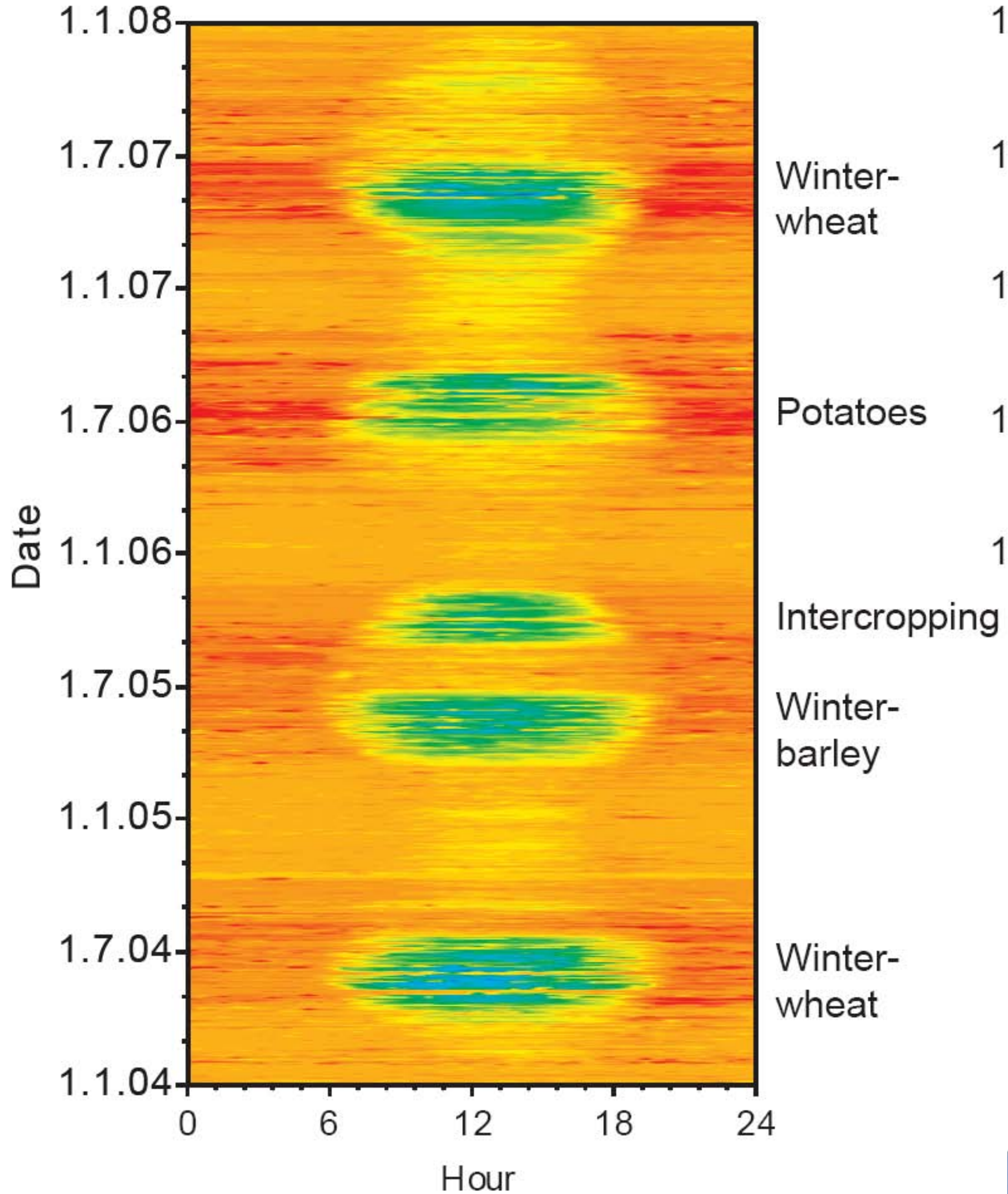
C uptake from the atmosphere = **sink**

(see also Dietiker et al. 2010)

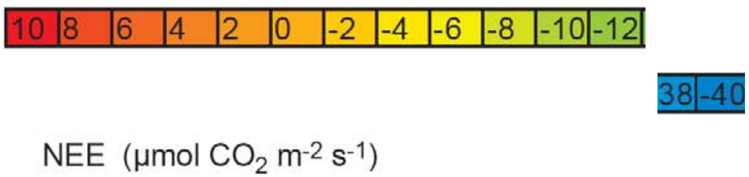
Annual carbon fluxes of a cropland?



4 years of CO_2 fluxes for crop rotation

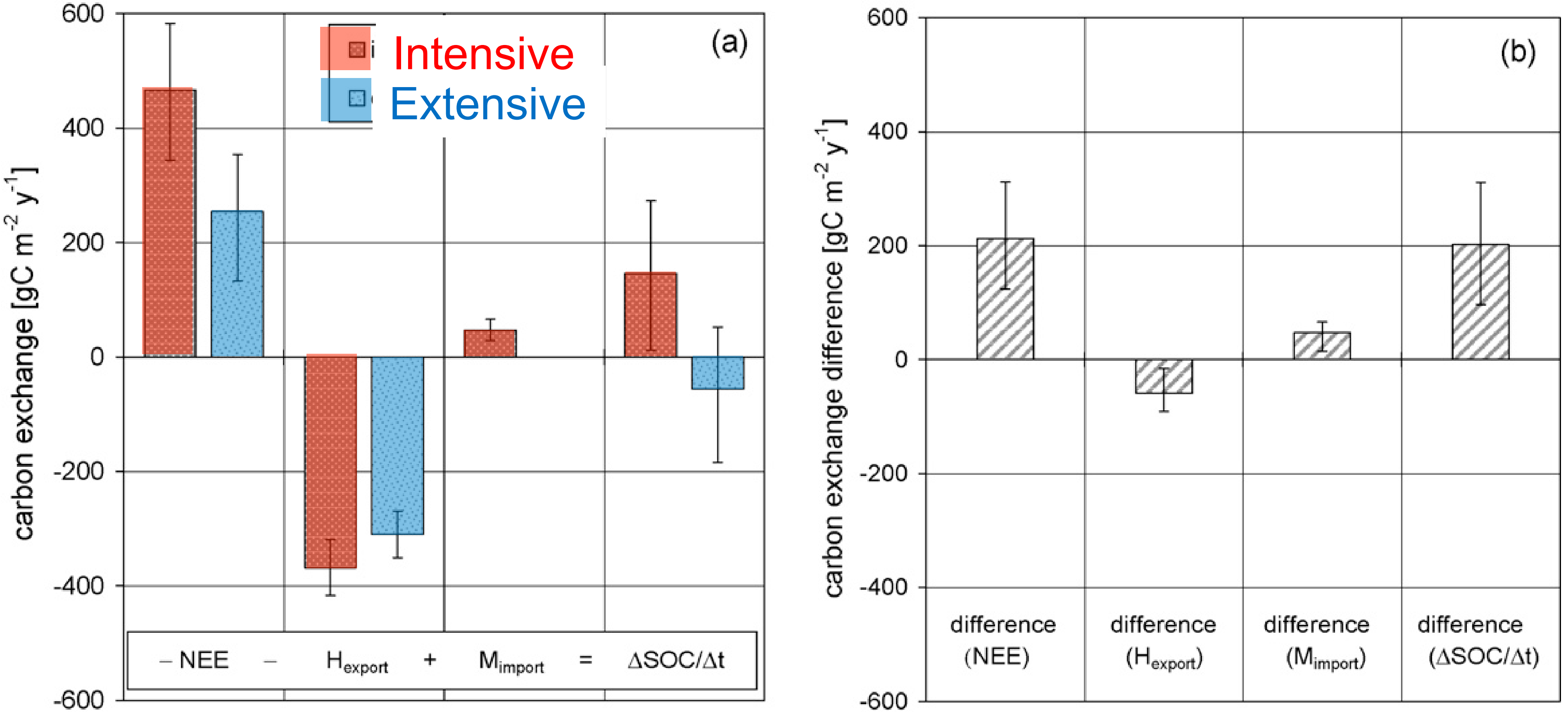


Oensingen, SO



(Kutsch et al. 2010)

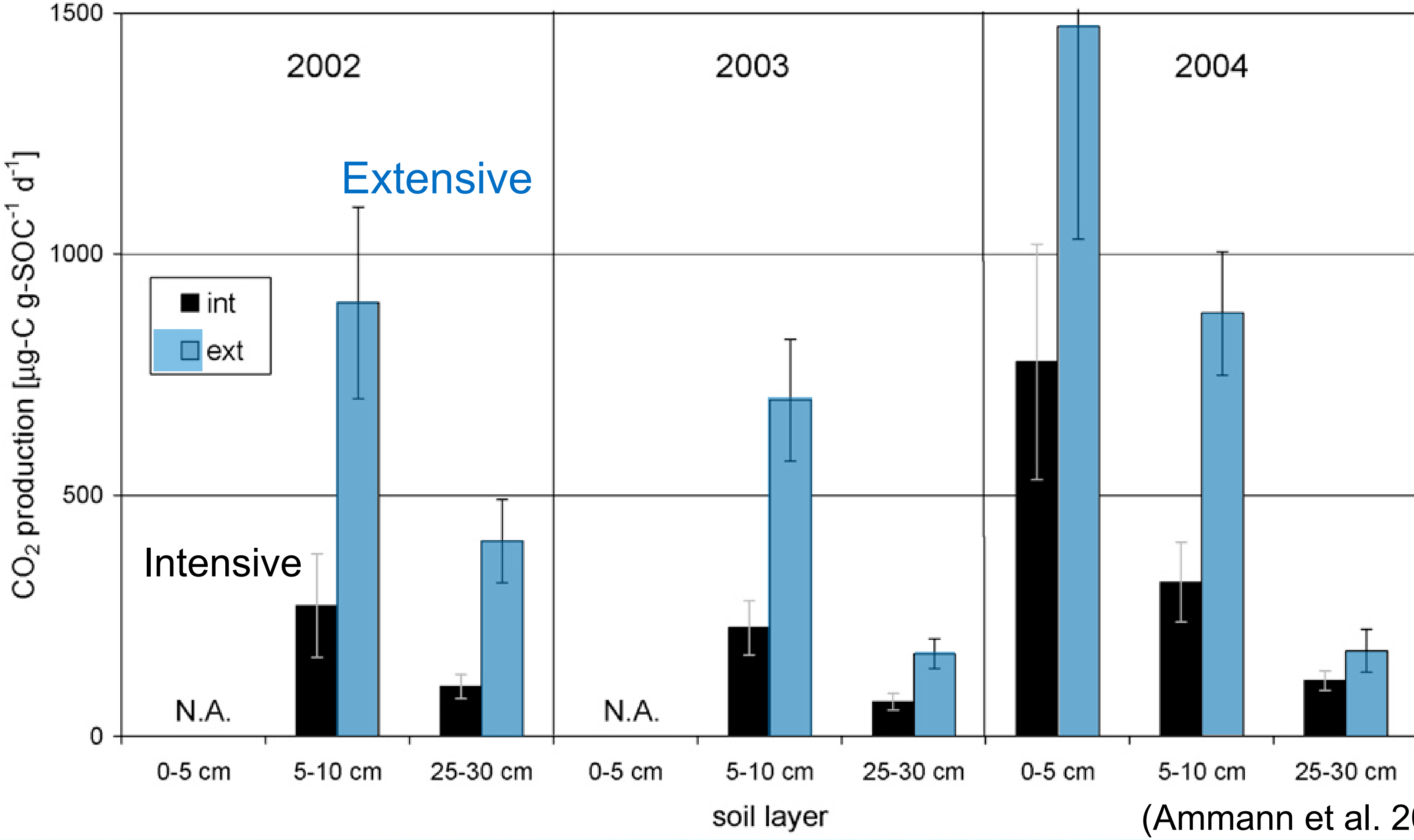
Oensingen: Intensive vs. Extensive Grassland



Soil C Stocks

(Ammann et al. 2007)

Oensingen: Intensive vs. Extensive Grassland



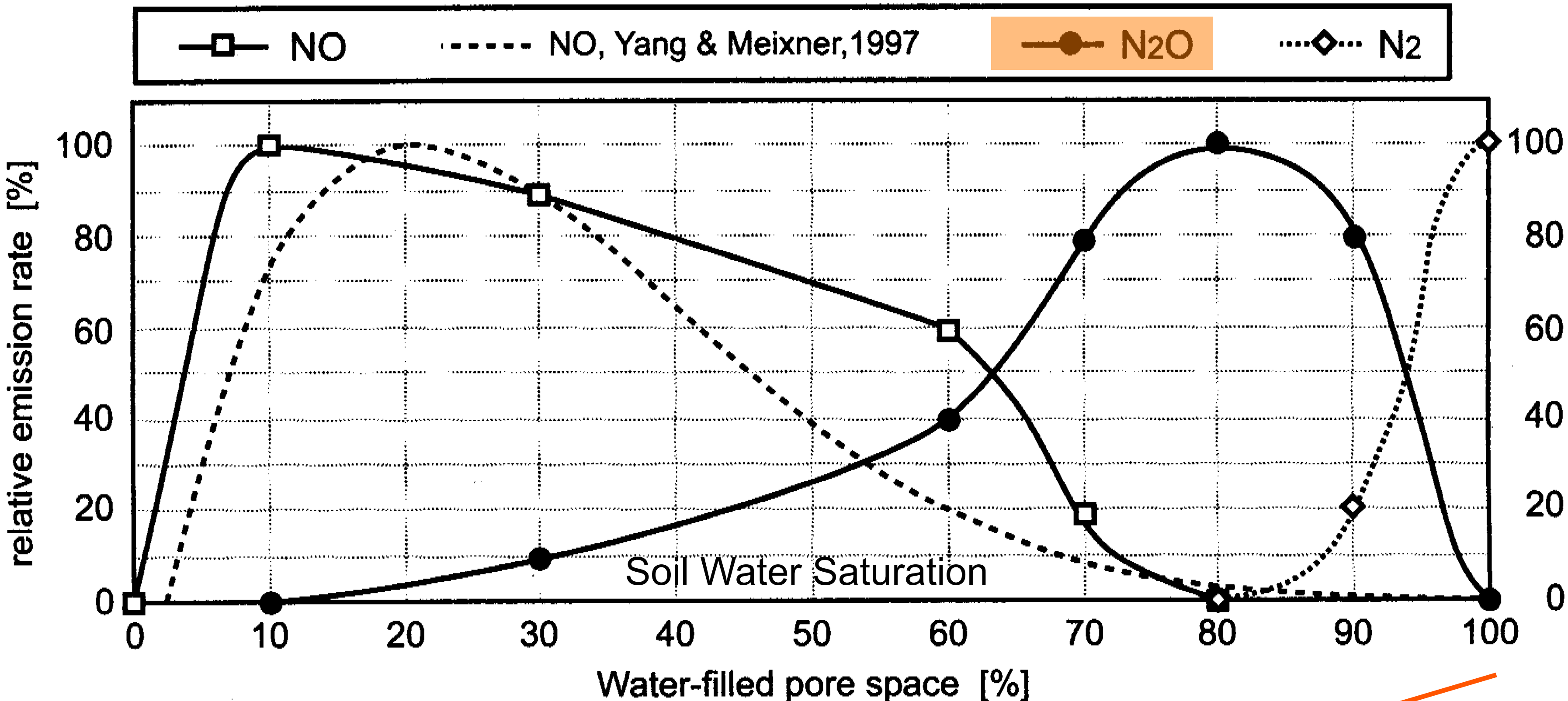
(Ammann et al. 2007)

Soil Processes: Importance of N_2O and CH_4

Chemically Reactive, Short Lifetime

GHG

Inert



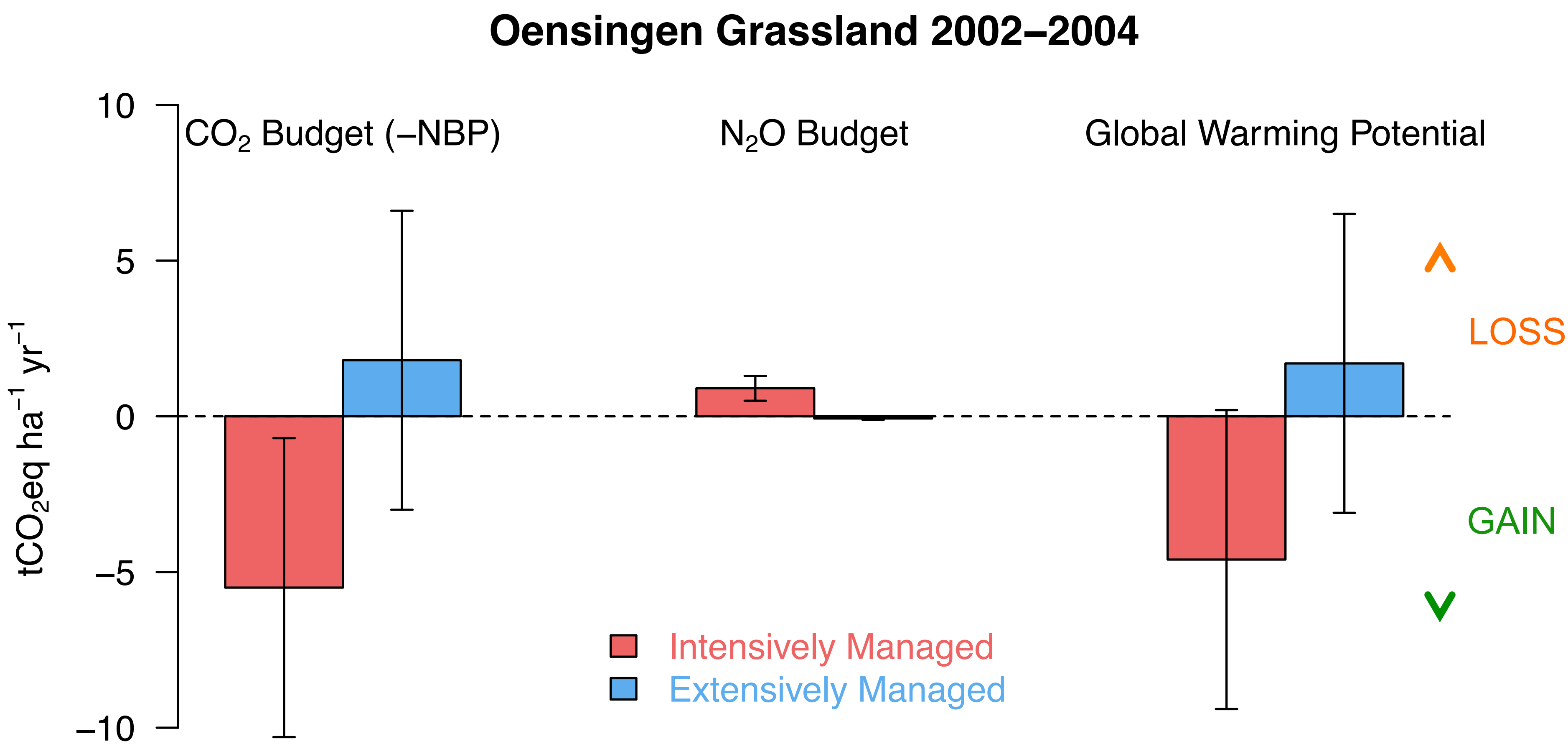
< CH_4 Uptake (Oxidation) >

< CO_2 Loss (Respiration) >

CH_4 CH_4

(mod. after Meixner and Eugster 1999)

Total Global Warming Potential Oensingen Grassland



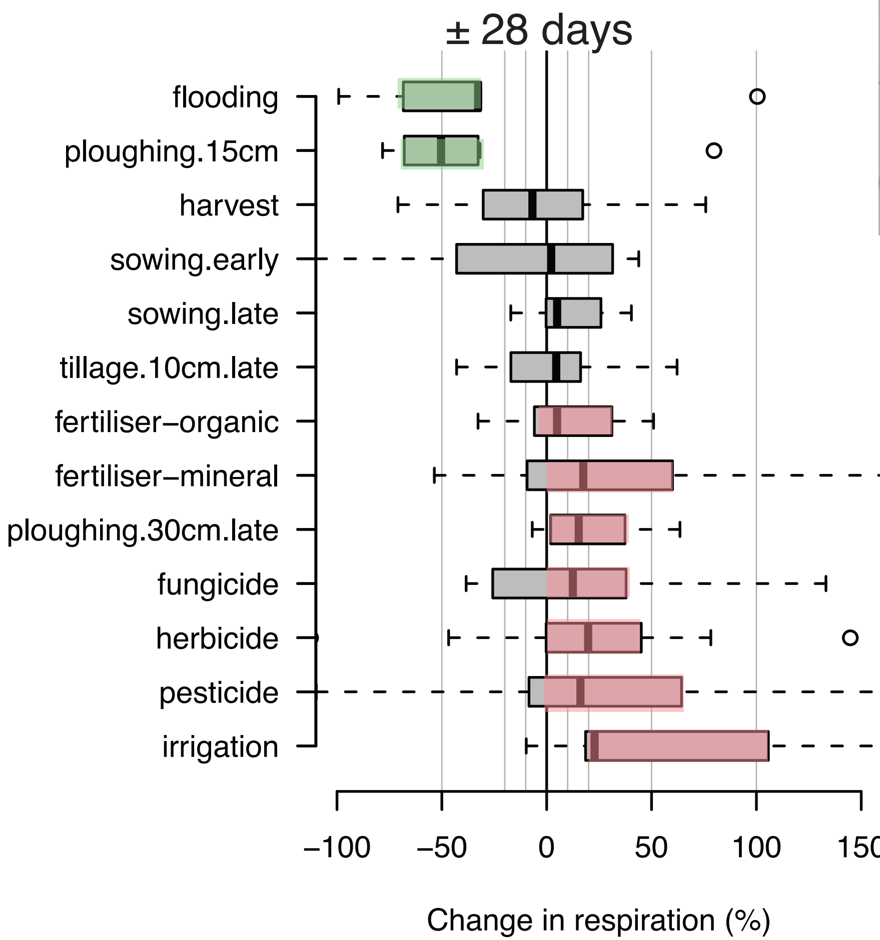
Data from Flechard et al. (2005)

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Management Effect on Cropland Respiration

flooding
ploughing (15 cm)

tillage (10 cm)



fertilizer

plowing (30 cm)

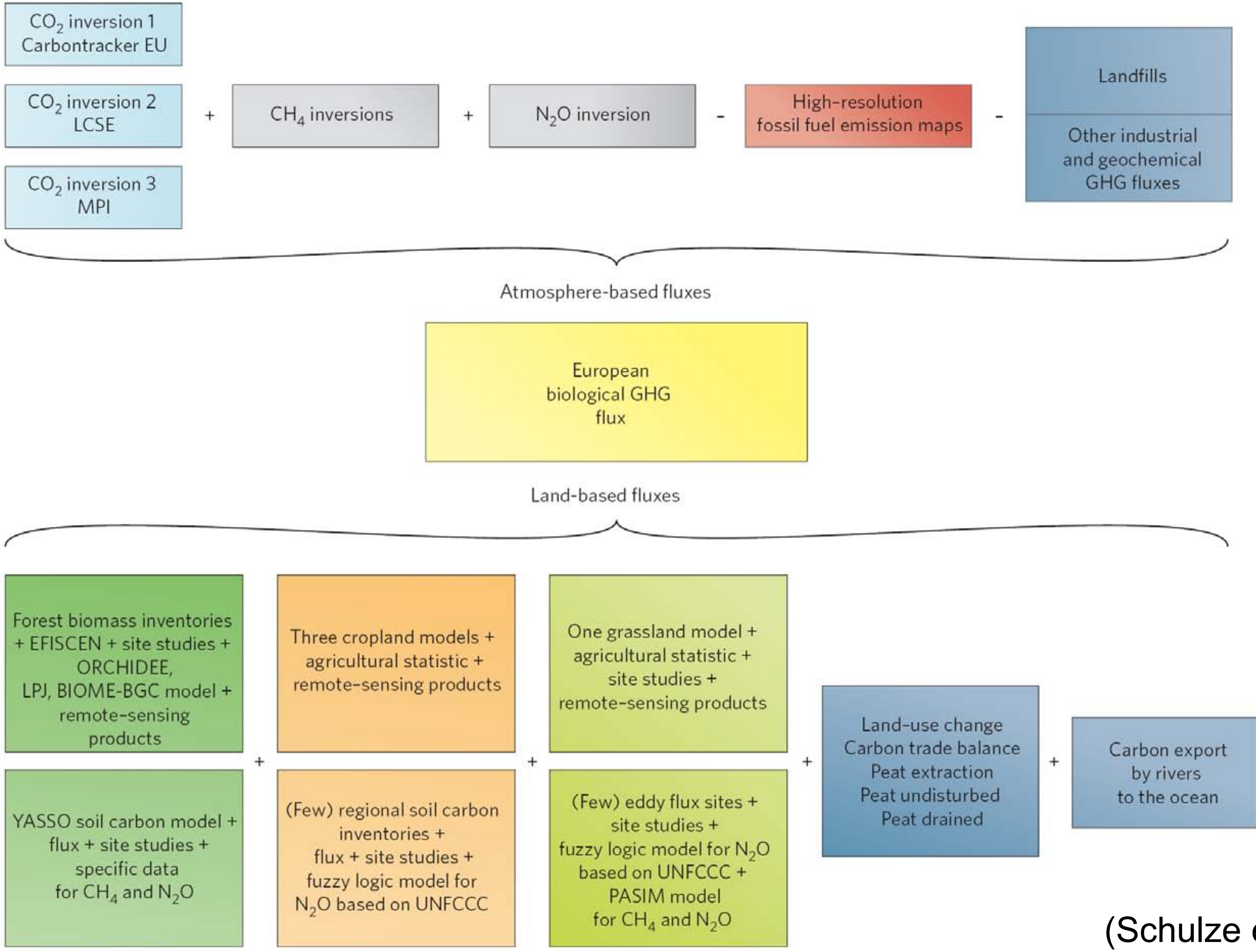
irrigation

LESS Carbon Loss <

> MORE Carbon Loss

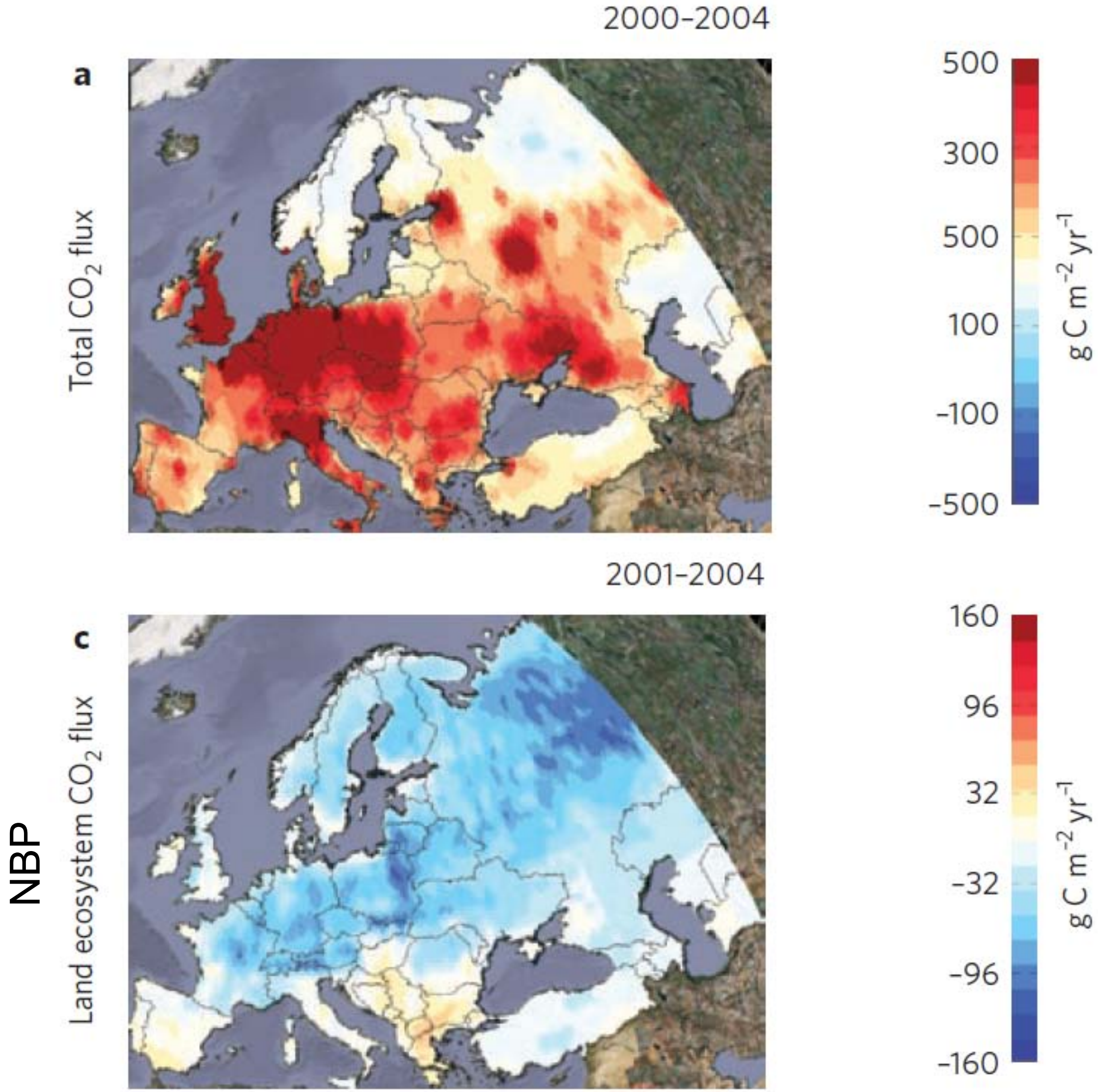
(Eugster et al. 2010)

Combined approach to estimate European GHG budget



(Schulze et al. 2009)

European CO_2 fluxes and NBP (Net Biome Productivity)

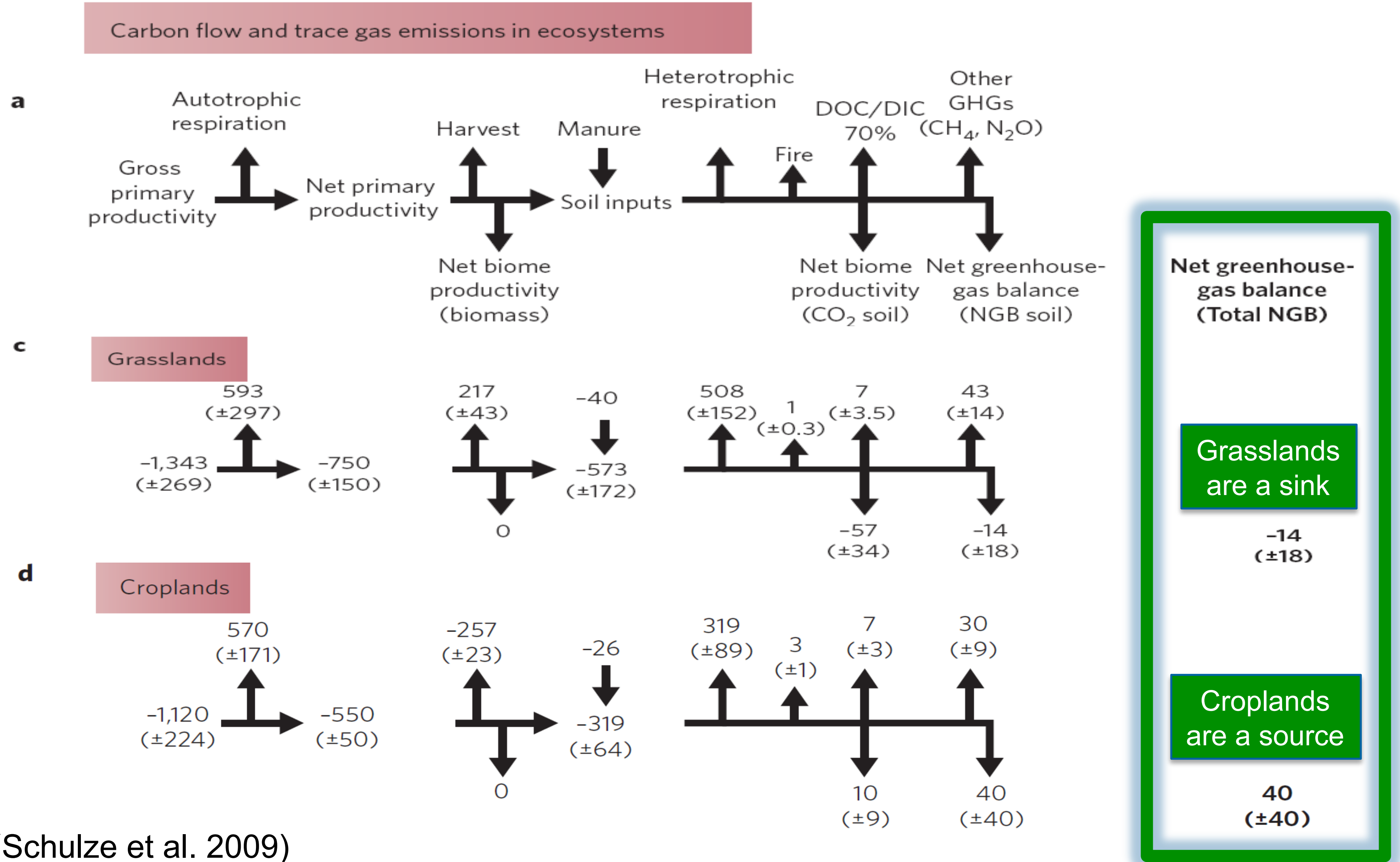


Europe

= Carbon sink

(Schulze et al. 2009)

European GHG budget for agricultural lands



(Schulze et al. 2009)

Afforestation vs. pasture in Panama

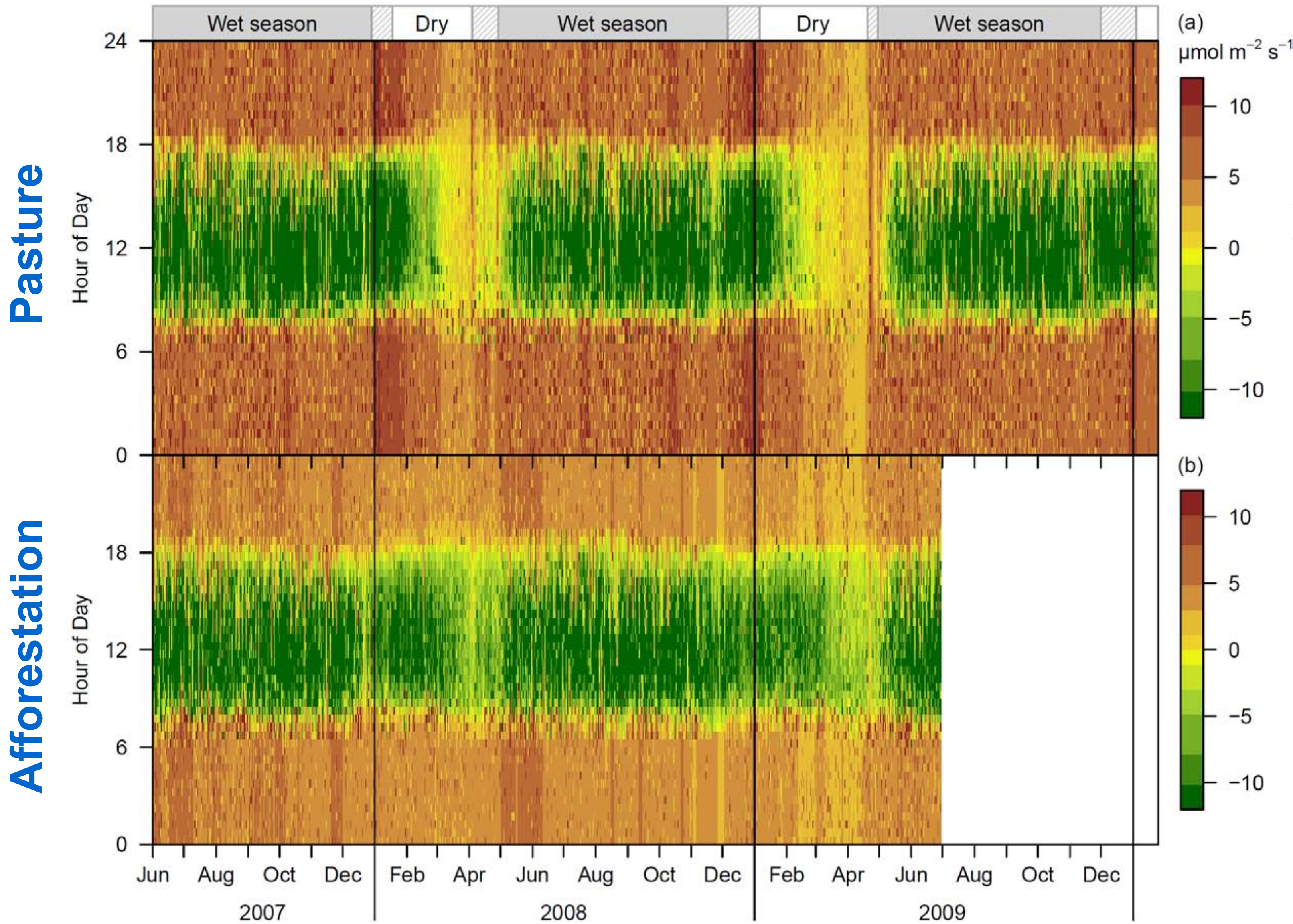
Sardinilla, Panama

(Wolf et al. 2010)

Afforestation vs. pasture in Panama

(Wolf et al. 2010)

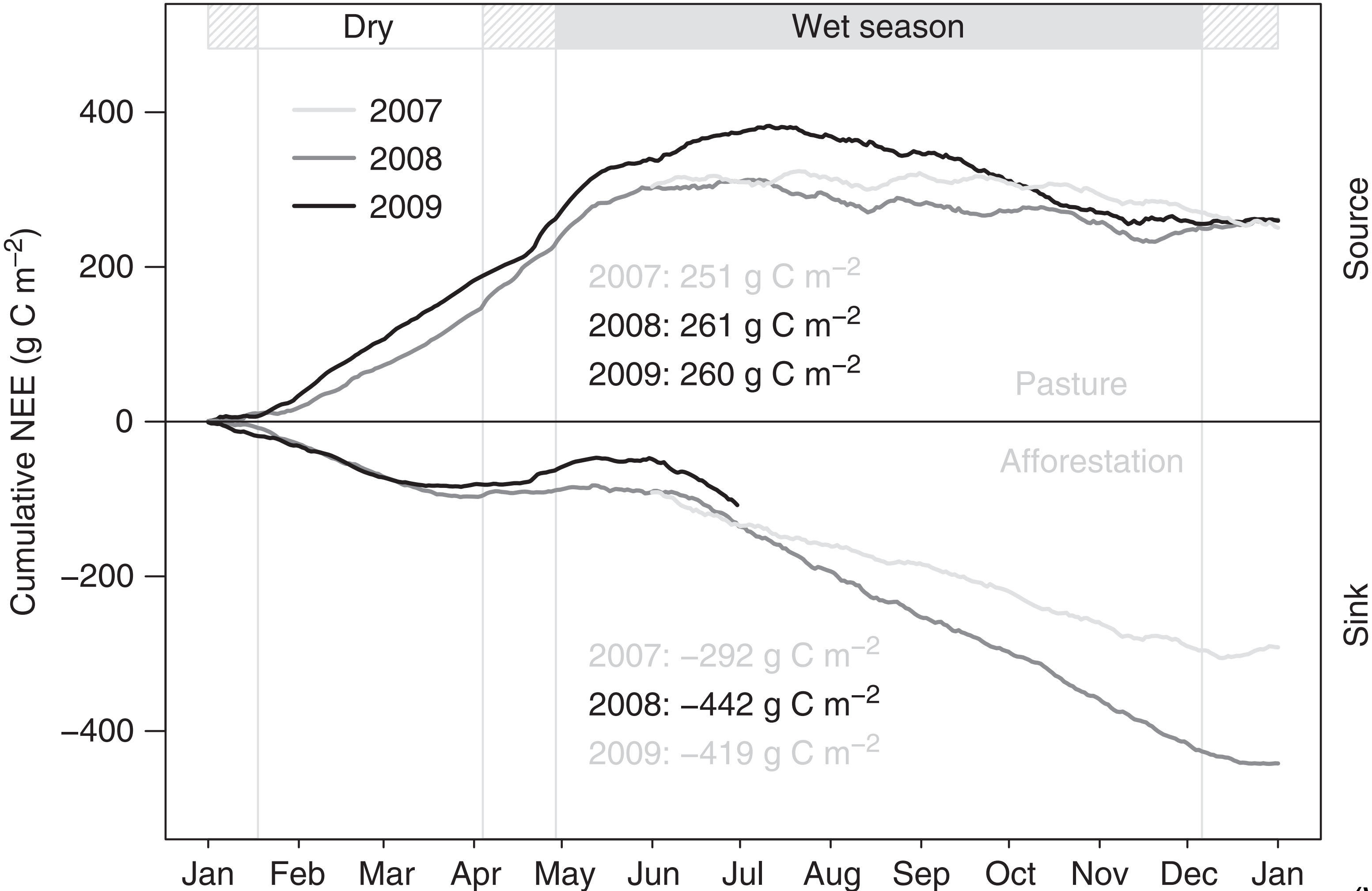
Afforestation vs. pasture in Panama



- C source
- C sink

et al. 2011)

Panama: Dry vs. Wet Season CO_2 Fluxes

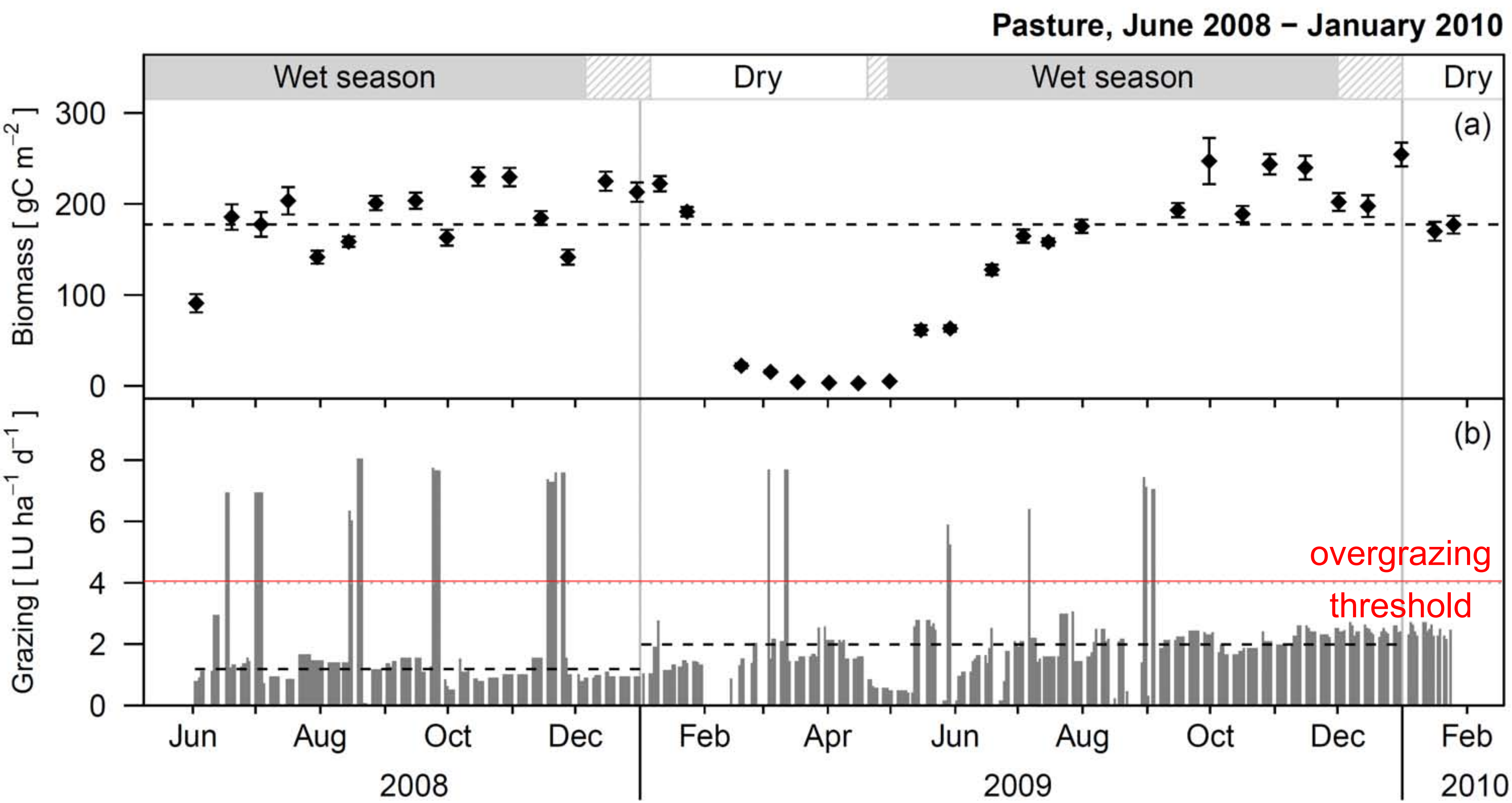


Pasture

Afforestation

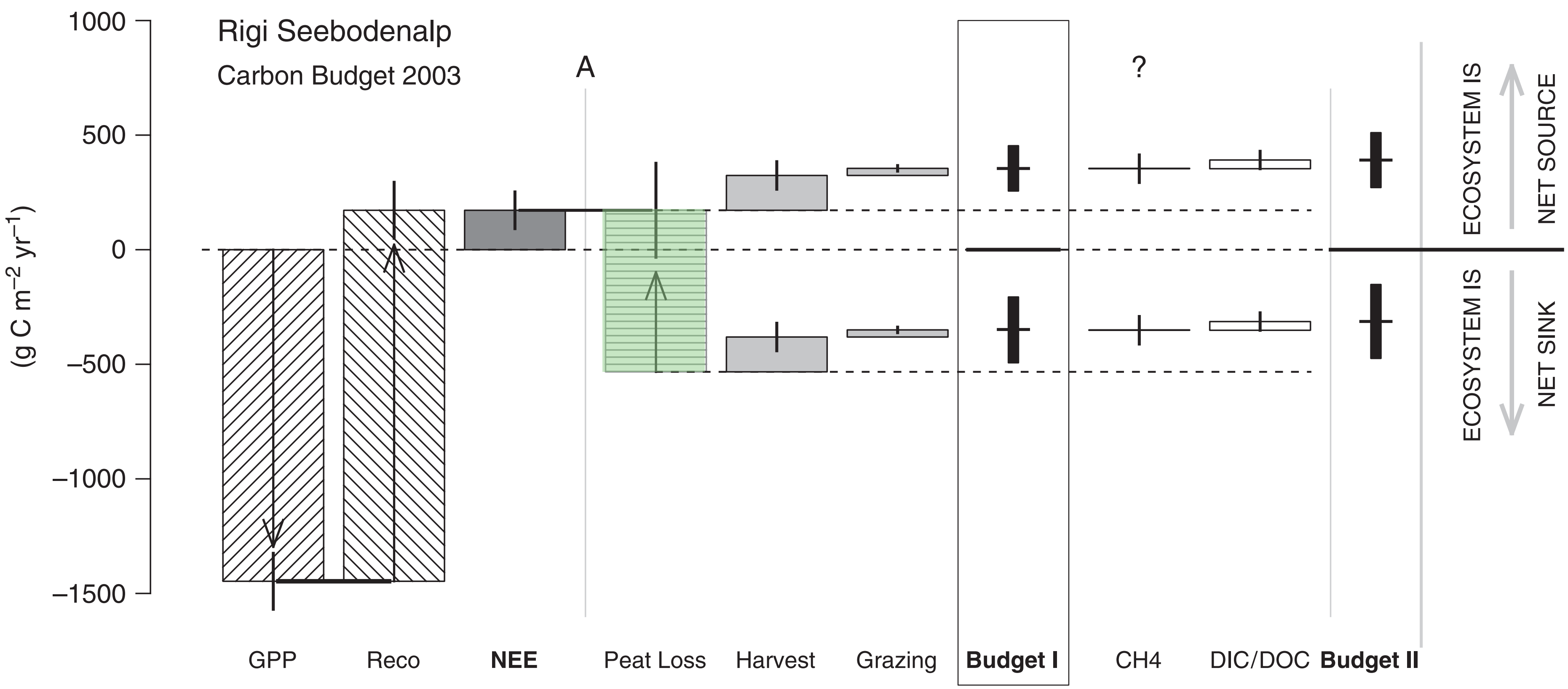
(Wolf et al. 2011)

Impact of overgrazing



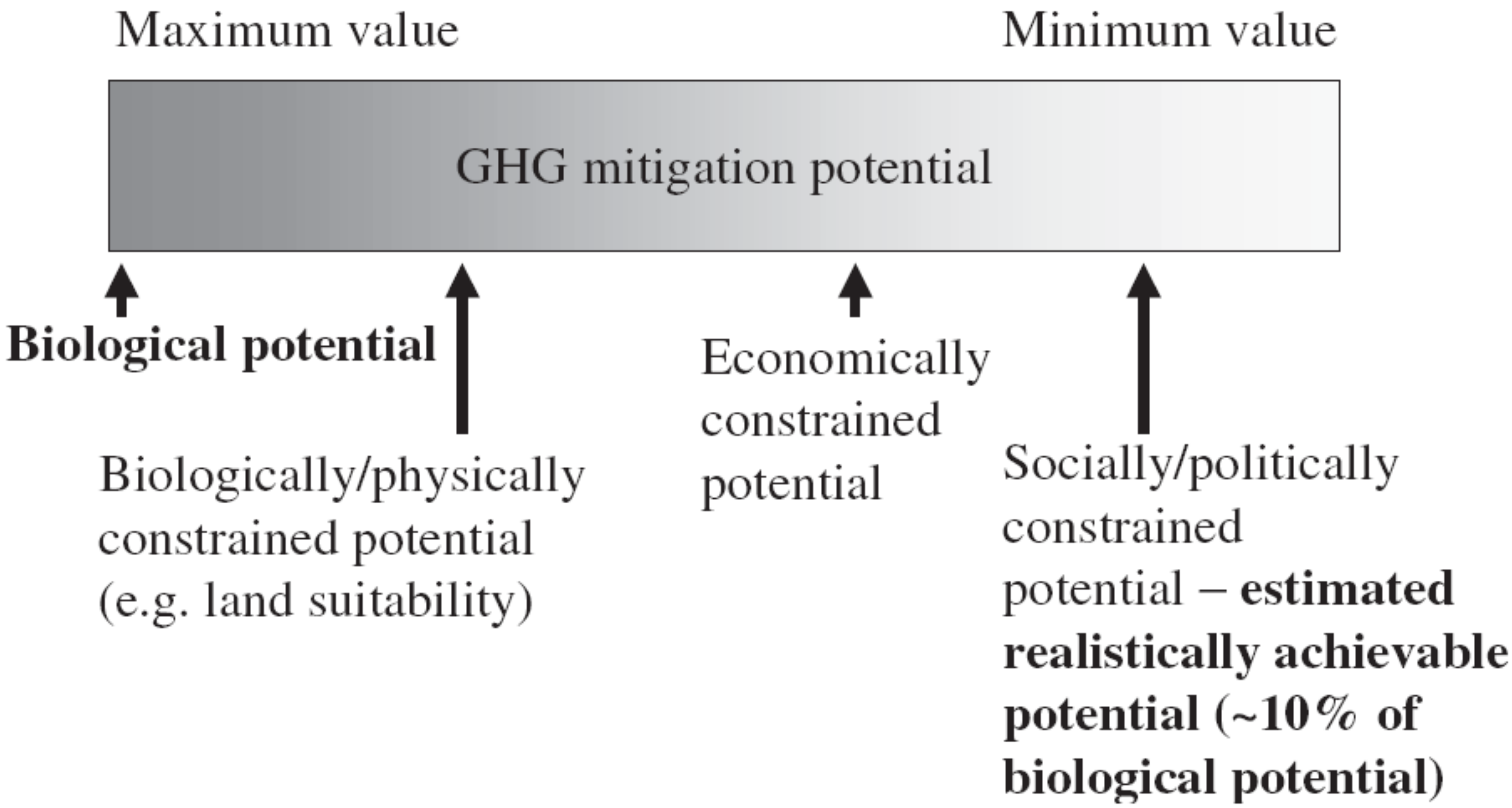
(Wolf et al. 2011)

C-Losses from Organic Soil: Rigi-Seebodenalp



(Rogiers et al. 2008)

Mitigation options “on land”?



(Smith et al. 2005)

Mitigation options "on land"?

According to IPCC (WG III, 2007): For **agriculture**

- Reducing emissions in agriculture *(e.g., fertilizer optimization)*
- Enhancing GHG removal through management *(e.g., zero-tillage, conservation tillage; conserve/increase soil C pools)*
- Avoiding emissions *(e.g., bio-energy, selection of new agricultural areas)*

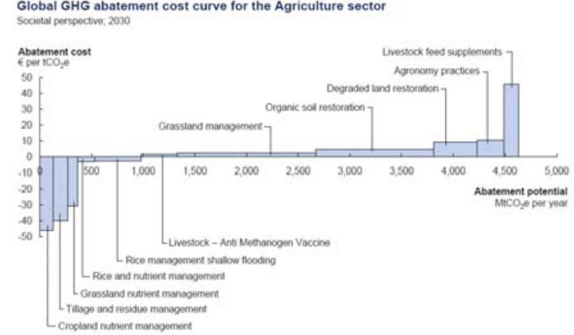
Mitigation options “on agricultural land”?

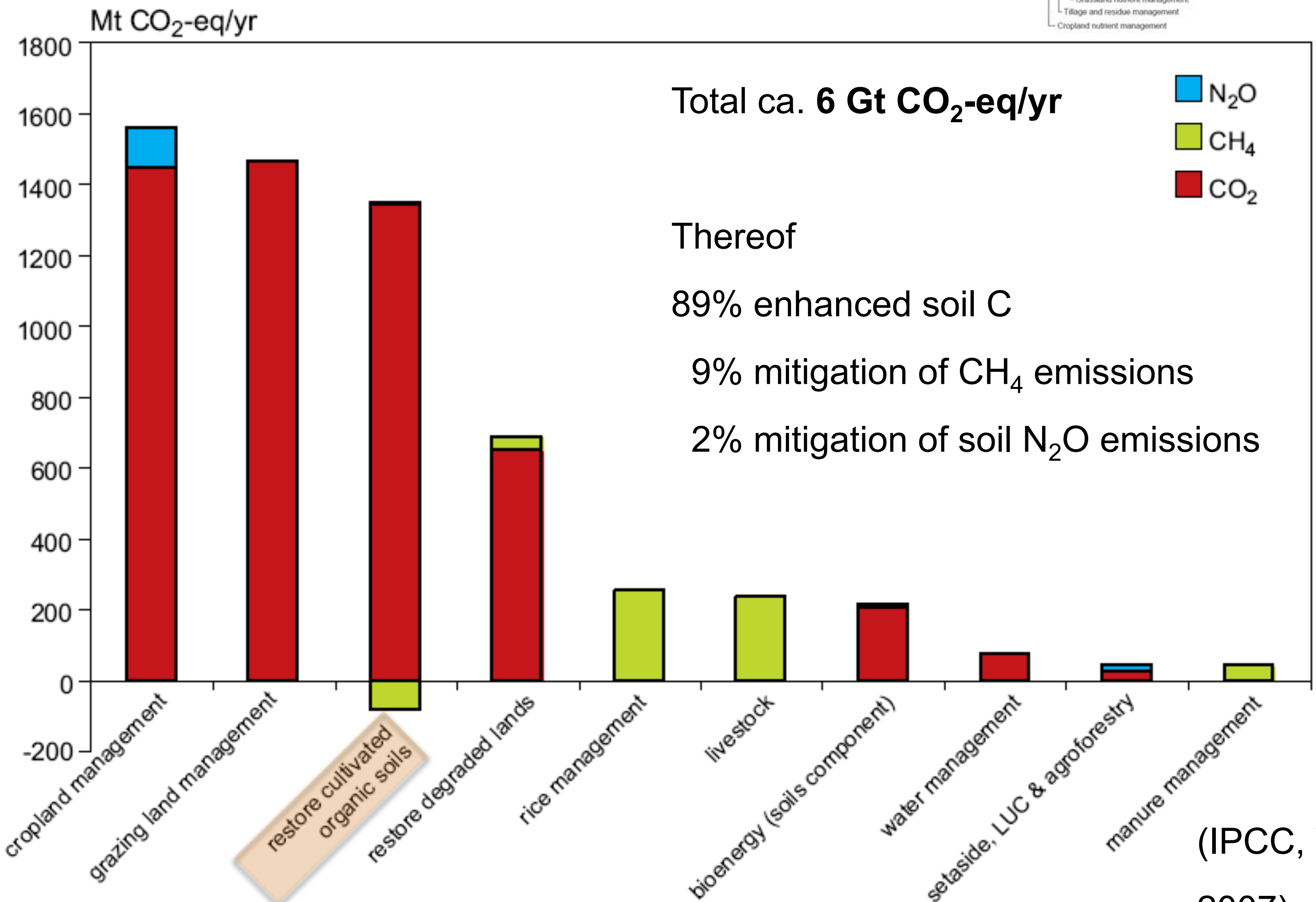
		Mitigative effects[1]			Net mitigation[2] (confidence)	
Measure	Examples	CO_2	CH_4	N_2O	Agree-ment	Evi-dence
Cropland man-agement	Agronomy	+		+/-	***	**
	Nutrient management	+		+	***	**
	Tillage/residue management	+		+/-	**	**
	Water management (irrigation, drainage)	+/-		+	*	*
	Rice management	+/-	+	+/-	**	**
	Agro-forestry	+		+/-	***	*
	Set-aside, land-use change	+	+	+	***	***
Grazing land management/ pasture im-provement	Grazing intensity	+/-	+/-	+/-	*	*
	Increased productivity (e.g. fertilization)	+		+/-	**	*
	Nutrient management	+		+/-	**	**
	Fire management	+	+	+/-	*	*
	Species introduction (including legumes)	+		+/-	*	**
Management of organic soils	Avoid drainage of wetlands	+	-	+/-	**	**
Restoration of degraded lands	Erosion control, organic amendments, nu-trient amendments	+		+/-	***	**
Livestock man-agement	Improved feeding practices		+	+	***	***
	Specific agents and dietary additives		+		**	***
	Longer term structural and management changes and animal breeding		+	+	**	*
Manure/biosolid management	Improved storage and handling		+	+/-	***	**
	Anaerobic digestion		+	+/-	***	*
	More efficient use as nutrient source	+		+	***	**
Bio-energy	Energy crops, solid, liquid, biogas, resi-dues	+	+/-	+/-	***	**

(IPCC, WG III, 2007)

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Mitigation options “on agricultural land”?





Total ca. **6 Gt CO_2-eq/yr**

Thereof

89% enhanced soil C

9% mitigation of CH_4 emissions

2% mitigation of soil N_2O emissions

(IPCC, WG III, 2007)

Mitigation options "on agricultural land"?

- Many options available
- Strongly dependent on local conditions (environment, management, society, politics, …)
- **Agricultural** mitigation:
  - options in 2030: up to 5.5 to 6 Gt CO_2-eq per yr (top-down models) without fossil fuel substitutions
  - most prominent options: improved crop and grazing land management, **restoration of drained soils and degraded land** → soil C sequestration
  - some technological development still needed

(IPCC 2007)