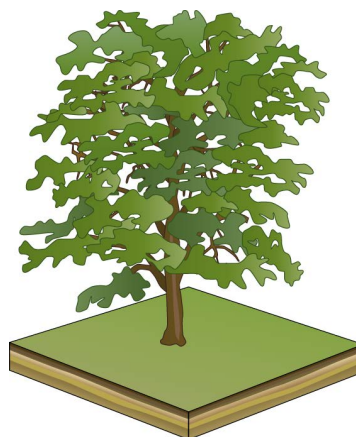# Beyond water: Hydrogen isotopes in plant organic compounds as indicators of the carbohydrate metabolism of plants
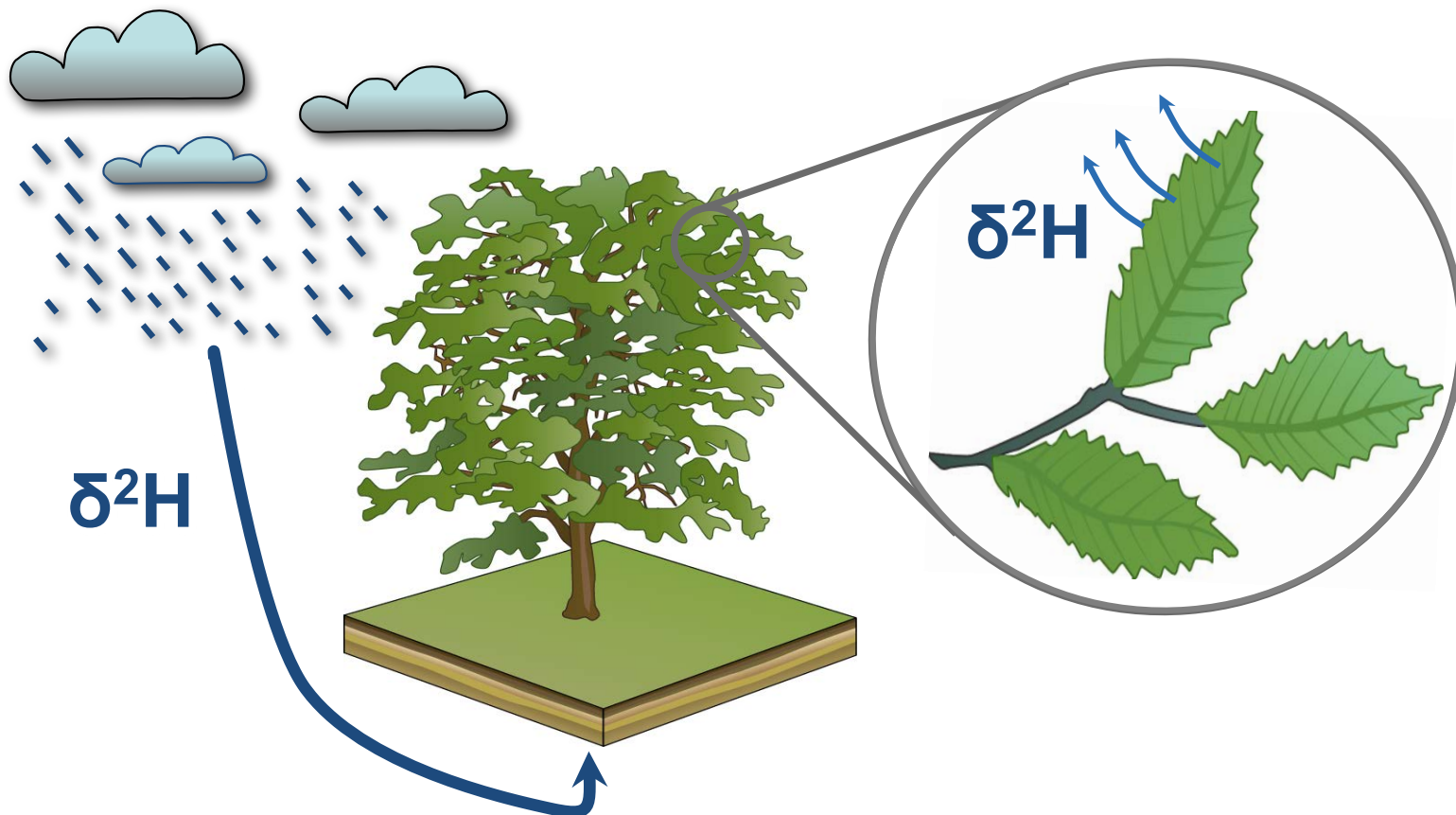
Ansgar Kahmen
Bruno Gamarra
Marc-André Cormier

Department of Environmental Sciences – Botany
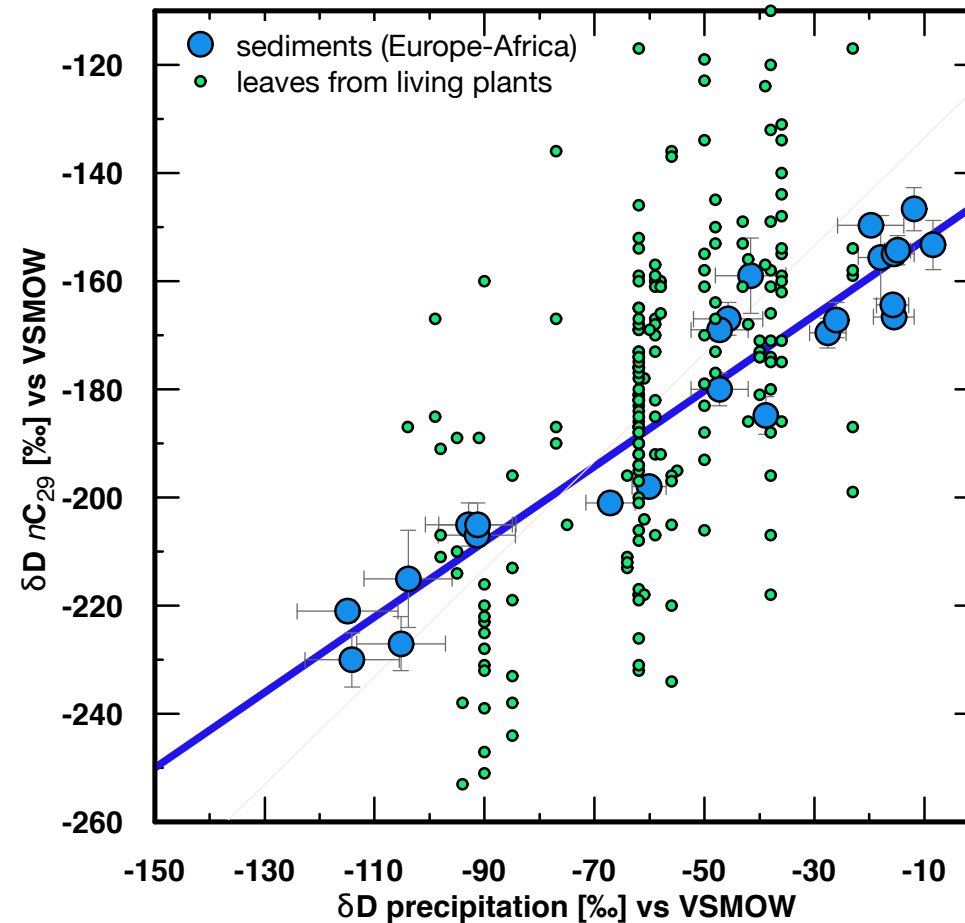University of Basel, Switzerland

Hydrogen Isotopes (δ^2H) in Plants

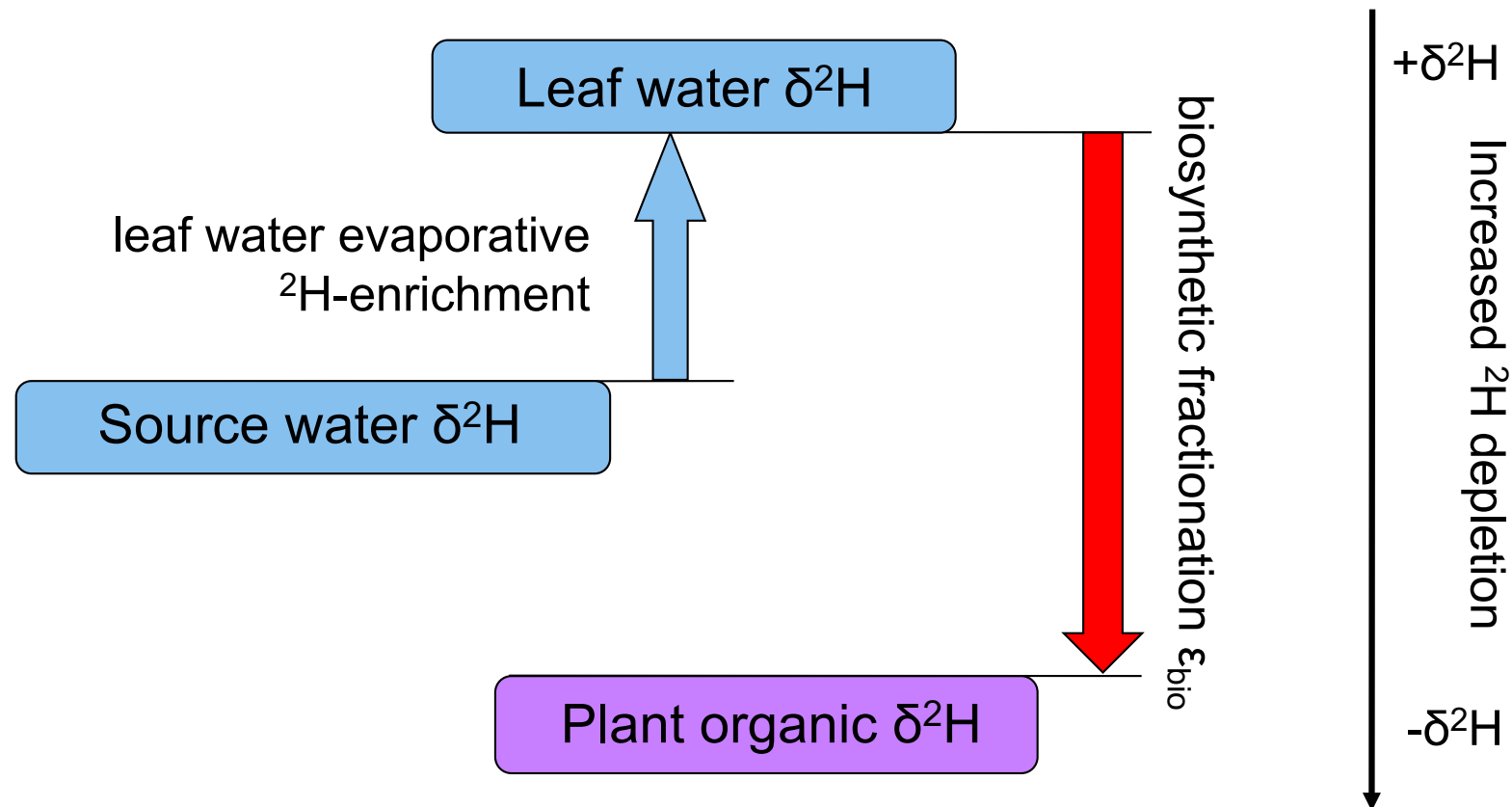δ^2H values in plant organic compounds are believed to record hydrological signals

δ²H in Leaf Wax *n*-Alkanes

n-Alkane δ²H correlate with precipitation δ²H values

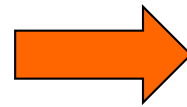# Hydrogen Isotopes (δ²H) in Plants

Biosynthetic H Fractionation in Plants

Experiments manipulating the plants C metabolism:
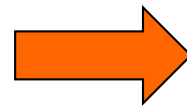
1) Manipulation of the <u>energy supply</u> (light)

2) Manipulation of the <u>substrate supply</u> (CO_2)

H_2O

Light

O_2

Light reactions

ATP   NADPH   NADP⁺   ADP + Pi

CO_2

Calvin Cycle
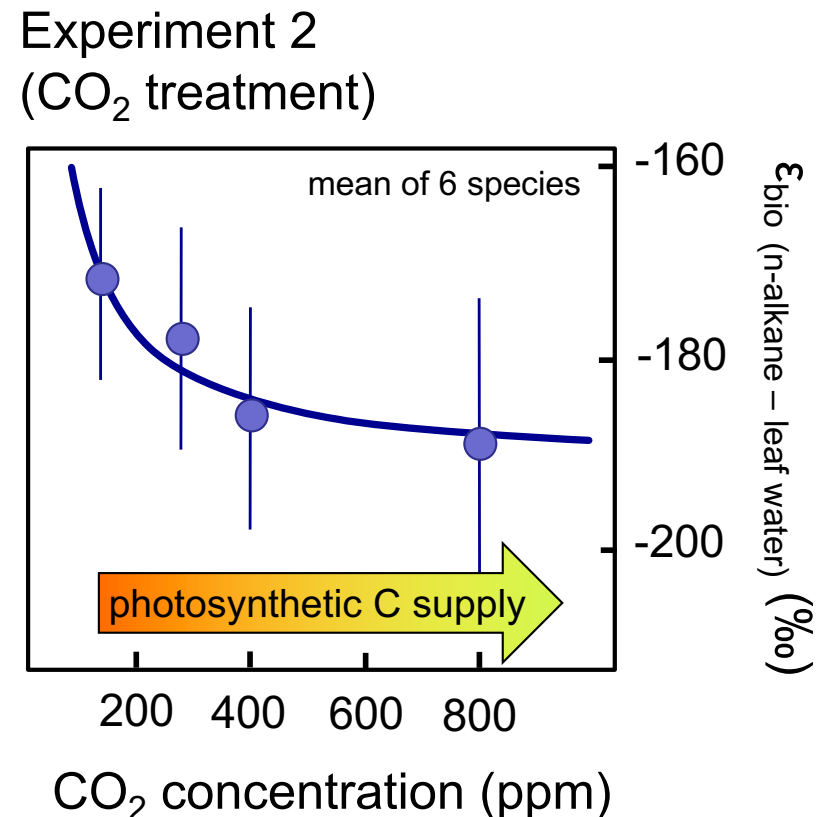
sugar

Biosynthetic H Fractionation in Plants

Strong effect of C-metabolism on plant δ^2H values
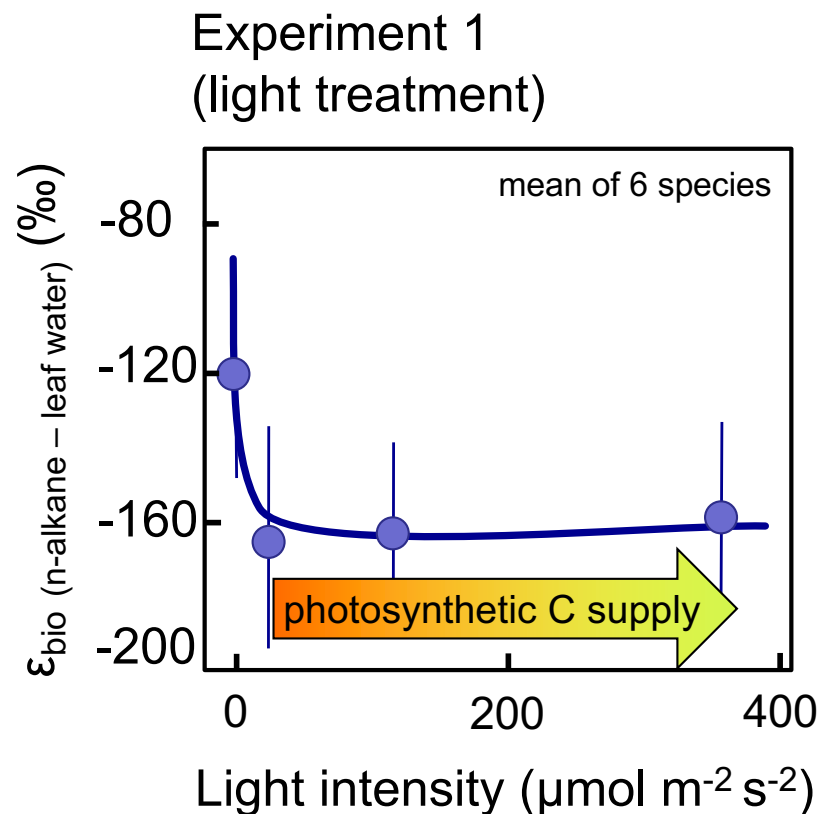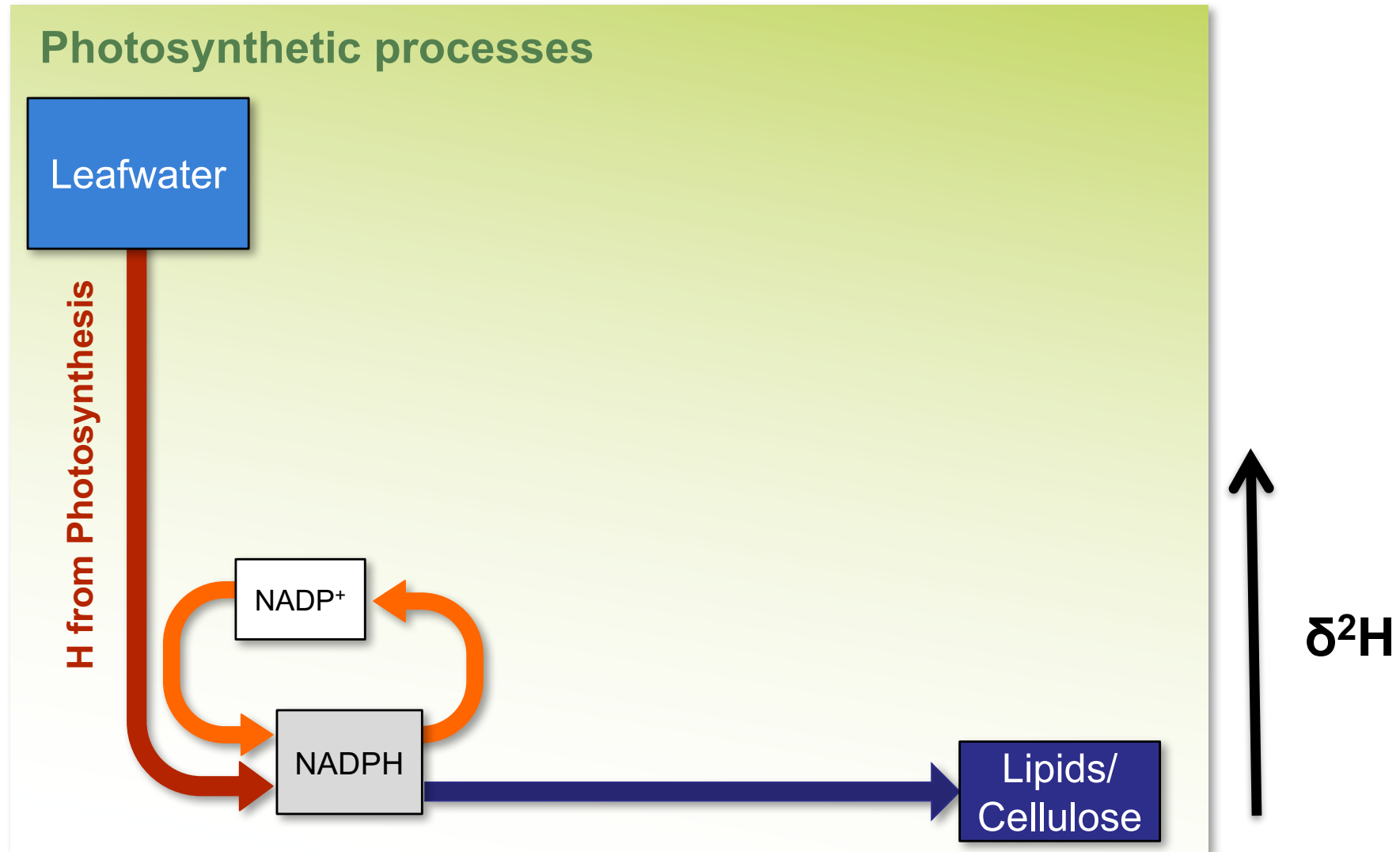
Experiment 1 (light treatment) — mean of 6 species. ε_{bio} (n-alkane – leaf water) (‰) vs Light intensity (µmol m^{-2} s^{-2}). photosynthetic C supply

Experiment 2 (CO_2 treatment) — mean of 6 species. ε_{bio} (n-alkane – leaf water) (‰) vs CO_2 concentration (ppm). photosynthetic C supply

Cormier et al. in review, *New Phytologist*

Biosynthetic H Fractionation in Plants

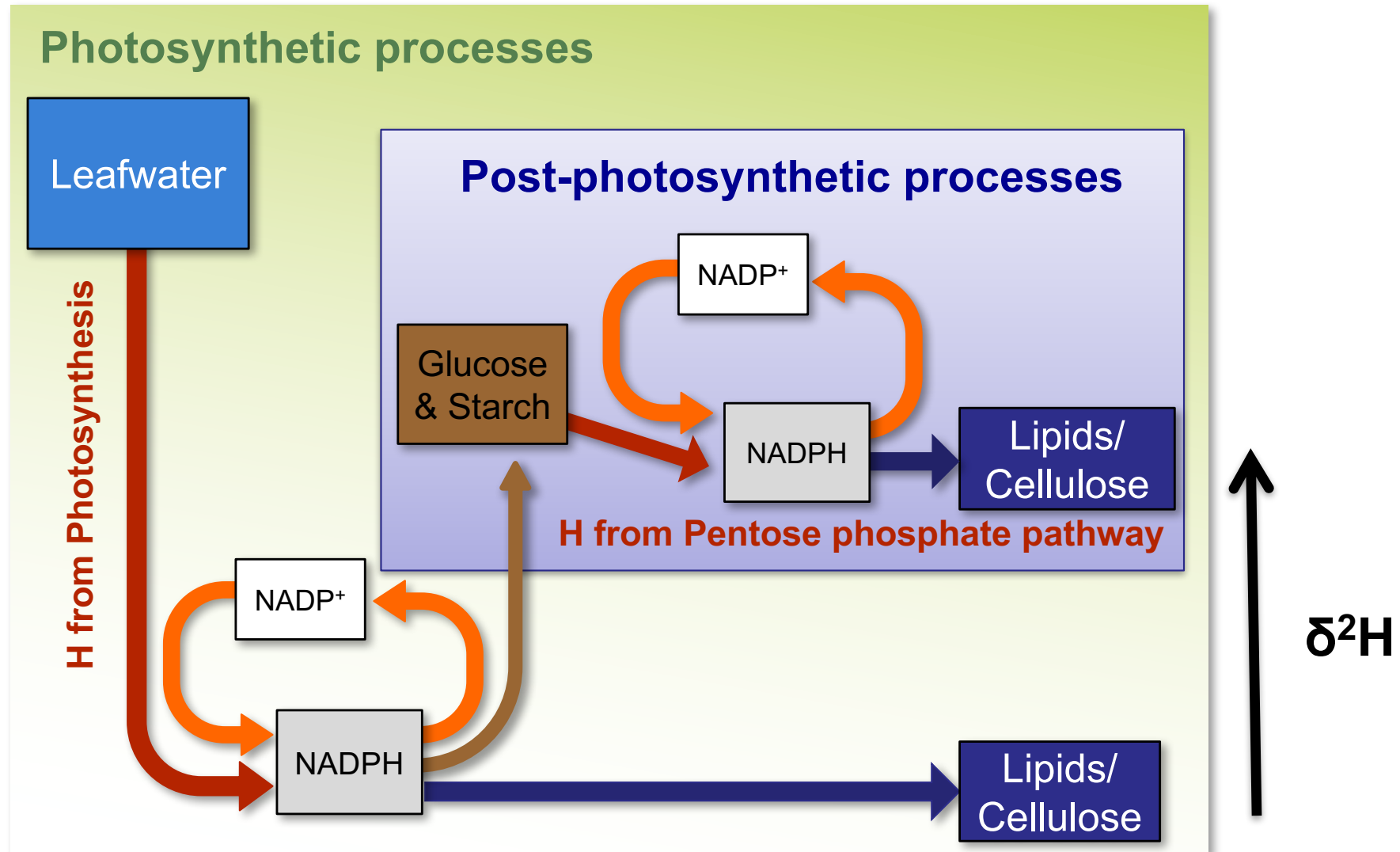Cormier et al. in review, *New Phytologist*

Biosynthetic H Fractionation in Plants
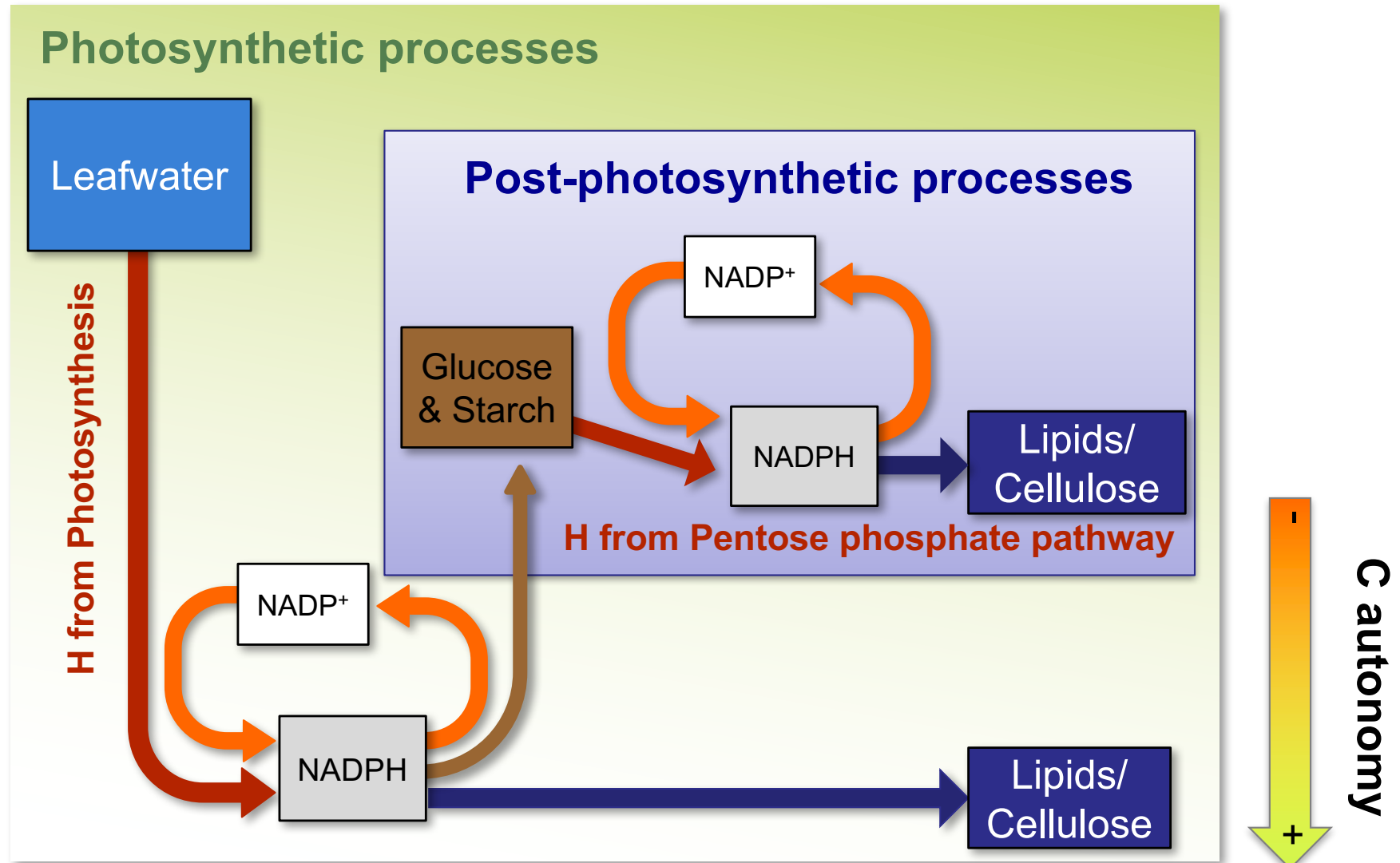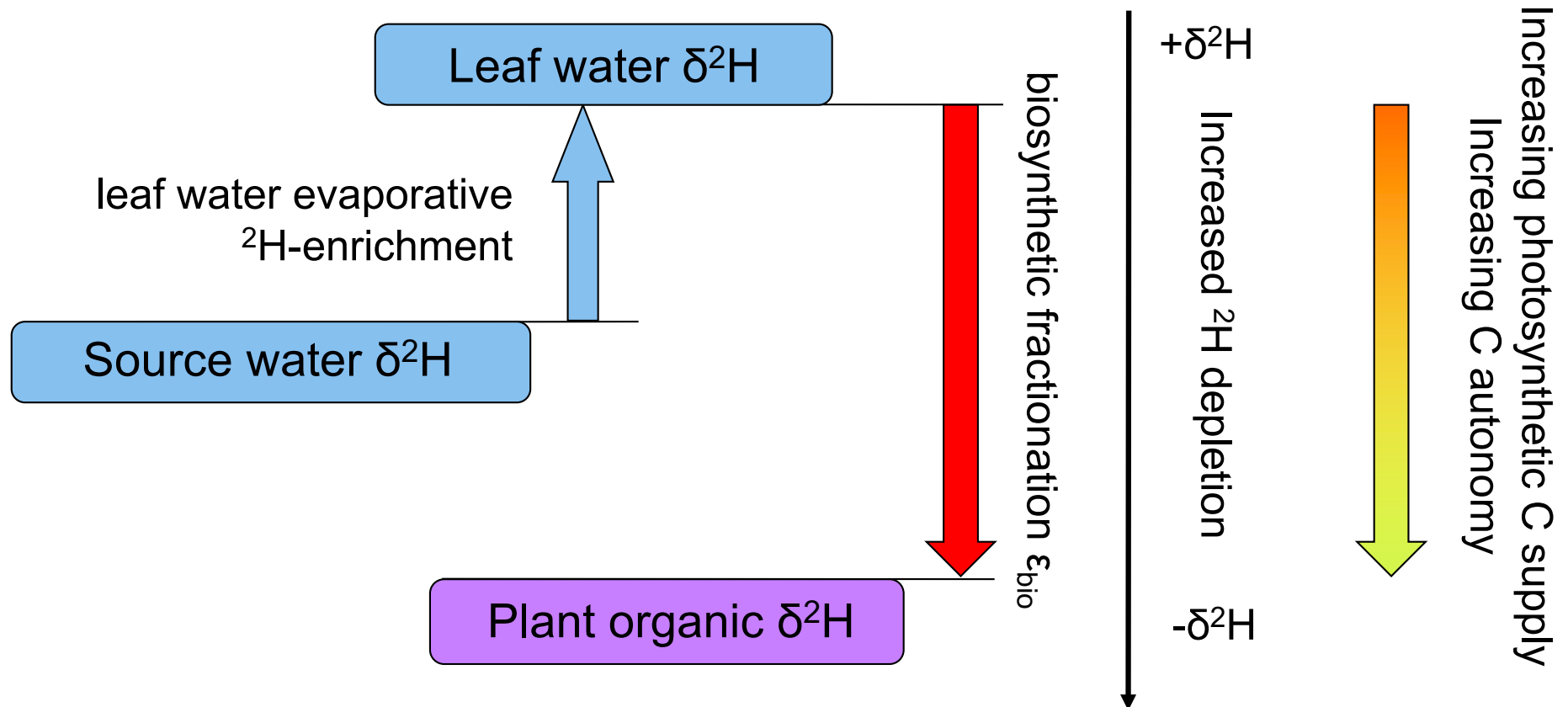

Cormier et al. in review, *New Phytologist*

Biosynthetic H Fractionation in Plants

Cormier et al. in review, *New Phytologist*

Biosynthetic H Fractionation in Plants

δ²H as Proxy for C Metabolism

Carbon transfer **between** plants

→ e.g. autotrophic and heterotrophic plants
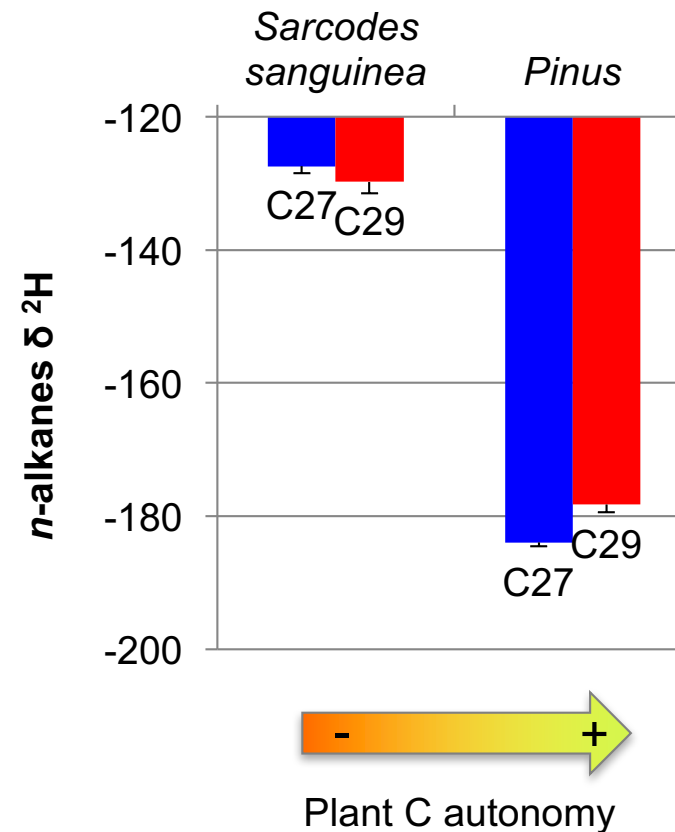
Sarcodes sanguinea (Ericaceae)

Orobanche hederae (Scroph.)

δ^{2}H as Proxy for C Metabolism

Carbon transfer **between** plants

→ e.g. tissue formation in autotrophic and heterotrophic plants
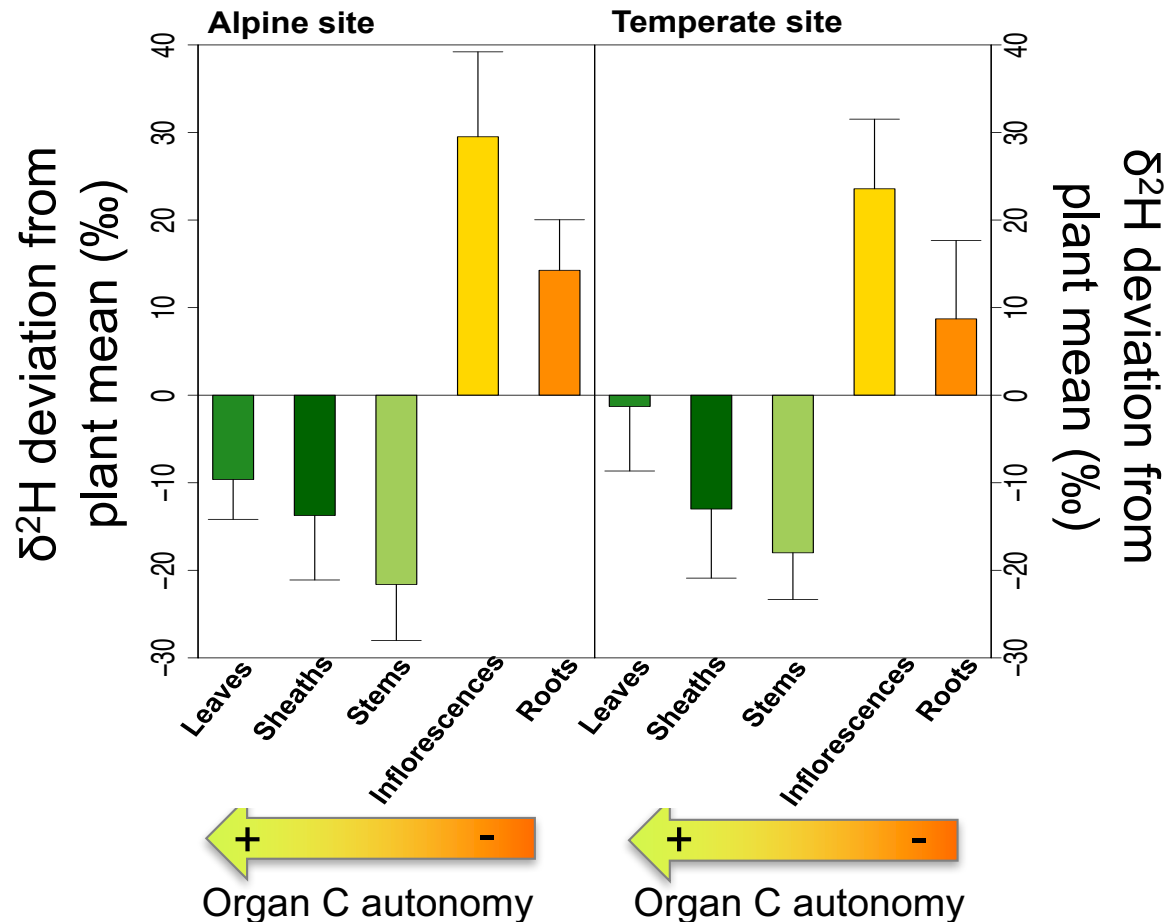

Cormier & Kahmen, in prep

δ²H as Proxy for C Metabolism in Plants

Carbon transfer **within** a plant

→ e.g. tissue formation of C autonomous vs. non-C autonomous plant organs

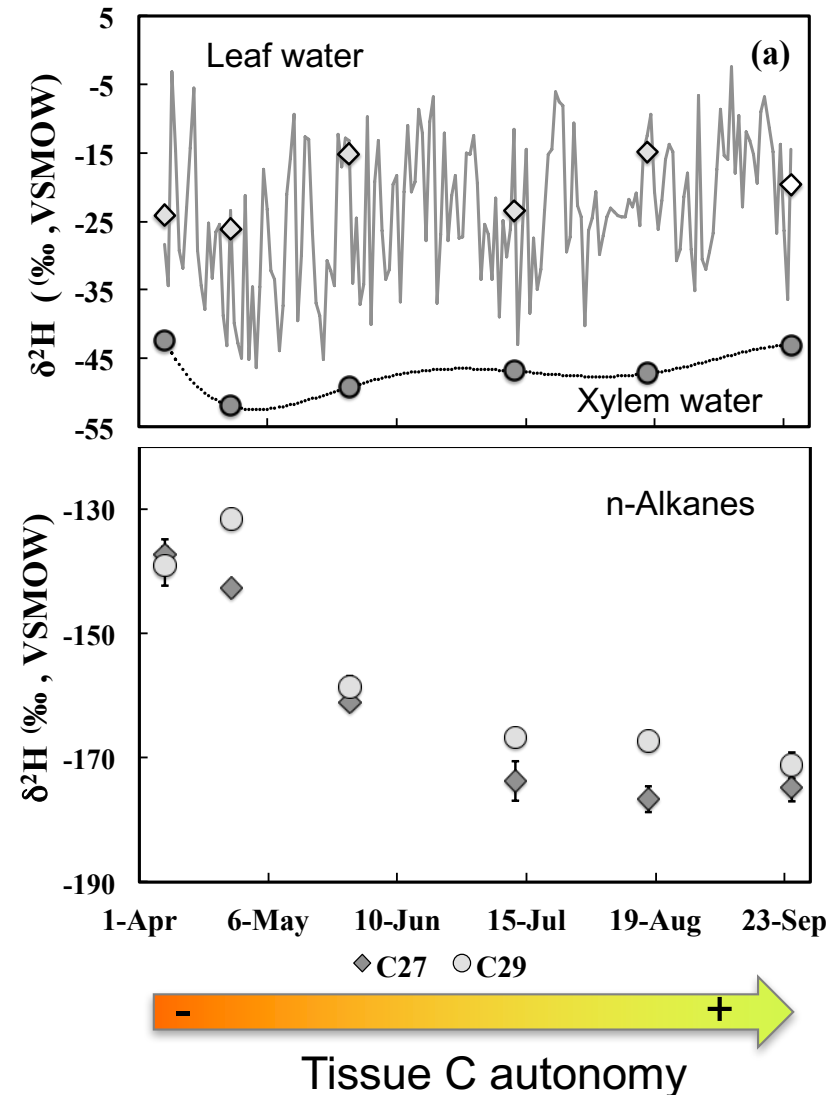
Gamarra & Kahmen 2015, *Oecologia*

δ²H as Proxy for C Metabolism in Plants

Carbon use **within** a tissue

→ e.g. seasonal variability of C used for cuticle formation

Salix sp.

Newberry at al. 2015, *GCA*

Stable Isotopes in Biological Archives

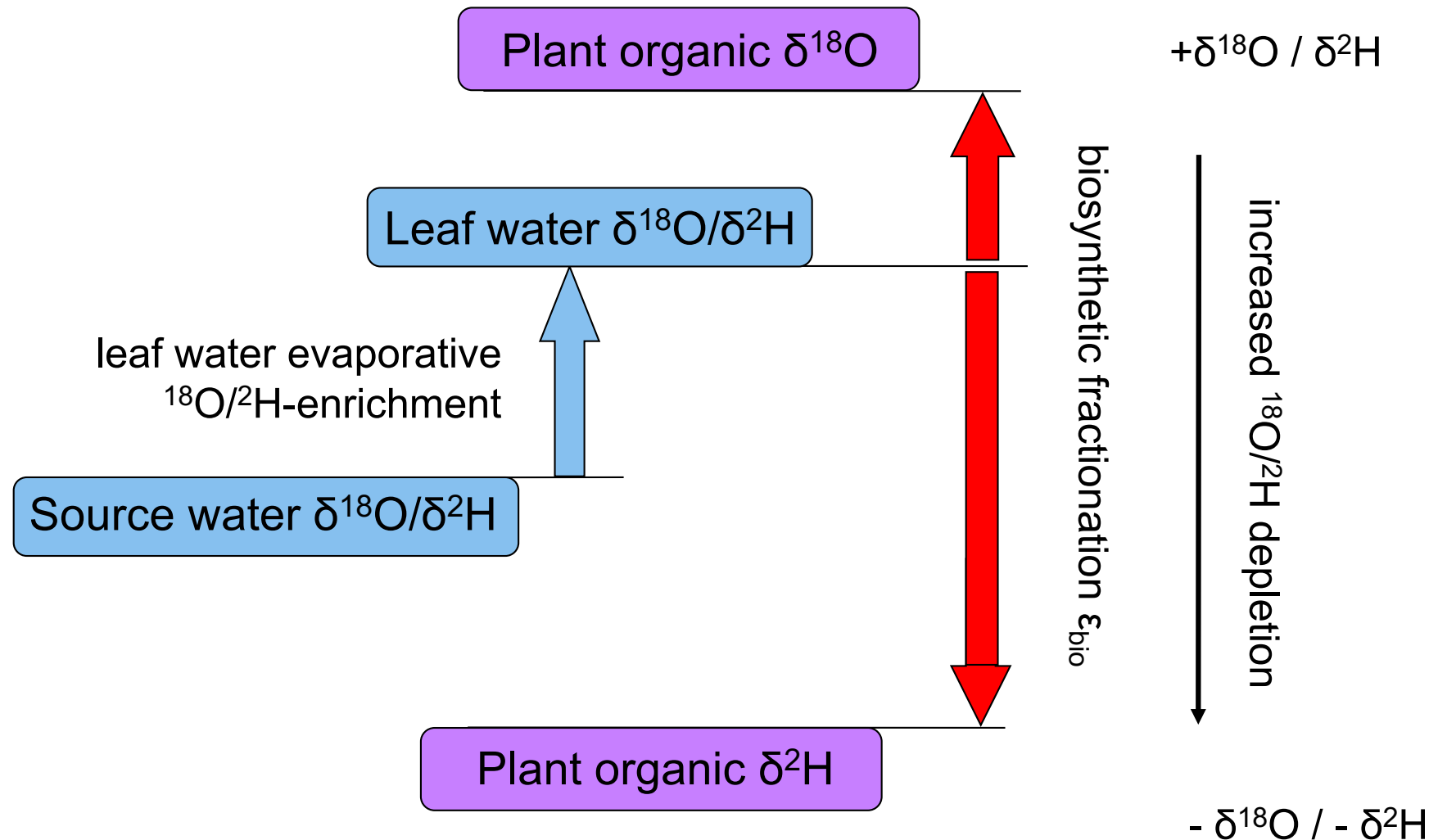## Can δ^2H inform on long-term shifts in C metabolism?

→ Oldest ecological experiment

→ Archived hay samples from 1860 – 2013

Hydrogen Isotopes (δ^2H)

How gets the precipitation δ^2H signal into the wax?

Plant organic δ^{18}O

$+\delta^{18}$O / δ^2H

Leaf water δ^{18}O/δ^2H

leaf water evaporative ^{18}O/^{2}H-enrichment

Source water δ^{18}O/δ^2H

biosynthetic fractionation ε_{bio}

increased ^{18}O/^{2}H depletion

Plant organic δ^2H

$- \delta^{18}$O / $- \delta^2$H

Stable Isotopes in Biological Archives

Hydrogen isotopes indicate metabolic changes in plants over the past century

Leaf waxes and cellulose from Rothamsted, UK

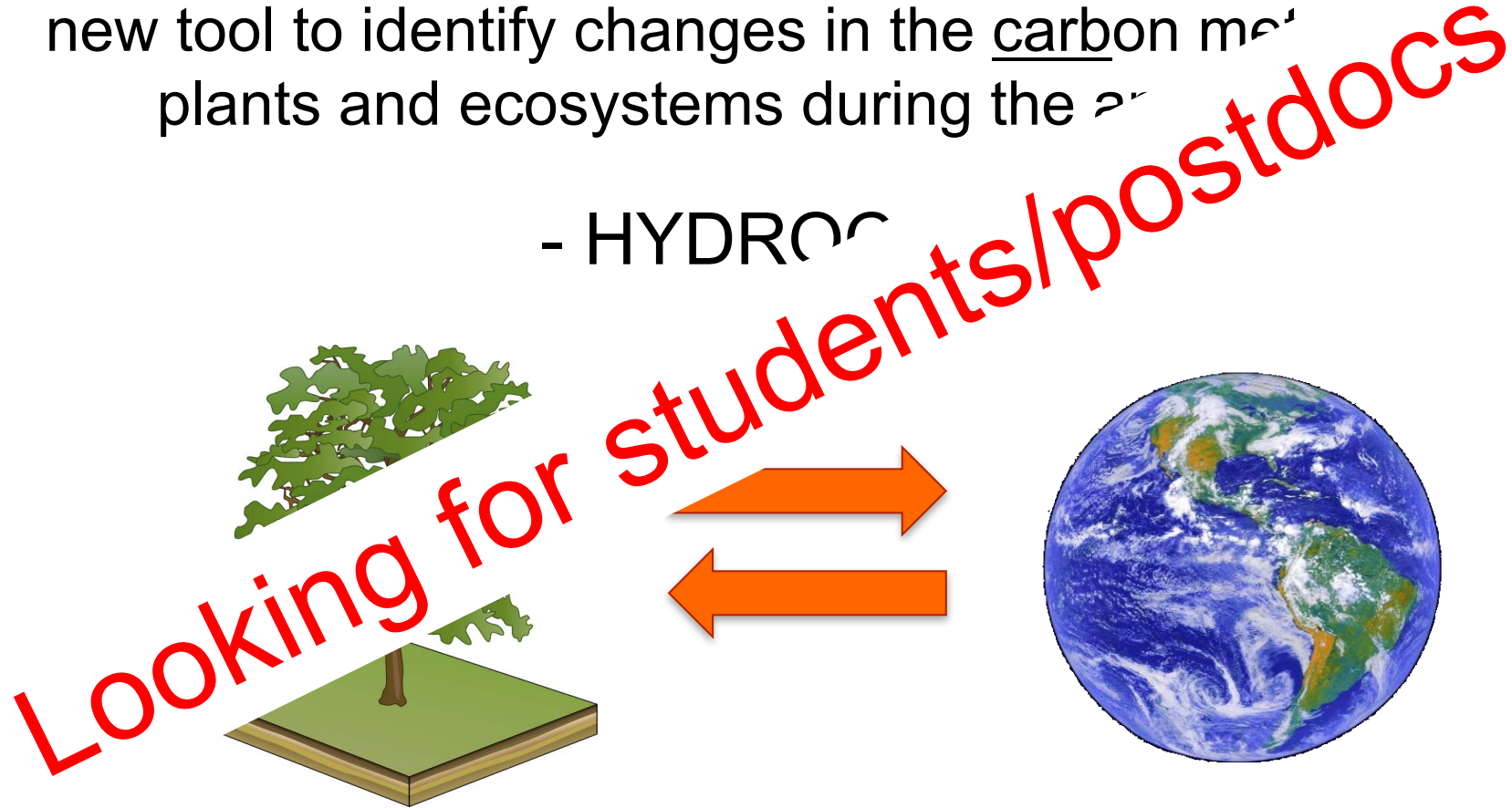Increasing photosynthetic C supply
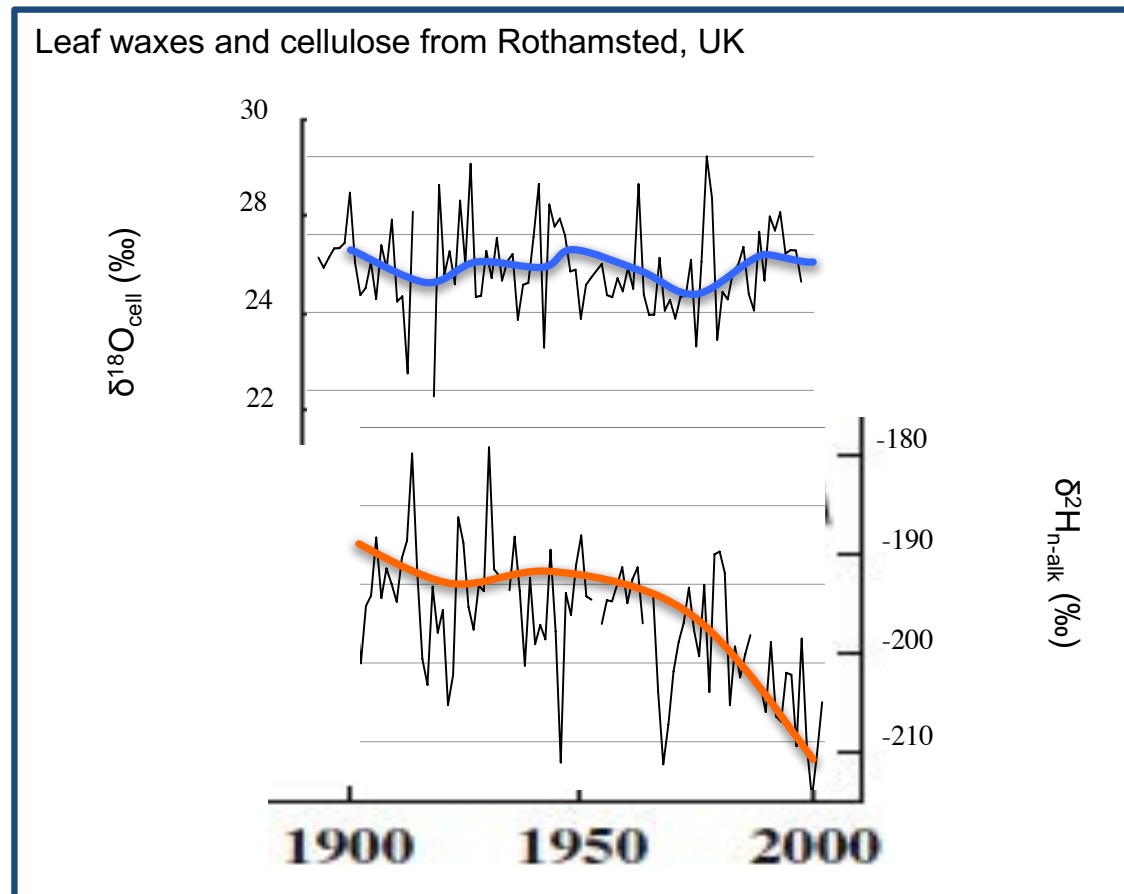
Cormier & Kahmen, *in prep*

Plants in a Changing Environment

Hydrogen isotopes in plant-derived organic compounds as new tool to identify changes in the carbon metabolism of plants and ecosystems during the anthropocene

- HYDROG

Looking for students/postdocs
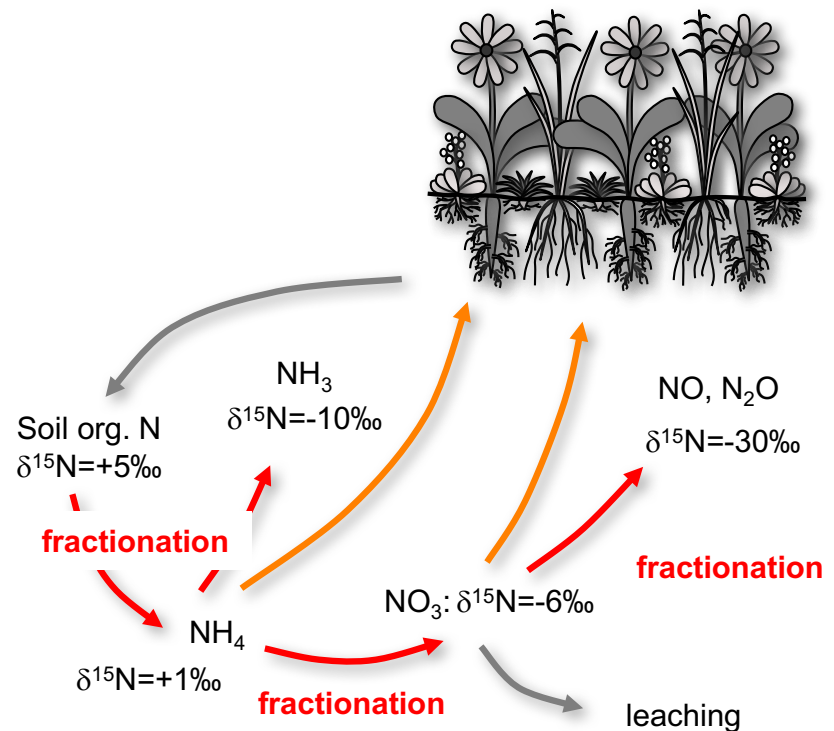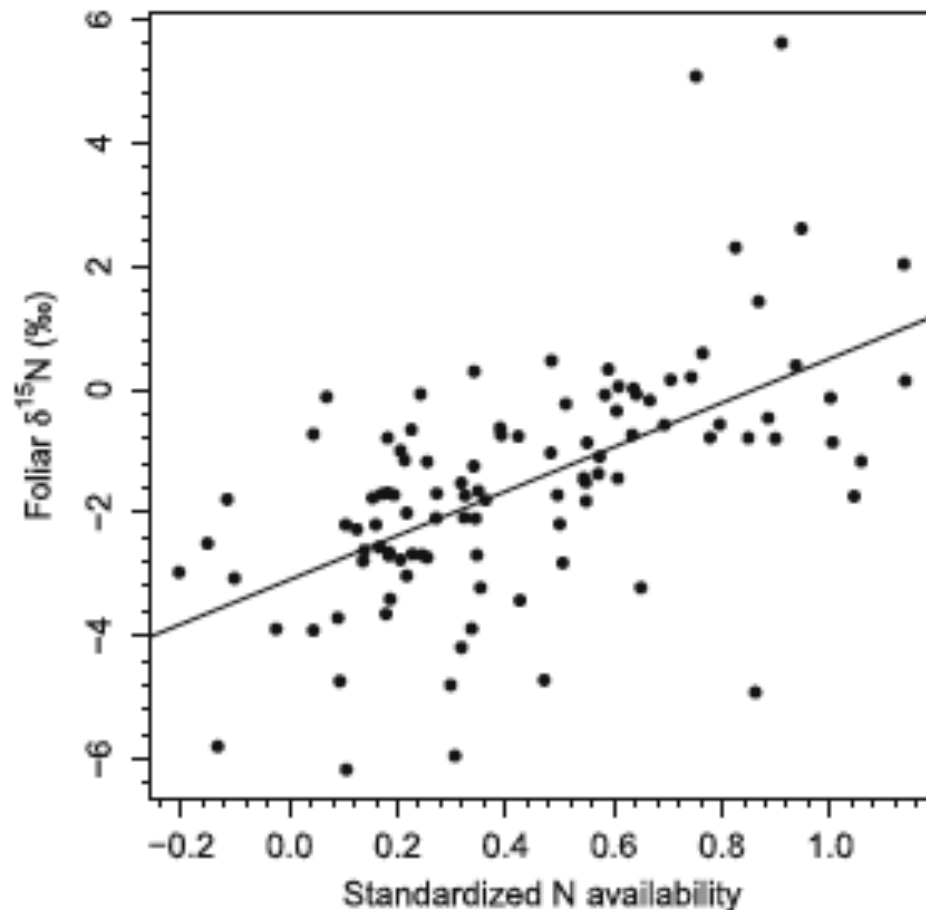
Prof. Ansgar Kahmen
University of Basel, Switzerland

Do foliar δ^{15}N values indicate a tighter nitrogen cycle in the 21st century?

Ansgar Kahmen & Cristina Moreno-Gutiérrez

Department of Environmental Sciences – Botany, University of Basel.

Foliar δ¹⁵N Values …

## ... reflect inorganic N availability in the soil.

Kahmen et al. 2008, Oecologia; Craine et al. 2015, *Plant and Soil*

Nutrient limitation of the C cycle

## Responses of trees to elevated CO_2

→ The effects of elevated CO_2 on forest growth decline and disappear over time in all experiments that have been done across the globe.

→ Other drivers than CO_2, in particular nutrients, limit the growth of forests.
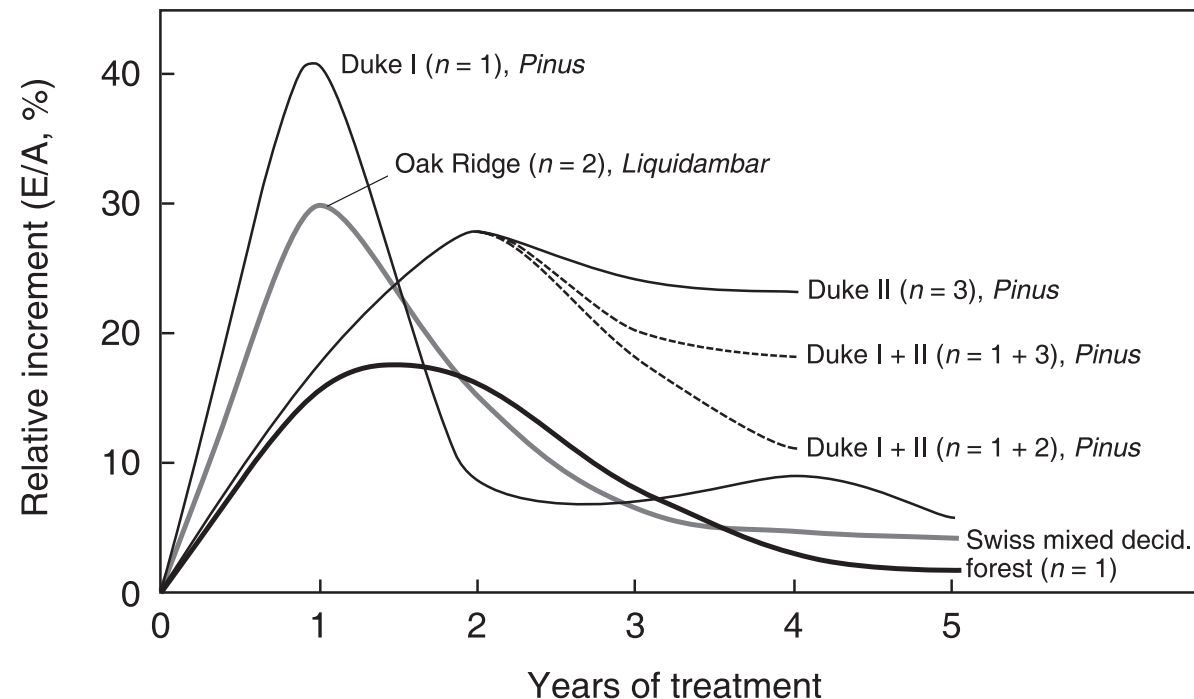
Körner et al. 2005, *New Phytologist*
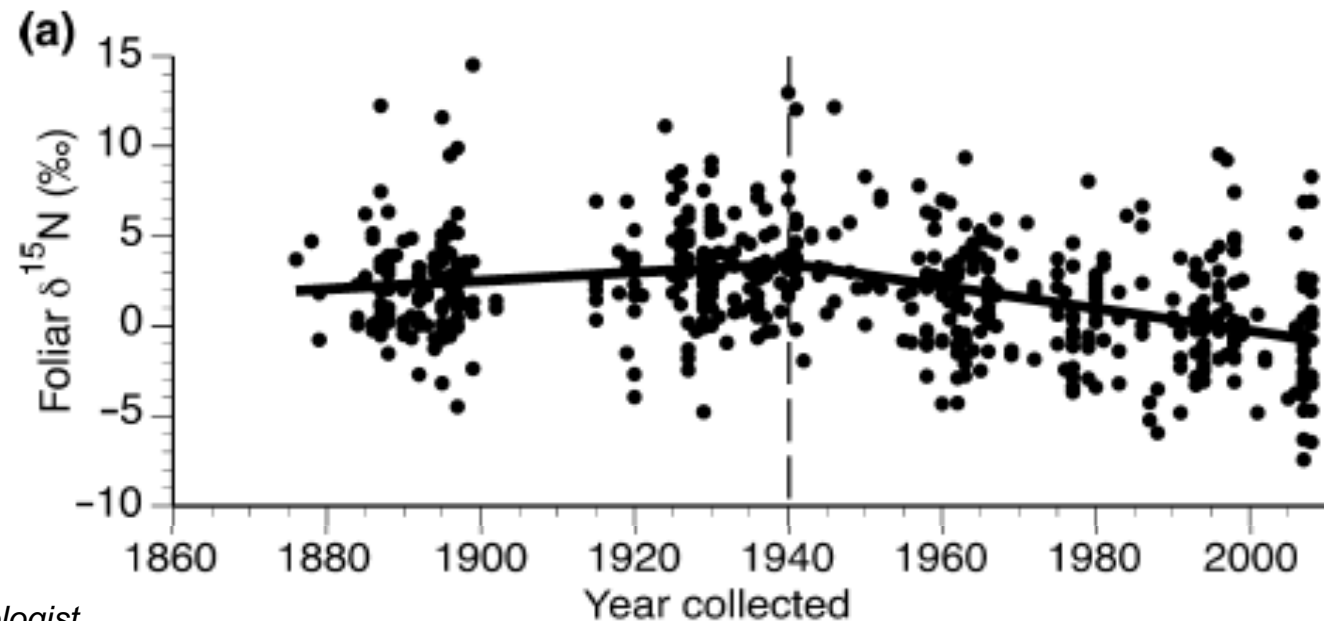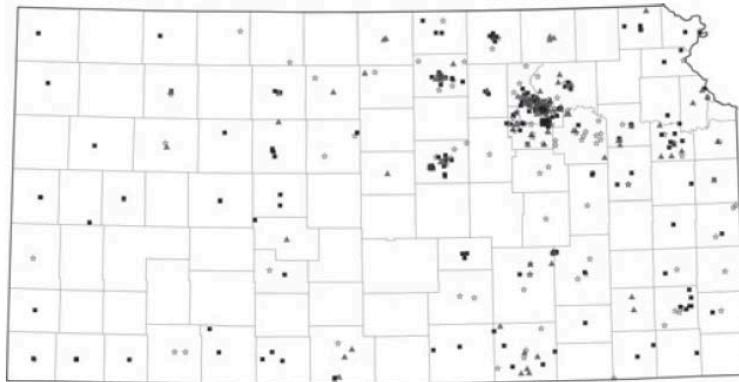
Nutrient limitation of the C cycle

Foliar δ^{15}N values suggest declining N availability under FACE

Open bars: ambient CO_2

Closed bars: elevated CO_2
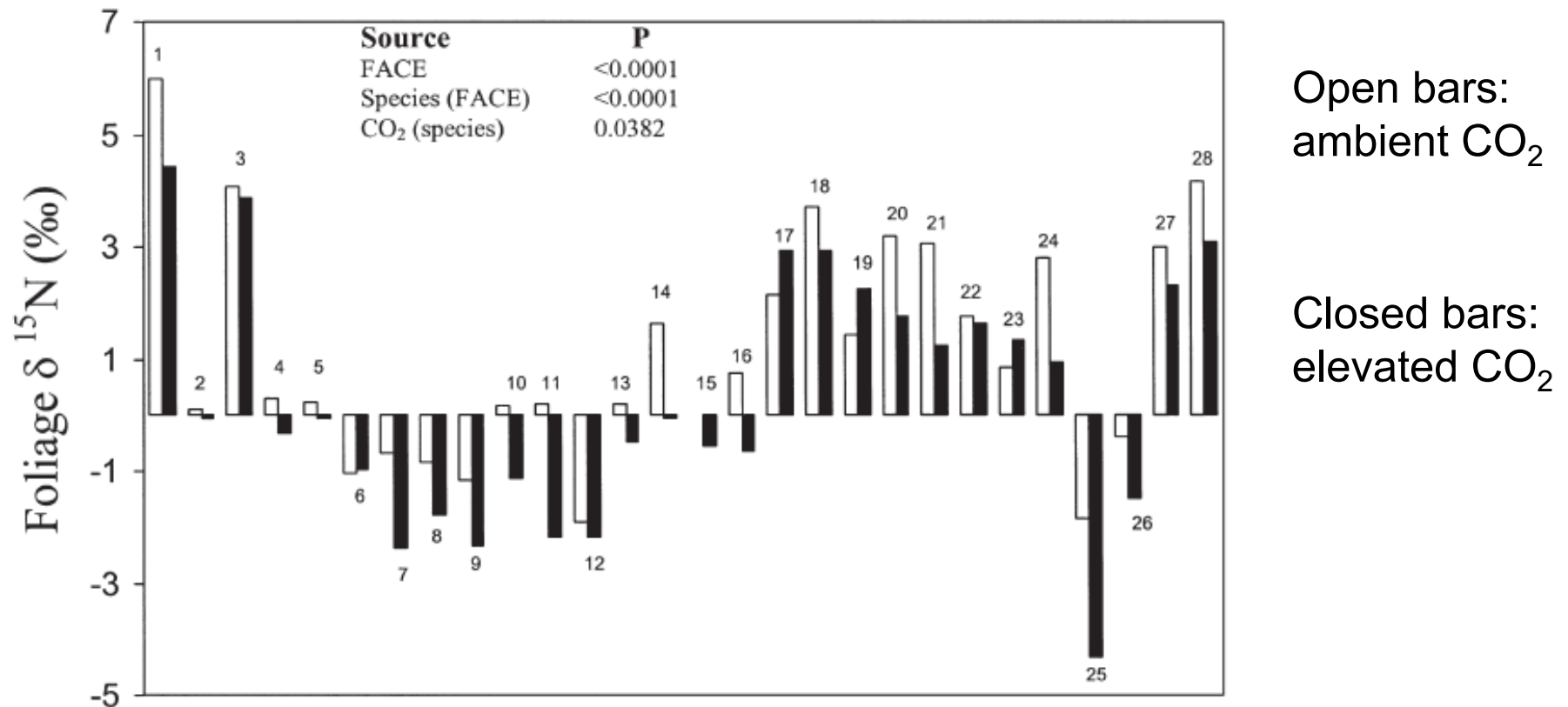
BassiriRad et al. 2003, *Global Change Biology*

Declining N availability in the 21st century?
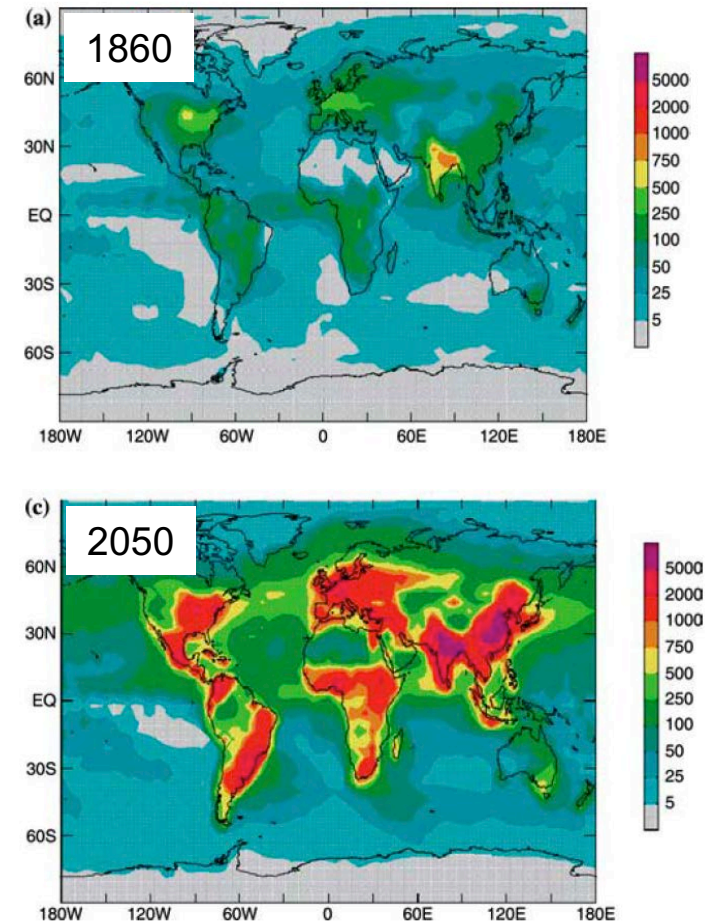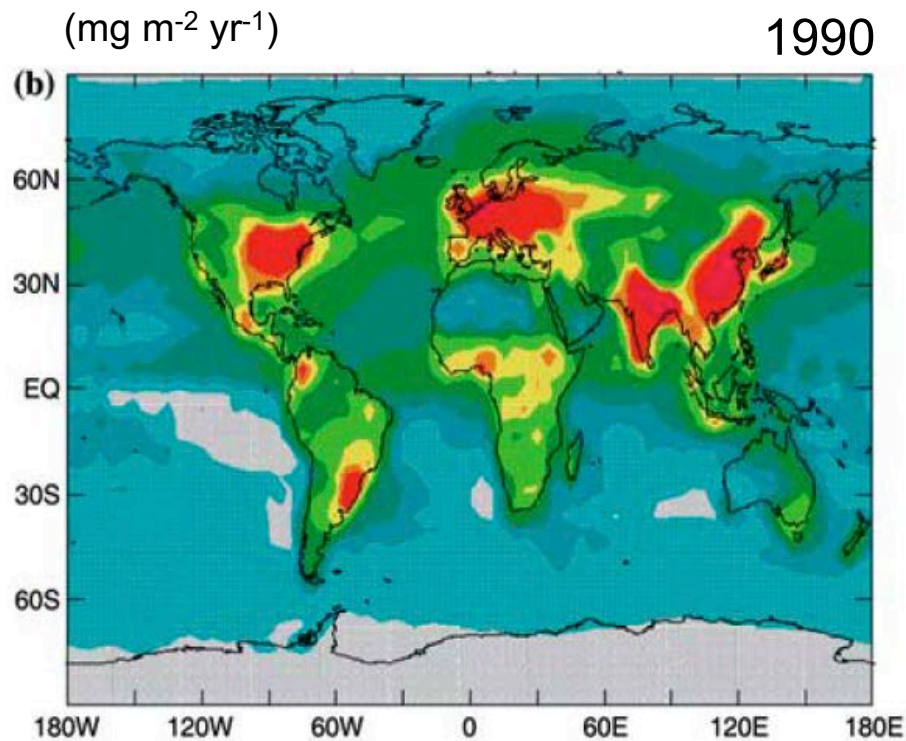
Herbarium specimen from the Kansas prairie

MacLauchlan et al. 2011, *New Phytologist*

Human footprint on the nitrogen cycle

Are we saturating terrestrial ecosystems with N?

→ global atmospheric deposition of NO_x, NH_4^+

→ up to 50 kg N/ha/yr

(mg m^{-2} yr^{-1})   1990

Galloway et al. 2004, *Biogeochemistry*
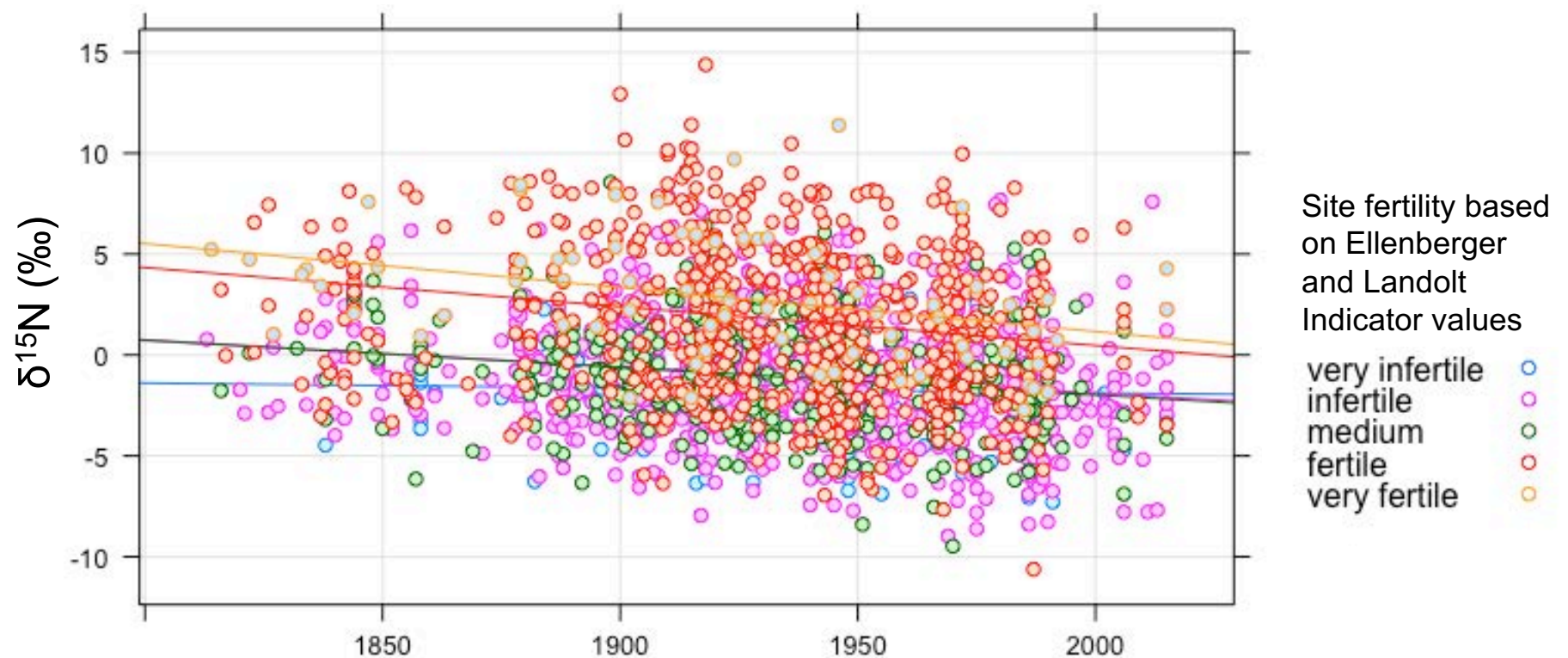
Herbaria Basel

Sampling

→ 3120 specimen

→ 74 plant species (42 forbs, 12 grasses, 10 legumes, 10 sedges)

→ From different locations and altitudes in Switzerland since year 1820

Declining N availability in the 21ˢᵗ century?

Declining foliar $\delta^{15}N$ also in European ecosystems
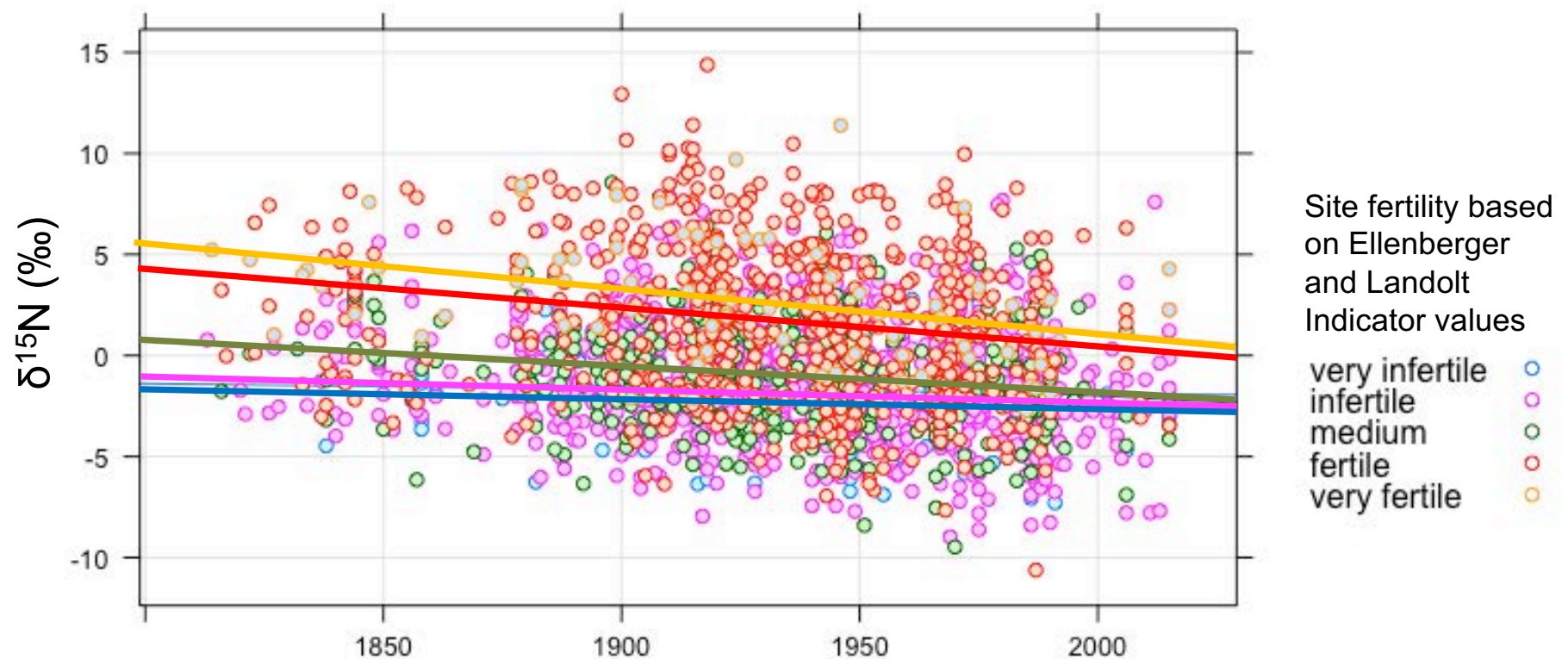

Gutierrez & Kahmen, *unpublished*

Declining N availability in the 21st century?
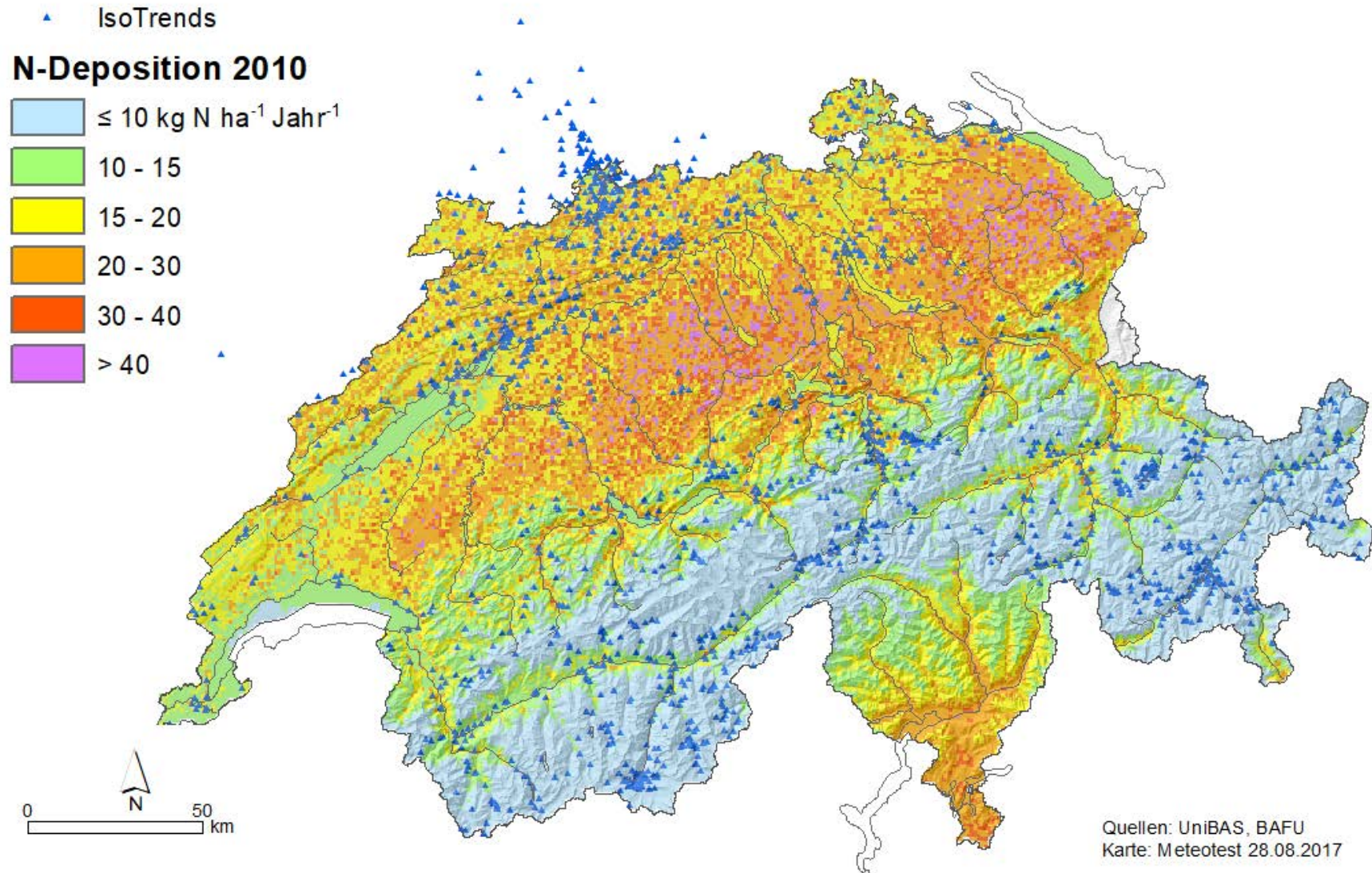
Declining foliar δ^{15}N also in European ecosystems

→ Trend is dependent on site fertility

Site fertility based on Ellenberger and Landolt Indicator values

very infertile ○
infertile ○
medium ○
fertile ○
very fertile ○

Gutierrez & Kahmen, *unpublished*

Declining N availability in the 21st century?

IsoTrends

N-Deposition 2010

≤ 10 kg N ha⁻¹ Jahr⁻¹
10 - 15
15 - 20
20 - 30
30 - 40
> 40

0   N   50 km

Quellen: UniBAS, BAFU
Karte: Meteotest 28.08.2017

Declining N availability in the 21ˢᵗ century?

Are we seeing the δ^{15}N fingerprint of deposited N?
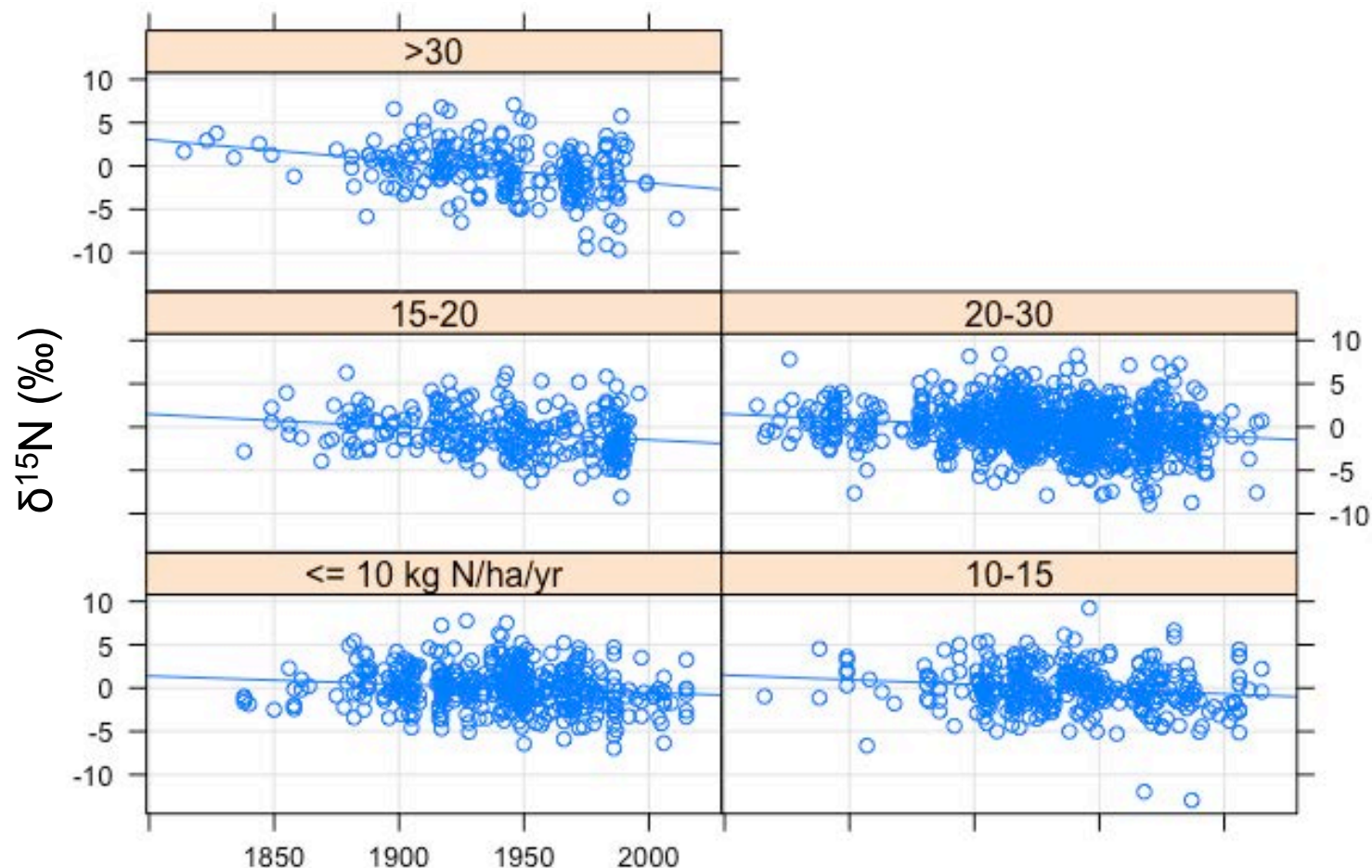
→ Reactive N in the atmosphere is ^{15}N depleted
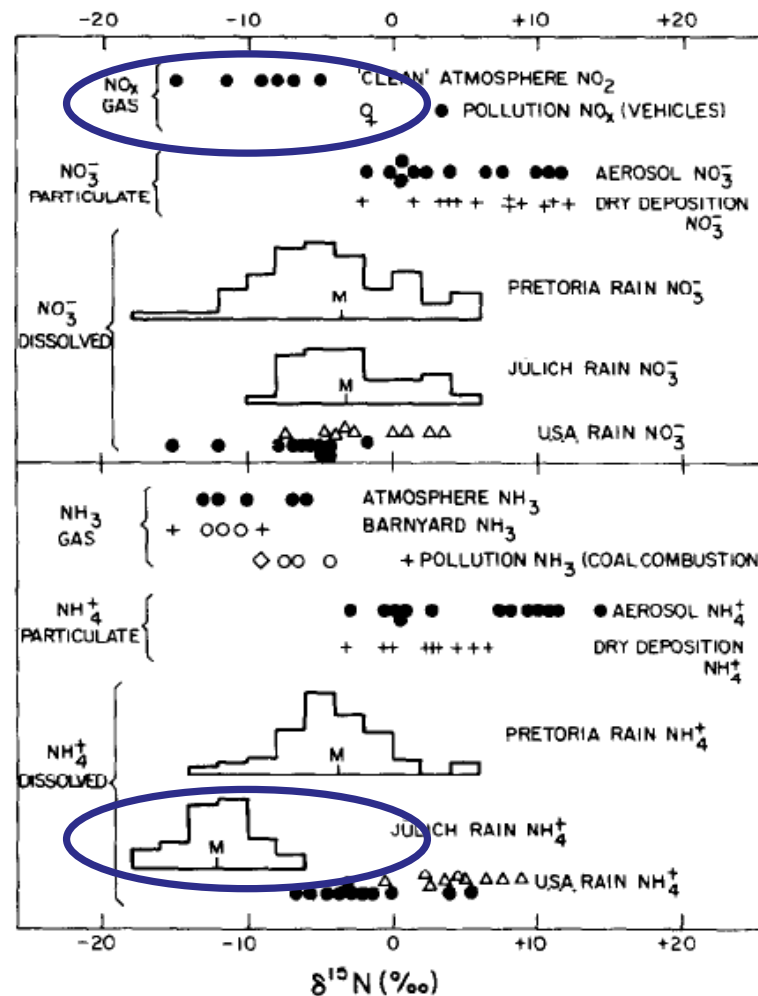
Heaton 1986, *Chemical Geology*

Declining N availability in the 21ˢᵗ century?

Are we seeing the δ¹⁵N fingerprint of deposited N?

→ …. δ¹⁵N trends are independent of N deposition rate

Gutierrez & Kahmen, *unpublished*

Thank You