Counteracting atmospheric nutrient deposition in heathland ecosystems

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Outline

1 Rationale, questions and hypotheses

2 Study area and Methods

3 Nutrient inputs: atmospheric deposition

4 Nutrient outputs: management and leaching

5 Nutrient balances

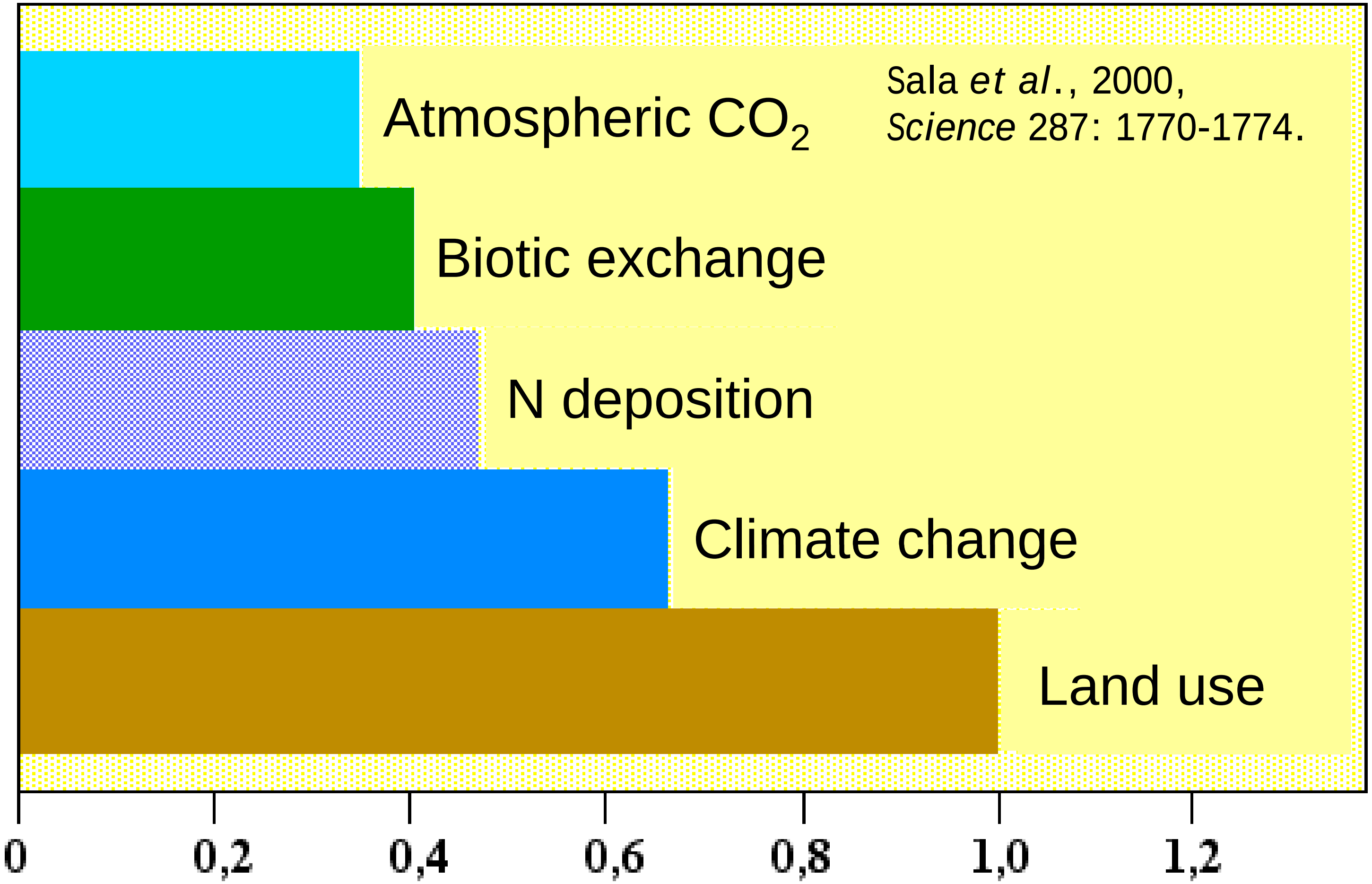
6 Long-term shifts in nutrient budgets

7 Conclusions

1. Rationale, questions and hypotheses

- One of the major threats to global biodiversity is the increase in air-borne nitrogen pollution
- N is the limiting macro-nutrient in most semi-natural and natural ecosystems
- N deposition is still increasing world wide
- Management measures have the potential to affect ecosystem responses to atmospheric N loads and may, thus, mitigate or even compensate for atmospheric nitrogen deposition.

1. Rationale, questions and hypotheses



Relative effect of major drivers of changes on biodiversity

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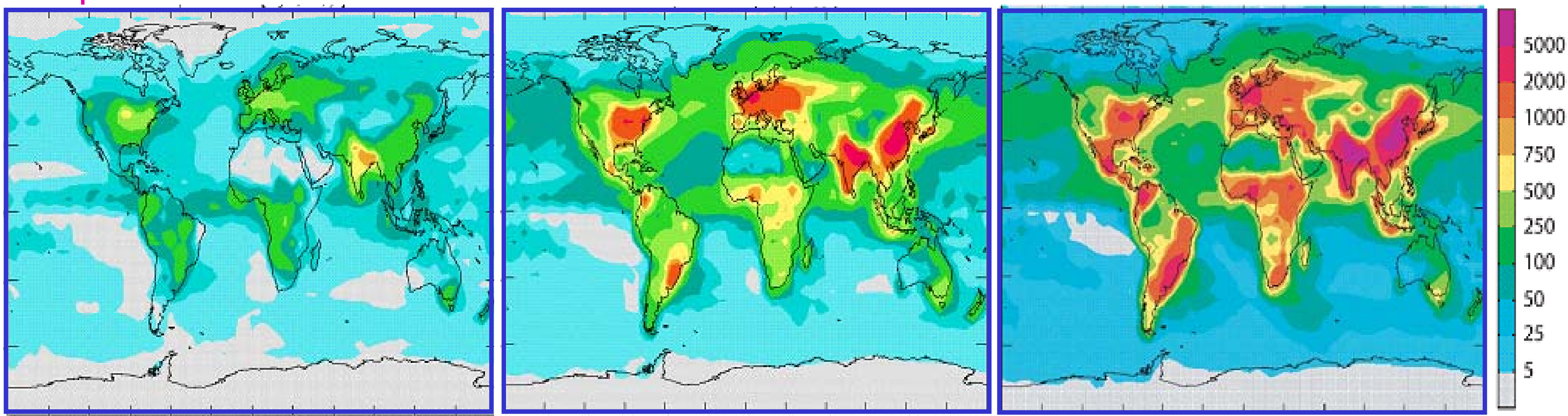
1. Rationale, questions and hypotheses

- One of the major threats to global biodiversity is the increase in air-borne nitrogen pollution
- N is the limiting macro-nutrient in most semi-natural and natural ecosystems

Galloway & Cowling 2002; **mg N m^{-2} yr^{-2}**



1860 **1993** **2050**

1. Rationale, questions and hypotheses

- One of the major threats to global biodiversity is the increase in air-borne nitrogen pollution
- N is the limiting macro-nutrient in most semi-natural and natural ecosystems
- N deposition is still increasing worldwide
- Management measures have the potential to affect ecosystem responses to atmospheric N loads and may, thus, mitigate or even compensate for atmospheric nitrogen deposition.

1. Rationale, questions and hypotheses

a) Can management (mowing, prescribed burning, grazing, sod-cutting) compensate for atmospheric N loads?

b) What is the fate of air-borne N in heathlands?

c) What are the possible long-term effects of shifts in N and P budgets? Is there a shift from N to P limitation?

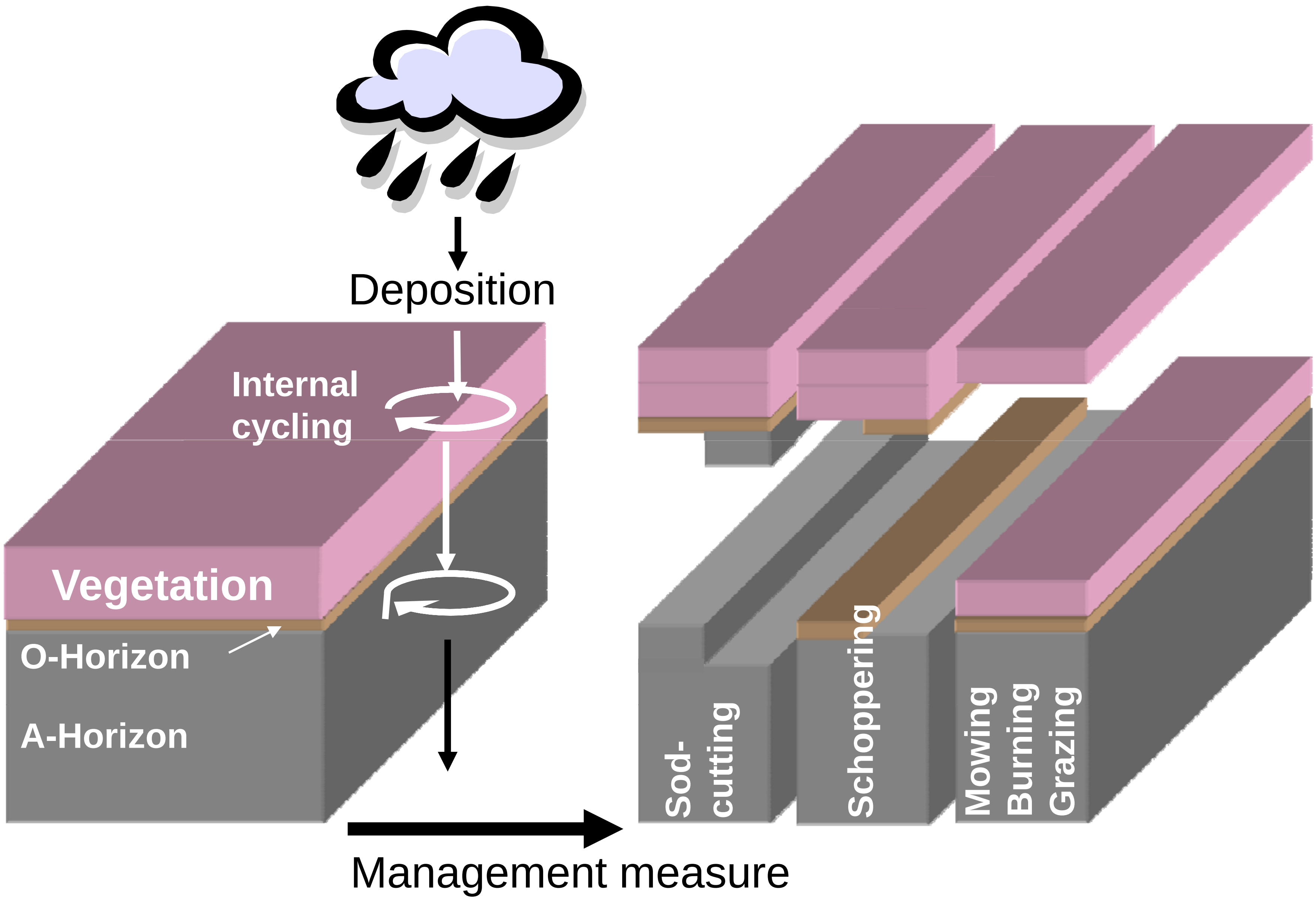
Lowland heaths:
Management systems, low-nutrient environments, limited by N (or N-P-co-limitation)

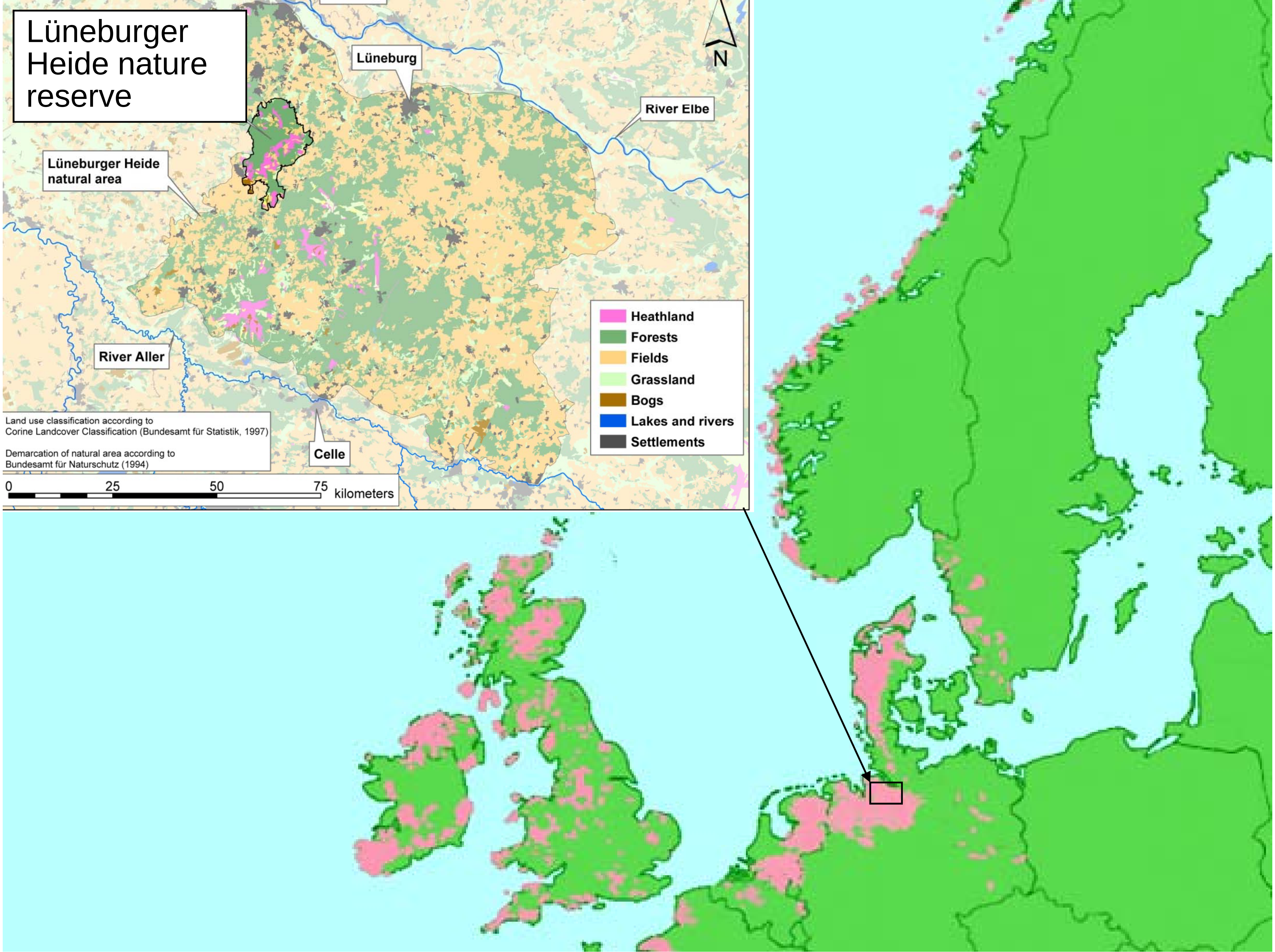

Heathland types:
- Lowland heaths (Lüneburger Heide)
- Coastel heaths
- Montane heathland
- Wet heaths (moorlands)


Mowing
Prescribed (winter) burning
Sod-cutting/ schoppering
Grazing

2. Study area and Methods

Comparision of high- and low-intensity measures



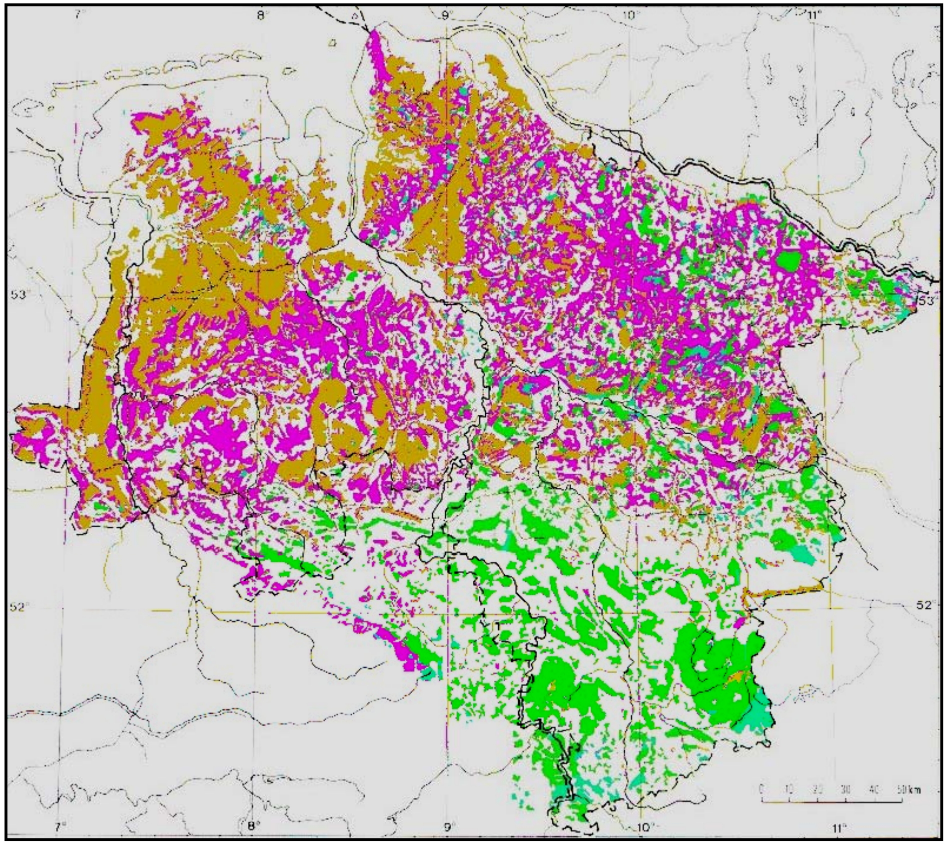


Lüneburger Heide nature reserve
Lüneburg
N
River Elbe
Lüneburger Heide natural area
River Aller
Celle
Heathland
Forests
Fields
Grassland
Bogs
Lakes and rivers
Settlements
Land use classification according to Corine Landcover Classification (Bundesamt für Statistik, 1997)
Demarcation of natural area according to Bundesamt für Naturschutz (1994)
0 25 50 75 kilometers

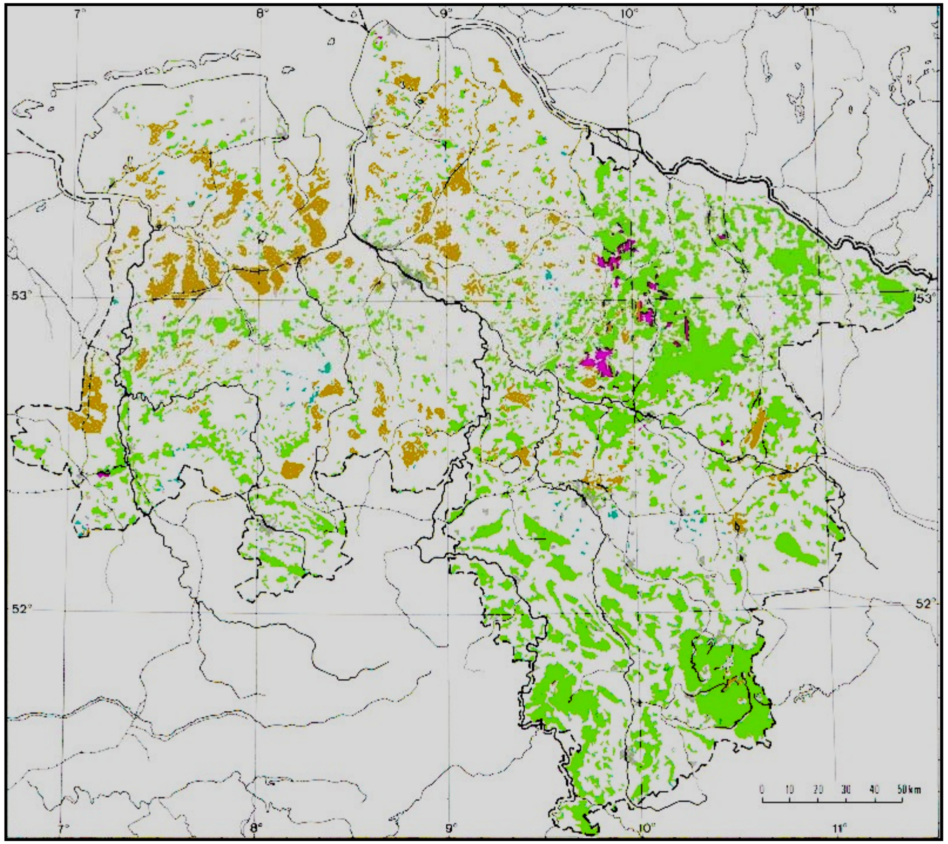
2. Study area and Methods

Decrease of heathland area in Lower Saxony

1800



1980



(from Heckenroth 1985)

2. Methods

- Atm. deposition — Bulk-sampler (n=12)
- Leaching — Lysimeter and Suction cups (n=4/2)
- Biomass — Harvest (1m x 1m sample plots ; n=4)
- Soil — Mixed samples (20m x 20m sample plots; n=4)
- Balance — Input rates vs. outputs rates

Elementar EA and masspectrometer

- N allocation,
  Fate of N
- Leaching
- 15N analysis

$^{15}NO_3$ $^{15}NH_4$ application

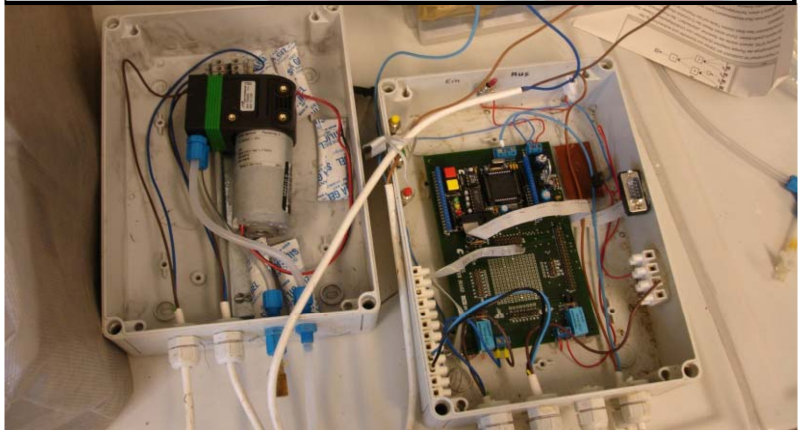
Lysimeter,

50 cm in diameter

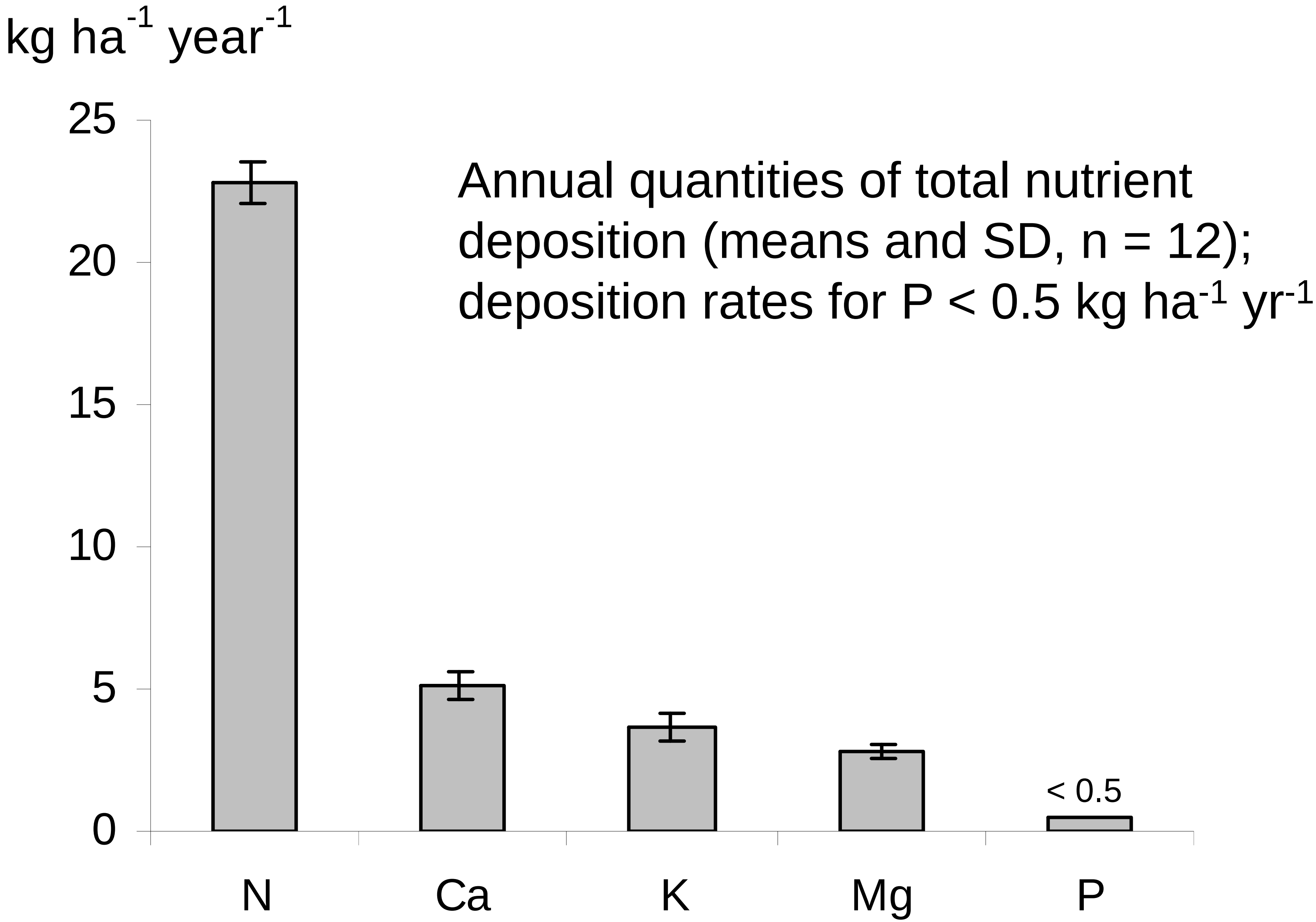
EA and MS

Elementar/

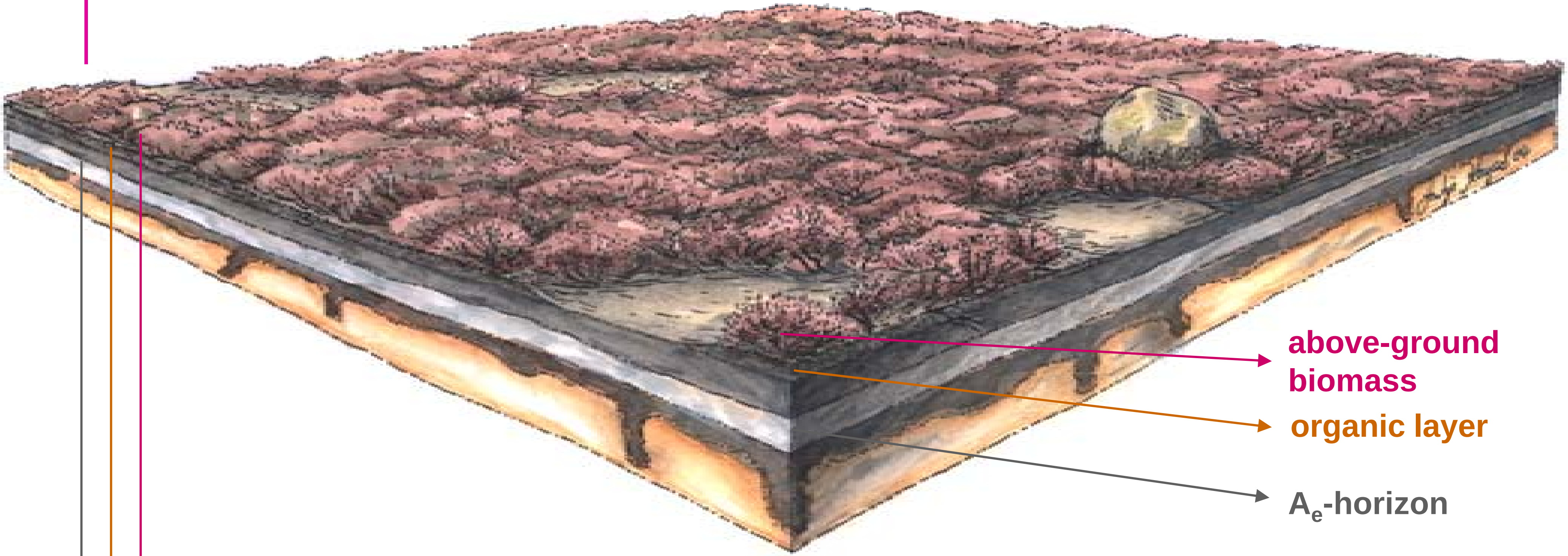
Isoprime



3. Atmospheric nutrient loads



4. Nutrient stores (biomass and soil)



	weight (tons ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
biomass (SD) (n = 26)	11.5 – 19.0	179.3 (20.1)	11.6 (2.1)	51.3 (12.2)
organic layer (SD) (n = 12)	7.8	937.5 (93.8)	31.4 (4.1)	41.3 (4.0)
A-horizon (SD) (n = 8)	1404	1481.0 (217.8)	99.0 (8.6)	330.4 (57.7)

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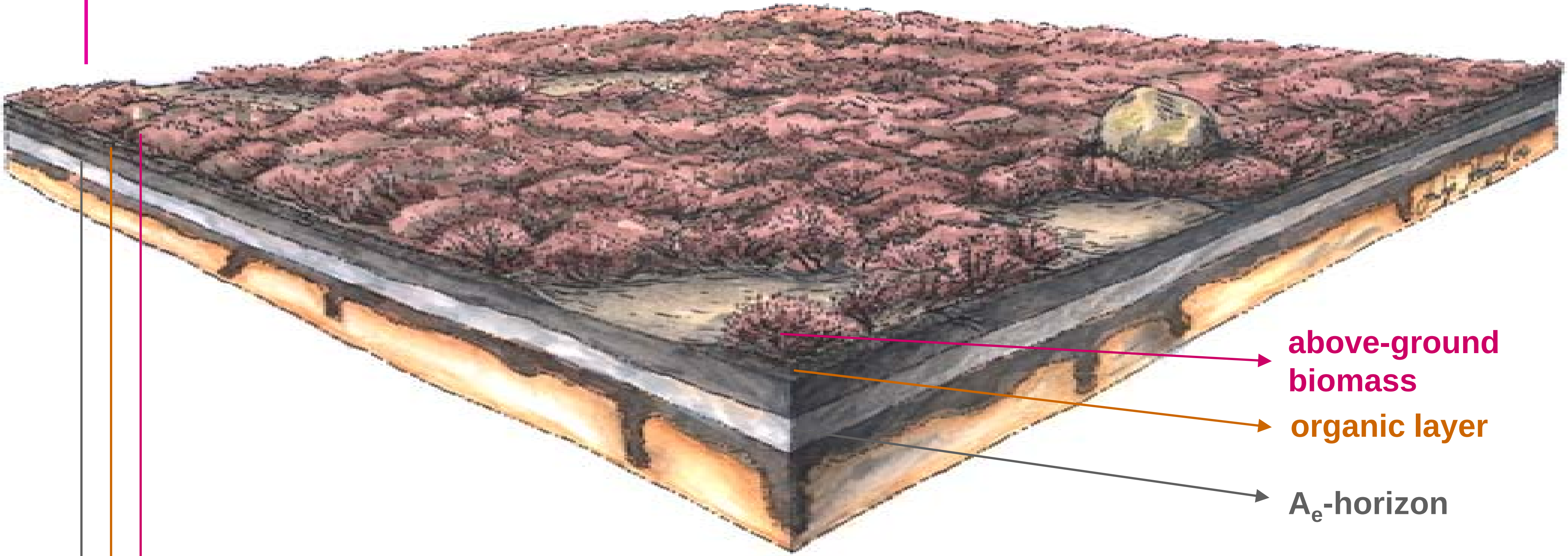

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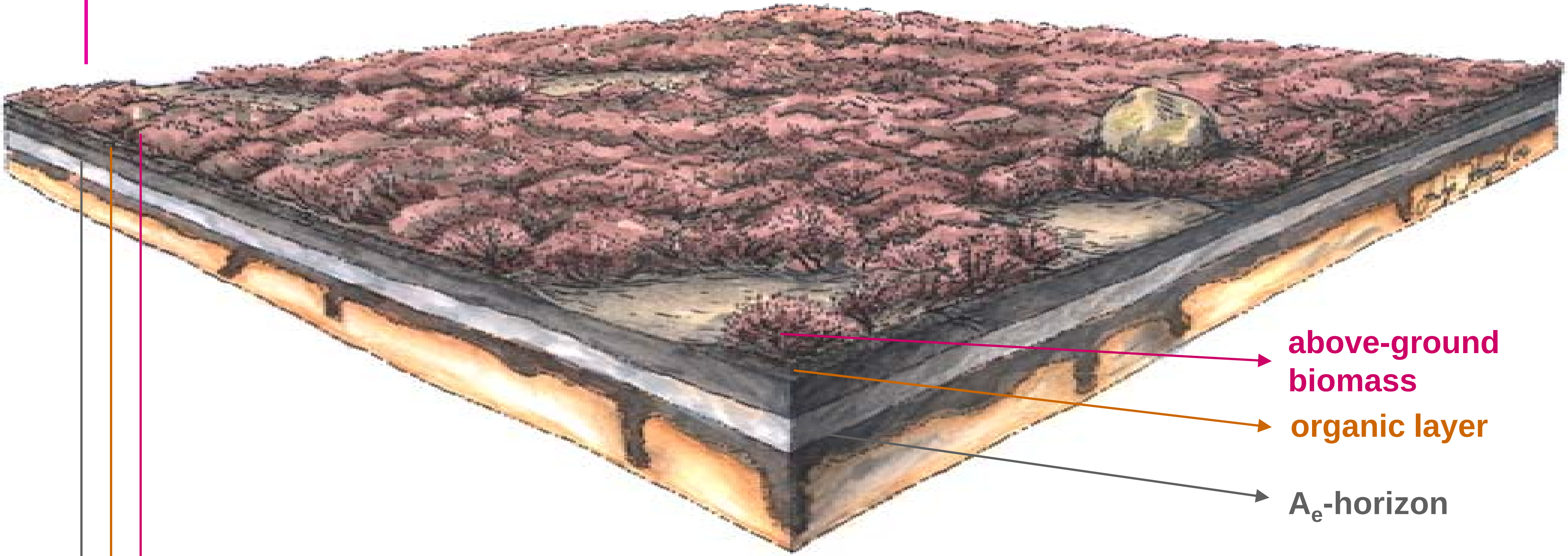

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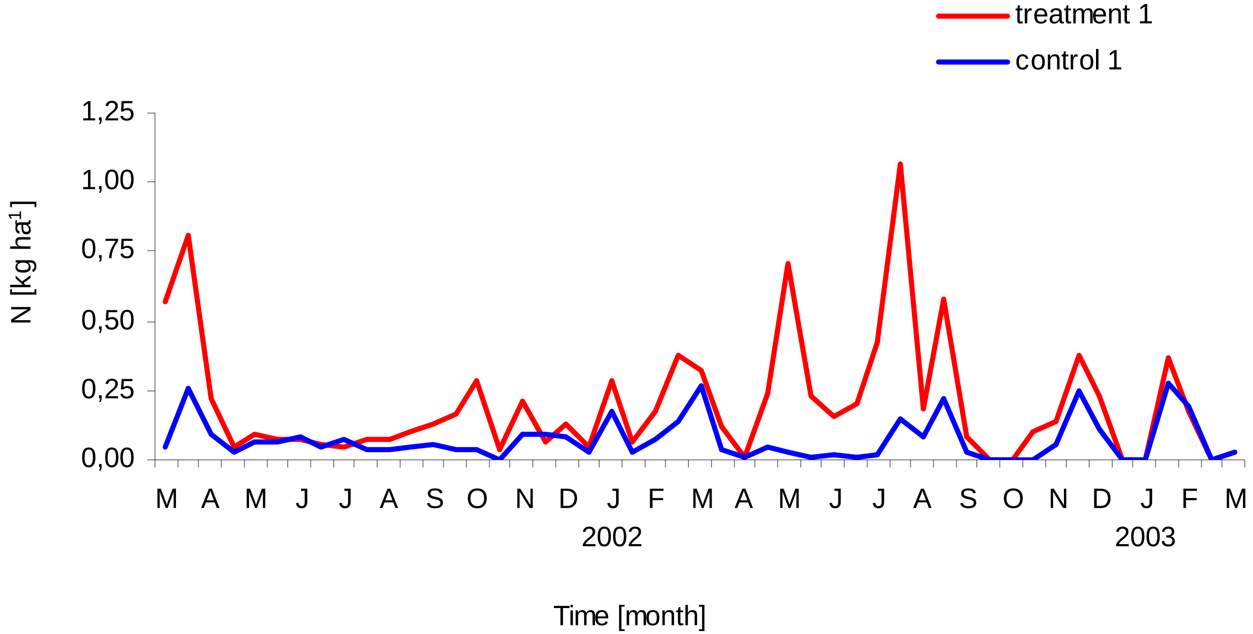
4. Leaching as affected by management (prescribed burning)



N-leaching (plot 1)

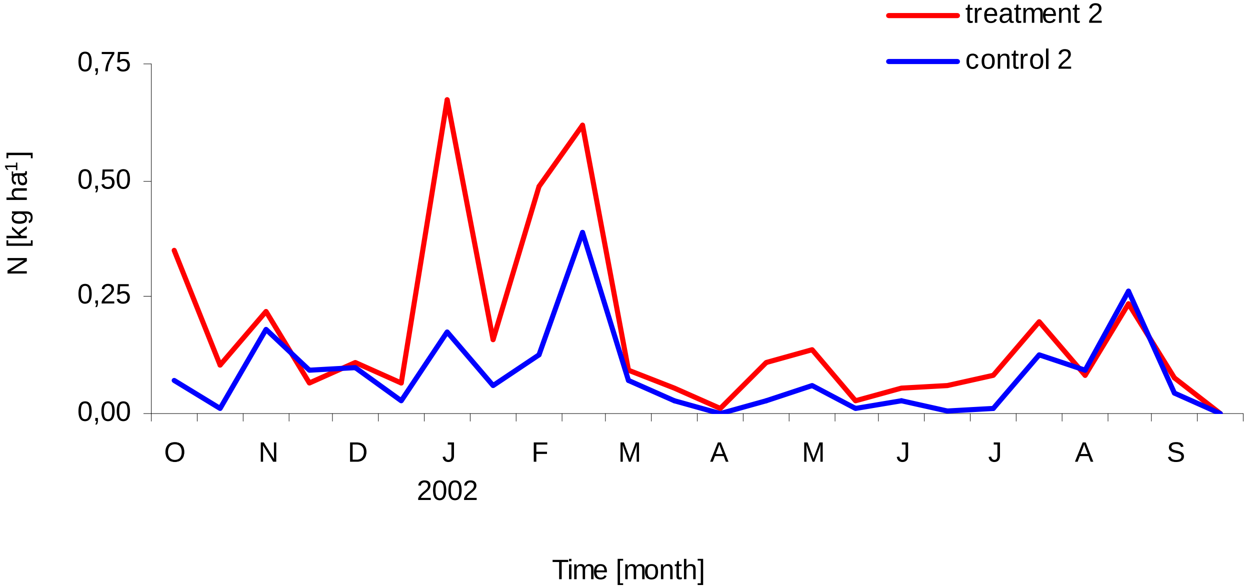
(p < 0,05)

1. year: **F1 = 4,2 kg/ha**

C1 = 1,7 kg/ha

2. year: **F1 = 5,7 kg/ha**

C1 = 1,8 kg/ha



N-leaching (plot2)

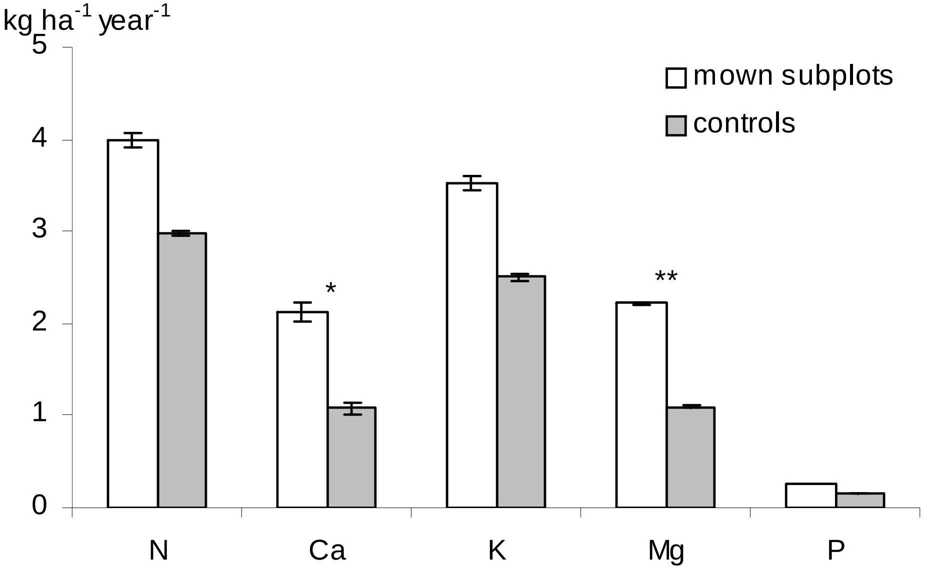
(p < 0,05)

1. year: **F2 = 4,1 kg/ha**

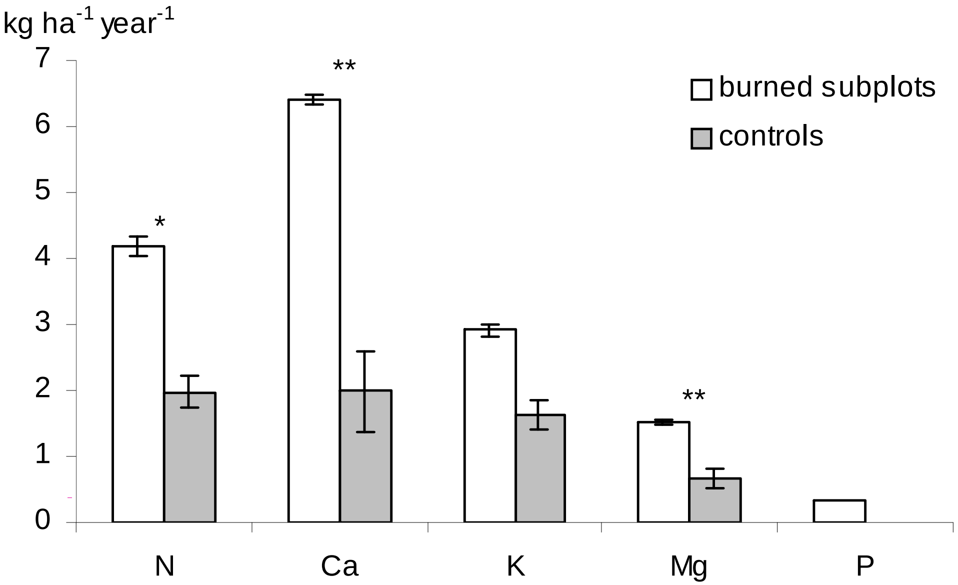
C2 = 2,0 kg/ha

4. Leaching (mowing, burning, sod-cutting)

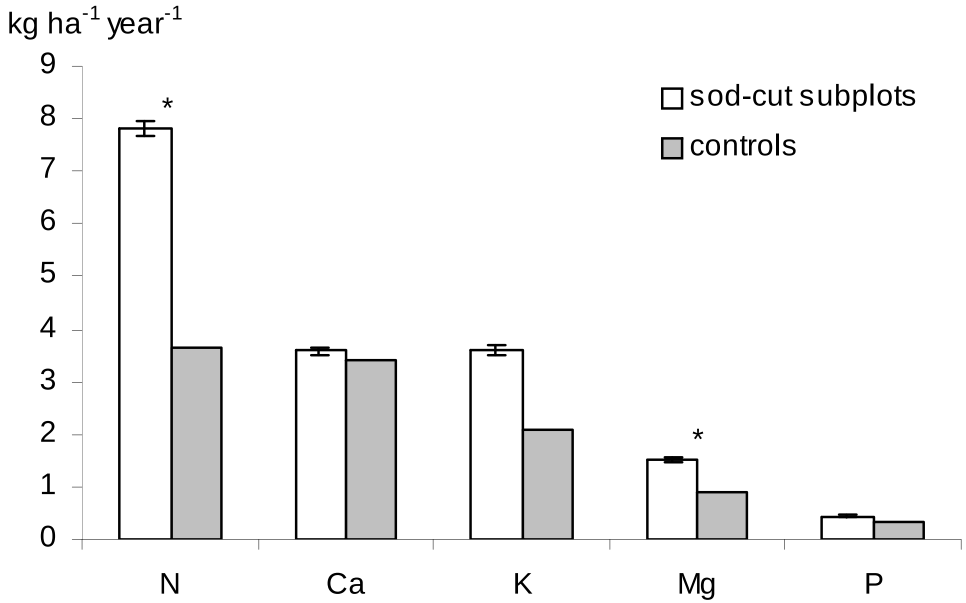
(a)



(b)

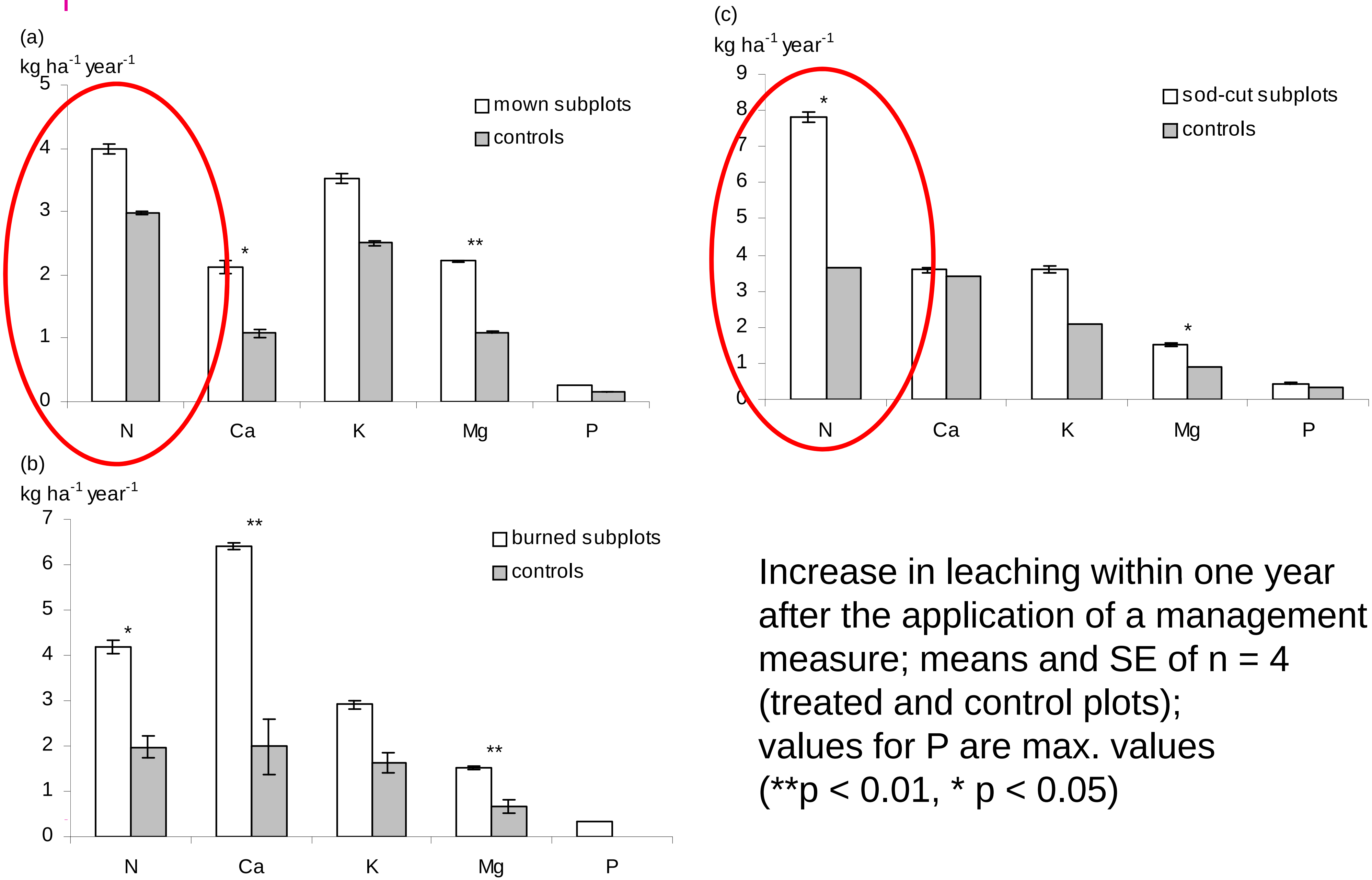


(c)



Increase in leaching within one year after the application of a management measure; means and SE of n = 4 (treated and control plots); values for P are max. values ($^{**}p < 0.01$, $^{*}p < 0.05$)

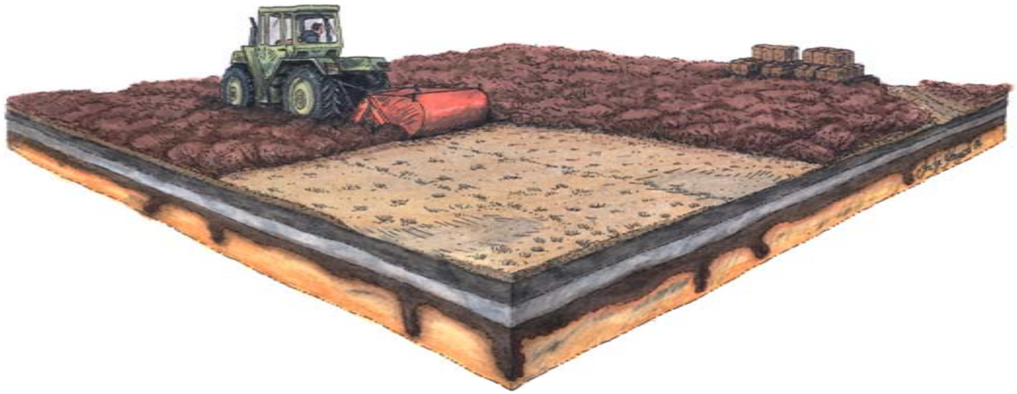
4. Leaching (mowing, burning, sod-cutting)



Increase in leaching within one year after the application of a management measure; means and SE of n = 4 (treated and control plots); values for P are max. values ($^{**}p < 0.01$, $^{*}p < 0.05$)

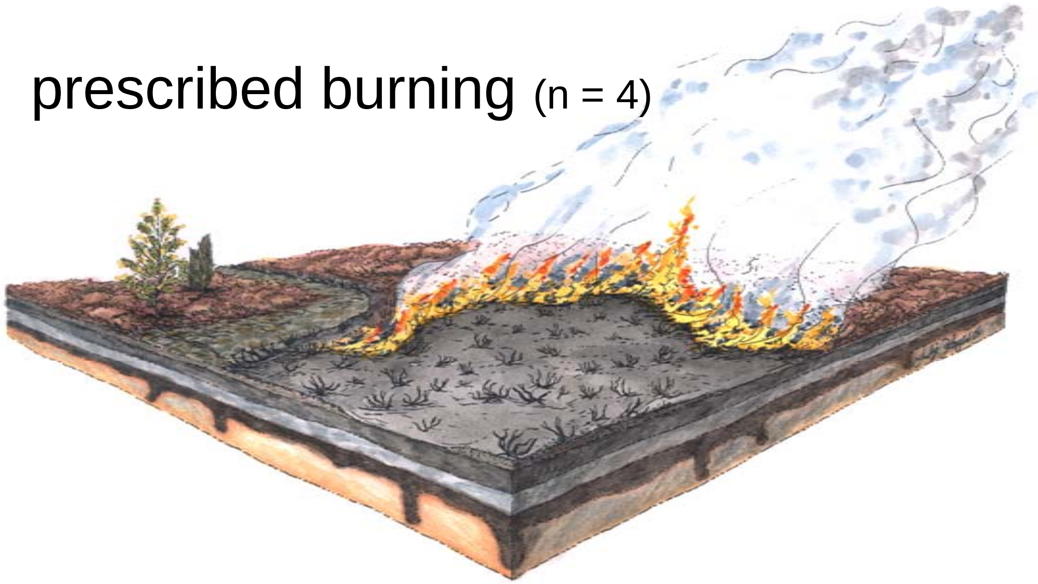
4. Management impacts on nutrient stores

mowing (n = 4)



	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
biomass	96.8	7.1	37.1
organic layer	n.a.	n.a.	n.a.
A-horizon	n.a.	n.a.	n.a.

prescribed burning (n = 4)



	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
biomass	104.2	1.6	25.2
organic layer	n.a.	n.a.	n.a.
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n.a. = not affected

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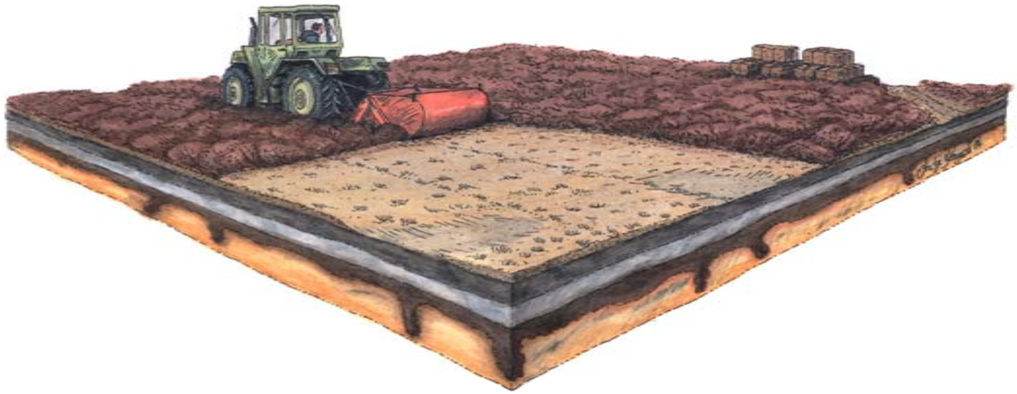

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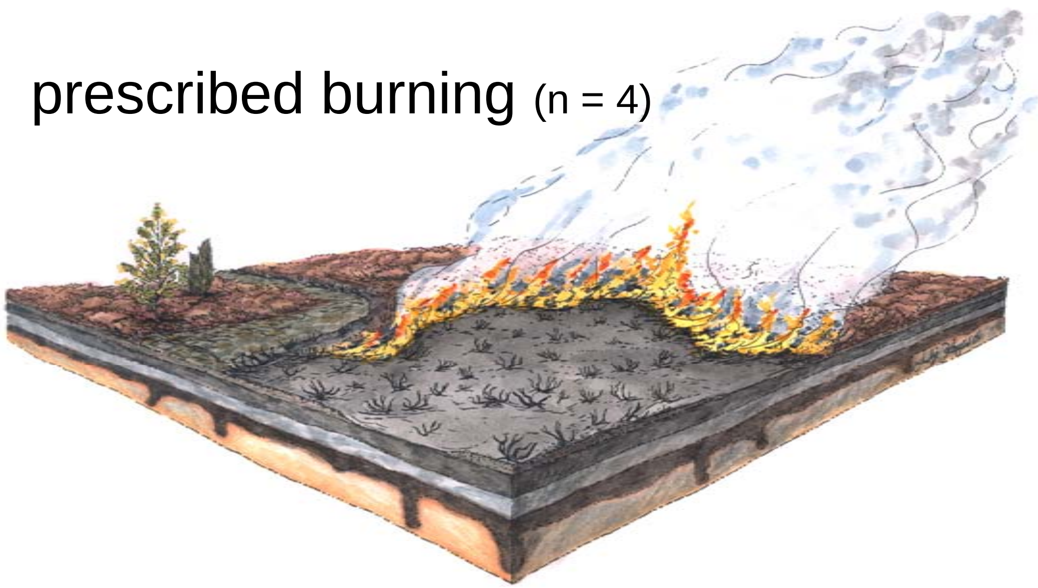

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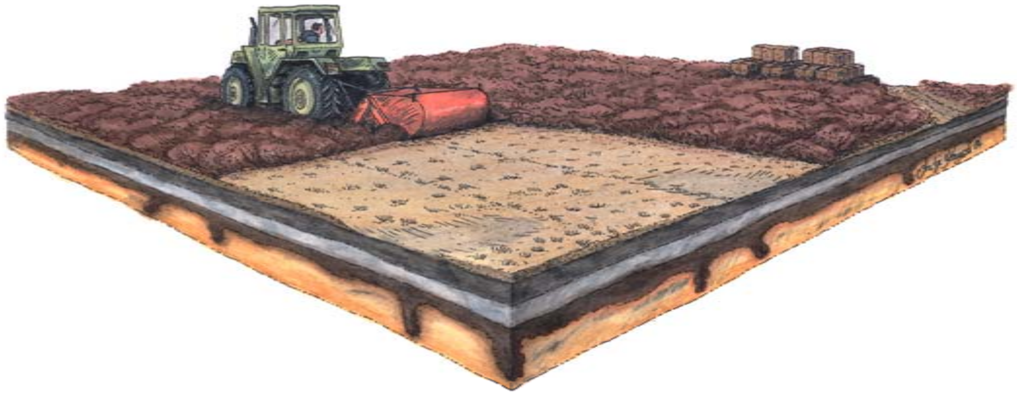

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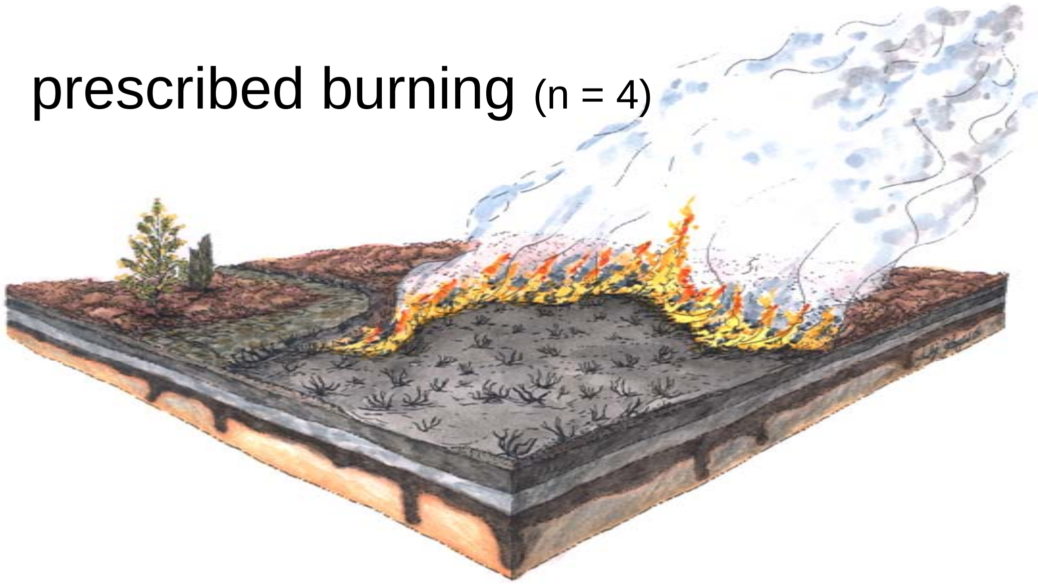

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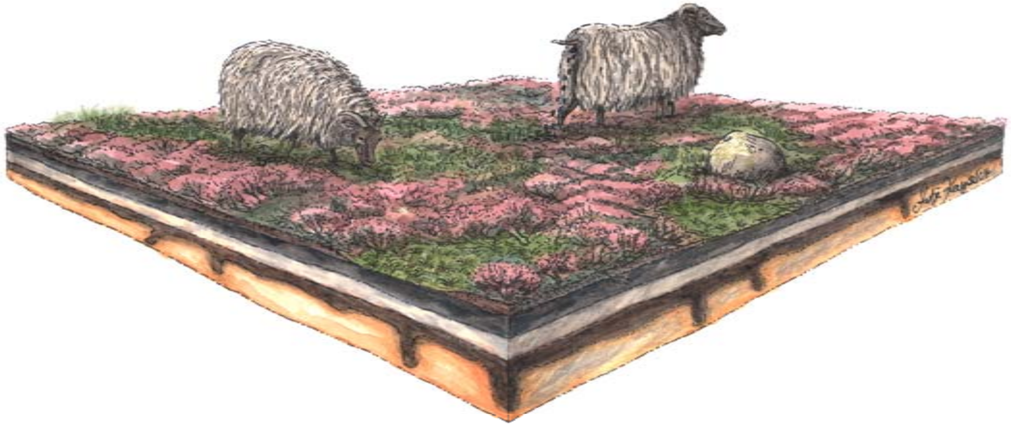
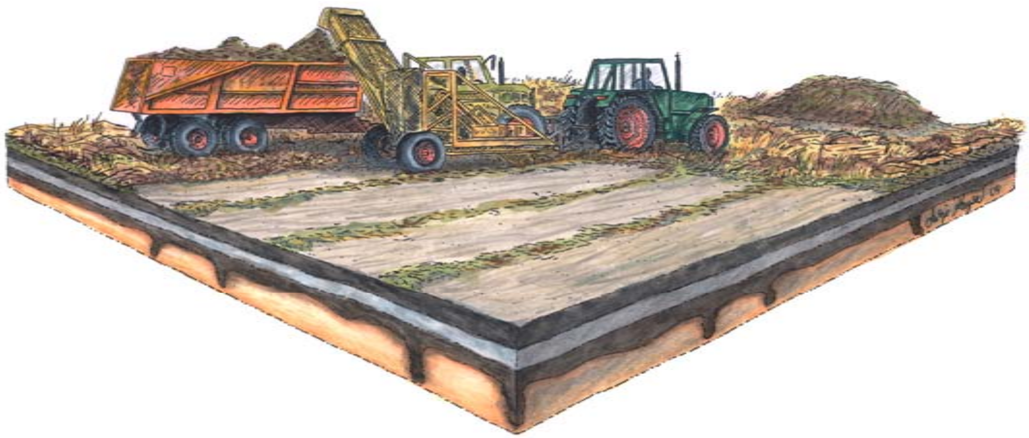
4. Management impacts on nutrient stores

grazing (net-output per year considered, n = 10)



	N (%)	P (%)	K (%)
biomass	26.5	2.1	9.3
organic layer	n.a.	n.a.	n.a.
A-horizon	n.a.	n.a.	n.a.

sod-cutting (n = 4)



	N (%)	P (%)	K (%)
biomass	121.6	7.4	35.8
organic layer	934.5	38.1	51.2
A-horizon	626.5	30.6	165.6

n.a. = not affected

4. Management impacts on nutrient stores

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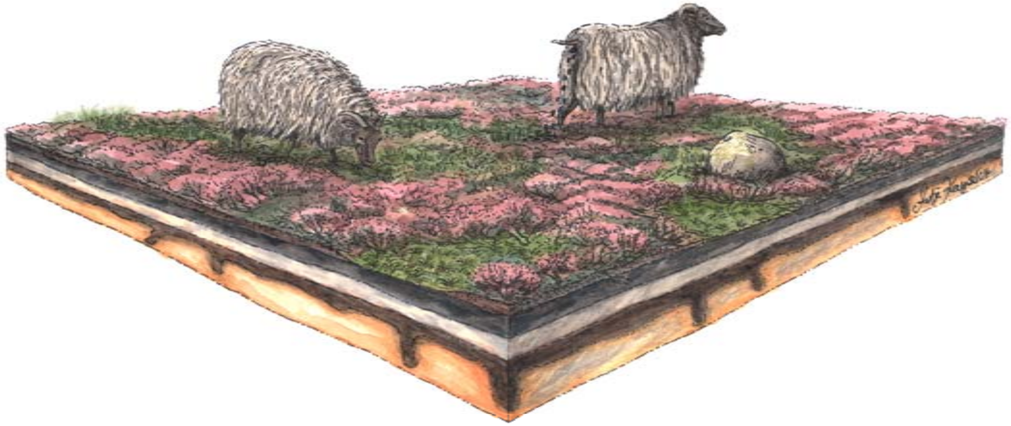

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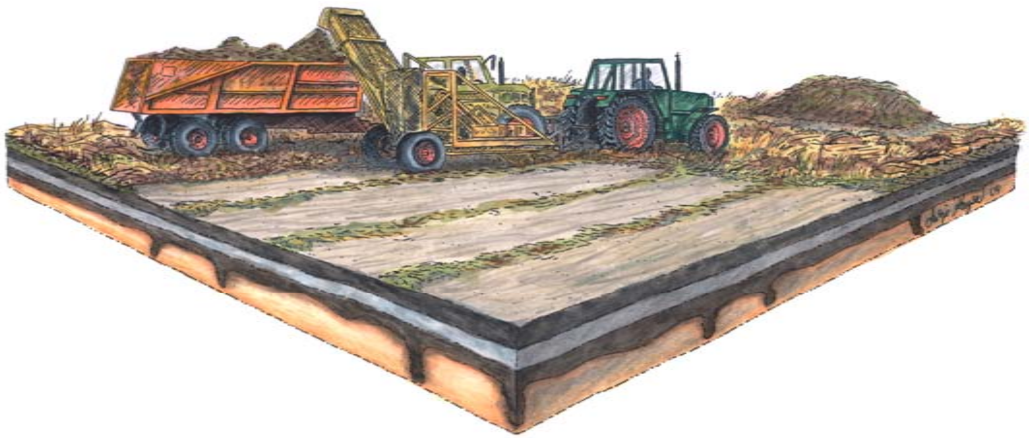

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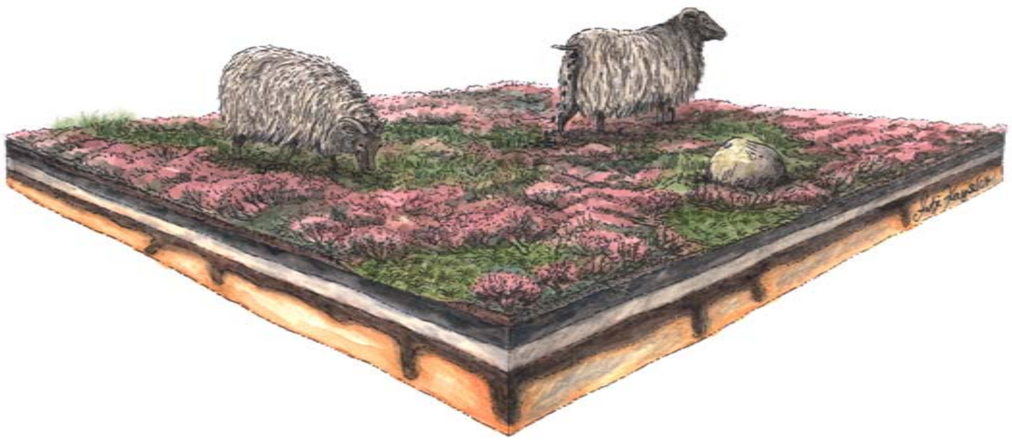
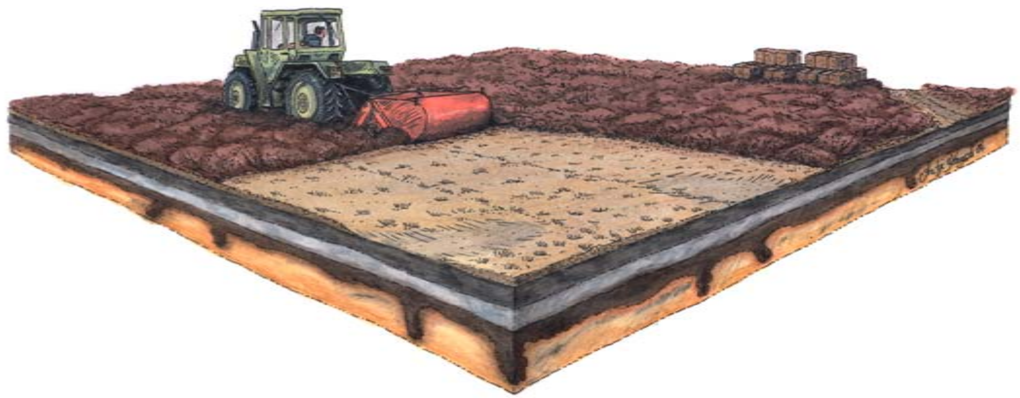
5. Balances

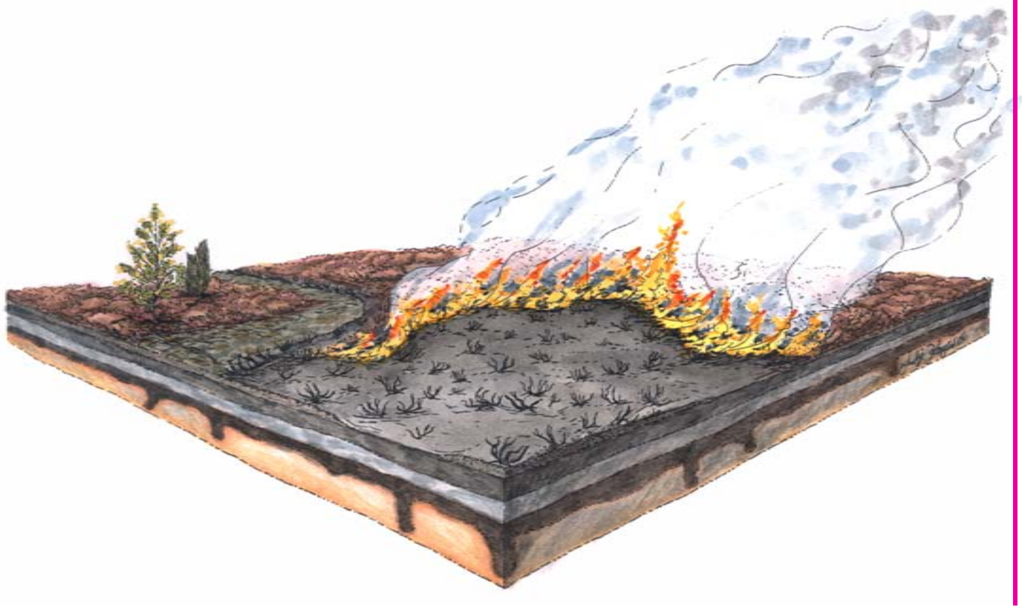
grazing



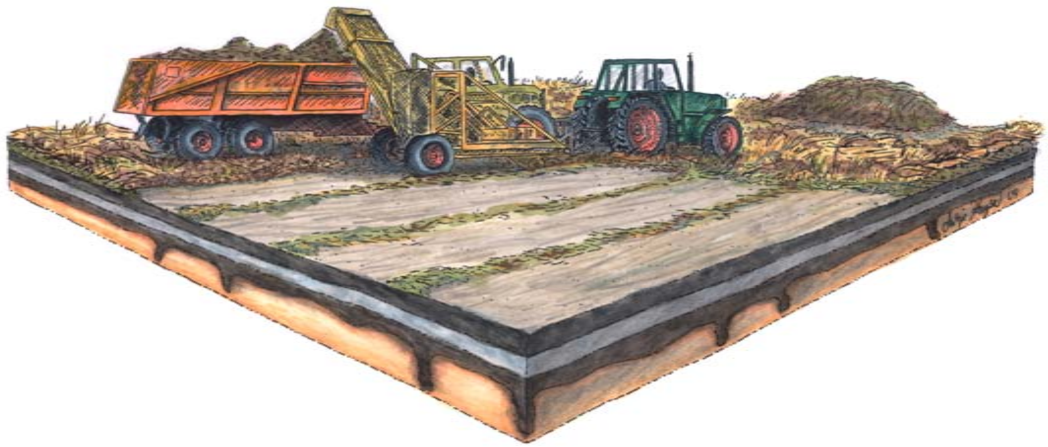
mowing



prescribed burning



sod-cutting

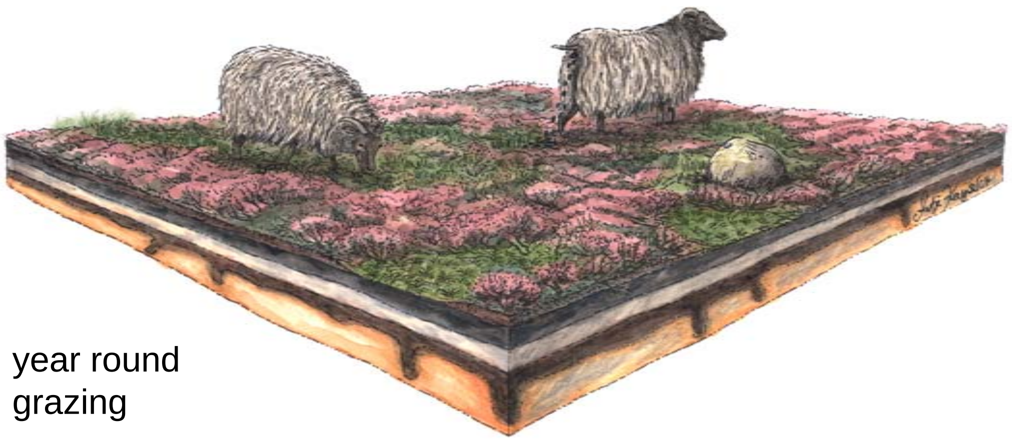


5. Balances **(input – output ha-1 yr^{-1})**

grazing

N - 1.5 kg ha^{-1} yr^{-1}

P - 1.6 kg ha^{-1} yr^{-1}

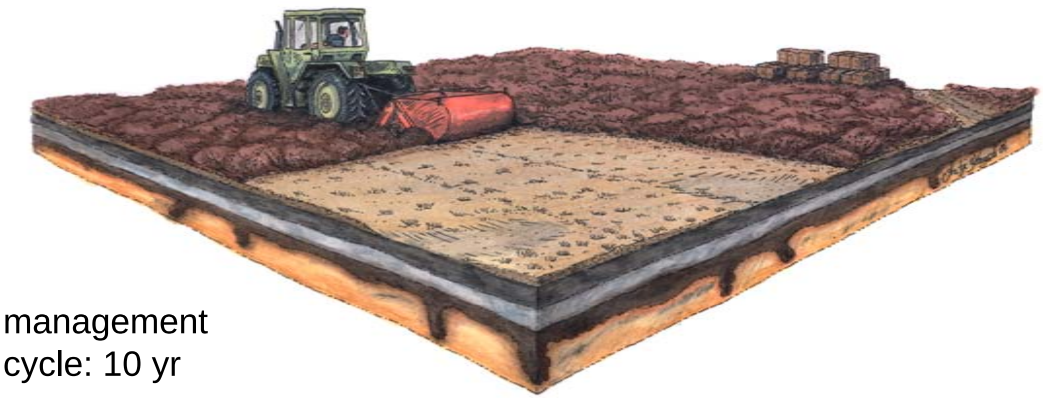


year round
grazing

mowing

N + 9.9 kg ha^{-1} yr^{-1}

P - 0.6 kg ha^{-1} yr^{-1}

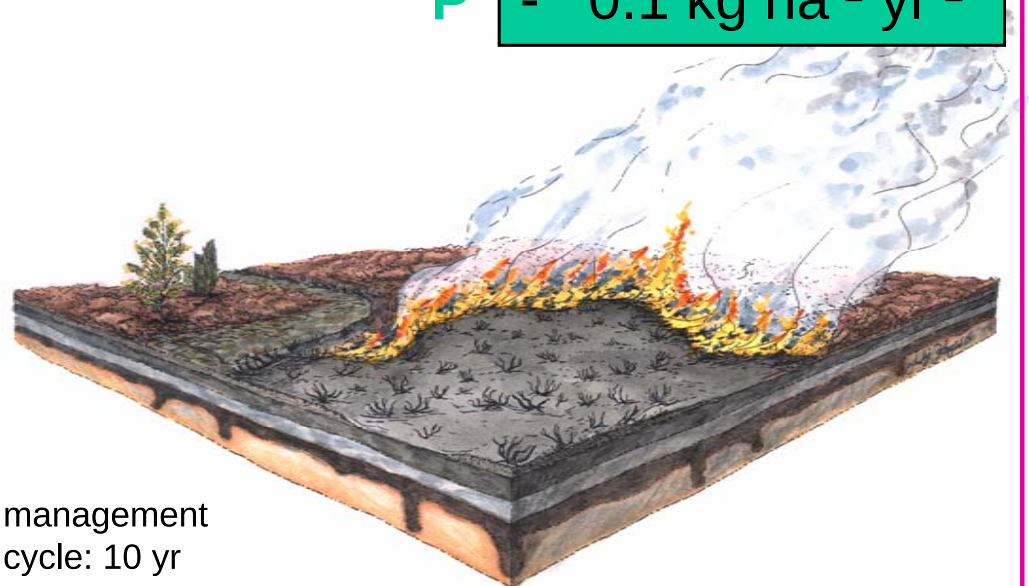


management
cycle: 10 yr

prescribed burning

N + 10.2 kg ha^{-1} yr^{-1}

P - 0.1 kg ha^{-1} yr^{-1}

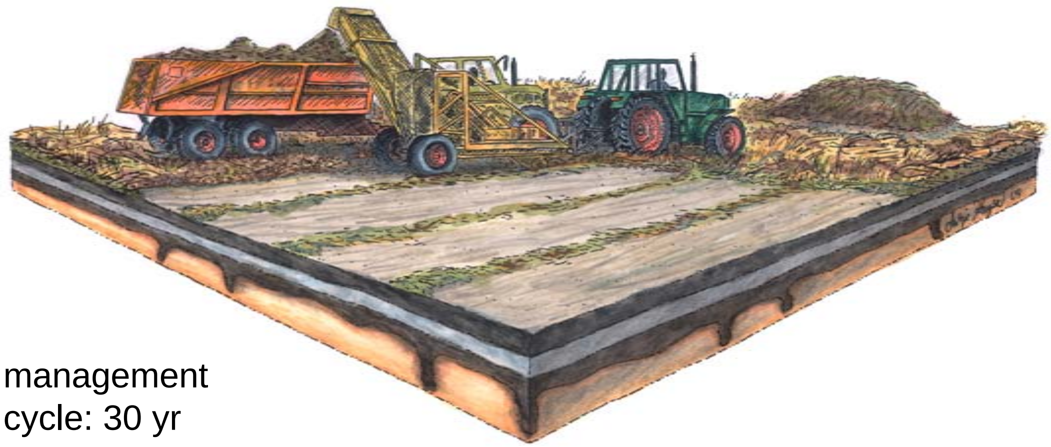


management
cycle: 10 yr

sod-cutting

N - 38.1 kg ha^{-1} yr^{-1}

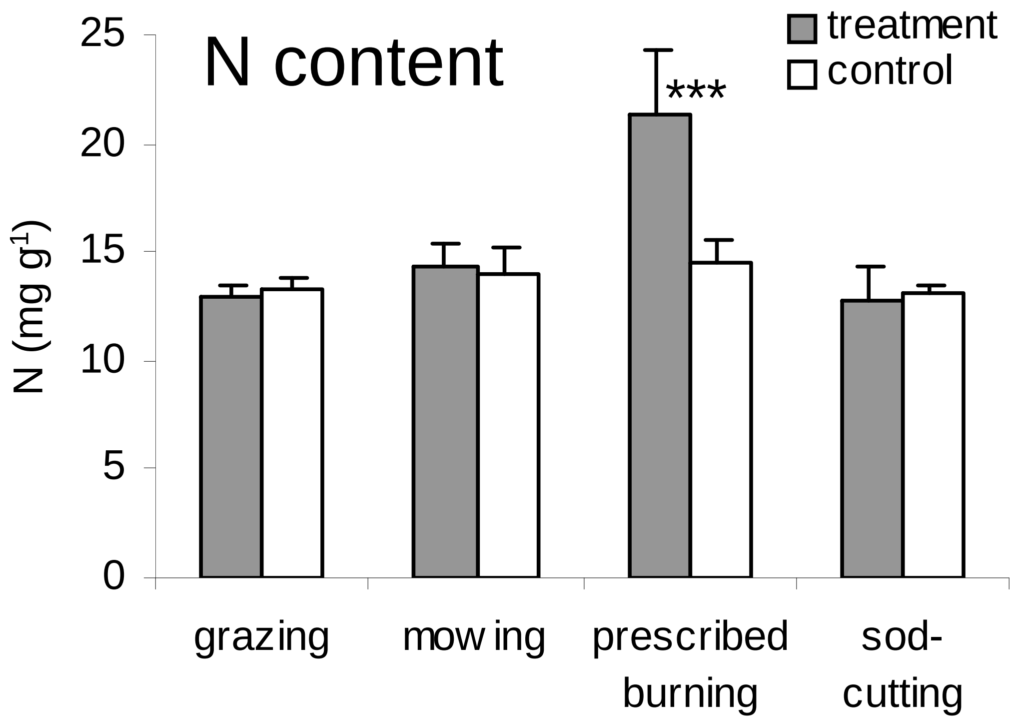
P - 2.5 kg ha^{-1} yr^{-1}

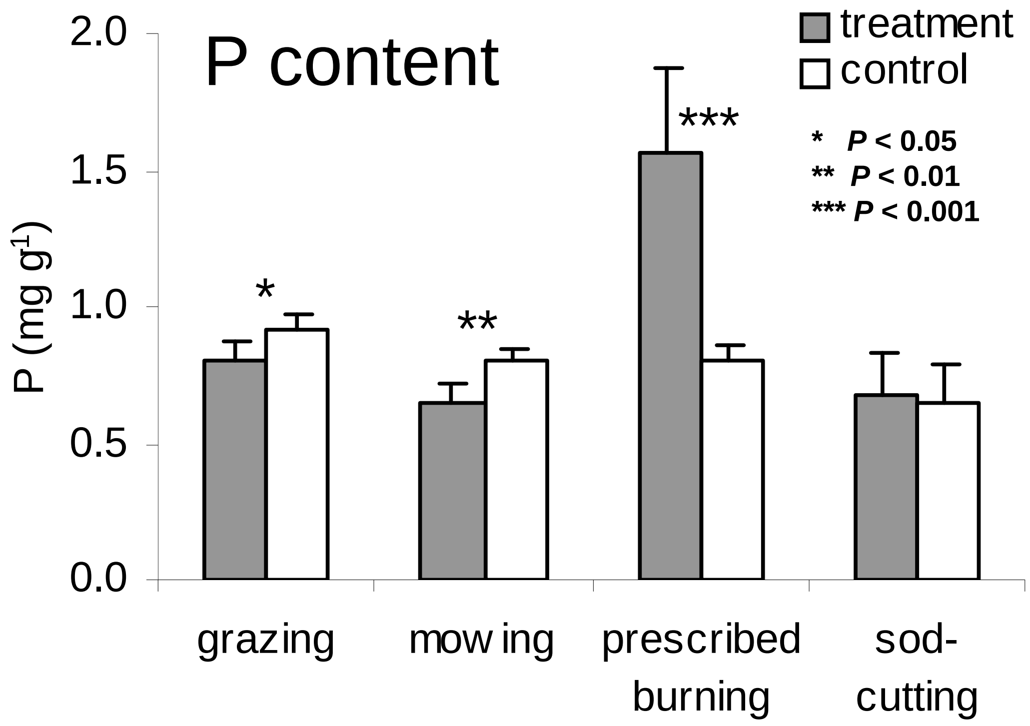


management
cycle: 30 yr

6. Long-term shifts in N and P-budgets

Calluna shoot N and P contents (5 years after application of measures)





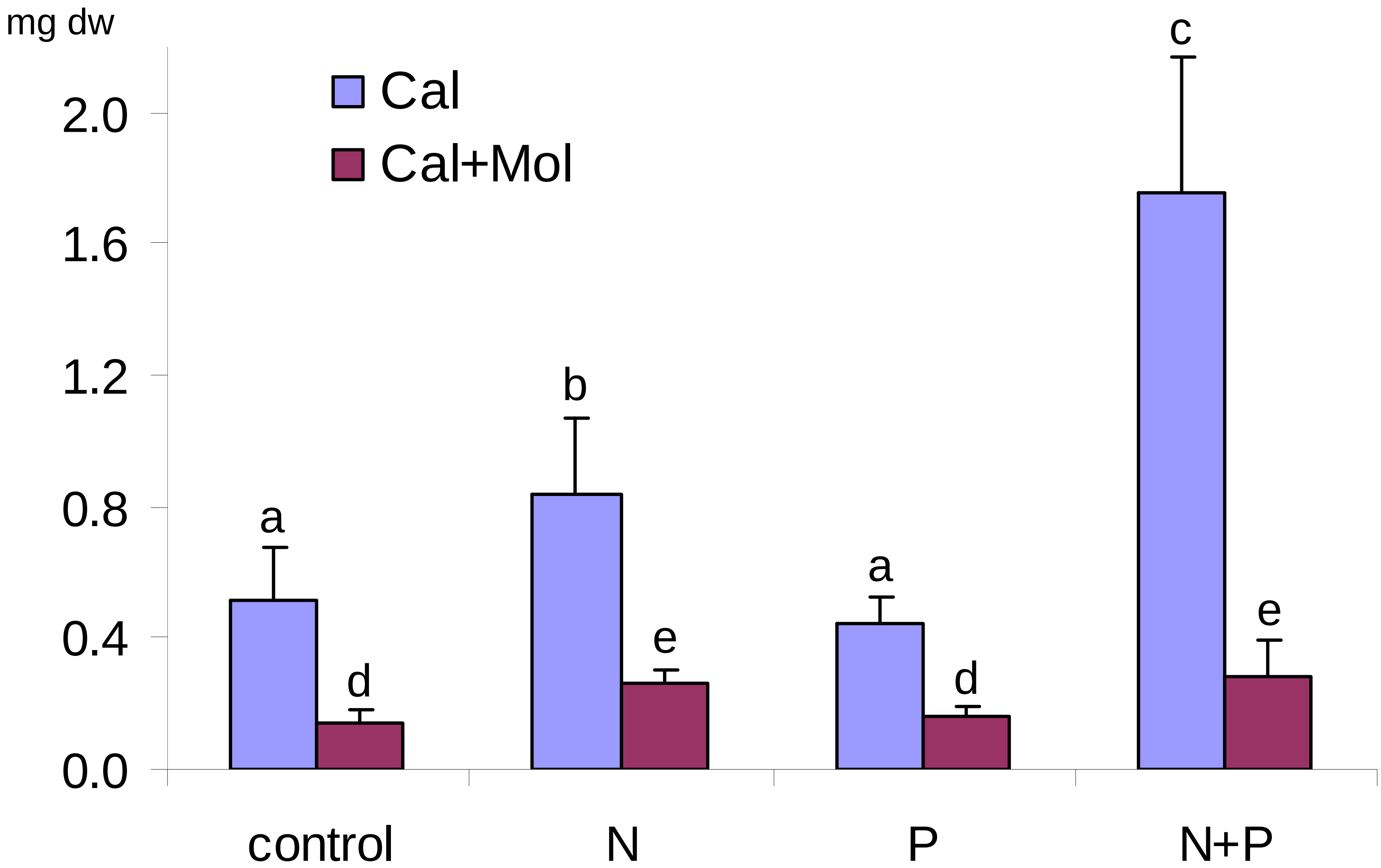
→ Poaceae – with arbuscular mycorrhiza (P-shortage)

→ Ericaceae – with ericoid mycorrhiza (N-shortage)

Hypotheses: improved N availability promotes graminoids

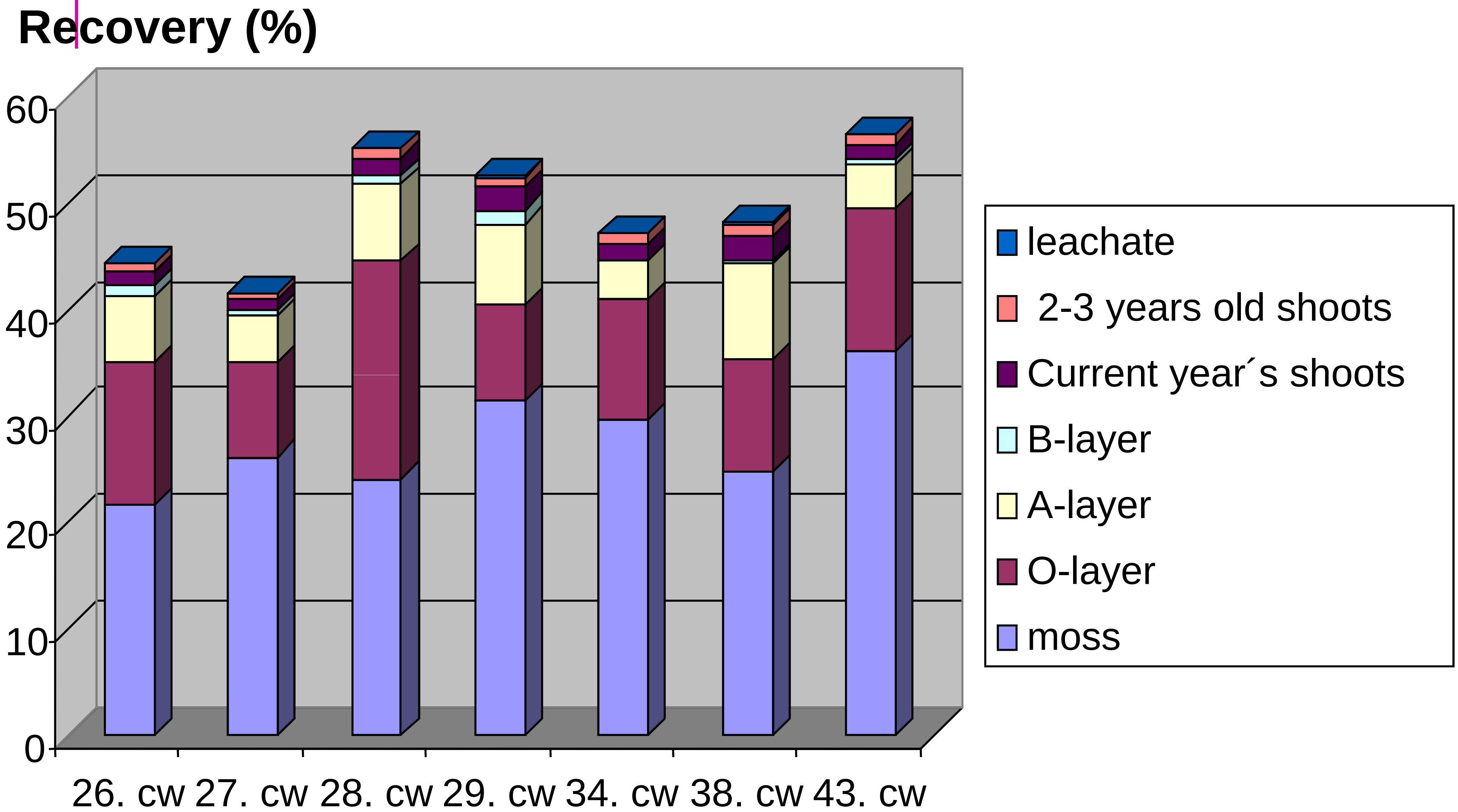
6. Long-term shifts in N and P-budgets

Calluna aboveground biomass without and with competition of *Molinia* in a common garden experiment (after 1 year)



6. Long-term shifts in N and P-budgets: fate of air-born N

Recovery rates of 15 N (in the first year after application)



7. Conclusions

a) Low-intensity measures (mowing, burning) cannot compensate for current atmospheric N loads. Only grazing and high-intensity measures have the potential to compensate for current deposition rates of N.

b) Grazing and mowing may cause an excessive output of P and, thus, may accelerate the deposition induced shift from N to P limitation (*Molinia* encroachment?).

c) Systems still appear to be (co-)limited by N. N accumulation mainly takes place in the biomass and O-horizons.

d) In order to maintain both a diverse structure and balanced nutrient budgets on a long-term basis, management schemes need to combine high-intensity measures (e.g. sod-cutting) with low-intensity measures. Prescribed burning proved to be the best

Thanks to

Dipl. Uwi. Kirsten Falk
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Dipl. Uwi. Sebastian Krieger
Dipl. Uwi. Angelika Krug
Dipl. Uwi. Kerstin Mischke
Dr. Abdelmenam Mohamed
Dr. Marion Niemeyer
Dr. Thomas Niemeyer
Dipl. Uwi. Britta Noll
PD Dr. Goddert von Oheimb

Some recently published results

2006, J. Appl. Ecol. 43: 459-469
2007, Biol. Conserv. 134: 344-353
2007, Appl. Veg. Sci. 10: 391-398
2007, Biogeochemistry 86: 201-215
2009, Ecol. Indicators 9: 1049-1055
2009, Ecosystems 12: 298-310
2009, Conservation Biology (in press)





Thank you
for your
attention