Mountain biota and global change

Christian Körner

Institute of Botany
University of Basel, Switzerland

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As height increases, area shrinks ...

Global land area (outside Antarctica)
134.6 Mio km$^2$ (=100 %)

> 300 m  ca. 30 Mio km$^2$
> 1500 m  ca. 11 Mio km$^2$
> treeline  ca.  4 Mio km$^2$

Land area per 100 m elevation steps starting from 1500 m (total = 11 Mio km$^2$).

C Körner (2007)
TREE 22: 569
The area of influence is far greater

Through river systems, half of the terrestrial surface is influenced.

Through effects on regional climate most of the world is influenced.
- uniform gradients in temperature
- variable gradients in precipitation

Rhone valley, 2000 m

Climatic warming
Treeline f(T)

Avalanche tracks

©Ch Kämmer
Plant architecture matters

Mean  13.6 ± 0.9  20.6 ± 1.4
Min    11.5        17.5
Max   17.5        26.3

Temperature (°C)

Montane forest
Alpine heath

Treeline ecotone

Rel. frequency (%)

Forest
Alpine heath

Treeline trees grow faster in response to recent warming.

Swiss Alps, ca. 2000 - 2200 m

Tree ring width (mm)

Year of growth

Experimental warming (transplants)

2650 m a.s.l.

2450 m a.s.l.

+1K

Warming
After 4 years:

**Sedges**

- Cool → Cool: n = 10
- N-addition: ↑ p < 0.001
- Warming: n.s.

**Grasses**

- Cool → Cool: n = 10
- N-addition: n.s
- Warming: ↓ p < 0.01

**Forbs**

- Cool → Cool: n = 10
- N-addition: n.s
- Warming: ↓ p = 0.08
- N-addition: 25 kg N ha⁻¹ a⁻¹

E Hiltbrunner, unpubl
Meteorological data do not match the true alpine climate
Swiss Alps, 2300 - 2800 m
Effect of exposure on growing season root zone root temperature

Central Alps, 2500 m

D Scherrer & Ch Körner, unpubl

Median of concurrent air temperature

D Scherrer & Ch Körner, unpubl
The effect of N deposition on alpine plants
Furka, 2500 - 2600 m

Early
- N
+ N

Late succession
- N
+ N

Acidic soils
Calcareous soils

Plant biomass (g m⁻²)

100 kg N
50 kg N
25 kg N
15 kg N ha⁻¹ a⁻¹

+270 % **
+125 % **
+ 27 %*
+ 53 %*

E Hiltbrunner, unpubl data
No biomass responses of alpine grassland to 4 years of CO$_2$-enrichment (Alps, Furkapass, 2500 m)

... irrespective of nutrition

Ch Körner et al. (1997) Acta Oecol 18:165
... repeated in pioneer vegetation using FACE
Negative effect of elevated CO$_2$ on plant growth

FACE-Glacier forefield plants, Furka, 2500 m

Aboveground biomass (g d.w.)

- **Luzula alpinopilosa**
- **Poa alpina**
- **Ranunculus glacialis**
- **Veronica alpina**

- Ambient CO$_2$
- Elevated CO$_2$

Species: $p < 0.001$

CO$_2$: $p < 0.05$

N: $p < 0.001$

Ch Körner
• No stimulation of montane spruce (Hättenschwiler et al. 1996, PCE)
• No CO₂ stimulation of treeline pine (Handa et al. 2006, GCB)
• Young treeline larch is stimulated, at least initially

... but forest C-pools per m² peak in montane forests
Substitution potential of fossil C by forest biomass and energy crops is very small

3-5 % fossil C-saving can be achieved by driving with 8.1 (Germany) or 8.3 (Switzerland) instead of 8.6 liter gasoline per 100 km.

Clotheslines should be subsidized: 300 kWh per household per year are wasted
Hydrological benefits of grazing: 5-10 % more yield

Grazed, dense, alpine swards lose less water by evapotranspiration than long grass.

At 2500 m grazing induced, enhanced seepage corresponds to an increased electric power yield of 150$ ha$^{-1}$ a$^{-1}$.

→ sustainable grazing can increase catchment value.
Water balance
Catchment yield
Erosion risk
Nothing makes sense in mountain ecology, except in an hydrology-erosion context.
Mountains are hotspots of biodiversity
Do we ‘need’ all those species?
Great Caucasus, 1500 m
A single species controls the edge
Keystone species may engineer landscapes.

Central Swiss Alps
C Huck et al, unpubl data

Central Caucasus
R Caprez et al, unpubl data

**Festuca valesiaca**

**Brachypodium pinnatum**
Swiss Alps, 1953 m - 2582 m

Soil aggregate stability (% wt)

Number of species

$r^2 = 0.36 ***$

M Pohl et al. Higher plant diversity enhances soil stability in alpine ecosystems. (submitted)
Mountain biodiversity secures catchments

• Catchment value depends on soil stability.

• Soil stability depends on a dense plant cover.

• A dense plant cover is secured by high plant species diversity.
The most fragile systems
Many taxa escape upslope ...

... but many became already extinct, e.g. in Costa Rica, JA Pounds et al (2006) Nature
Climatic change driven fire frequency on Kilimanjaro reduces water yield (Hemp 2005, GCB)
Plant species are migrating upwards - now!

Western European mountains


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Species responses to climatic warming

Mountains may be refugia (2, 4) traps (3, 5) or a chance (6)
At high elevation...

- elevated CO$_2$ does not stimulate growth
- warming reduces growth in the Alpine increases growth at treeline
- N-deposition: winners and losers!
- land use may outrange any other effect