Treeline advance in alpine zones: Effects on ecosystem carbon stocks

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Changes in Climate, Land Use & Grazing

2014: ~2.5 mill sheep in Norway

• In recent decades: Livestock grazing decreased in mountains
• More sheep on fewer, but bigger farms!

(Austrheim et al. (2008a).

Figure 22. Number of sheep and lambs in Norway during summer, 1835-2007. Data from Statistics Norway. Note that all statistics from the 19th century were recorded at 31 December, while later recordings were at 30 September (1917) or the 1 or 20 of June (the rest of the 20th century). Thus counts from the 19th century do not include lambs slaughtered in the autumn.

Figure 23. Number of Norwegian farms keeping sheep 1969 – 2006. Data from Statistics Norway

(Austrheim et al. (2008b).
Grazing, vegetation and soil carbon

- Effect of grazing on soil carbon:
  - Increase (Leifeld and Fuhrer 2009; Tanentzap and Coomes 2012)
  - Decrease (Tanentzap and Coomes 2012)
  - Little or no effect (Steffens et al. 2008) on storage of soil C.
Grazing Experiment

HIGH: 80 sheep km$^{-2}$
LOW: 25 sheep km$^{-2}$

2.7 km$^{-2}$

Norwegian University of Life Sciences
Japan - Norway Arctic Science and Innovation Week 2016
Birch recruitment

- Eight years of grazing: Birch recruit within whole altitudinal range of control. But limited at high grazing
- Distribution saplings or mature birch: no difference between treatments

- Grazing limits the treeline below its potential!
Ecosystem carbon stocks: from forest to tundra (across treeline ecotone)

Figure 1. Map of study area and grazing experiment showing the experimental enclosures and locations of sample plots. Observed young and mature birch individuals sampled along transects (Speed et al., 2010) are included for reference, and the thick solid line indicates the forest line. Universal Transverse Mercator grid zone 32V.

Carbon in standing vegetation

Carbon in soil increases with elevation

Total ecosystem carbon stocks

Discontinuous elevational pattern...

Minimum between forest line and tree line.
Change in above-ground biomass production after 5 year grazing

High sheep density: Decreased productivity

Low sheep density: Increased productivity

Control: no significant change

Austrheim, Speed, Martinsen, Mulder & Mysterud, 2014. AAAR.
Change in soil carbon after 7 year grazing

Differences between habitat

Reduction soil carbon stock at high grazing pressure

Increase soil carbon stock at low grazing pressure.

Main conclusions

• Tundra and forest have different predominant carbon stocks:
  – in soil organic matter in the alpine system
  – in woody biomass in the forest system
• Forest soils have greater turnover rate of soil organic matter than tundra soils, resulting in less organic matter in the organic horizon
Main conclusions

• Progression ecosystem C stocks due to treeline advance in warmer climate:

(1) Short term (some years). Decomposition increases, reducing soil C stocks. Increased growth of vegetation increases above-ground C stocks and litter inputs. Minor impact on ecosystem C stocks

(2) Longer timescale (decades). Shifts in vegetation. Increased tree recruitment above treeline. Changes in litter quality, increasing decomposability of soil organic matter. Ecosystem C stocks reach minimum

(3) Long run (several decades): Forest has increased standing C stocks, compensating decrease in soil C

• Modulated by herbivory!
Main conclusions

Herbivory: A significant but non-linear effect on vegetation structure and production

- Grazing at low densities increases productivity and may increase soil C stocks
- Overgrazing causes a decline in productivity and soil C stocks
Hol, southern Norway