Modelling the impacts of seasonal drought on herbage growth under climate change

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Drought and growth

Mosimann et al. (2013)
Long-term decline in grassland productivity driven by increasing dryness

E. N. J. Brookshire & T. Weaver

Figure 1 | Long-term pattern of grassland production and climate variation. (a) Above-ground net primary production in control plots showing all plot data (points) and locally weighted trend lines with 95% confidence bands for total (grey), grass (green) and forb (orange) production. The horizontal black bar on the y axis is ANPP for 1965-1967 at a nearby subalpine grassland (ref. 20). (b) Change in total above-ground carbon pools with 95% confidence bands. (c) Time series of the regional Palmer Drought Severity Index (PDSI, lower values indicate increasing dryness). (d) September temperature. (e) late-summer rainfall and (f) annual snowfall. All significant (P<0.001) trends in b-f are shown with a regression line (blue) and 95% confidence intervals.
The future

Figure 2: Change of temperature and precipitation for winter and summer as simulated by climate models. Large scale patterns are similar but details differ between models, time period and scenarios. The figure shows the multimodel mean change for 2070-2099 relative to 1980-2009, for an intermediate (A1B) greenhouse gas emission scenario.
Direct effects of water deficit on plant physiology

- Photosynthesis & assimilation ↓
- LAI, biomass ↓
- SLA ↓, leaf dry matter content ↑
- Leaf lifetime ↓
- Root machinery ↑
- BNF ↓

Meisser (2013)
Other important effects

- Increasing temperature
  ⇒ growing season ↑

- Elevated CO₂ concentrations
  ⇒ water & N use efficiency ↑

Meisser (2013)
Grassland models

Model complexity

low ➞ gap ➞ high

ModVege
(Jouven et al.)

PROGRASS
(Lazzarotto et al.)

ecosys
(Grant)

PaSim
(Riedo et al.)

HPM
(Thornley)
Fig. 5. Vertical profiles of root length density simulated 30, 60, 90, 120 and 150 days after planting (DAP) under 30 g N m$^{-2}$ of fertilization and (a) 30 mm week$^{-1}$ of irrigation, or (b) zero irrigation.
Model performance: ModVege

Calanca et al. (2016)
Model performance

Calanca et al. (2016) + unpubl.
Model performance

![Graphs showing model performance for ModVege, PROGRASS, and ecosys for the years 2002 and 2003. Each graph plots LAI (leaves per unit area) against year.]
Model application: ModVege

2003

Changins

2004

Posieux

2006

Calanca et al. (2016)
Model application: ModVege

Calanca et al. (2016)
Root dynamics

PROGRASS

ecosys
Co-existence & interactions

PROGRASS

ecosys
Conclusions

The sensitivity of grasslands with respect to drought depends on

- Phenology, overwintering & winter mortality
- Root dynamics
- Community dynamics & species interactions
- Short-term effects of management
- Long-term effects of management

There is room for improving the formulation of these processes in current grassland models

Moreover ...
Complicating factors

Meisser et al. (2013)
Complicating factors

Fig. 1 An aerial view of the Park Grass Experiment looking due north, taken on 23 May 2005. Note the sharp plot boundaries, many of which are clearly demarcated by differences in vegetation.
Complicating factors

LETTER

Grassland biodiversity bounces back from long-term nitrogen addition

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PROCEEDINGS
OF
THE ROYAL
SOCIETY

Soil moisture mediates association between the winter North Atlantic Oscillation and summer growth in the Park Grass Experiment

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