Heathland ecosystems, human impacts and time: A long term heathland trial investigating ecosystem changes that occur after exposure to climate change, elevated N deposition and traditional vegetation management practices
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Appendix 2

Details of the Soil Moisture Model

The soil moisture model used in Chapter 3 and Chapter 4 is a zero-dimensional finite difference model using a daily time resolution of rainfall data and air temperature data as model inputs. It was constructed and calibrated on approximately one year of observed soil moisture, rainfall and temperature data for 21 individual soil moisture sensors. The model comprises the following equations:

\[ Drain_t = \max(0; S_{\text{moist}_{t-1}} - \text{depth} \cdot fc) \cdot df \]  
\[ AvSmoist_t = \max(0; S_{\text{moist}_{t-1}} - \text{depth} \cdot wp) \]  
\[ ET_t = \min(T_{\text{temp}_t} \cdot tf; AvSmoist_t) \cdot ef \]  
\[ EfRain_t = Rain_t \cdot \left(\frac{S_{\text{moist}_t}}{\text{depth} \cdot \text{poros}}\right)^{rf} \]  
\[ S_{\text{moist}_t} = \min(\text{depth} \cdot \text{poros}; S_{\text{moist}_{t-1}} + EfRain_t) - Drain_t - ET_t \]

In the equations, \( t \) refers to a day. Equation (A2.1) calculates drainage (\( Drain_t \), in mm day^{-1}) as a linear reservoir with soil moisture (\( S_{\text{moist}_{t-1}} \), in mm) above a threshold (\( \text{depth} \cdot fc \)) as the driving force. \( Drain_t \) refers to the drainage of soil moisture from the soil layer under consideration (i.e. the top of the mineral soil down to \( \text{depth} \) mm); \( S_{\text{moist}_{t-1}} \) refers to the soil moisture in the soil layer under consideration, and \( \text{depth} \), \( fc \) (field capacity, as a fraction of the soil volume) and \( df \) (drainage fraction) are model parameters. The \( \text{depth} \) parameter is set to 100 mm, while the values for \( fc \) and \( df \) were identified by model calibration.

Equation (A2.2) calculates the soil moisture available for evapotranspiration (\( AvSmoist_t \), in mm) and the parameter \( wp \) (as a fraction of the soil volume) represents the wilting point below which only a negligible rate of evapotranspiration occurred. The value for \( wp \) was found by model calibration.

Evapotranspiration (\( ET_t \)) is calculated in Eq. (A2.3). Evapotranspiration is a modeled linear reservoir with either the air temperature or the available soil moisture as the driving force, depending of which factor is limiting. The parameter \( tf \) is set to 1 mm (°C){-1}, and the value for the parameter \( ef \) was identified by model calibration.

The effective rain, i.e. the rainfall which enters the soil layer under consideration (\( EfRain_t \), in mm), is calculated in Eq. (A2.4). \( EfRain_t \) is proportional to a soil saturation factor which contains two parameters: soil porosity (\( \text{poros} \)) and a rainfall factor (\( rf \)). The porosity is calculated by taking the maximum observed soil moisture content over the measurement period, while the rainfall factor is calculated by model calibration.

In Eq. (A2.5), an update of soil moisture is calculated by a balance equation, whereby it is assumed that any rainfall which cannot be stored in the soil layer under consideration is lost as surface runoff.

The water balance model thus contains eight parameters, three of which have fixed values (\( \text{depth} = 100\text{mm}, \text{poros} = \max_{\text{all} \epsilon}(S_{\text{moist}_t}/\text{depth}), \text{and } tf = 1\text{mm}(\text{°C})^{-1}, \text{and five of which}
Details of the Soil Moisture Model

were found via calibration ($df$, $ef$, $fc$, $rf$ and $wp$). Calibration was undertaken by minimizing the root mean squared error between observed and predicted soil moisture, using the optimization routine by Byrd et al. (1995), as implemented in the standard R function ‘optim’.

The fit of the soil moisture model for the different treatments is shown in the diagnostic plots of Figure A2.1. The plots illustrate that there is still quite some room for improvement in the soil moisture model. For each of the cases, the explained variance in the observed versus predicted plot is approximately 0.7.

Figure A2.1 Observed vs predicted soil moisture for the four vegetation communities in this study.

References