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# Combined effects of multifactor climate change and land-use on decomposition in temperate grassland

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A B S T R A C T

Climate change is likely to alter decomposition rates through direct effects on soil biotic activity and indirect effects on litter quality with possible impacts on the global carbon budget and nutrient cycling. Currently, there is a need to study the combined effects of climatic drivers and agricultural practises on decomposition.

In an in situ litter bag experiment, we studied the effects of rainfall variability (including drought combined with heavy rain pulses as well as regular irrigation) interacting with winter warming and increased winter precipitation and with changes in cutting frequency, on decomposition in a temperate grassland. Litter bags contained mixed and species-specific litter of all different climate and land-use manipulations and were placed within the plots of litter origin. Moreover, we aimed to disentangle the causes of changes in decomposition by investigating two further approaches: Firstly, we studied the effects of changes in leaf chemicals as a result of the manipulations by removing litter from the experiment that has been pre-exposed to the manipulations before placing it on an untreated standard plot outside the experiment. Secondly, we assessed the effects of changes in soil faunal activity by investigating the decomposition of standard material under differing rainfall variability.

As a result, decomposition was reduced when litter bags were exposed to drought for six weeks within an 11 months period. Neither additional winter rain nor winter warming had an effect on decomposition, likely because winter warming reduced snow cover and increased variability of surface temperatures. Climate manipulations did not change litter quality. Furthermore, decomposition on the untreated standard plot was not affected by the climate manipulations that the litter was previously exposed to. Thus, reduced decomposition under extreme rainfall variability and drought may mainly be caused by a decrease in soil biotic activity, as indicated by reduced decomposition of standard material during drought.

More frequent cutting strongly stimulated decomposition, however, this stimulating effect was absent under extreme rainfall variability including drought. The stimulation of decomposition under more frequent cutting was attributed to changes in litter quality, namely a decrease in C/N ratio. Accordingly, litter from more frequently cut communities decomposed faster on the untreated control plot outside the experiment.

Projected increases in drought frequency and increased rainfall variability under climate change may inhibit decomposition and alter nutrient and carbon cycling along with soil quality. Especially decomposition in frequently cut grassland appears vulnerable towards drought.



## 1. Introduction

Litter decomposition plays a major role in the carbon budget as well as for nutrient cycling in terrestrial ecosystems (Aerts, 1997; Chapin et al., 2002). Decomposition processes are mainly governed by the three factors (i) climate, (ii) leaf litter quality and (iii) the

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composition and activity of the decomposer community (Swift et al., 1979; Lavelle et al., 1993; Aerts, 1997). Thus, climate change is likely to alter litter decomposition, where changes in litter decomposition rates might severely affect soil quality along with carbon and nutrient cycling. As grassland biomes store up to 30% of soil carbon worldwide (Risch et al., 2007), effects of climatic change on decomposition in grasslands are of major interest. Positive feedback processes may intensify warming due to rising $CO_2$ levels (Bontti et al., 2009). Climate change not only means a gradual warming trend, but also increases intra-annual rainfall variability, causing longer dry periods and more intense heavy rain spells (Meehl et al., 2007). Moreover, within Central Europe, warming will be most pronounced during winter, during which the overall precipitation amount is also projected to increase (Christensen et al., 2007).

Changing climate is likely to alter decomposition processes through short term changes in soil moisture or temperature which directly affect soil biological processes, including microbial and soil community composition and activity (Hobbie, 1996; Aerts, 1997). Indirectly, climate change will alter decomposition through chemical changes of litter within single plants as well as through shifts in plant species composition (Hobbie, 1996; Aerts, 2006; Fortunel et al., 2009; Baptist et al., 2010; Osanai et al., 2012).

Reduced water availability or drought often have a negative affect on litter decomposition or soil respiration (Lensing and Wise, 2007; Risch et al., 2007; van Meeteren et al., 2008; Bontti et al., 2009; Joos et al., 2010), although these effects may be only short-termed (Kemp et al., 2003; O'Neill et al., 2003) or even non-existent (Kreyling et al., 2008). Constantly high water availability has also been shown to reduce decomposition (Tiemann and Billings, 2011; Lensing and Wise, 2007), whereas dry–wet cycles might increase decomposition (Xu et al., 2004; Miller et al., 2005). Warming has often been found to increase litter decomposition (Hobbie, 1996; van Meeteren et al., 2008; Kirwan and Blum, 2011) due to an increase in microbial and enzymatic activity (Chapin et al., 2002; Aerts, 2006; Allison and Treseder, 2011), although some studies suggest that this effect does not always occur (Giardina and Ryan, 2000; Risch et al., 2007). Furthermore, increased winter temperatures are likely to result in colder soil conditions due to a reduced layer of insulating snow (Hardy et al., 2001; Kreyling, 2010), which may even decrease decomposition. Thus, no consensus about the role of global warming on decomposition has yet emerged.

The few existing studies combining multiple climatic factors often found non-additive effects of the different factors. For instance, the combination of $CO_2$ enrichment and warming did not react in the same way as both factors alone on microbial biomass carbon (Andresen et al., 2010) or as temperature-dependence of decomposition depended on moisture-availability (Butenschoen et al., 2011). Thus, acceleration of decomposition caused by warming may be offset under drier conditions (Gavazov, 2010; Butenschoen et al., 2011).

Therefore, there is an urgent need to further study interactions between different climatic factors according to scenarios of future change, most importantly, the simultaneously occurring factors of warming and precipitation variability (Aerts, 2006; Butenschoen et al., 2011). Moreover, the impact of agricultural practise, such as frequency of cutting on decomposition needs to be addressed, as it may strongly alter decomposition, e.g. by changes in litter quality, due to reduced shoot–root ratio or higher nitrogen concentrations in younger leaves (Walter et al., 2012).

In order to study the combined effects of increased inter-annual rainfall variability with winter climate change scenarios and agricultural practise on decomposition, we conducted a litter bag experiment in a semi-natural grassland using different climate change scenarios and varying cutting frequencies. The grassland was subjected to summer drought followed by heavy rain pulses (extreme variability), regular irrigation (low variability) and to ambient rainfall (mid variability) in combination with winter warming, additional winter rain and two different cutting frequencies. We aimed to disentangle the causes for possible changes in decomposition, being either leaf chemical alterations or modifications in soil biotic activity, by testing decomposition in an in situ experiment as well as under standardized conditions.

Our hypotheses include:

(1) extreme rainfall variability including drought will reduce decomposition rates, whereas heavy rain pulses after drought will not have a long-term effect on decomposition
(2) more frequent cutting will stimulate decomposition, independent of summer rainfall variability, caused by more beneficial leaf chemistry, e.g. younger leaves with higher nitrogen content
(3) winter warming will increase decomposition, except for winter warming leading to a reduced layer of insulating snow and thus actually decreasing soil and surface temperatures
(4) additional winter rain will not affect decomposition as winters in Central Europe are already usually wet and decomposition should not be moisture-limited during this time

## 2. Material and methods

### 2.1. Study site and experimental setup

The study was conducted within the EVENT II experiment, which investigates the impact of inter-annual rainfall variability in combination with winter climate change and agricultural practise in temperate grasslands. The experiment was established in 2008 in a semi-natural grassland in the Ecological Botanical Garden of the University of Bayreuth, Germany, Central Europe (49°55′19″N, 11°34′55″E, 365 m asl) (Walter et al., 2012) and this study was conducted in 2010–2011, at the end of the third year of rainfall manipulations. Communities are dominated by tall grasses, especially *Alopecurus pratensis* L. (meadow foxtail) and *Arrhenatherum elatius* L. (tall oat grass). The regional climate is temperate and moderately continental.

The experimental design for this study consisted of five replications of three rainfall variability regimes applied in the vegetation periods in blocks 6 m × 4 m in size. For the manipulations of rainfall variability, the temporal distribution and the magnitude of rainfall per rainfall event in the growing season was altered, but annual rainfall amount has been constant since 2009 by applying compensation irrigations. A change of rainfall patterns, most notably an increase in the severity of drought and in the frequency of heavy rain spells, is projected under climate change, also for Central Europe and Germany (Meehl et al., 2007; Jacob, 2009). The three rainfall variability regimes were: (1) low variability, with weekly irrigation corresponding to the 30 year average amount of the respective week, ensuring a continuous water supply (low), (2) mid variability, receiving ambient rainfall plus compensation irrigations (4 times per year) to keep the annual rainfall amount constant at quarterly intervals (mid) and (3) extreme variability, subjected to a summer drought treatment, followed by heavy rain pulses (extreme). For the low variability treatment, amounts from 1971 to 2000 served as a reference (data: Foken, 2003). Missing amounts on natural precipitation were added if the weekly precipitation was less than the long-term average for the same week to ensure continuous water availability. If weekly precipitation exceeded the long-term sum, it was not deducted from the next irrigation. From September 1st 2010