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ScienceDirect
Applied Soil Ecology 35 (2007) 523–534
Applied Soil Ecology
www.elsevier.com/locate/apsoil

Impact of changes in rainfall amounts predicted by climate-change models on decomposition in a deciduous forest

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Received 20 January 2006; received in revised form 29 September 2006; accepted 29 September 2006

Abstract

Climate-change models predict a more intense hydrological cycle, with both increased and decreased amounts of rainfall in areas covered with temperate deciduous forests. These changes could alter rates of litter decomposition, with consequences for rates of nutrient cycling in the forest ecosystem. To examine impacts of predicted changes in precipitation on the rate of decay of canopy leaves, we placed litterbags in replicated, fenced 14 m^2 low-rainfall and high-rainfall plots located under individual rainout shelters. Unfenced, open plots served as an ambient treatment. Litter in the high-rainfall and ambient plots decayed 50% and 78% faster, respectively, than litter in the low-rainfall plots. Litter in the ambient plots disappeared 20% faster than in the high-rainfall treatment, perhaps via greater leaching during heavy rainfall events. Ambient rainfall during the experiment was similar in total amount to the high-rainfall treatment, but was more variable in intensity and timing. We used litterbags of different mesh sizes to examine whether changes in rainfall might alter the impacts of major categories of the fauna on litter decay. However, we found no consistent evidence that excluding arthropods of different sizes affected litter decay rate within any of the three rainfall treatments. This research reveals that changes in rainfall predicted to occur with global climate change will likely strongly alter rates of litter decay in deciduous forests.

Keywords: Arthropods; Litterbags; Litter decay; Precipitation; Rainfall

1. Introduction

On a global scale, differences in annual precipitation and evapotranspiration explain about 71% of the variability in rates of litter mass loss (Dyer et al., 1990). Studies have demonstrated increased rates of decomposition with increased rainfall and decreased decomposition under drier conditions. This correlation has been demonstrated in temperate deciduous forests, tropical forests, and grasslands (Knutson, 1997; Singh et al., 1999; Austin and Vitousek, 2000; Austin, 2002; Epstein et al., 2002; Salamanca et al., 2003). Rainfall directly impacts litter breakdown in the initial stages of decomposition through leaching of soluble compounds (Swift et al., 1979; Couteaux et al., 1995). Tietema and Wessel (1994) found that leaching accounted for 21% of the mass loss of oak litter during the first 6 weeks of decomposition. Aspen leaves also exhibit rapid initial losses due to leaching (Parsons et al., 1990). In addition to the direct effect of precipitation via leaching, rainfall can also indirectly affect decomposition through direct impacts on the microbes and fauna (Meentemeyer, 1978; Orchard and Cook, 1983; Tietema and Wessel, 1994; Vanlauwe et al., 1995). Populations of primary decomposers, bacteria and fungi, as well as the

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0929-1393/$ – see front matter
doi:10.1016/j.apsoil.2006.09.015

arthropod fauna, may be affected by precipitation. Although many fungi are able to tolerate drought conditions, low moisture can inhibit fungal growth and/or activity (Griffen, 1963; Kouyeas, 1964; Orchard and Cook, 1983; Schnürer et al., 1986; Carlile et al., 2001). Prominent litter and soil arthropods such as Collembola, mites, centipedes, and spiders are sensitive to changes in moisture and tend to thrive under conditions of greater water availability (Rushton et al., 1987; Badejo et al., 1998; Frampton et al., 2000; Blackburn et al., 2002; Ferguson and Joly, 2002; Lindberg et al., 2002; Wiwatwitaya and Takeda, 2005).

Arthropods have been implicated as playing a role in litter decomposition and nutrient cycling (reviewed in Swift et al., 1979; Moore et al., 1988; Seastedt, 1984; Filser, 2002; Wardle, 2002). Many arthropod indirect effects on decomposition are mediated through direct effects on microbes. Indirect effects of mesofauna include selective grazing of fungi, inoculation of litter with fungal spores, supplying mineral nutrients to microbes through feces and urine, stimulation of bacteria, compensatory growth by fungi in response to grazing, and mycelial disruption shifting the competitive balance between fungi (Lussenhop, 1992). Low- and intermediate-level grazing of fungal hyphae by Collembola can increase fungal growth and accelerate decomposition. However, overgrazing of fungi can deplete fungal populations and decrease the rate of litter breakdown (van der Drift and Jansen, 1977; Hanlon and Anderson, 1979; Moore et al., 1988; Bengtsson et al., 1993). Macroinvertebrates also modify decomposition and microbial activity by physically altering the environment via aeration of soil, comminution of litter, and mixing of litter and soil (Maraun and Scheu, 1996). Studies have shown that isopods and millipedes contribute positively to litter mass loss (Maraun and Scheu, 1996; Irmler, 2000).

Many studies have found a positive relationship between arthropod presence and the rate of litter disappearance. Vossbrinck et al. (1979) found that ca. 30% of litter disappeared when exposed to mesofauna as opposed to ca. 15% of litter disappearing when exposed only to microbes. Likewise, Bradford et al. (2002) showed that meso- and macrofauna generally increased litter disappearance even though their presence had negative impacts on microfauna and microbes. González et al. (2003) demonstrated a negative correlation between mass remaining of aspen and lodgepole pine litter and abundance of soil macrofauna and litter microarthropods. Exclusion of invertebrates led to slowed rates of decomposition in three different habitats within a tropical forest (Vasconcelos and Laurance, 2005). Tian et al. (1992) found a positive correlation between decay rate and litterbag mesh size, and also found that nutrient release increased with increasing mesh size, suggesting that faunal presence enhanced nutrient mobilization.

Other studies demonstrate that the impacts of arthropods on litter disappearance are variable and can be weak or non-existent. Wise and Schaefer (1994) found that arthropod effects on decomposition depended on litter type. The meso- and macrofauna accelerated herb litter disappearance, had no impact on fresh beech leaves, and only the macrofauna increased decomposition of aged beech litter. Although finding consistent negative effects of arthropod exclusion, Vasconcelos and Laurance (2005) found that effects were stronger on litter from old-growth trees compared to litter from successional species. Hunter et al. (2003) found that excluding macroarthropods had no impact on decay of chestnut oak or rosebay rhododendron litter but led to slowed mass loss of yellow poplar litter. Studies have also shown that soil fauna have a larger impact on decomposition in humid tropical forests than in dry tropical forests, subalpine forests, or temperate sites (Heneghan et al., 1999; González and Seastedt, 2001). Cragg and Bardgett (2001) found that it is the specific arthropods present rather than the diversity of arthropods that impact litter decomposition. When they tested several Collembola assemblages, only those containing *Folsomia candida* led to greater mass loss. Still other studies show no impact of arthropods on litter disappearance. Seastedt et al. (1983) found that an increase in arthropod densities over a 2-year litter decomposition study in a temperate forest did not lead to any difference in rates of litter mass loss. In an agroecosystem, microarthropod exclusion negligibly reduced litter mass loss (Beare et al., 1992). Macauley (1975) and Takeda (1988) found no impact of the fauna on *Eucalyptus* litter decay or pine needle decomposition, respectively.

Thus, it is clear that changes in precipitation, microbes, arthropods, and litter quality affect rates of litter decomposition in a complex fashion, and that these factors likely interact with each other to produce variable effects. Coupled with the variability is the fact that climate-change models predict both increases and decreases in rainfall (Houghton, 1997; IPCC, 2001). Therefore, research on how varying rainfall will alter rates of decomposition in diverse systems is essential for predicting the impact of global climate change on this major ecosystem process. We designed a field experiment to determine the effect of low- and high-rainfall regimes on the rates of disappearance of oak and