Soil Biology & Biochemistry 110 (2017) 116–133

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Soil fauna responses to natural disturbances, invasive species, and global climate change: Current state of the science and a call to action

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ARTICLE INFO

Article history:
Received 1 February 2017
Received in revised form
10 March 2017
Accepted 15 March 2017
Available online 28 March 2017

Keywords:
Belowground
Biodiversity
Climate change
Ecosystem function
Invasive species
Invertebrate
Taxonomy

ABSTRACT

Environmental disturbances seem to be increasing in frequency and impact, yet we have little understanding of the belowground impacts of these events. Soil fauna, while widely acknowledged to be important drivers of biogeochemical function, soil structure and sustainability, and trophic interactions, are understudied compared to other belowground organisms such as archaea, bacteria, and fungi. In this review we summarize the current state of knowledge of soil fauna as it relates to and is influenced by various disturbances. We focus our review on three main natural and anthropogenic disturbance types: 1) natural disturbances, including damage from wind and flooding; 2) invasive species, including above and belowground flora and fauna; and 3) climate change impacts on the atmosphere and temperature. We do not address the impacts of wildfires, forestry, agricultural practices, mining, or human-caused pollution, as these topics have all been covered in other works. We highlight knowledge gaps and suggest future avenues of research, with hope that the importance of soil fauna and their influences on ecosystems will be given greater emphasis in future research.

1. Introduction

Natural disturbances such as wind, flood, drought, and fire have shaped ecosystems and organisms within the global biosphere for millennia, and their influence on the structure and function of ecosystems has long been recognized by ecologists. Indeed, some of the earliest ecological research addressed plant community succession in disturbed habitats (e.g., work in the late 1800s by Eugen Warming) (Coleman, 1986). More recently, ecologists have come to appreciate that anthropogenic disturbances also can shape ecosystem properties, and similar to natural disturbances, span a vast range of intensity, and spatial and temporal scales (Fig. 1). The Earth is currently experiencing an unprecedented period of anthropogenic disturbances, and climate models predict increased intensity and frequency of future natural disturbances (Dale et al., 2001; IPCC, 2014). Although the discipline of "Disturbance Ecology" is fairly well developed for plant community ecology, including treatment in several book-length syntheses, little effort has been made to synthesize soil responses to disturbances. Further, despite the documented importance of soil organisms on ecosystem functioning (Coleman et al., 2004; Fierer et al., 2007; Wall, 2012; Wardle et al., 2004; Zak et al., 2003), even less attention has been given to soil ecological responses. Here we present a focused review of soil fauna responses to major classes of natural and anthropogenic disturbances across global ecosystems. Due to the prevalence of microbially-focused scholarship in recent years (Fig. 2), we intentionally emphasize *fauna* and exclude discussion of soil microbial responses to disturbances. At the heart of this work is our position that an appreciation and deeper understanding of the relationships between disturbance processes, soil fauna, and ecological function are of critical importance to the future

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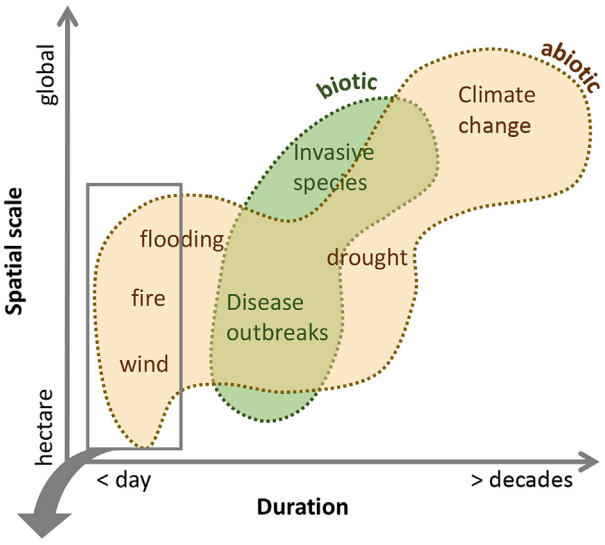
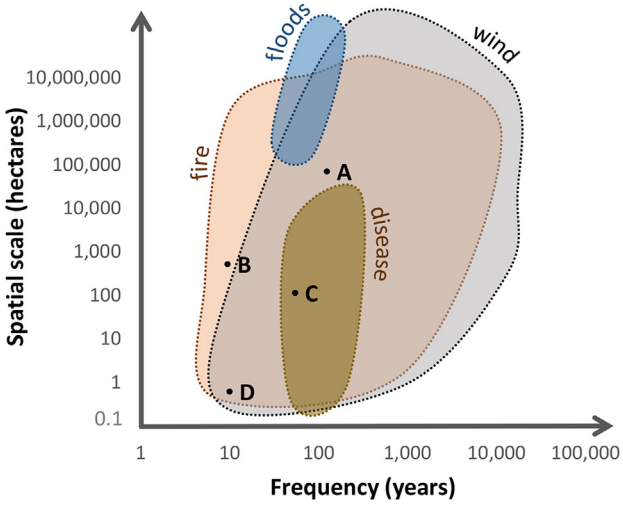
http://dx.doi.org/10.1016/j.soilbio.2017.03.008
0038-0717/



Abiotic and biotic disturbances alike span a large variety of spatial extents and temporal durations. For instance, global climate change could be called an abiotic anthropogenic disturbance that occurs over several decades. An outbreak of pine bark beetles, a naturally-occurring biotic disturbance, may affect a few hectares over a year.

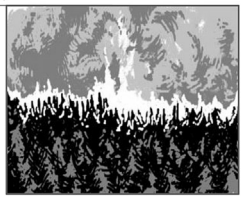


Discrete disturbances cause sudden, relatively abrupt instances of mortality. Disturbance size and intensity are generally positively correlated to frequency; the most extreme disturbance events tend to be rare. Most disturbance types include combinations of both anthropogenic and natural events.

Disturbance characteristics taken from the following published reviews of North American disturbance regimes: Foster et al. (1998), Greenberg and Collins (2015), Lorimer and White (2003), Seymour et al. (2002), and Sousa (1984).

A – Stand-replacing fire (Natural)

Before anthropogenic fire suppression, hardwood forests in northern Minnesota experienced severe surface and crown fires every ~100 years which burned 400 to 4000 ha at a time.

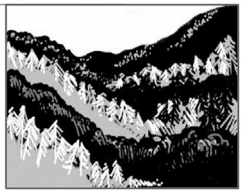


B – Surface fire (Anthropogenic)

Prescribed fires help maintain fire-adapted ecosystems (e.g. longleaf pine forests). Due to habitat fragmentation and fire suppression, humans now simulate a historic fire regime of low-intensity surface burns every 2-10 years.

C – Emerald ash borer (Anthropogenic)

Native and invasive pests can cause widespread tree mortality. The emerald ash borer (*Agrilus planipennis*), an invasive beetle, currently threatens urban and rural ash (*Fraxinus* spp.) populations throughout North America.



D – Small canopy gaps (Natural)

In Appalachian cove forests, disturbances are mainly single-tree mortality events from disease, lightning-strike, or wind. Gaps average 31 m^2, with a return interval of 50 to 100 years.

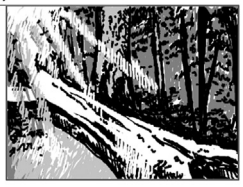


Fig. 1. Disturbance types, scales, and their interactions as they pertain to and impact soil fauna. Disturbance characteristics taken from the following published reviews of North American disturbance regimes: Foster et al. (1998), Greenberg and Collins (2015), Lorimer and White (2003), Seymour et al. (2002), and Sousa (1984).