Chapter 1
Disturbance Ecology: A Guideline

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Abstract The guideline contextualizes the field of disturbance ecology over time and space. It addresses fundamental elements of disturbance ecology, such as drivers of disturbances, adaptations of plants to disturbance, disturbance effects on biodiversity, disturbance resilience, disturbances in the context of ecosystem management, and climate change impacts on disturbance regimes. The chapter introduces the structure of the book and highlights the audience for which the book was written.

Keywords Biodiversity · Climate change · Conservation · Disturbance regimes · Ecosystems · Land use · Landscape ecology · Management

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1.1 Disturbances in Community Ecology and Ecosystem Dynamics

Disturbance ecology originated from vegetation science and quantitative landscape ecology, both fields that have a rich history. Vegetation science and its broader relative, geobotany (broadly, the biogeographical study of plants),[1] have dealt with the systematic sequence or succession of plant communities (Kratochwil and Schwabe 2001), creating overviews and characterizing vegetation units (e.g. Braun-Blanquet 1964; Ellenberg 1996). For a long time, the focus of research was on the ecological equilibrium of individual plant communities in given locations, especially in Central Europe. Today, many disciplines build on this past work in order to investigate the reactions of ecosystems and especially of plant communities to environmental change. The comprehensive study of ecosystems – from individuals to plant communities and vegetation landscapes – has generated new insights: that plant communities are dynamic systems, that they vary greatly in space (Sousa 1984), and that recurring patterns of temporal sequences occur during succession (Clements 1916; Watt 1947; Gurevich et al. 2006; Walker and Wardle 2014). Signs of previous interruptions of vegetation succession, such as fire scars or standing deadwood, indicate transient resource changes (Davis et al. 2000) and the alteration of undisturbed successional patterns. Thus, these signs provide evidence of a deviation from the ecological equilibrium – that is, they indicate a perturbation/disturbance (Odum et al. 1979).

In North America, the classical and static view of vegetation types was abandoned in the 1970s and 1980s, with a dynamic perspective of plant communities in the landscape – including disturbances – taking hold (Chap. 2). Synthesis work by Levin and Paine (1974), White (1979), and White and Pickett (1985) on the importance of disturbances for vegetation dynamics set the foundation for this new, dynamic perspective of vegetation. Also in the 1970s, groundbreaking studies on the interaction of species richness and disturbance were published (Grime 1973; Connell 1978). In the following decades, disturbance was a major focus of ecological research in the English-speaking world and was increasingly reflected also among vegetation ecologists across all continents (Fig. 1.1).

How did the field of 'disturbance ecology' develop in Central Europe? Impacts of disturbance are already implied in phytosociology (e.g. Braun-Blanquet 1964; Ellenberg 1996), a school of thought that was dominant in Europe for much of the second half of the twentieth century. In this approach, traces of disturbance are detectable in units and specific terms, for example, the interruption of succession leading to 'secondary succession', and the 'permanent communities' that result as a consequence of repeated disturbances. Nonetheless, these aspects have rarely been

[1] In the past, there has been some difference in the terms used between the European literature and the Anglo-American literature. In Europe, floristic geobotany was the term often used for the branch of biogeography concerned with the distribution of plant species. The equivalent term in the Anglo-American literature was phytogeography (Mueller-Dombois and Ellenberg 1974).

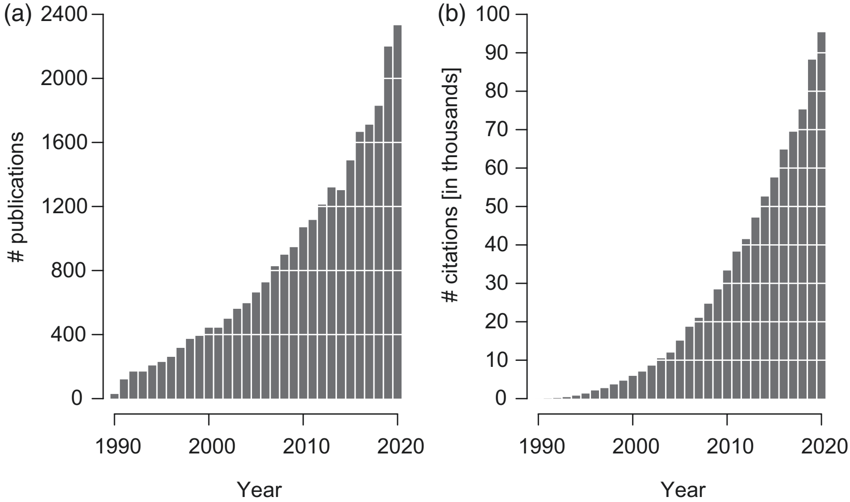

Fig. 1.1 Number of scientific publications per year containing the search terms 'disturb*' and 'ecol*', from 1990 to 2020 (**a**), and the annual number of citations to these publications (**b**). (Data retrieved from the Web of Science (WOS) on 17.03.2021)

the subject of in-depth studies in Europe as the main interest of research has been focused on plant communities that are 'stable' in their species composition and are thus in an equilibrium. In Europe, the broad scientific discussion of disturbances began much later than in the 'Anglo-American' world. This may be because in the 1970s phytosociology was still a dominant paradigm in many places, and its findings were increasingly applied in the field of nature conservation. The terms *perturbation* and *disturbance* (White 1979) were not yet established in Europe in the 1990s, and the German-language equivalent *Störung*, which often has negative connotations, was hardly used, for example, in forestry. As any kind of management intervention can be understood as an abrupt and spatially discrete event of tree mortality (see Chap. 14), the concept behind the word even generated strong opposition in some communities, which persist to this day. However, the term *disturbance* has increasingly been established in ecosystem research also in Central Europe (White and Jentsch 2001). Its significance has increased considerably over the past decades, both because of an increased relevance of disturbance processes and also because of substantial advances in research. This is also reflected in a widespread change in conservation paradigms towards protecting natural processes rather than individual species or communities (e.g. Scherzinger 1996; Müller 2015).

Disturbances occur in all plant communities (see Chap. 2) and contribute significantly to the spatial and temporal heterogeneity of ecosystems that enables many species to coexist (see Chap. 4). For several decades research has been conducted on the stability of ecosystems, which led to the concept of ecological resilience, that is, the ability of disturbed ecosystems to retain their functions and structures in the face of disturbance (see Chap. 5). In response to regularly occurring disturbances, organisms have also developed physiological and morphological adaptations (see Chap. 6).

Forests in Europe are exposed to abiotic disturbances such as fire (see Chap. 7), wind (see Chap. 8), and, in mountainous areas, avalanches (see Chap. 9). Biotic disturbances in these ecosystems are often triggered by extreme climatic events (e.g. dry-hot weather) or succeed previous disturbances (interaction) (e.g. bark beetle outbreaks after windthrow). Also plant diseases (see Chap. 10) cause disturbance, as do phytophagous insects (see Chap. 11) and especially bark beetles (see Chap. 12). These all contribute to the heterogeneity of the affected ecosystems. Large herbivores (i.e. animals with a bodyweight of ≥50 kg) shape the vegetation to different extents depending on their population size (see Chap. 13).

By far the largest influence on the current vegetation in Europe is exerted by humans. Practically all forests in Europe have been transformed in their structure and species composition during centuries or even millennia of multiple uses (see Chap. 14). Furthermore, grassland management (see Chap. 15) is exercised on a large part of the unforested areas. In other words, most of the current vegetation in Central Europe is a direct result of current and historical disturbance regimes (see Chap. 3), made up of both natural and anthropogenic disturbance agents.

1.2 Modern Disturbance Research

Abrupt changes in environmental conditions have developed into a key object of investigation in ecology since the 1980s (Johnson and Miyanishi 2007). An important approach in dynamic vegetation modelling uses disturbance-caused gaps (Churchill and Hansen 1958; Forcier 1975; Glenn-Lewin and van der Maarel 1992) as a starting point for forest development (Kienast and Kuhn 1989; Bugmann 1996). Newer model types increasingly integrate disturbances as an important element of system dynamics (Seidl et al. 2011; see Box 17.1, Chap. 17). Biodiversity research has identified numerous findings on the influence of disturbances on species communities (e.g. Thom and Seidl 2016; Thorn et al. 2018; see Chap. 4). A broad and important topic is the role of disturbances in the long-term maintenance of ecosystem heterogeneity, and thus the importance of disturbance for the conservation of biodiversity (Kulakowski et al. 2017). In turn, high levels of biodiversity increase the resistance to disturbances, especially to extreme climatic events such as prolonged drought as well as early and late frost (Isbell et al. 2015; see Chap. 6). This connects to topics of functional diversity (e.g. Hector et al. 2010; Ratcliffe et al. 2017), which provide the basis for experimental disturbance ecology, investigating, for example, the influence of weather extremes and land-use changes on ecosystem functions (Jentsch et al. 2007).

1.3 Disturbance Regimes Are Changing

The biomes of the world are characterized by typical disturbance regimes, shaped by both the prevailing climate and land uses (see Chap. 2). These regimes are currently undergoing significant change. Climate change is expected to shift disturbance regimes and extreme events (IPCC 2021), for example, with changes in the seasonality of precipitation, an increase of heavy rainfall events, and higher frequencies of strong winds expected for the future. Also, higher temperatures generally lead to a greater risk of wildfires and an increasing insect activity (see Chap. 16). Along with the changing climate, land use is also changing in manifold ways as societies adapt to the new environmental conditions (Shukla et al. 2020). Furthermore, global markets and political decisions trigger land-use changes and thus changes in the disturbance regimes, for example, in Europe (e.g. the bio-economy strategy of the EU; European Commission 2017).

Changing disturbances in space and time also pose risks for ecosystem management (see Chap. 17). Compared with the situation decades or centuries ago, the current demands for ecosystem services by society are quite diverse, which is mirrored by the growing public awareness since the Rio Convention on Biological Diversity (UN 1992). Quantifying these ecosystems services (Hassan et al. 2005; see Chap. 18) and assessing how changing disturbance regimes affect or constrain these services is an important task for research.

1.4 Who Is This Book For?

The 18 chapters of this textbook provide a broad overview of disturbance-related research results from various disciplines, with a focus on Central Europe. A total of 31 experts from universities and research institutions in predominantly German-speaking countries contributed to this textbook and ensure that the broad and diverse aspects of disturbance ecology are addressed. A previous version of this book was published in German in 2019 and was the first textbook on the subject of disturbance ecology in German. Numerous requests for an English translation demonstrated the broad interest in the book from colleagues in other parts of Europe and the world. This English version is addressed to students, researchers, and practitioners from around the world who are interested in a Central European perspective on disturbance ecology. The current book is a direct translation of the German version and not a second edition; nevertheless, some references have been updated and minor corrections were made in the course of the translation. We hope that this book is not only of interest to colleagues working on issues of disturbance ecology, but that it is also able to excite colleagues that are new to the field of disturbance ecology. Ultimately, we want to share our fascination for disturbance dynamics and hope to inspire readers to dive into the mesmerizing world of disturbances in nature.

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