


Editorial

# Natural Disturbance Dynamics Analysis for Ecosystem-Based Management—FORDISMAN

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**Abstract:** Forest ecosystems are shaped by disturbances and functional features of vegetation recovery after disturbances. There is considerable variation in basic disturbance characteristics, magnitude, severity, and intensity. Disturbance legacies provide possible explanations for ecosystem resilience. The impact (length and strength) of the pool of ecosystem legacies and how they vary at different spatial and temporal scales is a most promising line of further research. Analyses of successional trajectories, ecosystem memory, and novel ecosystems are required to improve modelling in support of forests. There is growing evidence that managing ecosystem legacies can act as a driver in adaptive management to achieve goals in forestry. Managers can adapt to climate change and new conditions through anticipatory or transformational strategies of ecosystem management. The papers presented in this Special Issue covers a wide range of topics, including the impact of herbivores, wind, and anthropogenic factors, on ecosystem resilience.

**Keywords:** disturbance ecology; ecosystem legacy; resilience

Disturbances drive forest dynamics in the boreal and temperate regions of Earth [1,2]. Climate change has altered historic disturbance patterns, and the direct and indirect effects of altered climate pose an increasingly uncertain future for forest ecosystems [3,4]. Adding to the uncertainty are two important elements: to what extent are in situ forest ecosystems the outcome of management activities, in terms of altered structure and composition [5,6]? Have altered disturbance regimes resulted in a novel ecosystem [7–9]? Addressing these questions brings to the fore the urgent need to better understand relationships between passively and actively managed forest ecosystems in the face of new climatic conditions with shifts in land use and social expectations.

Ecosystem resilience is a desired ecological property to be embedded in natural resource management systems [10]. Resilience is often described as the resistance of an ecosystem to stress and disturbance, or its capacity to recover to a predisturbance stable state and functioning [11]. Ecosystem management as a relatively new forest management paradigm has set the goal of resilience of the ecosystem to future disturbances by focusing on sustainability and what remains after resource extraction [12–16].

Knowledge of basic patterns of vegetation dynamics can be employed in management after severe disturbances or land use change to direct the ecosystem toward a desired condition. Incorporating resilience into management requires maintaining or creating adaptation mechanisms that shape the recovery trajectory and that result in desirable patterns of ecosystems and landscapes. There is growing evidence that managing ecosystem legacies can act as a driver to achieve goals in forestry [17–19]. Ecosystem legacies are remnants of previous conditions persisting after disturbances [10,20,21] and subsume the varied concepts of biological [22], ecological [23], disturbance [24], soil [25], and land use legacies [26].

The impact (length and strength) of the pool of ecosystem legacies and how they vary at different spatial and temporal scales is a most promising line of further research. In particular, the investigation of how the carbon cycle is directed by legacies is crucial to understanding climate change impacts. Analyses of successional trajectories, ecosystem memory, and novel ecosystems are required to improve modelling in support of forests.

Predictions related to a changing disturbance regime can be derived from legacy functions in the course of recovery of an ecosystem. The potential to support forest resilience to future disturbances can be enhanced by managing the biological components of ecosystem legacies [11,27,28]. For example, refuge areas in managed forest are suggested as mitigation to harmful effects of timber harvest or salvage [17,29].

Often research aims to account for forest ecosystem dynamics resulting from past disturbances. Ecosystem resilience patterns depend on the magnitude of human impact. The nature of disturbances and ecosystem memory (the pool of ecosystem legacies) can be characterized as legacy syndromes, characteristic grouping of legacies that result from differential patterns of editing of legacy elements, which typically can be arranged along a gradient of naturalness [20,21]. For example, forest succession after land use change relies on ecosystem memory, rendering highly varying pathways of vegetation dynamics [26].

Ecosystem resilience is an emerging hotspot of academic discussion; research questions that emerge include the following: Does traditional forest management ensure the resilience (resistance and recovery) of forests with anticipated climate change? Does naturalness of the ecosystem predetermine which legacy syndromes may have resilient patterns? These questions must be addressed in multitudinous specific socio-ecological contexts. Modelling provides methods for depicting ecosystem legacy syndromes and resilience to disturbances and may provide a key to begin to answer these intriguing questions.

Ecosystem restoration has gained international policy importance; the United Nations has declared that 2020 marks the beginning of the Decade of Ecosystem Restoration [30]. Restoration decisions should incorporate a vision of the desired future landscape that resonates with all stakeholders and utilizes the best available science [31]. In addition to the estimated 2 billion hectares of degraded land in need of restoration [32,33], climate change will increase the need for restoration. The unprecedented alteration of the natural environment by humans has raised the specter that planetary boundaries of sustainability have been breached—that we have gone outside safe operating space [34,35]. These concepts of maintaining ecosystem legacies and staying within safe operating space can inform management and explain the continuity of ecosystems over time amidst changes [23,36,37].

The ability to maintain or restore forest ecosystems to historic conditions will depend on the time-course of change driven by altered climate and societal responses, i.e., global change [38]. The nonequilibrium nature of forest dynamics sets the conceptual frame for resilience with novel boundaries [39] and the emergence of novel ecosystems [8,9,40]. Managers can adapt to new conditions through anticipatory or transformational strategies [1,41–43]. Such an approach offers the opportunity for reconciling complex systems with traditional scenario analysis [44].

This Special Issue of the journal *Forests* appears under the title “Natural Disturbance Dynamics Analysis for Ecosystem-Based Management”, which is the official name of the network abbreviated by the acronym FORDISMAN. New and old members of the FORDISMAN have exposed their work on various topics in field of forest research. This group of forest researchers from the Baltic and Nordic

Countries met in August 2002 in order to draft a proposal to the Nordic Forest Research Committee (SNS) for network funding. This meeting on Hiiumaa Island, Estonia was the start of the FORDISMAN network that has been active for almost two decades. The network has focused on one essential topic: the impact of natural disturbances on the forests of the region.

Originally, the network excluded anthropogenic disturbances from the array of research questions. It soon became obvious, however, that a long history of continuous forest management in the region has imprinted the forests with signs of human interventions [20,45,46]. Thus, the impact of natural disturbances on forest ecosystems is conditioned by management influences from the past, and they are inseparable in the condition of contemporary vegetation. Since 2011, a shift has occurred in the scientific interests of the group. More attention has been paid to the legacy components of forest ecosystems [21].

A milestone of this research community was a conference in 2014 on “Forest Landscape Mosaics: Disturbance, Restoration, and Management at Times of Global Change” held in Tartu, Estonia [47]. Particularly, the elaboration of theories on land use change and restoration potential was approached in the course of the conference. The role of ecosystem legacies in the course of dynamic processes of forest biomes was a prominent topic, suggesting that a thorough analysis was needed before implementing new silvicultural techniques. An essential feature was the gradient of ecosystem legacy assemblages, constituting ecosystem memory, which represents an ecological array of anthropogenic and natural disturbance patterns. These legacy syndromes, in which ecological memory is impacted by management activity, were suggested as a platform for designing ecosystem management in the future.

Network activities have produced many publications, Special Issues, and book chapters. Among many aspects studied in the frame of this network are questions of plant communities [48,49] together with impact of large herbivores [50]; they set the demarcation lines for the range of research interests. The activities of the FORDISMAN network are chronicled in preface chapters to past Special Issues [47,51]. The objective of this Special Issue is to contribute to the untangling of successional patterns and the driving forces of disturbances dynamics. To this end, scientists were solicited to share their cutting-edge research in ecosystem approaches to forest management.

The research reports of this Special Issue address the question of reintroducing big herbivores [52], and their direct impacts on trees [53,54]. The dynamics of coarse woody debris in hemiboreal hardwood forest is not well studied: Senhofa and coauthors [55] have addressed this topic using birch stands of different ages. Strong human impact is considered in studies of forest genetic composition [56], drained wetlands [57], and carbon fluxes after timber harvest [58]. Additionally, advance regeneration as an important legacy component is analyzed by Luguza et al. [59]. Economic aspects of windthrow are analyzed in [60].

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