Journal of Forest Economics 32 (2018) 42–71

Contents lists available at ScienceDirect

Journal of Forest Economics

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

# Economic analysis of natural forest disturbances: A century of research

Claire Montagné-Huck, Marielle Brunette*

*Université de Lorraine, AgroParisTech, INRA, BETA, 54000, Nancy, France*

ARTICLE INFO

*JEL classification:*
Q23
Q54

*Keywords:*
forest
economics
risk
natural disturbance
hazard

ABSTRACT

Natural disturbances have always affected forest ecosystems, altering or disrupting the flows of goods and services provided by forests. In response, people have had to adapt their economic activities and decisions to take such hazards into account and to limit their consequences. In this paper, we conduct a survey on how economic analysis deals with such an issue, considering the different natural hazards affecting forests. Our database (described in and publicly available from Data in Brief website Montagné-Huck and Brunette (2018)) includes 340 papers collected from 1916 to 2014. This literature review allows synthesizing the existing knowledge, characterizing forest disturbances and identifying gaps in the literature.

## Introduction

Natural disturbances are an important part of ecosystem health and functioning, and under normal circumstances in healthy surroundings, disturbances are an integral part of nature. However, catastrophic events can severely affect environmental functions (biodiversity; global, regional and local weather conditions and climate; carbon sinks) and nature-related human activities (livelihood and living conditions, raw material and food provision). For example, in 1997–1998 in Roraima, Brazil, wildfires following the El Niño phenomenon destroyed nearly 80% of the state's staple crops (Cochrane and Barber, 2009). In France, in 1999, windstorms Lothar and Martin devastated some 176 million $m^3$ of timber, equivalent to three times the French annual wood harvest (Gardiner et al., 2013). In North America, studies found that insect pests and diseases may affect large forest areas, with almost fifty times as much forest destroyed as that which is burned annually (Dale et al., 2001; Logan et al., 2003).

The understanding of such phenomena is essential to safeguard forest ecosystems and the related production of goods and services, and to avoid severe negative impacts on environment and human livelihoods. For many decades now, the scientific community has worked to increase our understanding of causes, mechanisms and ecological consequences of natural disturbances. Economists for their part, has developed and used economic methodologies and instruments to assess impacts of natural disturbances on nature related economic activities and has found ways to adapt and change behaviors to avoid or reduce the economic consequences of such phenomena.

Consequently, the objective of this paper is – at least – threefold. First, we summarize the topics that have been studied related to the economics of forest disturbances in order to have an integrated vision of the issue and to provide the reader with a rapid overview of and main bibliographic references about natural disturbances affecting forest ecosystems. Second, we fully characterize forest disturbances (definition, impact, response, etc.) and we provide definitions of related concepts (risk, vulnerability, etc.) in order to provide a common frame to address forest natural disturbances from an economic perspective. Finally, we synthetize how economic analysis understands and deals with such a topic from almost a century, in order to identify gaps in the literature and potential future research directions.

For that purpose, a review of the literature in the field of economic analysis of forest natural disturbances is presented and an extensive list of bibliographic references is provided. We collected some 340 articles based on an economic approach and classified them according to the natural disturbance that they focus on: wildfire, pests, pathogens, storms, damage due to wildlife, and ice and snow, allowing us to provide a precise characterization of each hazard. We identified several main messages. We show that most of the economic literature about forest natural disturbances published in the last century focused on wildfire in North America. More precisely on the responses to wildfire, while some disturbances like drought are not tackled, and a continent like Africa is quasi absent from the sample. We also observe that although several papers analyze the forest owner's decision-making from a microeconomic point of view, very few explicitly take into consideration the preferences of the owner (perception of risk, attitude towards risk and uncertainty, time preferences, etc.). Another interesting point is that very few papers analyze multiple hazards, and when they do, they assume that the occurrence of one hazard is independent

* Corresponding author.
*E-mail addresses:* claire.montagne-huck@inra.fr (C. Montagné-Huck), marielle.brunette@inra.fr (M. Brunette).

https://doi.org/10.1016/j.jfe.2018.03.002
Received 19 June 2017; Received in revised form 23 March 2018; Accepted 29 March 2018

from the occurrence of the others. Finally, we conclude with the fact that natural hazards in forest cannot reasonably be analyzed independently from climate change.

The paper is organized as follows. The second section clarifies main concepts and definitions and explains the methodology and materials used to find and select relevant papers. General results are presented in Section Results and classified according to several categories: disturbance studied, temporal and geographical distribution, type of research, etc. Sections Analysis and Discussion analyze and discuss our findings, respectively. Section Conclusion concludes.

## Materials and methods

### *Scope and definitions*

#### *From natural disturbances to risk analysis*

In the field of natural disturbances, multiple definitions and different conceptual frameworks exist because different groups (academic community from various disciplines, governments, statistical offices, risk/disaster management agencies, development and cooperation agencies, climatic change organizations, etc.) have different views and adopt different vocabulary and paradigms on the subject. Most of them have been extensively discussed (see for example van Westen et al., 2014). This section aims at identifying and clarifying relevant concepts for the economic analysis of forest natural disturbances and claims that common understanding and framing of precise and meaningful terminology have to be reached. The use, promotion and updating of collaborative tools such as the UNISDR Terminology on Disaster Risk Reduction seems to be an interesting step towards this end. Faced by this myriad of definitions and involved agencies and organizations, it is quite difficult to find robust global scale data illustrating the field of forest natural disturbances.

A forest disturbance is defined by the FAO as a "*Damage caused by any factor (biotic or abiotic) that adversely affects the vigor and productivity of the forest and which is not a direct result of human activities*" (FAO, 2010).

Biotic forest disturbances are linked to the propagation, growth and spread of biological organisms, which depend on forest resources to complete their life cycle. Such biotic disturbances may result from pests (herbivore insect species that eat plants and trees), invasive plants, diseases attributable to pathogens (such as bacteria, fungi, bacteria, phytoplasma, viruses and nematodes), or other biotic agents (such as wildlife browsing, grazing, physical damage caused by animals, etc.). Abiotic disturbances are the result of energy sources outside of the forest. They include climatic (snow, storm, drought) as well as geological (landslides, earthquakes, volcanic eruptions, etc.) disturbances. Wildfires are generally considered as a combination of both biotic and abiotic forest disturbances since their propagation depends on forest resources and host material availability and their extent and spread are limited by weather and climatic conditions (Holmes et al., 2008).

Natural disturbances can be characterized by their type, magnitude or intensity, speed of onset, duration, and area of extent (Turner et al., 1998). Such variables and the consequential damages of natural disturbances are generally driven by forest composition, structure and management; and by other environmental conditions such as weather and climate. There is a continuum of forest damages following a natural disturbance event, ranging from the breaking of branches or death of single trees to total ecosystem and landscape destruction. Thus, above a certain threshold for these variables ("normal range of variation"), consequences can be catastrophic and traumatic both for the natural surroundings and for the people concerned, and natural disturbances can become natural disasters (Dajoz, 2000; Schowalter, 2012). However, natural disturbances remains a natural and integral part of forest ecosystem functioning and generate various negative but also positive impacts on forests. Furthermore, disturbances interact with each other, adding to the complexity of forest dynamics.

Despites the evident complexity of the field, Table A1 (Part A – Biotic disturbances, Part B – Abiotic disturbances, Part C – Potential combination of Biotic and Abiotic disturbances) in Appendix A, built from environmental, ecological, silvicultural and forest management literature try to summarize some general statements about physical processes, main characteristics and relative comparisons across some principal natural disturbances. Of course such classifications and generalizations could be debatable and most of the features presented here need to be qualified, particularly as regards the local context and the set of relative disturbances under consideration. More details and comprehensive appraisal of natural disturbances dynamics and ecological modelling could be found in Kondratyev et al. (2006), Moore and Allard (2011), Seidl et al. (2011), van Lierop et al. (2015), Schmidt-Thomé (2006), for examples.

From an economist's point of view, a forest disturbance can be defined as "*an event that interrupts or impedes the flow of* [market or non-market] *goods and services provided by forest ecosystems that are desired by people*" (Holmes et al., 2008). This means that for stakeholders, forest disturbances are sources of economic risk that can be translated into lower incomes and/or higher expenditures than expected. This risk can be defined as "*the probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril, over a specified time period*" (Schneiderbauer and Ehrlich, 2004); or more generally as "*the combination of the probability of an event* [–hazard] *and its negative consequences*" (ISDR, 2009). Thus, as indicated in Fig. 1 below, risk combines three components: hazard, vulnerability and element-at-risk (Crichton, 1999; van Westen et al., 2014).

Hazard is defined as "*A potentially damaging* [–dangerous] *physical event, phenomenon and/or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation"* (Schneiderbauer and Ehrlich, 2004; ISDR, 2009). Hazards are defined purely by physical and biological attributes. They are characterized by features such as: origin (natural, technological, man-made or social), location, rate of spread, time, intensity and frequency and could be summarized by a probability of hazard scenario. Hazards can be single, sequential or combined in their origins and effects. At this time, a generally accepted definition of multi-hazard does not exist in risk management. The term is commonly used to refer to "*all relevant hazards that are present in a specific area*" and the terminology used when referring to more than one hazard is wide and sometimes unclear, are encountered for example: interactions, chains, cascades, dominos effects, compound hazard, coupled events, etc. (van Westen et al., 2014). The most precise approach for this issue of multiple hazards is probably the one due to ecological sciences that differentiate "disturbance event" (i.e., a single event on a territory) and "disturbance regime" (i.e., a temporal sequencing of events on a territory).

Such hazardous events are potentially harmful to people, property, infrastructures, economy, activities, but also to the environment, which are all grouped into the term "elements-at-risk". Elements-at-risk are characterized by their type, temporal variation, spatial location and other intrinsic characteristics, which considered together, define its proper vulnerability. Vulnerability is defined as "*the characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made disaster*" (Schneiderbauer and Ehrlich, 2004) or in brief as "*the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard*" (ISDR, 2009). It characterizes the sensitivity of an asset to a given hazard and arises from various physical, social, economic, and environmental factors. This concept also encompasses several aspects of assets' resilience, mitigation, and coping capacity that contribute to increase (or decrease) the susceptibility of a community to the impacts of hazards and to turn hazards into disasters. Some uncertainties (imperfect and/or unknown information on natural disaster occurrence or consequences) and subjective features related to the personal perception of risks (Fig. 1[1]) must be added to these three major components of risk.

[1] The simplest representation of risk is a multiplicative functional form of natural hazard, vulnerability and element-at-risk; however, in some cases other functional forms may offer a more accurate representation of risk (Schneiderbauer and Ehrlich, 2004).