Forest Ecology and Management 361 (2016) 194–207

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Review and synthesis

Trends in post-disturbance recovery rates of Canada's forests following wildfire and harvest

Samuel F. Bartels [a,1], Han Y.H. Chen [a], Michael A. Wulder [b,*], Joanne C. White [b]

[a] Faculty of Natural Resources Management, Lakehead University, 955 Oliver Road, Thunder Bay, ON P7A 5E1, Canada
[b] Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5, Canada

ARTICLE INFO

Article history:
Received 20 July 2015
Received in revised form 6 November 2015
Accepted 7 November 2015
Available online 21 November 2015

Keywords:
Forest
Disturbance
Recovery
Regeneration
Boreal
Canada
Remote sensing
Landsat

ABSTRACT

The recovery of forests following stand-replacing disturbance is of widespread interest; however, there is both a lack of definitional clarity for the term "recovery" and a dearth of empirical data on the rates of forest recovery associated with different disturbance types. We conducted a quantitative review of literature to determine recovery times following wildfire and timber harvest and to evaluate variation in recovery rates across Canada's diverse forest ecosystems. Recovery was assessed according to the rate of change associated with certain forest structural attributes that have traditionally been used as indicators of forest growth and productivity. The recovery of forest canopy cover, tree height, and stand basal area varied at rates that depended on disturbance type, forest biome, and ecozone. We found that, on average, it took 5–10 years, depending on factors such as location and species, for most forest ecosystems of Canada to attain a benchmark canopy cover of 10% after wildfire or harvest. Similarly, regenerating stands in Canada's boreal forests were capable of attaining average heights of 5 m within five to ten years after wildfire or harvest. Stands in the Boreal Plains ecozone post-harvest reached stand basal area, benchmarked at 10 m^2 ha^{-1}, faster than those in the Boreal Shield, attributable to differences in tree species composition and the rich mineral deposits of the Boreal Plains. Overall, recovery of canopy cover, tree height, and stand basal area was similar or more rapid following wildfire than harvest. Our review provides temporal benchmarks for gauging recovery times after disturbance. Building upon these temporal benchmarks, and conditioned by disturbance type, site conditions, and location, we present opportunities for using dense time series of remotely sensed data to inform on regional and national trends in forest recovery following disturbance.

Contents

* Corresponding author.
E-mail address: mike.wulder@canada.ca (M.A. Wulder).
[1] Current address: Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2H1, Canada.

http://dx.doi.org/10.1016/j.foreco.2015.11.015
0378-1127/Crown Copyright © 2015 Published by Elsevier B.V.

1. Introduction

Canada's forests are recognized globally for the important ecosystem services that they provide; however, these forests are dynamic in nature and subject to a wide range of natural and anthropogenic disturbances that vary in severity, extent, and frequency (Bergeron et al., 2001; Stocks et al., 2002; Boucher et al., 2009; Brandt et al., 2013). Disturbances such as wildfire and timber harvesting can directly impact forest structure and composition (Lavoie and Sirois, 1998; Brassard et al., 2008; Fleming et al., 2014), and indirectly impact soil properties (Certini, 2005), thereby altering ecosystem productivity and function. The ongoing nature of disturbances to Canada's forests (Brandt et al., 2013), combined with uncertainty related to climate change (Price et al., 2013), necessitates an improved understanding of forest dynamics and increasingly sophisticated and flexible management practices (Bergeron et al., 2004; Burton et al., 2006). Despite advances in knowledge and management practices, uncertainty remains in the rates of forest recovery associated with different disturbance types across the range of forest ecosystem conditions in Canada (Sturtevant et al., 2014). Forest recovery can also be understood from different perspectives, for instance silvicultural and ecological, with different assessment criteria and definitions present as a result.

Disturbances are relatively discrete events that disrupt the forest ecosystem and cause a change in the physical structure of vegetation, soil substrate, and resource availability (White and Pickett, 1985; Clark, 1990). Although disturbed forests will recover if left long enough, of interest is the extent and rate at which forests will return to pre-disturbance condition. Early studies of post-disturbance recovery in Canada's forests have largely focused on general descriptions of successional sequence (Black and Bliss, 1978; Bergeron and Dubuc, 1989), recovery of net primary production (Amiro et al., 2000), and advance regeneration (Gradowski et al., 2010; Spence and MacLean, 2012; Veilleux-Nolin and Payette, 2012). While these and other studies (Johnson, 1996; Greene et al., 1999; Chen and Popadiouk, 2002) have contributed to an increased understanding of post-disturbance stand dynamics, there remains a paucity of quantitative information and synthesis on rates of forest regrowth and the factors that influence the forest recovery process.

The nature and rate of forest recovery may depend on several factors relating to the nature and severity of disturbance, presence of biological legacies, and inherent productivity of the site (Johnson, 1996; Franklin et al., 2002; Chen et al., 2009; Ilisson and Chen, 2009a). Different disturbances contrast markedly in terms of biological legacies (Franklin et al., 2007), and forests faced with repeated perturbations tend to be less resilient (Payette and Delwaide, 2003). Rates of forest change following disturbances may ultimately depend on multiple interacting factors, such as disturbance history, pre-disturbance stand conditions, local site factors, regional species pool, and species life histories, among others (Foster et al., 1998; Harper et al., 2005; Mansuy et al., 2012; Girard et al., 2014). However, it is unclear how these factors interact to explain variation in rates of forest recovery. Some initial efforts have been made to better understand regional level variability of forest recovery across Canada's forested ecosystems (Goetz et al., 2006; Mansuy et al., 2012). A better understanding of forest recovery rates and patterns in different environmental and climatic conditions is necessary to understand the overall dynamics of Canada's forests and devise effective strategies for sustainable forest management.

Among the challenges encountered in characterizing rates of forest recovery is the absence of a universal definition of what is meant by the term recovery in a forest context. Because recovery involves the return of vegetation cover, terminologies such as "revegetation," "regeneration," and "regrowth" are often used, sometimes synonymously, to describe what happens to forests following disturbance. Some consider recovery as the reestablishment or redevelopment of forest biomass and canopy structure characteristics after the impact of a particular disturbance (Frolking et al., 2009). However, it is not entirely clear at what stage or condition a forest that has experienced disturbance can be described as returning to its function as a forest. In the context of these broader interpretations of forest recovery, for the purposes of this study, we are interested in the re-establishment and regeneration of vegetation at a site following a stand-replacing disturbance, specifically wildfire and timber harvest.

The Food and Agriculture Organization (FAO) defines a forest as an area of land greater than 0.5 ha in size with greater than 10% tree canopy cover, and trees that are capable of reaching a minimum height of 5 m (FAO, 2010). This includes young stands or temporarily unstocked areas that have not yet—but are expected to reach—a crown density of 10% and a tree height of 5 m (FAO, 2010). According to this definition of forest, it is possible to ascertain from early indicators whether a disturbed forest has recovered or is headed toward recovery. Therefore, the term recovery describes a long-term process, whose endpoint ultimately depends on one's interest or point of view (i.e., ecological, economic). In the context of this review, we consider a site to be regenerating or recovering if vegetation is reoccupying a site, if trees capable of reaching a certain height are re-establishing, and if there exists the potential of the trees to reach a given canopy cover.

Disturbance processes are increasingly well understood and systematically captured through remote sensing approaches (Frolking et al., 2009). The capacity of remotely sensed data to characterize vegetation recovery post-disturbance is increasing with the widespread availability of data and methods that enable dense time series analyses (Kennedy et al., 2014). Information on forest recovery is of interest from forest management, ecosystem services, and climate change perspectives (Anderson-Teixeira et al., 2013). While plot-based studies focused on the site-specific return of vegetation following disturbance have informed the forest management and ecological understanding of forest recovery (e.g., Drever et al., 2006), there is a need to bridge between the contexts offered by plot-based measurements and associated knowledge with