chapter one

What is forest restoration?

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1.1 Introduction

The need to repair habitat and restore forest structure and function is recognized throughout the temperate and boreal zones as a component of sustainable forest management (Krishnaswamy and Hanson 1999; Dobson et al. 1997). Forest restoration is a complex task, complicated by diverse ecological and social conditions, that challenges our understanding of forest ecosystems. The term restoration is used indiscriminately and it is difficult to define in a way that encompasses all situations found in the literature and in practice. Generally, restoration is seen as symmetric with degradation: an undisturbed forest in a natural or historical condition can be degraded, and a degraded forest can be restored to that natural or historical condition. As will become apparent, reality is more complicated and the fully restored state is probably unattainable (Cairns 1986; Stanturf and Madsen 2002). Terminology, however, is not merely an academic issue; definitions related to forestry and restoration are used under several international conventions such as climate change and biodiversity where distinctions and nuance have important policy implications (FAO 2002). The objective of this chapter is to provide a conceptual framework for the terms used throughout this book, in order to facilitate understanding of the diverse cultural and ecological contexts for restoration of temperate and boreal forests. This chapter has three parts: an historical context for restoration, which differs geographically; a conceptual framework for understanding the relationship between degradation and restoration; and an attempt to define restoration terms within that framework.

1.2 Historical context

Throughout history, forests have been a residual landuse; external pressures such as expanding human populations have caused forests to be cleared, usually for agriculture

(Noble and Dirzo 1997). The conversion of forest habitat to other uses has occurred at different rates and different times in history (Goudie 1986; Dobson et al. 1997). For example, most of Europe and Asia were settled millennia ago, while human occupation of the Americas is much shorter. Nevertheless, the transformation of landuse is not unidirectional; wars, plagues, population movement and fluctuations, and climate changes cause agricultural abandonment and reversion to forests. Significant changes have occurred within the last 200 years as developed nations shifted from a biomass energy economy to fossil fuels (Clawson 1979; Ericcson et al. 2000; Johan et al. 2004). Further changes are likely in the industrialized nations of the temperate zone, as changing policies for agriculture and nature conservation provide incentives for land-use shifts from agriculture to forest.

Forest restoration in the broad sense is not a new endeavor. Agricultural abandonment and natural invasion from remnant forests is a passive form of restoration that continues to occur (McIver and Starr 2001), notably in some former communist countries within the Commonwealth of Independent States (FAO 2001). Active restoration also has a long history; if the indirect effects of efforts to restore productivity to degraded land can be considered unintentional restoration. The development of secondary spruce forests in central Europe is an example of the complex pathway of degradation and restoration (Johan et al. 2004). Similarly, the loblolly pine forests of the southeastern United States were established to protect water and soil resources (USDA Forest Service 1988; Stanturf et al. 2003). In many countries, coastal dunes and heathland were planted to reclaim wasteland (e.g., Denmark; see Madsen et al. this volume). Active but unintentional restoration was motivated by the threat of timber scarcity and movements to improve nature, often with sociopolitical overtones such as providing employment and patriotic duty (Heske 1938; Orni 1969).

Forest restoration in industrialized countries at the beginning of the 21st century emerges from these earlier, more utilitarian concerns but with greater emphasis on restoring more natural forests (Farrell et al. 2000). Restoration ecology is an emerging science that developed out of restoration projects at specific sites (Hobbs and Norton 1996; Hobbs 2004). Ecological restoration "is an intentional activity that initiates or accelerates recovery of an ecosystem with respect to its health, integrity and sustainability" (SER 2002). Explicit in this definition is that ecological restoration is relative to reference conditions (Wagner et al. 2000; Perrow and Davy 2002a, b; SER 2002), which are related to a notion of natural conditions for a site (Hobbs and Norton 1996; Egan and Howell 2001). Thus, "true" restoration has the most ambitious goal of reconstructing a prior ecosystem (van Diggelen et al. 2001; SER 2002); less ambitious efforts only seek to partially restore naturalness (rehabilitation) or generally increase biodiversity (reclamation). To the purist, restoration is different from rehabilitation or reclamation because its objective is to return an ecosystem to some preexisting, natural state that often presumes an absence of human disturbance (Hobbs and Norton 1996).

Practitioners within the restoration ecology community (Hobbs 2004; Davis and Slobodkin 2004) and other resource professionals (Wagner et al. 2000; Stanturf et al. 2001) have challenged the notion of naturalness as an objective. The crux of the debate is whether naturalness represents a scientifically defensible concept (Anderson 1991) or is simply a statement of a preference for one kind of ecosystem over another (Hobbs 2004). Some restoration ecologists are moving away from the purist position, especially the more ideological views that set the goal of restoration to be an idealized pristine state, which implies a static view of ecosystems (Hobbs 2004; Davis and Slobodkin 2004). Nevertheless, a lively debate has ensued over whether the endpoint of restoration can be set in a way that is free of values (Winterhalder et al. 2004).

Crucial to the debate are the starting and ending points, and a practitioner's perception of the extent of human influence in a forested ecosystem. Forests today are human-dominated

systems (Noble and Dirzo 1997; Vitousek et al. 1997; Ericsson et al. 2000), although there is a tendency in the Americas to underestimate the extent to which indigenous peoples influenced the forests described by the first European naturalists (Stanturf et al. 2002). If the starting point is a degraded forest only slightly removed in time from a natural or seminatural forest, suitable reference stands may be available for setting endpoints. Suitable reference conditions are unavailable and are likely to be unknowable if a forest minimally influenced by humans is hundreds or thousands of years distant from the starting point (Wagner et al. 2000; Hobbs 2004). Recognizing the difficulty of setting restoration goals on the basis of re-creating past conditions (Parker and Pickett 1997; Hobbs and Norton 1996; Sprugel 1991; Bradshaw, this volume) leads to the conclusion that the endpoint is a sociopolitical decision (Hobbs 2004) that can be informed by science (Keddy and Drummond 1996), but cannot be determined by science alone. What constitutes successful restoration will be defined within a cultural and ecological context, including financial costs and unexpected consequences (Anderson and Dugger 1998; Holl and Howarth 2000; Palik et al. 2000; Anand and Desrochers 2004). The appropriate intervention will be determined largely by the degree of degradation (Hobbs 2004) and the likelihood of success.

1.3 Degradation and restoration processes

Forest condition is dynamic, subject to natural developmental processes (Oliver and O'Hara, this volume) as well as natural and anthropogenic disturbances (Covington et al. 1997; Turner et al. 1998; Angelstam 1998; Stanturf et al. 2001; Beatty and Owen, this volume). Degradation results from changes to forest structure or function that lowers its productive capacity (FAO 2002), including limited biodiversity. Degradation is not synonymous with disturbance; disturbance becomes degradation, however, when it crosses a threshold beyond the natural resilience of a forest type. The simplest conceptualization of the relationship between degradation and recovery processes is to place a forest on a continuum from natural to degraded (Bradshaw 1997; Harrington 1999). Levels of state factors such as biomass or biodiversity in a forest subjected to degradation follow a linear trajectory. At any point along the trajectory, recovery toward a natural forest can be initiated once the stress or disturbance abates.

Intervention can facilitate recovery from disturbance or degradation. For convenience, intervention can be divided into three levels of increasing effort: self-renewal, rehabilitation, or reconstruction/reclamation (Stanturf et al. 2001). In the self-renewal phase, resistance and resilience mechanisms maintain or return the forest more or less to its original state, without human intervention, in a relatively short time. Sustainably managed forests rely on self-renewal processes, for example, naturally regenerated forests managed for timber. Intervention at this stage will be to ensure that composition and structure meet management objectives. Plantations of native species can be within the scope of self-renewal, where intervention (reforestation) is undertaken to control species and stocking.

At intermediate levels of disturbance, beyond the self-renewal phase, degradation occurs. If a forest is degraded but remains in forest landuse, meaning it is not deforested, it can be rehabilitated to a forest condition that is within the range of self-renewal mechanisms. Recovery to a more natural forest will take longer, but the time required can be shortened by human intervention. Rehabilitation by reforestation of forests consumed by wildfire is an example. In the most degraded state, forest cover is removed and the land is converted to another use: this is deforestation (FAO 2002). A forest degraded by acute air pollution may be deforested to a nonforest condition and the land becomes wasteland. In the most degraded conditions, after the pollution or other landuse ceases, the forest may recover to a natural forest condition in a century or longer. The recovery period may be shorter, possibly decades, with human intervention (reconstruction or reclamation). In this

chapter, restoration encompasses all interventions into degraded forests, those stands disturbed beyond the range of self-renewal processes. Rehabilitation refers to restoration of degraded forests; reconstruction and reclamation encompass restoration of forests from nonforest landuses.

1.3.1 Degradation processes

The dynamic relationship between processes degrading and restoring forests is more easily understood if considered in light of two dimensions, changes in land cover, landuse, or both (Stanturf and Madsen 2002). Taking as the starting point the undisturbed, idealized natural mature forest (Westhoff 1983; Goudie 1986), then, conversions to other landuses such as agriculture (cultural landscape) or pasture (seminatural landscape) are through deforestation (Figure 1.1). Relatively frequent but moderate disturbance (plowing, herbicides, grazing) maintains the nonforest cover. Similarly, a change in both land cover and landuse occurs when forests are removed and the land is converted to urban areas, flooded by dams, or removed along with topsoil and overburden in mining and extractive activities. Such drastic degradation involves deforestation, usually accompanied by ongoing disturbance. The nonforest cover is maintained more or less permanently by structures, more so than by cultural activities (Figure 1.1). Agricultural land can also be converted to urban uses.

Harvesting a mature forest in a sustainable manner is a change of land cover but not landuse (FAO 2002). A new, young forest will result from natural regeneration or by reforestation (within the envelope of forest cover in Figure 1.1). Unsustainable harvesting without securing adequate regeneration, however, may degrade stand structure or diversity.

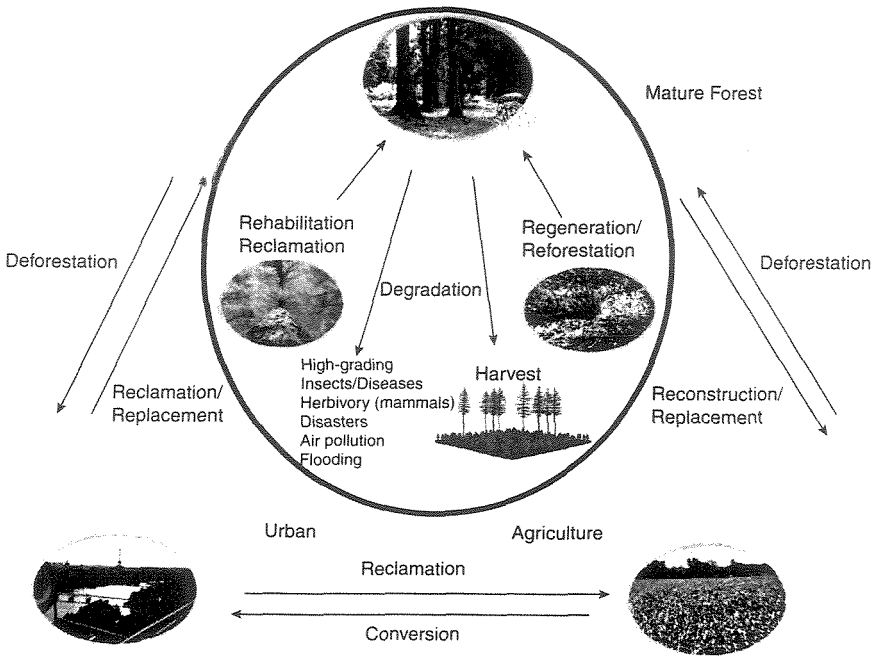

Figure 1.1 Forest restoration begins with forests that have been degraded (rehabilitation) or after deforestation and conversion to other land uses (reconstruction or reclamation). Self-renewal processes operate within forests that are disturbed but not degraded (regeneration/reforestation). (Adapted from Stanturf and Madsen, Restoration concepts for temperate and boreal forests of North America and Western Europe, *Plant Biosyst.*, 136, 143, 2002).

Outbreaks of insects or diseases (especially exotic species), fire suppression and disruption of natural fire regimes, invasion by aggressive exotic plants, or disasters such as hurricanes or wildfires can degrade forest stands and change attributes of land cover, but these stressors do not change landuse (Figure 1.1). Chronic low-level pollutant loading may degrade a forest without changing landuse, although heavy loading may deforest an area and change use into wasteland.

1.3.2 Restoration processes

Forests are resilient: given sufficient time and the cessation of disturbances, agricultural and urbanized land will revert to forest. Abandonment and reversion to forests, although secondary, seminatural, or degraded forest types, will be on a time scale of a few decades to centuries as existing forests expand into nonforest areas, or natural invasion occurs. Human intervention, however, can accelerate the reversion process (Ferris-Kaan 1995). Reconstructing forests through afforestation of agricultural land may consist of simply planting trees, although more intensive techniques are available (Stanturf et al. 2001). Reclamation of urbanized land usually requires extensive modification, including stabilization of spoil banks or removal of water control structures, followed by tree planting. Because severe site degradation may limit the possibility of restoring to natural forest condition, reclamation is sometimes called replacement (Bradshaw 1997).

1.4 Restoration terms

The dualistic notion of degradation and restoration as opposing trajectories of forest development leads to an understanding of restoration in a broader context than ecological restoration (SER 2002). In this view, the restored forest that results from reconstruction, reclamation, or rehabilitation may never recreate the original state for all functions (Cairns 1986; Bradshaw 1997; Harrington 1999). Any endpoint within the natural range of managed forests where self-renewal processes operate is acceptable as restoration. Thus, restoration to an early seral stage would be acceptable for a forest that is likely to attain a more complex structure through typical stand dynamics. How quickly the forest moves to the self-renewal phase is a function of forest type, site resources, and the amount invested to overcome the degraded conditions. This model offers a broader context for restoration on private land; landowners with management objectives other than preservation are able to contribute to ecosystem restoration (Farrell et al. 2000; Stanturf et al. 2001).

Commonly used restoration terms can be understood within a conceptual framework (Figure 1.2) that takes into account the relationships between changes in forest cover and landuse (Figure 1.1). This is not an attempt to standardize these terms, but to harmonize (FAO 2002; Hasenauer 2004) them for consistent use in the chapters that follow. The Degradation trajectory begins with the idealized forest at Ω as the starting point (Figure 1.2). This beginning point is culturally and situationally determined. In some contexts, it may represent an actual historical reality, or it may be a conceptual model of the potential natural vegetation for an area. The degradation trajectory moves toward a degraded endpoint, A in Figure 1.2. The possible endpoints are shown in Figure 1.1; the most degraded states will include deforestation and conversion to nonforest landuse. The intermediate points B_1 to B_3 represent forests degraded by air pollution, exploitive harvesting, natural disasters, etc. These degraded forests, as well as nonforest conditions (A), represent starting points for restoration trajectories. For ease of representation, the A to Ω trajectory is presented as linear; in reality it is probably more complex (Anand and Desrochers 2004).

The path extending from A to Ω, labeled Recreation, represents the strictly defined ecological or historical restoration (SER 2002). Re-creating the ideal natural or historical

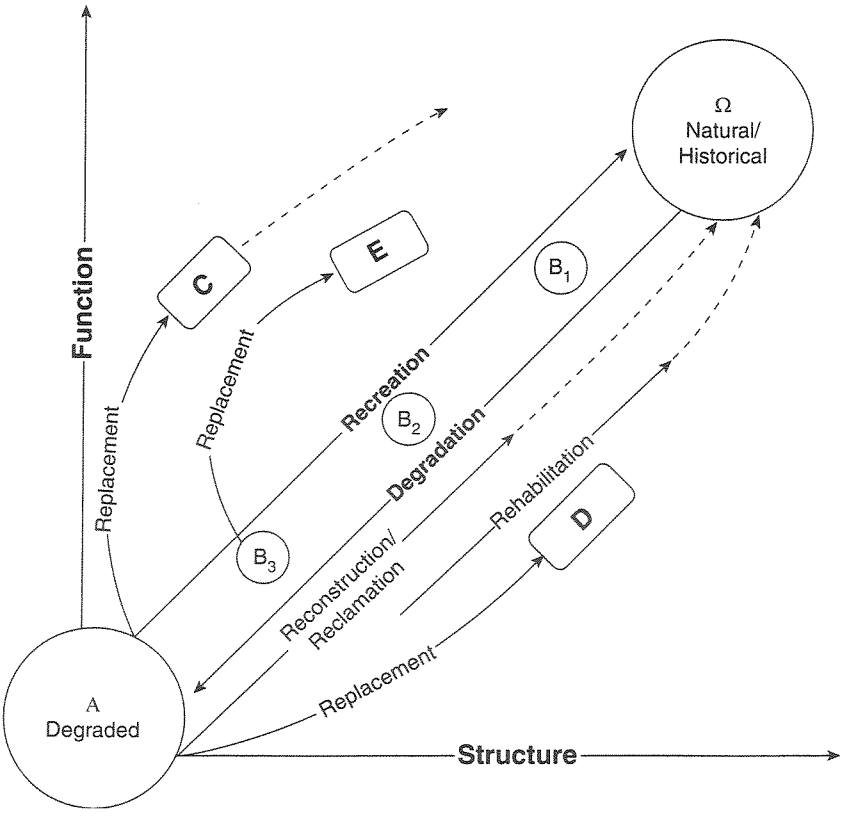

Figure 1.2 A conceptual framework for forest restoration has a starting point of a degraded forest (A) and an idealized endpoint of a forest restored to some natural or historical endpoint (Ω). The symmetric degradation/re-creation trajectories have intermediate points that represent starting/ending points (B_1 to B_3) for reconstruction or reclamation of severely degraded forests (deforested and converted to other landuse) or less severely degraded forests (rehabilitation). Replacement trajectories denote restored forests that lack the structure or species composition of native forests

forest ecosystem is unlikely to be successful over large areas (van Diggelen et al. 2001) and will certainly be expensive. Reconstruction refers to restoration of forest conditions to agricultural land (Figure 1.1), through afforestation or natural invasion. The endpoint for reconstruction (B_1 to B_3) may be a less diverse natural forest (B_2) or a mixed species plantation of native species (B_3). Alternatively, a site may be so degraded that native species are replaced by exotics; this pathway (to C) would be termed replacement.

Reclamation begins with urban or built land-use and may require land stabilization as well as afforestation. In North America and the U.K., reclamation is commonly used in the context of mined land. In the older literature, reclamation had an opposite meaning of putting derelict land to good purpose, such as draining swamplands or irrigating arid lands. For both reconstruction and reclamation, continuing intervention over time may move the forest condition closer to the natural endpoint (shown as a dashed line in Figure 1.2).

Rehabilitation of degraded forests has one of the intermediate conditions (B_1 to B_3) as a starting point; forest cover has been removed or degraded but no change to nonforest landuse has occurred. Rehabilitation encompasses many techniques to restore stand structure, species composition, natural disturbance regimes, or to remove exotic plants. Specific forms of rehabilitation are termed conversion (Nyland 2003; Spiecker et al. 2004) or transformation (Kenk and Guehne 2001).

The conditions at C, D, and E represent Replacement; these are forests that deviate from the natural range of variability but restore forestry landuse. Plantations of exotic species, for example, have a simple structure but high functioning as compared to non-forest landuse (C). Over time, with or without further intervention, even replacement stands could move toward the natural endpoint by gaining structure or additional species. For example, the conversion or transformation of Norway spruce to broadleaved forests in central Europe follows this restoration trajectory (Spiecker et al. 2004; Hanson and Spiecker, this volume; Baumhauer et al. this volume; Hahn et al. this volume). Spruce was planted on broadleaved sites for a variety of reasons (Johan et al. 2004), following the A to C trajectory (Figure 1. 2). Conversion or transformation back to mixed broadleaved forests (C to B_1 or to Ω) completes the restoration of a natural forest within the range of self-renewal processes. Starting point D represents the rehabilitation of forests with disrupted natural disturbance regimes, such as fire-suppressed conifer forests in North America (stands with high structure but low functioning). Rehabilitation requires altering structure and composition before reintroducing fire (Brockway et al. this volume; Kaufmann et al. this volume).

1.5 Conclusion

Forests are human-dominated ecosystems (Noble and Dirzo 1997). Reconstructing forests where they are now absent, as well as altering existing forests to more natural conditions, are important aspects of sustainable forest management. Important tasks for forest restorationists are to understand how ecosystems were degraded, how to reverse degradation processes, and how to efficiently initiate recovery processes (Hobbs and Norton 1996). Silviculturists and forest ecologists have important tools — diagnostic and predictive skills and effective intervention techniques — that are critical to successful restoration of complex ecosystems. These tools must be used appropriately, however, within diverse sociopolitical, ecological, and historic contexts.

A broad conception of restoration allows more diverse goals (endpoints) than the narrow construct of re-creating particular, preexisting ecosystem states (reference conditions). Greater flexibility in setting restoration objectives is not a retreat from basing restoration on ecological science (Wagner et al. 2000). Rather, it is a recognition that incomplete knowledge of past ecosystem states (Hobbs 2004), changes in the global environment (Vitousek et al. 1997), costs, and the scale of degradation argue for a pragmatic approach.

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