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Tamm review

Contemporary forest restoration: A review emphasizing function

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ABSTRACT

The forest restoration challenge (globally 2 billion ha) and the prospect of changing climate with increasing frequency of extreme events argues for approaching restoration from a functional and landscape perspective. Because the practice of restoration utilizes many techniques common to silviculture, no clear line separates ordinary forestry practices from restoration. The distinction may be that extra-ordinary activities are required in the face of degraded, damaged, or destroyed ecosystems. Restoration is driven by the desire to increase sustainability of ecosystems and their services and restoration is likely to have multiple goals arising from the motivations of those involved. The process of setting restoration objectives translates vague goals into feasible, measurable targets and ultimately actions on the ground. Our objective for this review is to synthesize the science underpinning contemporary approaches to forest restoration practice. We focus on methods and present them within a coherent terminology of four restoration strategies: rehabilitation, reconstruction, reclamation, and replacement. While not a consensus terminology, these terms have a logical foundation. Rehabilitation restores desired species composition, structure, or processes to a degraded ecosystem. Reconstruction restores native plant communities on land recently in other resource uses, such as agriculture. Reclamation restores severely degraded land generally devoid of vegetation, often the result of resource extraction, such as mining. Replacement of species (or their locally-adapted genotypes) with new species (or new genotypes) is a response to climate change. Restoration methods are presented as available tools; because adding vegetation is an effective restoration technique, the discussion of methods begins with a description of available plant materials. We then discuss altering composition under different initial overstory conditions, including deployment methods depending upon whether or not an overstory is present, how much of the landscape will be restored, and the complexity of the planting design. We present some major approaches for altering structure in degraded forest stands, and describe approaches for restoration of two key ecosystem processes, fire and flooding. Although we consider stand-level designs, what we describe is mostly scalable to the landscape-level. No restoration project is undertaken in a social vacuum; even stand-level restoration occurs within a system of governance that regulates relationships among key agents. Gathering information and understanding the social dimensions of a restoration project is as necessary as understanding the biophysical dimensions. Social considerations can trump biophysical factors.

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1. Introduction

Worldwide, an estimated 2 billion ha of forests are degraded (Minnemayer et al., 2011) with roughly half in tropical countries (ITTO, 2002). Lack of consensus on the definition of "degraded" stymies efforts to inventory these forests (FAO, 2010). Nevertheless, several international efforts are directed toward restoring degraded ecosystems and have set goals, such as restoring 15% of degraded ecosystems (CBD, 2010) or 150 million ha of deforested and degraded forests (WRI, 2012) by 2020. In addition to anthropogenic alterations of global ecosystems (Foley et al., 2005; Kareiva et al., 2007; Ellis et al., 2013), the anticipated effects of global climate change suggest the future need for restoration will be even greater (Steffen et al., 2007; Zalasiewicz et al., 2010).

Restoration is driven by societal values that are often in conflict (Lackey, 2001) and motivated by vague goals (Clewell and Aronson, 2006) that generally fall within the concept of sustainability, for instance: repairing ecosystem functions or other desired attributes (Ciccarese et al., 2012), enhancing or enlarging specific ecosystems and habitat for species of concern (Thorpe and Stanley, 2011), or enhancing ecosystem capital, such as biodiversity (Seabrook et al., 2011). Although sociopolitical processes set goals that may be strategic, more often goals are pragmatic (Burton and Macdonald, 2011; Hallett et al., 2013; Burton, 2014) determined by those with the power to decide that restoration will occur and willing to pay for it. Because of this human component, attempts to formulate a universal definition of restoration or its various aspects continue to generate discussion and elude consensus (Stanturf, 2005; Hobbs et al., 2011).

The process of setting restoration objectives, conditioned by the scale, social context, and level of restoration desired, translates vague goals into feasible, measurable targets and ultimately actions on the ground. Given the large areas in need of restorative treatments, landscape-level approaches that emphasize functional ecosystems may be more effective than traditional approaches focusing on historical composition and structure of small areas, such as forest stands (Lamb et al., 2012; Oliver, 2014). A defining feature of functional restoration is its focus on sustainability of multi-scale ecosystem processes, including hydrologic cycles, ecosystem productivity, food web interactions, rather than particular compositions and structures. The focus prevalent in many restoration programs has been (and often still is) on restoring stands to some previous, putatively "natural" state (Burton and Macdonald, 2011; Stanturf et al., 2014). A functional perspective, as a primary objective of restoration, becomes more urgent and logical given unprecedented rates of change in global drivers of ecosystems, including climate change and changing land use. Given these changes, a focus on historic compositions and structures becomes less achievable because the characteristics deemed desirable now may become unsustainable in the not too distant future. A focus on restoring function avoids this pitfall and is still directly related to achieving stakeholder goals of ecosystem sustainability, economic efficiency, and social wellbeing, as derived from functioning landscapes.

In most landscapes, broadening the scope of a restoration beyond the site or stand will require integration of the restoration activity with other land uses, beyond that usually included in restoration planning (Stanturf et al., 2012a,b). Further, restoration will have to accommodate the diverse management objectives of multiple owners, and explicitly incorporate human livelihood needs (Lamb et al., 2012; Maginnis et al., 2012; Sayer et al., 2013). Achieving the ultimate restoration goal may require meeting subordinate, incremental objectives through sound ecological principles, applied dynamically with flexibility to meet the scope and limitations of each unique project (Pastorok et al., 1997; Ehrenfeld, 2000; Joyce et al., 2009). Where restoration will occur, how much will be restored, and what methods will be used to achieve it are choices that must be made (Clement and Junqueira, 2010; Wilson et al., 2011; Pullar and Lamb, 2012). Our goal is to synthesize the science underpinning contemporary, international approaches to forest restoration, particularly from a functional perspective, with focus on methods presented within a coherent terminology of four restoration strategies: rehabilitation, reconstruction, reclamation, and replacement. Restoration methods are presented as available tools, including appropriate materials and methods for altering composition, structure, and