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A national approach to leverage the benefits of tree planting on public lands

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Abstract

The number of global initiatives for forest restoration, and the scope of these initiatives, continues to increase. An important tool for meeting objectives of these global initiatives is reforestation, achieved by natural processes or by tree planting. Worldwide, organizations are challenged to most efficiently and effectively direct resources to the most critical reforestation needs. Currently in the United States, the reforestation efforts of the Department of Agriculture, Forest Service, are challenged by changes in policy, funding, climate change, and mega-fires, to name a few, and identifying strategies for timely successful reforestation at scale is needed. A 2016 conference brought together reforestation experts from across North America to discuss potential benefits of reforestation activities in the face of mounting challenges from invasive species, wildfires, diseases, and climate change. As a result of that effort, here we provide background on the challenges confronting successful reforestation on lands managed by the Forest Service, and describe the six manuscripts in this special issue and their foci: barriers to natural regeneration, when to actively plant trees or not to ensure a heterogeneous landscape, ecological and economic concerns when reforestation is delayed, employing traditional and novel silvicultural techniques in support of reforestation, leveraging reforestation to improve resilience of species affected by introduced pests, and the potential carbon sequestration benefits of a robust reforestation program.

Keywords Natural regeneration · Tree planting · Wildfire · Climate change · Diversity

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Introduction

Worldwide, tree planting was recently recognized as the natural land management approach having maximum potential to mitigate changes to climate, nearly 3× more effective than the next best approach (Griscom et al. 2017). In addition to the obvious potential to sequester carbon (Bernal et al. 2018), restoring degraded forests through tree planting can restore, maintain, or improve forest functions (Stanturf et al. 2014) and biodiversity (Pawson et al. 2013). The latter is important for maintaining ecosystem resilience to disturbance, including climate change (Liang et al. 2016; Seidl et al. 2016). Moreover, healthy forests are a keystone for social sustainability (Parrotta et al. 2012). Thus, it is not surprising that a number of international efforts focused on forest restoration have a reforestation component, with the potential for tree planting being immense (see Haase and Davis 2017). Specifically for the United States (USA), Fargione et al. (2018) calculated the potential benefits of natural land management practices to mitigate climate change. Similar to Griscom et al. (2017), they noted that reforestation, which they defined as conversion from non-forest (< 25% tree cover) to forest (> 25% tree cover) in areas where the historical natural vegetation is forest, had the highest, annual, maximum potential to mitigate greenhouse gases (307 Tg in CO_2 equivalents [CO_2e]), about 25% of the total (1.2 Pg CO_2e year^{-1}) mitigated by all 21 land management techniques examined. In the USA, the Department of Agriculture, Forest Service has pledged to annually reforest 13,000 ha (130,000 ha by 2025) of post-disturbance lands needing reforestation to mitigate climate change (USDA 2016), part of its pledge of 15 million hectares in response to the Bonn Challenge (IUCN 2011).

The Forest Service has been actively managing 780,000 km^2 of public lands for more than a century; growing and planting tree seedlings has always been an important tenet (Dumroese et al. 2005). At their onset in the early 1900s, Forest Service nurseries had a primary goal of growing seedlings and planting them to stabilize soil and protect watersheds after large wildfires and previous indiscriminate logging. For decades, nursery staff and Forest Service scientists were leaders in developing nursery production systems. From this initial focus on forest restoration, the nurseries and reforestation efforts on public land have cycled through periods focused on conservation, job creation, post war timber production, and back again to a primary focus on restoration dominated by holistic ecosystem management and public participation (Dumroese et al. 2005; Williams 2000). The Forest Service is now challenged to continue this successful national reforestation effort because of changing dynamics (i.e., unintended consequences of policy implementation, climate, funding, and wildfire) that require new approaches to meet emerging priorities and objectives.

A substantial decrease in timber harvesting on National Forests (Burch 2005; Williams 2000) has resulted from implementation of the Multiple-Use Sustained-Yield Act of 1960, the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the National Forest Management Act of 1976. These four national laws, when combined, require that all potential uses and benefits of federally managed lands be considered in combinations that best meet the needs of citizens, that public participation is mandatory in management planning and implementation, and that endangered plants and animals must be identified and protected in their critical habitats. Timber harvests historically have been the primary funding for Forest Service tree planting activities with a portion of the revenue generated by timber sales set aside for reforestation. During the peak timber harvesting period (1950 through 1980), timber harvest revenues funded about two-thirds of the Forest Service reforestation efforts and generally had sufficient reserves to allow for additional planting needed after unplanned events, mainly wildfire (Burch 2005). With the shift in policy that caused a substantial decrease in timber harvesting, revenues for tree planting also decreased. By 2005 only half of the Forest Service reforestation efforts were funded this traditional way (Burch 2005); from 2009 through 2018 the rate was only 20%. While timber receipts still provide sufficient funds for reforestation after harvesting, such revenues are insufficient to meet the reforestation demands now being generated by mega-fires (very large wildland fires), hurricanes, ice storms, etc. and the demand for non-commercial species needed for other forest restoration activities.

From its inception, a primary function of the Forest Service was fighting wildland fire. By the mid-1930s, aggressive suppression of all fires was the norm (Williams 2000). This suppression has resulted in 40 million hectares of overstocked timberlands in the western USA (USFS 2005), exacerbated by a legacy of silviculture in the 1980s that focused on high-density plantation-style forests for timber production (North et al. 2019; Odion et al. 2004), the aforementioned decrease in harvest levels, and changes in climate (Liu et al. 2013). Together, these factors have contributed to more frequent occurrence of very large fires (Dennison et al. 2014) with even greater areas projected to burn in the future (Keyser and Westerling 2019). On Forest Service-managed lands, the need for fire-caused reforestation has jumped from 15% of the total reforestation need in 2007 to 81% of the total in 2017; the current fire-caused need far surpasses that caused by harvesting (Figs. 1, 2).

Forest Service data suggest that the agency is meeting only about 20% of annual reforestation needs; the agency defines annual reforestation needs as the sum of all accumulated, unmet needs from past years (due to a time lag necessary to implement reforestation,

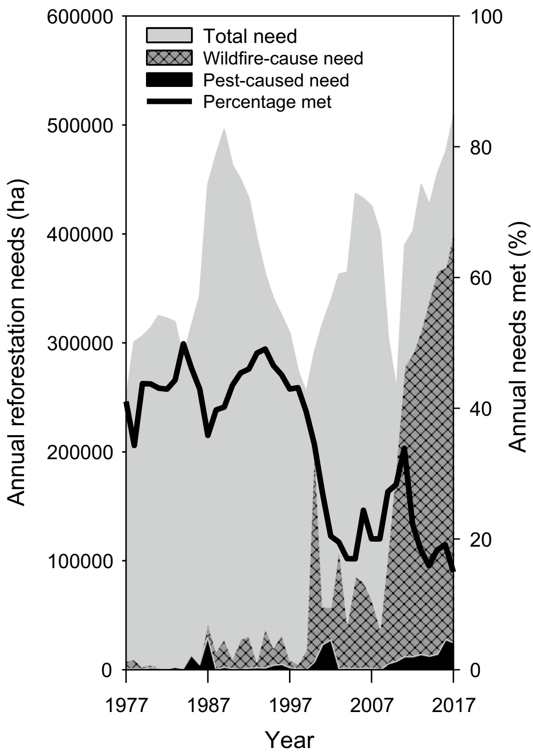

Fig. 1 Although the annual reforestation need for lands managed by the Forest Service has averaged around 400,000 ha, the amount of reforestation need caused by wildfire began to rise at the turn of the century and continues to increase exponentially. From 1980 through 2000, the Forest Service annually met about 45% of its reforestation needs, but during the past 20 years that figure has dropped to about 25%

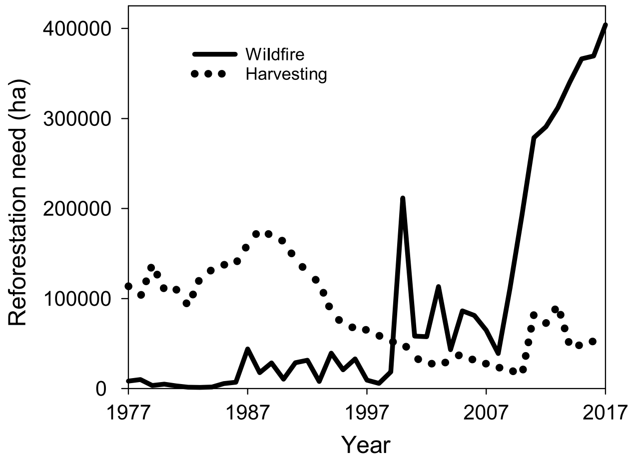

Fig. 2 Since the beginning of the twenty-first century, the annual reforestation needs on Forest Service-managed lands caused by harvesting have remained low whereas needs caused by wildfires have increased dramatically, and now account for most of the annual reforestation needs of the agency

often including seedling production) plus new needs in the current year, less needs met during the current year.

Currently, of the land area reforested annually, about one-third is achieved through planting, with the remaining two-thirds of reforestation relying on natural regeneration, either with or without site preparation (Fig. 3). This reliance on natural regeneration has advantages and disadvantages. On one hand, it maintains a high level of genetic diversity

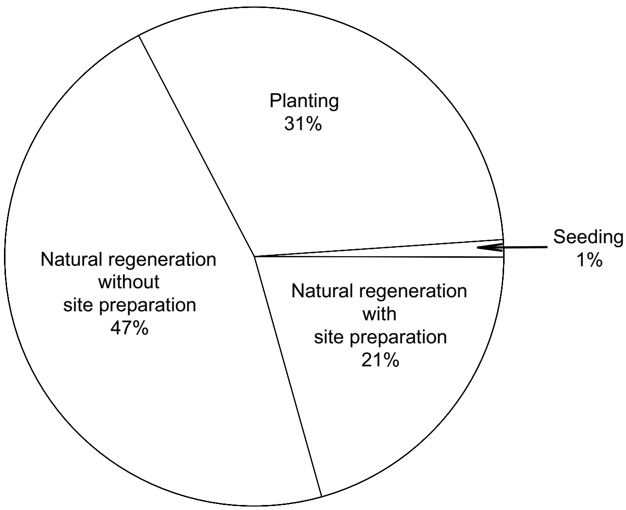

Fig. 3 Currently in the United States, on lands managed by the Forest Service, the relative proportions of natural regeneration and tree planting used within different regions can vary substantially. Overall, however, natural regeneration is practiced on about two-thirds of Forest Service-managed lands, and may be accomplished with or without site preparation. The remaining one-third of the reforestation effort is accomplished almost entirely by tree planting

(although not necessarily greater than tree planting; e.g., Al-Hawija et al. 2014), which may be important for adapting to climate change (Valladares et al. 2014). Compared to planting, natural regeneration is less expensive to implement. On the other hand, changes in climate are expected to occur much faster than during any historical period (Williams and Jackson 2007), and the natural movement of tree species and their populations across the landscape may not keep pace with their optimal climate niches (see Williams and Dumroese 2013). For example, Iverson et al. (2004) modeled that in 100 years *Pinus taeda* would colonize less than 10% of the new, suitable habitat for that species created by climate change. Therefore, assisted migration, the intentional movement of species or their populations in response to climate change, has been discussed as a mitigation and adaptation technique (Stanturf et al. 2015, 2018; Williams and Dumroese 2013) and is a logical extension of traditional tree planting (Guldin 2019). Incorporating assisted migration after disturbances may be prudent, especially those where natural regeneration is unlikely to occur at a pace to meet management objectives and on the most productive forest sites. By focusing on the most productive sites, Sample (2017) estimates that 44 million metric tons of CO_2e could be sequestered, and on Forest Service-managed lands, reforesting productive sites can achieve nearly 20% of the nation's sequestration potential. Planting will also be the most efficient way to reintroduce native tree species traditionally bred or bioengineered for resistance to introduced pests that have decimated their populations (Dumroese et al. 2015), as is already being done, for example, with *Pinus monitcola* and blister-rust (*Cronartium ribicola*) in the western USA (Bingham 1983), and as proposed for American chestnut (*Castanea dentata*) bred for resistance to chestnut blight (*Cryphonectria parasitica* = *Endothia parasitica*) (Jacobs et al. 2013).

Tree planting can be important for climate change mitigation and adaptation, but it will require more seedlings, including a greater diversity of species, than are being currently produced and additional professionals well-trained in seedling production and deployment (Haase and Davis 2017). Successful tree planting will require seedlings grown with specific traits to meet the challenges of particular sites (Dumroese et al. 2016) and can be an invaluable tool to re-introduce species that are adapted to a given site, but missing because of local extirpation due to past land use activities. The Forest Service is now challenged to most efficiently direct resources to the most critical reforestation needs. It is likely that the reforestation issues faced by the United States, that is, establishing seedlings at increasingly larger scales and stewarding those stands into a resilient forest, have similar analogs worldwide (Locatelli et al. 2015; Paul et al. 2016; Silva et al. 2018).

Purpose and summary of the conference

In April 2016, a Reforestation Matters conference was held in Portland, Oregon USA, as a follow-up to a Reforestation Summit convened the previous year by Forest Service Deputy Chief Leslie Weldon. This convention called for each management region of the Forest Service to prepare reforestation plans to guide development of a national reforestation strategy for the agency. As foundation for the strategy, the Reforestation Matters conference was intended to help provide a science-based, multidisciplinary underpinning. The conference was attended by 33 subject matter specialists representing academia and Forest Service Research and Development. Sixteen presentations included a variety of reforestation issues under these broad canopies: law and policy, economics, ecological implications, genetics, interactions with other management objectives, and climate change responses (assisted migration and carbon sequestration). The underlying objective was to answer this question: Given current challenges, how do we maximize the long-term benefits of tree planting? Can we do this strategically?

From those presentations, a total of 6 articles were selected for inclusion in this Special Issue.

Although much of the reforestation in the USA is by natural regeneration, a plethora of changes, including those related to climate, invasive species, disturbance regimes, herbivory levels, societal preferences, and fire regime, have reduced the potential of forests to naturally regenerate (Dey et al. 2019). Moving forward, successful natural regeneration will require active management that links all of the critical steps in the regeneration process, from seed production on parent trees to seedling establishment, growth, and persistence.

Identifying contexts in which active reforestation or passive recovery may best promote desirable post-disturbance, ecological trajectories is the focus of White and Long (2019). These authors, focusing on fire as a primary disturbance, suggest conceptual frameworks for assessing landscape conditions and determining areas that may be the highest priorities for tree planting, recognizing that avoiding tree planting on some sites may support natural recovery of important plant communities (e.g., resprouting hardwood groves, meadows, and shrubfields) and the ecological function and services they provide.

The economics that drive or constrain reforestation is the topic of Zhang (2019), who provides an example of the substantial financial costs of delayed reforestation in the southern USA, with commentary on reforestation from public policy and ethical perspectives.

Guldin (2019) discusses how changes in climate will require a suite of silvicultural approaches, both traditional and novel, to promote genetic diversity and species diversity in natural and planted stands, as well as other stand characteristics to maintain productive forests. Guldin notes that assisted migration, a technique often advocated to deal with uncertainty associated with climate change, is essentially an exercise in artificial regeneration, albeit more complicated because of limited research concerning the technical and practical challenges of planting species at the margins or beyond their natural range.

Nonnative pests and pathogens continue to threaten native forest communities. Schoettle et al. (2019) introduce a framework that provides a decision-making structure to prioritize stands and landscapes having the best likelihood of being managed for the long-term. Forest regeneration dynamics that lead to increasing host population size, the frequency of genetic resistance traits within that population, overall genetic diversity, and connectivity among populations are key.

Nave et al. (2019) considered the potential carbon sequestration benefits associated with reforestation, noting that the magnitude of the benefits varies among ecoregions. They found that planting trees on previously cultivated lands results in significant amounts of carbon being sequestered in topsoil, and these areas have potential to sequester even more carbon as suggested by the carbon content of natural forest soils. Reforestation creates aboveground woody biomass and contributes to coarse woody debris pools, both of which deliver carbon sequestration benefits immediately and for decades.

Conclusions

The capacity of forests to mitigate climate change and provide other ecosystem services is underutilized. More than two billion hectares of degraded areas worldwide need restoration; in many countries timely reforestation following harvests or disturbances is lagging or lacking; and forest management could be sustainably intensified to sequester more carbon. Increasingly, global change and human-induced disturbances raise the need for accelerating restoration and reforestation programs, although consensus is lacking on which techniques to use, what objectives to pursue, and at what scales. The key points from this conference are:

- Reforestation is important to mitigate climate change, and attention to adaptation to future climates is crucial to increase resilience.
- Reforestation on federally-managed lands can be critical to achieving mitigation objectives. We can use current and novel silviculture techniques to implement reforestation. But over-reliance on natural regeneration will fail to provide all desired results.
- The growing frequency and size of mega-fires is increasing the need of reforestation, but revenue streams traditionally used are insufficient to meet management objectives.
- Wise decision-making by land managers to target sites that will benefit most from reforestation is important at the landscape level for creating, maintaining, or enhancing ecological services.
- Effective reforestation can also provide resilience in the face of invasive pests.
- Not practicing reforestation in a timely manner can increase subsequent management costs, suffer opportunity costs from loss of functions, and reduce potential positive impacts, including carbon sequestration.

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