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Reforestation to mitigate changes to climate: More than just planting seedlings

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Abstract

Global interest in reforestation to help mitigate climate change is increasing demand for nursery-produced seedlings. Often governments, the public, and non-profit organizations simplify reforestation to the physical act of tree planting without comprehension of the entirety of the process needed for reforestation to be successful. A range of tasks from planning to implementation to post-planting monitoring and care are necessary (i.e., the reforestation pipeline). And, often, a one-size-fits-all approach to reforestation is promoted without appreciation for the diversity of ecosystems needing restoration, exacerbated by climatic uncertainties that challenge reforestation conducted status quo. While some recent attention has focused attention on the reforestation pipeline, considering a climate-smart, or climate-informed approach to reforestation in conjunction with a smooth transition from initial tree planting to on-going forest management to support long-term resilience has yet to be fully explored. Considering reforestation more holistically and through a climate lens could provide more effective reforestation and increase the trajectory for achieving long-term climate, carbon, biodiversity, and social goals expected from initial tree planting efforts.

Keywords: Reforestation, planting, climate change, nursery, forest management

Introduction

The effects of changing climate on every facet of the human and environmental condition now permeates the literature, from health to macroeconomics to infrastructure safety to frequency of global pandemics to agriculture and forestry. A quick Google Scholar literature search in October 2021 using “climate change effects” as a search phrase generated almost 4 million hits. In addition, the global state and threat to forests is also garnering much discussion. Human exploitation and overuse annually convert about 10 Mha of forests to non-forest uses (deforestation) (FAO 2020). A decade ago, about 2000 Mha of forests were degraded worldwide (Minnemeyer et al. 2011), a number that has undoubtedly increased. Reforestation is often an important part of forest restoration (Stanturf et al. 2014). Thus, it is not surprising that the nexus of climate change and reforestation has become prominent.

Mitigation, Adaptation, and Reforestation

Reforestation is considered the best (by far) natural method for mitigating changes to climate (Griscom et al. 2017; Fargione et al. 2018). The obvious potential of reforestation to sequester carbon to mitigate climate change is recognized by policymakers and scientists (Locatelli et al. 2015; Bernal et al. 2018). While carbon sequestration through reforestation is touted for mitigating climate change, mitigation benefits are more diverse. For example, reforestation can provide mitigation by affecting local to global biophysical attributes (e.g., temperature, evapotranspiration, precipitation) and by promoting sustainable use of forests and construction products (Locatelli et al. 2015). Moreover, reforestation as a forest management activity can also support forest ecosystem and societal adaptation by reducing the vulnerability of ecosystems and humans to current and future climate change (Doswald et al. 2014; IPPC 2014; Vose et al. 2018). Adaptation may include restoring, maintaining, or improving forest functions and ecosystem services (Millar et al. 2007; Stanturf et al. 2014), especially biodiversity (Pawson et al. 2013) that fosters ecosystem resilience across scales (Loreau et al. 2021). The social aspect of the reforestation contributions to adaptation could include, for example, diversified employment opportunities that provide economic sustainability (Parrotta et al. 2012; Long et al. 2014), and intangible yet highly valued social and cultural benefits such as "sense of place" (Bawa 2017).

Well-practiced reforestation involves inclusive consideration of co-derived benefits or possible trade-offs of climate change mitigation, adaptation, and their potential synergism. Together, thoughtful reforestation supports the win-win-win ideal of the climate-smart forestry response to climate change: society adapts to changes in climate, climate change effects are mitigated, and ecosystem resilience is enhanced (Locatelli et al. 2015).

Despite all these diverse, allied benefits of reforestation, too often, however, the focus simply becomes the act of inserting a seedling into the ground, rather than acknowledging and considering the entire sequence of events necessary to successfully conduct reforestation (through natural regeneration and tree planting) effectively, efficiently, economically, and environmentally.

The Reforestation Pipeline

Recent publications highlight the need for a reforestation approach that incorporates all the necessary steps to ensure success on the landscape. This approach has been referred to as the reforestation pipeline (Fargione et al. 2021) and includes everything from planning and assessment to seed procurement to plant material selection to nursery production to site preparation, to post-planting monitoring to on-going stand tending. The goal is to produce high quality seedlings needed for reforestation at a pace and global scale to make a meaningful effort to mitigate climate change and support adaptation of resultant forests to actual or anticipated environmental changes. For planting programs, the projected need to meet a plethora of regional, national, and international programs is enormous, placing focus on seed availability, nursery facilities, and well-trained professionals necessary to meet these goals (Haase and Davis 2017). Incorporating the Target Plant Concept can help guide the process of deciding whether to allow natural regeneration to proceed or to plant seedlings, and if the latter, what seedling characteristics (e.g., species, seed source, stocktype), site preparation, and outplanting techniques are necessary (Dumroese et al. 2016). This deliberation may also include the need for assisted migration (Williams and Dumroese 2013, 2014; Dumroese et al. 2015) and the use of plant materials bioengineered for resistance/resilience to invasive plants, pests, and pathogens (Dumroese et al. 2015). When determining the appropriate target plants for the diversity of global reforestation needs (ruling out a one-size-fits-all approach), climate change within the pipeline must also be considered (Fargione et al. 2021).

Harnessing the full mitigation and adaptation potential afforded by well-practiced reforestation will require an operational "adaptation" to climate-change challenges as well. Land managers will need to decide whether a site can successfully regenerate naturally, if it should be planted, or if neither approach is likely or desirable in the long term. If a site is suitable for a particular tree species and planting is desired, then selecting and using an adapted seed source is critical. Climate change will influence how land managers approach initial seedling densities, spatial arrangements, species composition, and early stand tending of planted and naturally regenerated seedlings with the goal to balance short-term seedling resistance to stress so that long-term forest resilience can be promoted. Adapting new, sustainable techniques and procedures to produce seedlings and care for them post-planting can make the reforestation pipeline more sustainable. Seedling production in container nurseries could become more sustainable using renewable energy options for heating and cooling greenhouses (Cuce et al. 2016; Yano and Cossu 2019; Ntinas et al. 2020). In bareroot nurseries, solar-powered robots could control weeds (Bawden et al. 2017; Gorjian et al. 2021). In nurseries, incorporating biochar to improve water holding capacity of substrates could reduce irrigation needs and increase fertilizer-use efficiency, thereby reducing equipment use, energy inputs, labor, and production costs (Vande Hey 2007; Matt et al. 2018). Biochar added to container nursery substrates would be efficiently and economically delivered to field sites as part of the root plug (Dumroese et al. 2011). Stand tending to control tree density could become more sustainable using bio-based fuels and lubricants (Park and Choi 2020; Salih and Saliman 2021; Sellars 2021). And, finally, long-term monitoring and management activities are necessary to ensure goals are achieved.

Social Perspectives

Prioritization of reforestation and climate mitigation and adaptation actions and interactions within challenging, multi-dimensional decisions will reflect societal values and appetites for taking management risks due to high levels of uncertainty (Ciccarese et al. 2012; Stanturf et al. 2014). Climate mitigation and adaptation actions can be synergistic (e.g., increase carbon sequestration and reduce soil erosion) or force known or unforeseen tradeoffs (e.g., reforestation carbon sequestration may negatively decrease forest biodiversity). On public lands in the United States, community engagement with land managers and stakeholders is central to the decision-making mechanism. While land managers tend to be risk adverse, especially when considering impacts of climate (Brunette et al. 2020), they enjoy high levels of trust and support from the public compared with that of policy makers (McFarlane et al. 2012; Schindler et al. 2014; Nelson et al. 2017; St-Laurent et al. 2019). Thus, increasing the scale and scope of reforestation within a changing climate that seemingly forces faster adoption of riskier activities will require scientists to provide more contextually based evidence of potential risks and benefits (Lenart and Jones 2014) to land managers and the public.

Conclusions

Reforestation has a role in mitigating the deleterious effects of climate change through carbon sequestration, as well as fostering improved adaptation of forests and society to climate-induced conditions. To be most successful, the entire reforestation process must be thoughtfully assessed, recognizing that natural regeneration and planting often share the same management needs. Doing so will assist land managers in adapting new techniques and procedures to produce and care for seedlings, and to ensure that future forests are adapted to changes in climate. Considering the target plant materials for reforestation is a critical step. For adoption and use of perceived riskier reforestation techniques, such as assisted migration, scientists must deliver to land managers and the public more relevant, contextually based information of risks and benefits toward overcoming risk aversion. Fully garnering the potential mitigation and adaptation benefits of reforestation will require public input and support throughout the decision-making process.

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