Restoring Mexican Tropical Dry Forests

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Deforestation is the dominant threat to tropical dry forests (TDFs) in Mexico. Its causes include agriculture, tourism, and mining. In some cases, unassisted forest regeneration is sufficient to return diverse forest cover to a site, but in other cases, changes in land use are so severe that active restoration is required to reintroduce tree cover.

Keywords: tropical dry forest ; ecological restoration ; restoration drivers

1. Introduction

Only 10% of the tropical dry forests (TDFs) biome in Mexico is under some scheme of protection [1].. As a result, 70% of its pre-Hispanic extent has been converted to other non-forest cover types [1]. Deforestation is the dominant threat to TDFs in Mexico. Its causes include agriculture, tourism, and mining. In some cases, unassisted forest regeneration is sufficient to return diverse forest cover to a site, but in other cases, changes in land use are so severe that active restoration is required to reintroduce tree cover. Efforts to develop strategies for planning this recovery have been variable and highlight the need to develop a science-based and indicator-driven planning process that identifies barriers to and drivers of success.

2. Trends of Restoration Success

The survival of planted individuals is the most commonly used metric of restoration success. In the reviewed studies, the survivorship of outplants in TDF restoration projects can vary from 0% to 80% [2][3][4][5][6][7][8][9]. In other Neotropical countries, such as Panama and Argentina, the reported survival values range between 0% and 95% [10][11][12]. Even though the surveyed restoration efforts were mainly in small areas with short-term experimental objectives, these studies have made it possible to identify robust restoration strategies while also identifying optimal seasons for direct planting and types of additional management that can enhance success. Based on the concept of precision restoration [13], it is necessary to focus management efforts at the plant level, using the lessons learned from previous efforts and available technologies. Some of the management actions that appear to be broadly successful at enhancing seedling survival can now be listed as recommendations for larger-scale efforts. These include (1) fertilization in karstic soils such as in the Yucatan region [3][5]; (2) the use of plastic mulch in the central region of the country (e.g., Morelos State) or in soils characterized by water stress [8][9][14]; (3) the selection of species that combine pioneer and later successional species; (4) a greater genetic and functional variability [15][16]; (5) using nurse trees in the Bajio region [16].

Survival showed high sensitivity to mean maximum annual temperature and the Lang Aridity Index across the reviewed studies. An important future research area is understanding the role of periodic and unanticipated warm spells or droughts in driving low restoration success. Specifically, it is important to determine to what extent low survivorship is a function of unusually dry or warm conditions at a restoration site, and whether sites that are already warmer and drier are more susceptible to such events. If there is a connection between especially low survivorship and anomalous climate events, then investments in better climate prediction to managers may be needed to effectively guide the timing of planting or identify a need for additional practices that can assure water availability. Given the time it takes to collect and propagate seeds, advanced drought warning systems are especially valuable, for example, identifying potential rainfall patterns based on multi-year El Niño-Southern Oscillation estimations.

The lack of relationship between survival rates and soil fertility in analyses contrasts with previous studies in diverse TDF regions including Mexico, which have found that the carbon–nitrogen ratio (C: N) was correlated with planting survival [4][5][7][17][18]. In TDF of India and Thailand, soil microclimatic conditions have been found to be important correlates of seedling survival [19][20]. For places where the initial conditions are unfavorable for plantings, success could be increased by preparation practices such as the removal of unwanted plants such as invasive grasses [21][22], soil reclamation, the establishment of artificial shade areas to reduce evapotranspiration, or implementation of low-cost actions such as artificial perches to favor the arrival of seed-dispersing species [23][24]. Unsurprisingly, rainy season plantings showed higher survival rates than dry season plantings, though the impact of seasonality decreased when plantings were irrigated. In other cases, the use of fertilizers or mulches can enhance survival [3][4][8][14]. In regions such as the Caatinga in Brazil, some strategies for recovery of soils and vegetation included the use of nurse trees to enhance microclimate conditions, the use of litter from adjacent intact forest to recover mycorrhizal fungi and provide mulch and nutrients, and mixed plantings including endemic species [25][26][27]. These strategies seek to reduce the impact of water limitations on seedling survival and growth.

This may be because planting several species increases the likelihood of planting at least one that is well suited to a site or site conditions [4][28][29][30]. Some authors have highlighted the need to incorporate a functional attributes perspective into the selection of species for restoration projects [29]. For example, Ceccon et al. [31] found that soil recovery could be achieved using species mixtures that include members of the Fabaceae, such as Pithecellobium dulce or Leucaena leucocephala, which have rapid growth and quick canopy closure and produce abundant nutrients, especially nitrogen-rich litter. The Yucatan Peninsula provides another example of the importance of species selection where three primary forest species (Brosimum alicastrum, Enterolobium cyclocarpum, and Manilkara zapota) were used to successfully accelerate structural and compositional recovery [32]. Clearly, there are multiple avenues to increase the success of direct planting, and there is a need for expanded site-specific research into next-generation prescriptions for TDF. Making informed decisions when planning, designing, implementing, and monitoring success in a restoration project enhances the probability of ecosystem recovery while reducing costs [15][33]. By identifying the advantages, disadvantages, and site specificity of different practices, more appropriate and adapted projects can be promoted for each context. Additionally, defining the logistical, ecological, and social elements is useful to the development of restoration projects.

3. Are Current Restoration Initiatives Enough?

The Mexican government has increased investment in the restoration of forest ecosystems, which has been reflected in the signing of high-level international agreements. Some of the efforts have focused on different government entities that have estimated the Anthropic Impact Index and Ecological Degradation Index of Mexico's diverse TDF ecosystems, thus categorizing sites with respect to restoration priority [34][35]. Larger-scale efforts have also developed prioritization schemes for TDF restoration across Latin America [36][37] and highlight the importance of understanding landscape variables (e.g., connectivity) and human impact (e.g., degradation due to land use) for selected restoration sites. However, multiple sectors have recognized that <1% (~28,000 ha) of the TDF biome has recovered a forest canopy, which is insufficient to meet Mexico's larger environmental goals. Legislated restoration mandates will inevitably result in expanded restoration of the TDF in Mexico, and the findings suggest that this expansion will benefit from strong investment in the science of restoration, including the identification of cost-effective and site-specific restoration practices—recently defined as precision restoration [13]—or more general practices optimized for a wide diversity of sites. By developing a TDF restoration framework for Mexico, national-scale restoration planning can help to more effectively prioritize restoration investments into projects that are most likely to succeed [33][38][39]. This framework would further help resource managers to identify practices and prescriptions that are suitable given the climatic, edaphic, and ecological condition of a site to avoid applying more generic practices that may not lead to successful or timely restoration. This framework would also serve restoration practitioners well by providing easily implementable monitoring ideas with metrics that are simple to understand and interpret.

Mexico does not currently have a long-term national plan for the ecological restoration of its ecosystems. However, in the region, there are examples that aim to remediate environmental situations similar to those faced by Mexico, such as deforestation, invasive species, overexploitation of natural resources, pollution, and climate change [40][41]. Large-scale restoration frameworks have focused primarily on seven principles: (1) a landscape approach is necessary to restore ecological functions; (2) taking into account the local-territorial context of local communities to understand their needs; (3) generation of instruments for planning, designing and monitoring restoration projects; (4) promoting local and national economic sustainability; (5) promote participatory governance that allows transparency and credibility of projects; (6) guaranteeing management and incorporation of ancestral, cultural and technical knowledge; (7) having a solid normative structure that shields projects and their goals. The experience of the regional guidelines for national restoration allows to identify that it is necessary to develop an action plan based on existing efforts.

Moreover, direct planting is logistically and economically costly and shows variable success rates [2][4][5][15]. Direct plantings of native species have also been used as part of the efforts carried out by the government, mainly using only one species with fast growth rates, such as Cedrela odorata [42]. However, considering the lack of planning instruments, in many cases, the implementation of forest restoration plantings promotes the replacement of natural ecosystems, such as grasslands or natural shrubs [31][43]. These types of experiences, knowledge, and data must be collected and analyzed to generate the basis for a national restoration plan. It is important to recognize that TDF restoration efforts in Mexico need to increase in number and extent to compensate for the high rates of transformation and disturbance.

4. Ecological Restoration Needs Society

In Mexico, 43% of the land base is controlled through collective land concessions, or “ejidos”, which support a wide diversity of communities including 68 indigenous groups [43]. However, as with previous Mexican and the Neotropical TDF studies [11][43][44], this included only two studies that considered social drivers of restoration practice of success. In most of the restoration efforts in the Neotropics, the communities are included in the execution phase, as support in the fieldwork and the monitoring of progress. In a few cases, local communities are consulted for the project design, mainly with regard to site and species selection [45][46]. Studies that included social aspects in the restoration project did not combine ecological metrics and vice versa, which makes it difficult to integrate social and ecological dimensions of the restoration process [46]. Ideally, future studies will increasingly include both ecological and social dimensions of restoration efforts [2][47][48]. There are calls for increased recognition and engagement of communities in the planning and development of TDF restoration projects, in order to enhance project success in the recovery of ecosystem biodiversity and function to meet the needs of local communities [4][11][43][44].

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