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Review

Opportunities for Integrating Social Science into Research on Dry Forest Restoration: A Mini-Review

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Abstract: Seasonally dry tropical forest ecosystems have been greatly reduced in areas through conversions to alternate land uses such as grazing and crop production. The U.N. Decade on Restoration has focused attention on both restoration globally, and also regional attention on tropical dry forests, as they are excellent candidates for regeneration and reforestation. As such, the science of how we restore dry forests is advancing; however, few studies of dry forest restoration include collaborations with social scientists. This is unfortunate, because restoration projects that embrace a people-centered approach have the highest chances of success. Here, I review recent studies that have incorporated aspects of social science and human dimensions into the study and design of dry forest restoration practices. I focus on three key topics that merit a closer integration of restoration research and practice and social science: (1) recognizing that local people are central to project success, (2) cost benefit or effectiveness analyses that evaluate the relative costs of alternative management strategies, and (3) identification of land-use tradeoffs, synergisms and priority mapping. I conclude that closer collaborations among dry forest restoration researchers and a wider group of partners including social scientists, local communities, environmental educators, and geographers will increase the value of restoration research and the likelihood that such projects achieve multiple ecological and societal benefits.

Keywords: social science; people-centered; cost effectiveness analysis; trade-offs

Citation: Powers, J.S. Opportunities for Integrating Social Science into Research on Dry Forest Restoration: A Mini-Review. *Sustainability* **2022**, *14*, 7351. https://doi.org/10.3390/su14127351

Academic Editors: Rodolfo Dirzo, Christian P. Giardina and Julio Campo

Received: 22 March 2022
Accepted: 10 June 2022
Published: 16 June 2022

1. Introduction

After decades of research, the issues and threats facing seasonally dry tropical forests (SDTF) are by now relatively well known [1,2]. The seasonally dry tropical forest biome was once vast, accounting for ~40% of tropical forests worldwide [3]. Centuries of land use has reduced the area of SDTF considerably [4,5]. Challenges to the persistence of SDTF and to their restoration now include anthropogenic fires [6], climate change [7], and soil degradation [8], among others. However, precisely because so much of the dry forest biome has been converted to alternate land uses and/or degraded, this opens up the possibility of restoration and reforestation at large spatial scales [9]. The strong dry season that defines SDTF imposes constraints on restoration practices—both in terms of tree planting and assisted or unassisted natural regeneration; thus, much work has been done to synthesize the abiotic, environmental, and biophysical challenges for restoration and secondary succession of tropical dry forests, as witnessed by at least six excellent reviews of this topic in the literature [10–15].

By contrast, comparatively little of the published research focused on restoration of tropical dry forests has integrated social sciences or human dimensions (Table 1). To illustrate this point, I performed a citation search in the Web-of-Science database using search terms that included "tropical dry forest restoration" and different terms that might indicate social sciences approaches (Table 1). I acknowledge that this cursory search may miss some papers that do include socio-ecological or socio-economic perspectives and that I only searched for terms in English language publications. Not surprisingly, the number of papers on dry forest restoration has increased over time (Figure 1). However, of the 669 items retrieved from this search, fewer than 15% showed indications of social sciences perspectives ("soci*"), less than 4% included indications of cost benefit analyses, and even fewer still included the terms "livelihoods" or "traditional ecological knowledge" in the title, keywords or abstract. Overall, this simple exercise highlights the lack of social science perspectives in the tropical dry forest restoration literature.

Table 1. References returned from a Web of Science Search (14 January 2022) with the following search terms expressed as the total number of references returned and as the percentage of references returned from the search term "tropical dry forest restoration". Note that the asterisk functions as a "wild card" term in search engines and will include all words with the letters before the asterisk (for example, "cost*" will return terms "cost", "costs" and "costly", etc.).

Search Terms	Total Number of References	Percentage of "Tropical Dry Forest Restoration"
tropical dry forest restoration soci*	99	14.80
tropical dry forest restoration species selection	43	6.43
tropical dry forest restoration cost* benefit*	25	3.74
tropical dry forest restoration livelihood*	23	3.44
tropical dry forest restoration local ecological knowledge	15	2.24
tropical dry forest restoration	669	100.00

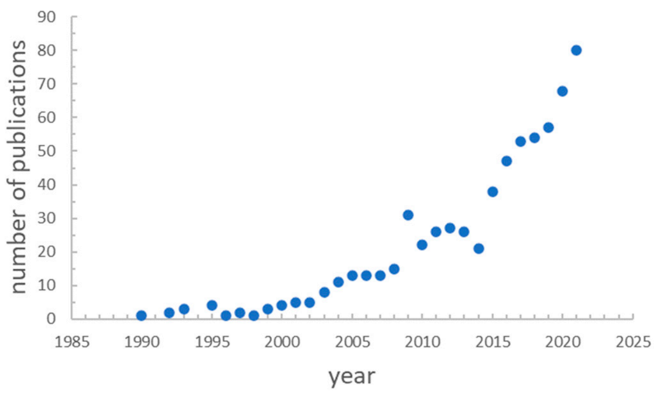

Figure 1. Number of papers per year containing the search terms "tropical dry forest restoration" published up until 2022 retrieved from a Web-of-Science query.

There is increasing recognition of the need to incorporate social sciences and a stronger appreciation of the context of human dimensions into restoration practice [16,17]. My goal in this narrative review is to complement the large body of research that is focused on the ecological aspects of dry forest restoration by discussing ways that restoration researchers can partner with a wider spectrum of collaborators to improve the outcomes of SDTF restoration projects. To accomplish this goal, I synthesized many of the articles identified in the literature search reported in Table 1 that included social science perspectives within the context of dry forest restoration research. Below I make the case for why it is imperative to integrate social science into dry forest restoration research and then discuss three emergent themes that exemplify this. I conclude by calling for restoration practitioners and researchers to collaborate more closely with social scientists and other partners.

2. The Case for Integration of Social Science into Tropical Dry Forest Restoration Research and Practice

Why is integrating social science perspectives into restoration practice and research projects critical to their success in general, and especially for dry forests in particular? Globally, dry forests support hundreds of millions of people through the goods and ecosystem services they provide including fuelwood, pollination services, fodder, wood for construction, non-timber forest products like medicinal plants and foods, watershed protection, tourism opportunities, and cultural and spiritual benefits (Figure 2a–c) [18–21]. This is not a new phenomenon, as Indigenous peoples have lived in, managed, and interacted with dry forest environments for millennia [22–28], and European colonizers of Latin America and the Caribbean preferred drier climates that more closely resembled those of Europe. The historical and current close proximity or adjacency of people and dry forests suggests that integrating people into the design, implementation, and continued monitoring of restoration projects is essential to their success [29]. Indeed, recent studies document cases where restoration projects have failed to meet desired objectives, in part because local people were not incorporated [30–32].

Figure 2. People have a long and continued reliance on tropical dry forests for necessities such as fuel wood (**a**); the history of these interactions is documented on the trees themselves; (**b**) shows markings on a *Manilkara chicle* tree that was tapped decades ago; restored forests provide ecosystem services such as watershed protection (**c**); and an environmental educator and students in the Guanacaste Conservation Area, Costa Rica (**d**).

Here, I review recent research identified in the literature review presented in Table 1 that occurred in the SDTF biome, which highlights the potential benefits of incorporating a social science perspective in the design, implementation, and monitoring of restoration projects in tropical dry forests—with the explicit goal of improving the outcomes from multiple perspectives, i.e., both biological (carbon, biodiversity, etc.) and societal (livelihoods, cultural values, and spiritual values). While I hope to engage a broad audience, I have approached the multiple layers of complexity inherent in socio-ecological restoration from the perspective of a natural scientist who wishes to integrate social science dimensions into research and practice. I focus on three key topics that emerged from the literature summarized in Table 1, which are areas that merit a closer integration of restoration research and practice and social science (summarized in Table 2): (1) recognizing that local people are central to project success, (2) cost–benefit or effectiveness analyses to evaluate the relative costs of alternative management strategies, and (3) identification of land-use tradeoffs, synergisms, and priority mapping. While restoration activities occur along a spectrum from spontaneous, unassisted restoration to sites requiring heavy management and rehabilitation [33], my review is targeted at practices that involve active management of trees or seedlings.

Table 2. Topics, key partners and recent examples of collaborations leveraging social science approaches in the understanding of tropical dry forest restoration research.

Topic	Key Collaborators from Social Sciences and Other Fields	Recent Examples in the Literature
Achieving people-centered restoration for better outcomes; selection of species to plant based on local preferences and valorization; environmental education as a key dimension of restoration	Anthropologists, environmental educators, governance and policy experts, non-governmental organizations (NGOs), local communities	[16,17,32,34,35]
Cost benefit or effectiveness analyses of restoration practices	Economists	[36,37]
Identification of land-use synergies, trade-offs, and priority mapping	Geographers, GIS and remote sensing specialists, and economists	[29,37–42]

3. People-Centered Restoration

There is a mutual interdependence between local people and restored forests; this necessitates consultation and collaboration with local people at all phases of the restoration process, from planning to ensuring the long-term permanence of restored forests. There are a number of ways that closer collaboration between restoration researchers and practitioners and people with other disciplinary backgrounds, including anthropologists, policy analysts, and environmental educators, can facilitate people-centered restoration.

Social scientists such as anthropologists can bring a more holistic view of coupled social ecological systems and facilitate people-centered natural climate solutions. Local people or residents are usually the key actors in landscapes (regardless of whether they are legally empowered as owners or managers) and thus understanding them and their interests and uses of the land an essential first step towards restoration, which inherently means changing how the land is used. Sometimes the key restoration interventions might involve changing something about the social system rather than changing trees. For example, in central India, raising living standards through providing households with liquified petroleum gas to replace wood cookstoves and financing for durable housing materials (concrete rather than wood, mud, and dung) decreased bare ground surrounding villages as measured through remote sensing analysis [43]. In other words, increasing living standards lead to decreased reliance on forest products and thus facilitated regeneration. This example illustrates how insights into social systems was key to achieving a desired restoration outcome.

Another opportunity to leverage the close interdependence between people and restored forests is through local ecological knowledge (LEK, a term that I am using to encompass many categories of knowledge including indigenous knowledge, traditional ecological knowledge and local ecological knowledge). Indigenous people and local communities have firsthand, extensive knowledge of the ecosystems they live and work in that is relevant to restoration such as familiarity with flora and fauna, understanding of reference conditions against which to compare restoration success, management of fire or invasive species, and/or how to propagate species, which can complement science-based approaches to restoration [44]. There is a growing body of studies that integrate LEK to help identify which species to plant [19,34,35,45–49]. For example, in tropical dry forests landscapes in Peru and Ecuador researchers conducted interviews and field walks with local residents of eight villages to identify which plant species were considered useful, threatened, and resistant to local stress factors including climatic factors, topographic and edaphic conditions, and grazing [38]. This analysis allowed them to recommend species for restoration that were deemed both highly useful and highly threatened. Assessments of species' threat status and stress resistance from local experts was largely consistent with reports in the scientific literature for the same species. This echoes results from a study in Nicaragua where local communities assigned lower social valorization indices to forest patches that were considered degraded in ecological terms [49]. The implicit assumption of these studies is that favoring species that have local value should enhance the viability and eventual benefits of restoration projects. Thus, including LEK of residents and non-governmental organizations at the planning and implementation stages of restoration projects complements and reinforces other strategies for selecting target species to cultivate that use considerations such as viability under changing climatic conditions [8,50]. However, it is essential to develop relationships that avoid "extracting" LEK and instead promote the co-creation of knowledge and equitable sharing of the benefits of restoration [44,51,52]. There is a clear role for social scientists to help bridge the gap between this local knowledge and restoration practices.

Last, there are other examples of large-scale, long-term dry forest restoration projects whose success relied heavily on integration of forest regeneration and conservation into the context of local communities [53]. The Guanacaste Conservation Area in northwestern Costa Rica was established as a protected area in 1971 on lands that had previously been used for grazing and other agricultural activities [53]. The Conservation Area's goal was to regrow the dry forest and ensure its continued existence in perpetuity [54]. To achieve this goal, they developed an approach they termed "Biocultural Restoration" [55]. In brief, the philosophy was to demonstrate the value of the conservation area to local people, not by keeping them out, but by inviting them in. Environmental education was a key part of their strategy [56].

The Programa de Educación Biologica (PEB, or the Biological Education Program in English), was founded in 1986 and brings in local children in the 4th, 5th and 6th grades for four visits a year to the different ecosystems in the Conservation Area [56]. Environmental educators lead these field trips and discuss the natural history, biodiversity, ecological interactions, and ecosystem services such as water provisioning that the Conservation Area protects and provides (Figure 2c,d). Parents are invited on these field trips, and by now two generations of students have benefitted from this program. The link between environmental education and restoration promoted by PEB is strong: allowing young people to experience and understand the biodiversity of the restored ecosystems ensures that they treasure these areas and protect them in the future. This case study demonstrates how coupling environmental education with restoration efforts is essential for the long-term viability of restored ecosystems.

4. Cost–Benefit Analyses

Although the restoration ecology literature is growing (Figure 1), there are only a handful of studies that incorporate economic analysis [11,57,58] (Table 1). A recent review of 30 dry forest restoration papers found that only 20% of these reported on costs associated with restoration activities. This is unfortunate, as information on the potential costs relative to outcomes is useful for both planning and managing restoration projects, and can contribute to analyses of alternative land-use scenarios [37]. Quantification of the costs of different management choices such as site preparation, nursery costs, soil amendments, fencing, fire management, weed control, mulching, fertilization schedules and doses, and especially watering—which can be pivotal to seedling success in climates with strong rainfall seasonality—are all important for understanding the inputs that go into restoration projects [8,36,59]. The benefits or effectiveness against which the costs should be weighed include ecological variables like seedling growth and survivorship, as well as social outcomes such as community engagement [11]. There are other study design decisions that could greatly increase the value of research on dry forest restoration. The average length of monitoring periods for planted seedlings/saplings in dry forest restoration projects is <24 months [11]. This limits our ability to understand the long-term success of different treatments and to weigh costs of post-planting management against those of replanting seedlings that died.

Such data also can contribute to a larger understanding of the pros and cons of restoration approaches beyond choices made at the site level. When combined with data on the net ecosystem service benefits of restored ecosystems, cost–benefit analysis can help to identify which restoration approaches are likely to yield the highest overall benefits [37], taking local conditions into account. For example, Birch et al. generated spatially explicit maps of alternative land-use scenarios for four regions in Mexico, Argentina and Chile, comparing the different benefits such as carbon sequestration, non-timber forest products and tourism potential against the costs of different restoration practices including passive restoration, assisted natural regeneration (fencing and fire suppression), and active restoration (tree planting with fencing and fire suppression) [37]. They found that while the costs of active restoration varied among regions by a factor of ten owning to local costs associated with labor and materials, overall scenarios involving passive restoration yielded higher cost-effectiveness for all regions [37].

In summary, most projects or grants operate on fixed budgets and thus are already tracking expenditures. Translating this into cost–benefit or cost-effectiveness analyses should become a routine component of reporting results from dry forest restoration experiments or projects, even though they may vary by species and microsite conditions [36]. Similar methods can be adapted at the post-implementation phases of restoration projects to quantify the realized economic and social benefits to communities as a component of evaluation [57].

5. Identification of Land-Use Tradeoffs and Synergisms and Priority MappING

The last few decades have witnessed a host of that papers integrate restoration priorities and ecosystem services into larger landscape contexts [29,37–42]. These approaches are interdisciplinary by design and provide multiple perspectives on the social, economic, geographic, and ecological trade-offs and/or synergies that accompany different land-use scenarios [41], as well as incorporating multiple perspectives into assessment of restoration needs [40].

Some methods are well suited to integrating multiple information sources including ecological and sociological data streams. For example, researchers used econometric valuation methods to help quantify the value of provisioning and regulating ecosystem services provided by different successional stages of secondary dry forest in Jalisco, Mexico [41]. They used surveys of landowners to assign economic values to different ecosystem services. As secondary forest competes with other potential land uses such as pasture, this analysis can help design policy programs like Payment for Ecosystem Services to minimize the perceived trade-offs and accentuate synergisms [41]. Similarly, state-transition models (STM) allow quantitative and qualitative formulations of ecosystem states and dynamics, and can be based on input from different groups of stakeholders. For example, some researchers J compared the states of vegetation including arid land, simplified forest, shrub-dominated land, semi-natural forest and natural forest that were informed by expert ecologists versus knowledgeable local people for a region in Ecuador to identify areas of agreement on the causes of degradation and thus forge a commonly agreed on solution [40].

Other useful methods leverage GIS and geo-spatial analyses to map out tree distributions, threats, and priorities for restoration. For instance, Costa et al. generated spatially explicit maps of where to prioritize restoration based on supply of and demand for key ecosystem services provided by different tree species [38]. Fremout et al. (2020) used species distribution modeling for 50 common species in a dry forest region encompassing Southern Ecuador and Northwestern Peru and scored their vulnerability to five different threats (climate change, fire, habitat conversion, overgrazing and overexploitation) based on species traits [39]. They then used spatially explicit data layers of the different threats and overlaid these with species distributions maps to derive species-specific estimates of vulnerability. This allowed them to make maps of priority areas for restoration and conservation. This tool is freely available online in multiple languages and can be adapted for conservation and restoration planning for other regions. Collectively, these studies exemplify how approaches that combine restoration science with insights from other disciplines can extend the scope and impact of restoration research.

6. Discussion and Conclusions

The United Nations Decade on Ecosystem Restoration has focused global attention on the promises that restored ecosystems may bring. As seasonally dry tropical forests have been subjected to centuries of conversion to alternate land uses [3,4,60], there exist large opportunities to restore these forests [9] and the ecosystem services and benefits they provide [20]. The number of studies focused on restoring tropical dry forests has clearly increased over time (Figure 1); however, very few of these studies integrate perspectives from the social sciences and/or human dimensions (Table 1). Moreover, the majority of research on tropical dry forest restoration has occurred in protected areas opposed to private lands [11]. This can lead to a disconnect between academic researchers, practitioners, and local communities. In addition, the success of plantings and plant performance can differ between on-farm settings and experiment stations [45], which underscores that additional efforts may be required to translate the results of research to other settings that are outside of experimental stations.

There are multiple ways that researchers engaging in the study of dry forest restoration from largely biological or natural science perspectives can partner with a wider range of collaborators to increase the ultimate reach and usefulness of their work. These include partnering with anthropologists, NGOs, and local communities to identify plant species with desirable traits, to partnering with environmental educators who can help connect local people to the value of restored forests. Restoration ecologists would also benefit from closer collaboration with economists and should make reporting the costs of restoration projects standard practice, just as many journals now require authors to make their data available. Last, collaboration with geographers and economists can help to contextualize how restored forests fit into the larger landscapes of alternate land-use scenarios and prioritize areas where restored forests maximize multiple benefits. There are undoubtedly other creative ways that restoration researchers can engage with a wider range of partners to ensure the success of restoration projects. I view collaboration among restoration ecologists, social scientists, practitioners, and local communities as a "two-way or more street"; strengthening these ties and co-creation of knowledge will hopefully result in restoration outcomes with both ecological and societal relevance.

Funding: This research was funded by a University of Minnesota Grant-in-Aid of Scholarship.

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to the fact that it was a literature review.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: I thank Forrest Fleischman for discussions that improved this manuscript.

Conflicts of Interest: The author declares no conflict of interest.

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