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Stakeholders' perspectives of species diversity in tree plantations: A global review

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RESUMO: *Increasing the diversity of commercial tree plantations is a promising approach to adapt forests to climate change, but it may complicate management. Here, we assess stakeholders' perspectives about tree-species diversity in plantations and explore policy alternatives to make mixed plantations a viable strategy for climate change mitigation and adaptation. Current evidence shows that enhancing the diversity of tree species in plantations can be a viable, scalable, and economically-accessible strategy for sustainable wood production and reconciling economic and environmental benefits. Tree diversity is particularly important in the context of global environmental changes and associated increases in abiotic and biotic stresses, such as severe droughts and pest outbreaks. Even though there is substantial scientific evidence supporting mixed-tree plantations, most forest plantations globally are still conventional monocultures. Our findings (i) describe the geographical distribution of publications investigating human perspectives about forest plantation diversity, (ii) build understanding of how political engagement and governance systems can support forest initiatives on forest conservation, management and restoration, and (iii) demonstrate how these perspectives can create possibilities and opportunities for sustainable development in forestry. We conclude that new strategies will only be widely applied if there is political and institutional interest, particularly in strengthening land-governance systems.*

Palavras-chave: plantios mistos, sustentabilidade, percepções

Introduction

Mixed tree plantations simultaneously grow two or more tree species on the same land for commercial or protective purposes, which may result in more complex forest structure and functioning than monocultures (Pretzsch, 2014). A growing body of evidence suggests that mixed tree plantations are more resilient to many types of disturbances, making tree diversity a central element in adapting forests to climate change (Messier et al., 2022). Mixed tree plantations can have greater carbon sequestration and productivity than monocultures due to asynchrony of tree species dynamics (Morin et al., 2014), primarily related to deciduousness and light interception. A large variety of species increases functional diversity, so mixed plantations tend to better explore and use

available resources in space and time (nutrients, light) and better cope with stresses related to climate change and pests (Grossman et al., 2018). However, the resulting multifunctionality and ecosystem services strongly depend on which species or varieties are planted in the mixture, as well on their management.

To maximize the applicability and visibility of mixed forests to forest managers worldwide, it is vital to understand perspectives on the diversity of plantation species held by forest stakeholders. These include forest managers, citizens, academics and rural communities, a term we apply to any group of people who develop and live in the countryside, far from urban centers. We review the literature to capture the perspectives of stakeholders involved in tree plantations associated with forest conservation, restoration and management. Our objective was to understand how stakeholder perspectives about species diversity in plantations can contribute to better policies to foster and enable mixed plantations appropriate to mitigate and adapt to climate change. To achieve this, we i) review the existing literature on stakeholders' perspectives about species diversity in forest plantations; and ii) synthesize information from these studies on how to promote more diverse plantations.

Material and methods

We searched Web of Science for papers about stakeholders' perspectives on tree species diversity. Selected articles must contain at least one keyword from each of the following groups: (a) 'perception' or 'perspective' (b) 'community', 'citizen' or 'stakeholder'; (c) 'forest', 'forestry', 'tree' or 'plantation' and (d) 'diversity', 'mixed' or 'monoculture'. We focused on keywords associated with methods like questionnaires and interviews. Our survey addressed English-language primary literature published between 2000 and 2021. We considered articles from the last 20 years because this subject is relatively new and few relevant publications predate this period. This search returned 345 articles. All their abstracts were read to determine if they addressed (a) a human perception or perspective and (b) forestry at any level of species diversity.

Results and discussion

The selected articles reported responses from 6,905 people, of whom 53% were from rural communities (n=3,637 respondents), 34% were urban inhabitants or tourists (n=2,374 respondents), 12% forest managers (landowners, forestry company workers, public sector employees, NGOs; n=854 respondents) and 1% academics (n=40 respondents). Most of these stakeholders viewed mixed plantations as positive. Studies on mixed-species forests and plantations (with productive or

protective intentions) represented 66% of the cases evaluated, while monocultures totaled 33% of the sample.

Forest conservation: When rural inhabitants were asked about the ecosystem services provided by mixed forests, only positive feedback was obtained (Grilli et al., 2016); people who recognized and were aware of the importance of forest ecosystem services and forest conservation were more likely to prefer mixed forests. Forest managers had a higher probability of preferring mixed forests, compared to monocultures, especially when considering two ecosystem services: carbon sequestration and biodiversity conservation. In contrast, urban citizens manifested a lower preference for mixed forests.

Forest management: We identified a consensus in the reviewed articles that sustainable forest management needs more political engagement to be effective for mixed tree plantations, whether for restoration and protective actions, or for timber production. Governance systems were considered the best way to bridge the gap between scientific knowledge and decision making in forestry in tropical regions (Scheidel; Work, 2018).

A lack of knowledge on spatial-temporal scales hinders the operationalization of forest-management techniques. Thus, it follows that more studies on management are needed, especially considering that mixtures are often more complex than monocultures, which makes planting and management more complicated, sometimes needing more operational interventions (Nichols; Carpenter, 2006) dependent on specialized knowledge. Although studies demonstrate the benefits of mixed plantings, most of them are still established at an experimental scale, and often use only manual procedures.

On the other hand, forestry operations deployed on thousands of hectares commonly use monocultures because they depend heavily on machinery, perform standardized silviculture and harvesting operations, and process uniform products preferred by industry. These activities are still designed for homogeneous forest stands (Evans, J. & Turnbull, 2004). Bridging the gaps between scales and operational procedures is a central issue to be considered to foster mixed plantations.

Forest restoration: It can be carried out through different methods, including the mixed planting of trees (combined with other actions). This is currently a popular strategy with potential to mitigate climate change if widely disseminated. Even so, some studies suggest it must be better studied to properly incorporate the ecological and social consequences of these actions.

Figure 1: The locations where reviewed publications' samples (interviews and questionnaires) took place. The points sizes are proportional to the number of respondents, and their colors indicate the stakeholder type.

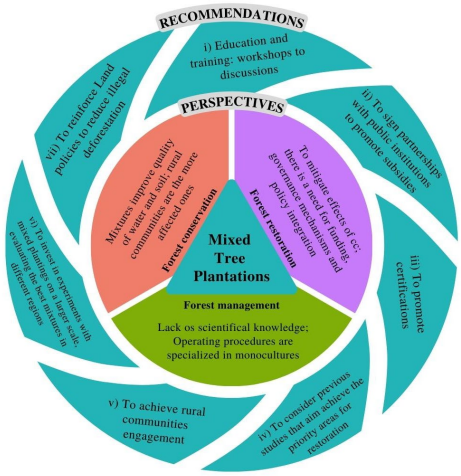

Figure 2: Synthesis of the main stakeholders' perspectives about forest management, restoration, and ecosystem services, and seven recommendations for promoting mixed-tree plantations at a broader scale.

Conclusion

Our review shows that many strategies are available to foster sustainable practices in the forestry sector using mixed tree plantations. This may be achieved through operational and educational actions, promoting training on technical knowledge of planting in regions suitable for these activities. Broad-scale activities with national or international impact for the recovery of habitats and planting to protect fragile areas and prioritize areas for conservation and restoration may be useful. Yet these strategies and visions will only be widely disseminated, applied and productive if there is political will and organizational interest.

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