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Designing multifunctional forest systems in Northern Patagonia, Argentina

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Multifunctional productive systems based on native species management, a new paradigm that counters colonial worldviews, offer sustainable sources of food and materials while preserving biodiversity. Despite extensive discussions in herbaceous and agricultural systems, applying this concept to native forests in Northern Patagonia remains unclear. Multifunctional system implementation can be approached from a fractal perspective, with evaluations at the stand level being essential for understanding ecological processes across scales. Here, we exemplify research and management for multiple native species, integrating results from 10 years of field experiments on the impacts of biomass harvesting intensity (HI) on nine Nature's Contributions to People (NCPs), including habitat creation, pollination, soil formation, hazard regulation, prevention of invasions, and provision of energy, food, materials, and options. Our findings reveal that some regulating NCPs peak with null HI, while certain material and regulating NCPs maximize at the highest HI. Low to intermediate HI (30–50%) show a more balanced provision of all NCPs. Our results suggest that some biomass extraction is necessary to enhance most NCPs, emphasizing the importance of balancing material provisioning and biodiversity conservation in management schemes. We propose future directions for designing multifunctional forest systems, advocating for low-density plantation of native tree species with high wood quality within the natural forest matrix. This approach may yield higher NCPs levels over time compared to the current cattle breeding and wood extraction system, with implications beyond Patagonia, considering historical associations of such practices with colonial worldviews globally.

KEYWORDS

biodiversity, bioenergy, biomass, colonial practices, ecosystem services, forest management, fruit plants, Nature's Contributions to People

1 Introduction

During European colonization, the Americas underwent a significant transformation as Europeans aimed to establish control over vast, unfamiliar lands (Veracini, 2010; Hixson, 2013). This process involved reshaping ecosystems to serve economic interests, introducing crops, livestock, and agricultural practices (Kaltmeier et al., 2016, 2019; Ficek, 2019; Markowitz, 2022). Enterprises from dominant countries sought cost reduction and operational advantages, often overlooking the role of biodiversity in production (Bousfield, 2019; Kaltmeier et al., 2019). The dominant species introduced were typically exotic and potentially invasive (Fajardo et al., 2022), with significant consequences for indigenous populations and existing ecosystems (Laterra et al., 2021). In these productive systems shaped by colonial worldviews, questions arise about implementing management alternatives for the benefit of both nature and people.

When designing new management schemes, it is crucial to consider not only the short-term production of commodities but also the broader spectrum of contributions that ecosystems offer to people. Nature's Contributions to People (NCPs) encompass a diverse range of benefits and detriments resulting from human interactions with the natural world (Hill et al., 2021; Kachler et al., 2023). These contributions can be categorized into three groups: material, non-material, and regulating NCPs. Material NCPs include tangible resources such as water, food, fibers, and energy. Non-material NCPs cover subjective aspects, such as cultural identity and aesthetic inspiration. Regulating NCPs refer to nature's role in shaping environmental conditions (Hill et al., 2021). These concepts are integral to multifunctional productive systems, where ecosystems interact with society to produce a wide range of NCPs (Bruley et al., 2021).

In many rural systems, the capacity to simultaneously provide numerous NCPs has declined due to conventional intensification and agricultural expansion shaped by colonial worldviews (Fagerholm et al., 2020). The prevailing trend toward intensification primarily focused on maximizing a single NCP, like food or material production, often comes at the expense of other vital services such as biodiversity conservation, clean water provisioning, and the safeguarding of local knowledge, cultural identity, and cherished places (Renting et al., 2009; Song et al., 2020). Recognizing and capitalizing on opportunities to enhance system multifunctionality, offers a means to navigate the complex interplay between trade-offs and synergies among NCPs (Benz et al., 2020). Multifunctional productive systems play a pivotal role in supporting climate regulation and furnishing essential NCPs, fundamental to good quality of life (Sardeshpande and Shackleton, 2019; Song et al., 2020; Westholm and Ostwald, 2020). Structural, biological and productive diversity in these systems grants a larger capacity to adapt to ever changing scenarios and is related to higher socio-ecological resilience (i.e., recovery from disturbances, such as natural phenomena or market fluctuations; Foley et al., 2005; Hölting et al., 2019).

Forests provide multiple NCPs, including regulating contributions, such as climate regulation through carbon storage (Lal, 2005; Griscom et al., 2017; Zhang et al., 2021) and habitat provision for a diversity of organisms (Lindenmayer, 2016). Material contributions, such as the extraction of wood and non-wood products like fruits and seeds (Guariguata et al., 2010), and non-material contributions, such as those related to psychological aspects (e.g., developing a sense of place; Gould et al., 2014), are also integral. However, forests usually cannot maximize all these NCPs simultaneously due to trade-offs associated with their multivariate nature (Bennett et al., 2009). As a consequence, each forest management decision has intrinsic synergies and trade-offs (Duncker et al., 2012; Wang and Fu, 2013; Syswerda and Robertson, 2014). For example, partial cutting or uneven aged management is unsuitable for high biomass production but, as structural complexity increases, thereby improving habitat quality, it can improve other services like biodiversity conservation and carbon sequestration (Sing et al., 2018). Understanding how different management options affect NCPs, with an emphasis on revealing trade-offs and synergistic effects, is an approach toward attaining sustainable management that balances and maintains multiple NCPs.

The enduring legacy of colonization, and more recent global processes related with increasing consumption and climate change, is evident in contemporary forests of Patagonia. The proliferation of livestock establishments, exotic conifer plantations, and various exotic plant species (Raffaele et al., 2014) are all testimony of that legacy. These forests also bear the imprint of enduring traditions of conservation practices and urban development. This amalgamation, often unintentional, has given rise to a multifaceted regional management scenario, encompassing the stewardship of national territories, privately owned lands, and sovereignty claims advanced by indigenous communities (Laterra et al., 2021; Peri et al., 2021). In the Northern Patagonian region of Argentina in particular, native forests have frequently been perceived as unproductive, leading to their conversion to other uses (Raffaele et al., 2014). Notably, the introduction of livestock and invasive tree species had detrimental consequences within the region's ecosystem (Raffaele et al., 2014). Through trampling, browsing, and other factors, livestock breeding has resulted in deleterious impacts (Mazzini et al., 2018; Ballari et al., 2020; Rodríguez and Soler, 2023). In addition, exotic tree plantations have induced alterations characterized by invasive behavior, competitive interactions, and increased susceptibility to wildfires (Franzese et al., 2022; Fernandez et al., 2023). However, Northern Patagonian forests also maintain a high level of pristine conservation compared to other forests worldwide. In this complex scenario, it becomes imperative to improve our understanding of the implementation of multifunctional productive systems, unraveling the intricate web of interactions within them. This study holds global significance as it addresses the enduring impact of colonial legacies and contemporary challenges, such as climate change and increasing consumption, on forest systems. By advocating for multifunctional management approaches and emphasizing the importance of preserving Nature's Contributions to People (NCPs), it offers valuable insights applicable beyond Argentina, informing sustainable practices for forest management and conservation worldwide.

2 Advancing native species management and research in Patagonia

Patagonia hosts considerable diversity in ecological regions and plant species, ranging from arid steppe areas dominated by herbaceous vegetation to temperate rainforests with abundant trees (Dezzotti et al., 2019; Secretaría de Gobierno de Ambiente y Desarrollo Sustentable de la Nación, 2019; Rosas et al., 2021). In particular, Patagonian forests have historically provided various goods and services, with biodiversity conservation and wood supply being prominent (Peri et al., 2021). Combining low to mid-intensity forest harvesting enhances productivity, ecosystem health, and biodiversity conservation (Gadow et al., 2006; Coulin et al., 2019; Carron et al., 2020; Chillo et al., 2020; Goldenberg et al., 2020a; Nacif et al., 2020). Climate-smart forestry, for example through canopy openings, protects trees, facilitates the provision of non-wood forest products, and enhances forest growth (Löf et al., 2019; Nacif et al., 2021).

Plantations with native trees provide a sustainable alternative to exotic plantations, enhancing the environmental and social value of forests (Cusack and Montagnini, 2004). For example, enriching native woodlands with locally adapted, native tree species of high economic value preserves ecosystems without complete replacement, offering a product appreciated by the market without relegating key ecological interactions (Álvarez-Garreton et al., 2019; Altamirano et al., 2020). Successful tree plantations require careful species and provenance selection, as well as site preparation, offering economic benefits through biomass extraction of the natural forest as a by-product (Goldenberg et al., 2020a; Nacif et al., 2023). *Nothofagus* and *Austrocedrus* trees are good examples of native trees with high timber quality and suitability for sustainable management (Speziale and Ezcurra, 2011; Donoso and Promis, 2015). Suitable harvesting intensities combined with native tree plantations, can provide an optimal balance between economic benefits and biodiversity conservation. We advocate for more empirical research to test these trends, contributing to long-term strategies.

In addition to native tree species, native fruit plants are of interest when designing forest enrichment schemes for multifunctional systems. Plants yielding fleshy, edible fruits have become a focal point of research in Patagonia, due to their nutraceutical potential. In the Patagonian region, 73 species of plants with edible fleshy fruits were identified, ∼80% of which are native (Chamorro and Ladio, 2020). When assessing the cultural importance of these edible plants, it became evident that native species held greater significance than their exotic counterparts. The native species with the highest cultural importance index among the edible flora of the region was *Berberis microphylla* G. Forst ("calafate"). This shrub is native to South America and produces solitary yellow flowers resulting in dark blue, fleshy, edible fruits. The collection of its fruits, leaves, stems, and roots is a traditional practice in Patagonia among indigenous peoples. It is a frequent component of the understory and one of the non-wood forest products with the greatest economic potential of the Patagonian forests, offering high antioxidant and anthocyanin content, surpassing that of other native species (Ruiz et al., 2013) and widely marketed exotic fruits. Because of this attribute, *B. microphylla* has gained market interest for various products. Its production can be complemented with that of other native species, like native strawberry [*Fragaria chiloensis* (L.) Mill.] and native currants (*Ribes* spp.), Patagonian raspberries (*Rubus geoides* Sm.), and maqui [*Aristotelia chilensis* (Molina) Stuntz], with important nutritional and nutraceutical properties (Schmeda-Hirschmann et al., 2019).

3 Data supporting the paradigm shift

To exemplify the multivariate response of different scenarios of native forest management, we evaluated the response of 10 indicators of nine NCPs to biomass harvesting in a specific ecosystem at the plot level. Indicator data were obtained from various published or in-press studies based on the same experimental plots in *Nothofagus antarctica* (G.Forst.) Oerst. forests of Río Negro province, Argentina. The study site ("Conciencia") is private land dedicated to forest conservation and research, located near El Foyel (41° 38′ S, 71° 29′ W). It has an annual mean temperature of 7.0°C, a mean winter temperature of 2.5°C, and an annual rainfall of 1,100 mm (Goldenberg et al., 2020b). The canopy is dominated by *N. antarctica*, *Diostea juncea* (Gill. et Hook.) Miers., *Maytenus boaria* Molina, *Schinus patagonicus* (Phil.) I.M. Johnst. ex Cabrera, *Lomatia hirsuta* Diels ex J.F.Macbr., and *Embothrium coccineum* J.R.Forst. and G.Forst., with the presence of *Austrocedrus chilensis* Pic. Serm. et Bizzarri (Coulin et al., 2019; Goldenberg et al., 2020b).

The experiment was designed to evaluate the effect of biomass extraction at different percentages of harvesting intensity (HI) on several response variables. During 2013, four treatments were implemented by delineating six strips per plot (31.5 × 45.0 m) with varying widths. These widths determined the extent of tree and shrub removal at ground level, with the treatments comprising 0% (no plant cover removal), 30% (1.5 m wide), 50% (2.5 m wide), and 70% (3.5 m wide) removal (Nacif et al., 2023). Within each of the plots, we planted six native tree species, namely, *Austrocedrus chilensis*, *Nothofagus dombeyi*, *N. pumilio*, *N. antarctica*, *N. alpina*, and *N. obliqua* and monitored tree survival and growth for 9 years (Nacif et al., 2023).

We selected response variables based on two criteria: the estimated variable had to be a clear indicator of an NCP and have a statistically significant response to HI. When more than one variable was related to an NCP, the variable that best represented each NCP was chosen based on the authors' professional opinion (Table 1). For hazard regulation, however, we focused on fire prevention, and included two separate indicators because they had opposite responses and were equally strong indicators (see details in Goldenberg et al., 2020b). These were: live fuel moisture content (%, henceforth related to "hazard regulation 1") and fuel amount ($m^2.ha^{-1}$, henceforth related to "hazard regulation 2"). Exceptionally, food provision values were obtained from the same site but not from the same experimental design. Here, we focus on *B. microphylla*, though it should be interpreted as an illustrative example. *Berberis microphylla* fruit production was evaluated through a natural gradient of canopy openness (Appendix Figure 3, Fioroni et al., 2022), selecting and averaging data from natural

TABLE 1 Summary of the 10 selected indicators for nine different Nature's Contributions to People (NCPs) evaluated at the same study site in *Nothofagus antarctica* woodlands.

NCP indicator	NCP category	NCP group	References	Sampling years
Litter structural α-diversity (H')	Habitat creation and maintenance	Regulating	Fernández et al., 2022	2016–2018
Fuel amount ($m^2.ha^{-1}$)	Hazard regulation (2)	Regulating	Goldenberg et al., 2020b	2015–2017
Live fuel moisture content (%)	Hazard regulation (1)	Regulating	Goldenberg et al., 2020b	2015–2017
Exotic pinaceae seedlings (No)	Invasion prevention	Regulating	Dimarco et al., 2024	2013–2016
Natives bees and wasps (Ln $ind.ha^{-1}$)	Pollination	Regulating	Agüero et al., 2022	2014–2019
Aerial soil cover ($m^2.ha^{-1}$)	Soil protection	Regulating	Goldenberg et al., 2020b	2015–2017
Firewood ($m^3.ha^{-1}$)	Energy	Material	Goldenberg et al., 2018, 2020a	2018
Total fruits ($fruits.plant^{-1}$)	Provision of food	Material	Fioroni et al., 2022	2020–2021
Multispecific height (m)	Provision of materials	Material	Nacif et al., 2023	2013–2021
Plant diversity (H')	Maintenance of options	Non-material	Goldenberg et al., 2020b	2015–2017

The table includes the broad NCP group, citation, and sampling years. Both hazard regulation indicators included relate to fire protection.

levels of canopy opening near the range of the experimental design values. For each variable, data were averaged for each level of HI to represent the average short-term response to HI (i.e., around 5 years) irrespective of particular year climatic conditions. Each variable was rescaled relative to the maximum value and compiled in radar plots to represent the multifunctionality of each of the four treatments. The variables "exotic Pinaceae seedlings" and "fuel amount" were multiplied by −1 so that desirable conditions (invasion prevention and hazard regulation, respectively) were represented by high score values.

Harvesting intensity affected the different regulating, material, and non-material NCPs (Figure 1). At one end of the spectrum, 0% HI scored highest at four NCPs that relate only to regulating contributions (Figure 1: habitat, hazard regulation 1, invasion prevention, soil protection) and scored lowest at five NCPs (Figure 1: materials, food, energy, pollination, hazard regulation 2). At the other end, 70% HI scored highest at four NCPs (Figure 1: two regulation and two material NCPs; also Appendix Figure 3) but scored lowest at four NCPs (i.e., those that were maximized with 0% of harvesting intensity). One indicator of fire protection was maximized (live fuel moisture), and the other minimized (fuel amount) at 0% HI. The opposite occurred in the 70% HI scenario. We intentionally included both variables because it is difficult to predict which has a greater effect on fire reduction. Material NCP was only provided with some degree of harvesting (Appendix Figures 1–3), and thus low to intermediate HIs (30 or 50%) had a more balanced provision of all NCPs (Figure 1). In particular, low HI (30%) provided seven NCPs and scored highest at only one. Intermediate HI (50%) was the only management option that provided all nine NCPs while also maximizing two types of NCPs: material and non-material (Figure 1).

4 Designing multifunctional forest systems

Sustainable management of native forests at the stand level proves to be both feasible and effective for enhancing distinct NCPs. However, to promote enduring, larger-scale effects, it is crucial to shift the paradigm from colonial worldviews to multifunctionality also across the landscape (see Introduction). While we presented data at the plot level (Section 3), designing multifunctional forest systems at a larger scale needs identifying landscape elements, modeling, and optimizing their configuration based on climatic, geomorphological, biological, cultural, and socio-economic variables. This approach will promote multiple NCPs and a good quality of life. Some practices identified as part of the colonial vision, such as cattle rearing, native wood extraction, and prescribed fires, may not necessarily be completely removed (Figure 2). These activities can coexist in the landscape as long as they are managed to ensure continuous biodiversity conservation and landscape diversity. We suggest six possible target objectives that should be considered when designing and implementing multifunctional forest systems.

- **Restore native forests as the main target in the working landscape matrix:** Passively native forest recovery may be possible by restraining human activities to different extents (particularly removal of livestock), or by active interventions that may include plantation of native trees and understory species, systematic removal of exotic seedlings/saplings, etc. Areas to restore should be prioritized based on their biodiversity importance and their potential to provide NCPs. Restoration times will highly depend on the current degradation status, the celerity of its detection, and management response (Puettmann and Bauhaus, 2023), as well as on internal and external factors, such as the occurrence of extreme weather events.
- **Progressively reduce livestock and exotic animals abundance and improve their management:** Many authors agree on free-range grazing from exotic livestock being detrimental to many native forest functions, especially due to soil compaction and seedlings depletion (Ballari et al., 2020; Rodríguez and Soler, 2023), but results depend on the forest system and its productivity, the variables measured, and the grazing history (Mazzini et al., 2018). Confining

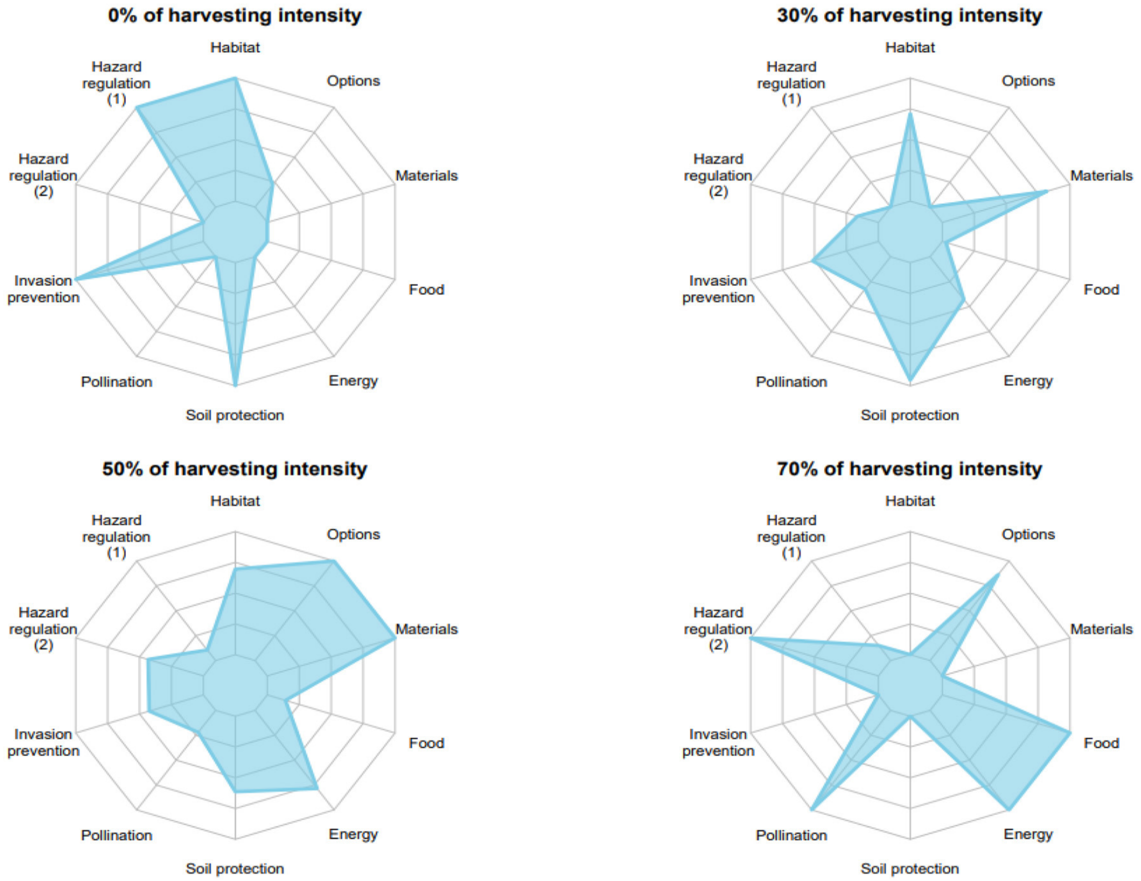

FIGURE 1
Low to intermediate harvesting intensities show a more balanced provision of all Nature's Contributions to People (NCPs). Effects of harvesting intensity (0, 30, 50, and 70%) on the 10 selected indicators (see Table 1) for nine NCPs evaluated at the same study site in *Nothofagus antarctica* woodlands. Data values were normalized by the maximum reported value for each variable. A full axis indicates that the NCP provision was maximized at the given harvesting intensity, while values closer to the center indicate that it was minimized. Hazard regulation NCP relates to fire protection and is calculated using two indicators: 1: live fuel moisture content, and 2: fuel amount.

livestock to designated areas, which may include forest patches under controlled silvopastoral practices, may offer a compromise solution. Frameworks such as the Forest Management with Integrated Livestock (Peri et al., 2022) can constitute useful tools, particularly if incorporated into legislation and financially supported and instrumented by governmental agencies.

- **Progressively reduce exotic plantations cover:** Multispecificity in planted forests has been shown to increase resilience and the provision of NCPs (Messier et al., 2022; this study). However, some exotic species, such as pinaceae, can become invasive with many detrimental effects. In this regard, attention will be needed to control exotic invasive saplings as early as possible (Núñez et al., 2017). These species may change the soil physico-chemical and hydrological properties, and thus, specific treatments may be needed to replace them with native species or a diversity of native and exotic species. Although distinct native species respond differently, it has been shown that through selective cuts, exotic species can shelter and benefit the establishment of newly planted native trees (e.g., Lesko and Jacobs, 2018).
- **Manage wood products and biomass extraction:** Wood is the main product extracted from forests, both for timber and fuel. While colonial worldviews have mainly focused on commercial criteria for forest harvesting, in recent decades, there has been increasing interest in applying management practices, such as retention forestry (Martínez Pastur et al., 2009; Gustafsson et al., 2012; Peri et al., 2021), and restoration thinning (Dwyer et al., 2010) due to their numerous co-benefits. Indeed, if these practices are planned appropriately, they can allow for trees, understory, and ground recovery while still admitting continuous harvesting in the long term.
- **Incorporate profitable alternatives:** While colonial practices are the current source of income for people living in and around native forests, replacing some of those activities, at least partially (e.g., reducing the animal load), may be possible if other commodities are added as forest values. Such alternatives can help dispel perceived trade-offs between conservation and profit. Examples of possible alternative include harvesting non-wood forest products (such as leaves, fibers, fruits, and fungi, collected for food, ornamental, aromatic, pharmaceutical, and medicinal purposes; Burgener

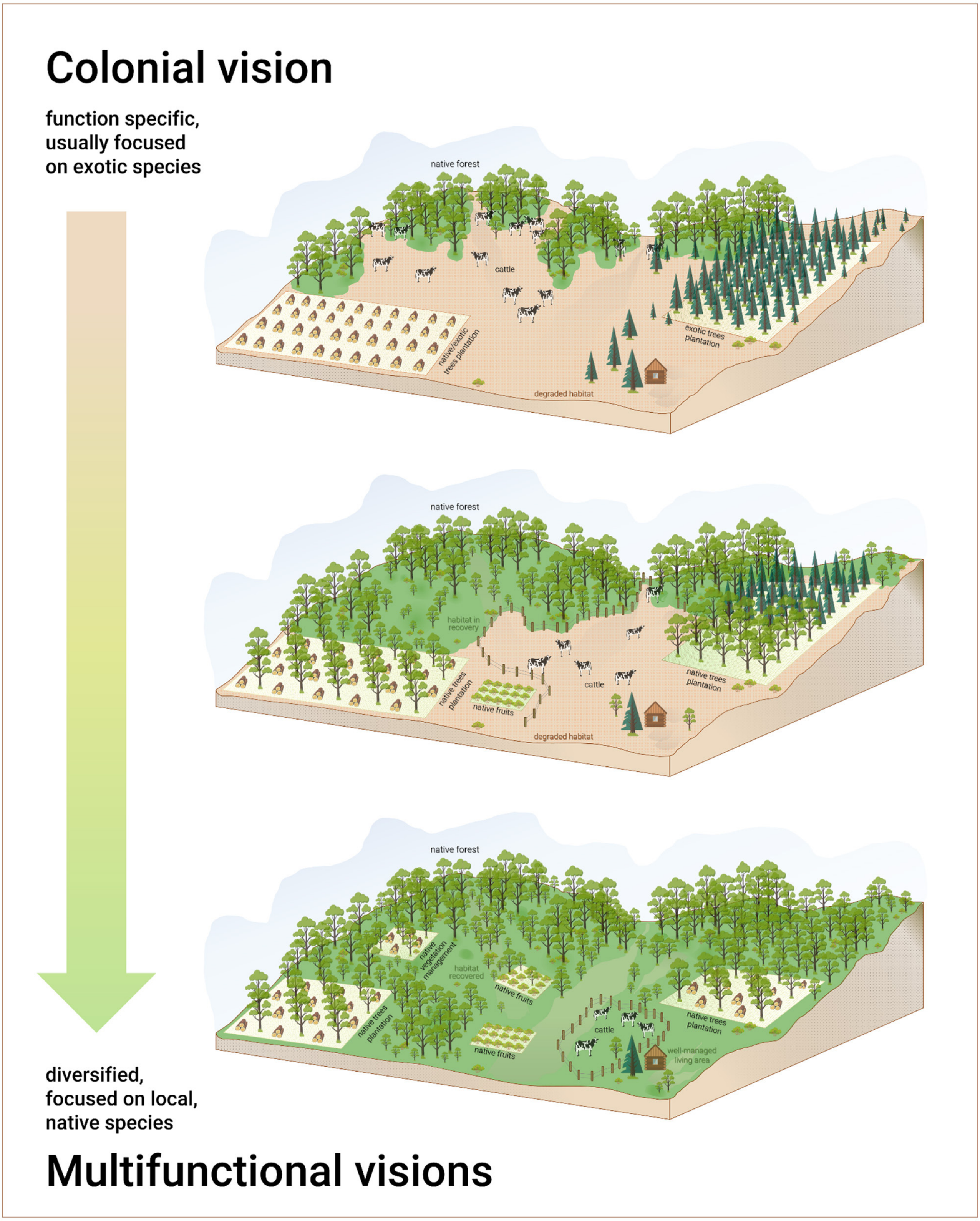

FIGURE 2
Transition from colonial to multifunctional native forest management. Currently, native forest lands present large degraded areas where land has been utilized for cattle rearing, unsustainable native wood extraction, and the introduction of exotic plantations. Although there are different degrees of degradation, colonial practices have been characterized by function-specific exploitation of habitats and resources, focusing on introduced species for livestock and timber production. The multifunctional views foster Nature's Contributions to People, aiming at dynamic diversification and maintenance of options for a better quality of life, acknowledging and attending to the needs associated with the multiplicity of realities on the territory. For example, it implies forest landscapes where people can live, develop more sustainable cattle-rearing practices, and manage native wood extraction, replacing existing plantations of exotic invasive species with native species. It also encompasses other forest products including cultivating/harvesting native fruits, ecotourism, biodiversity, and carbon offset credits.

and Walter, 2007) for local or regional trade, and different types of tourism (rural, scientific, and agrotourism). Mapping naturally occurring non-wood forest products patches on the landscape and incorporating new ones at selected locations can allow for more strategic management in terms of increasing biological and productive diversity. Biodiversity and carbon credits are also emerging as potentially profitable options. There are various global initiatives aiming at forest protection, restoration, and sustainable management (e.g., REDD+, COP26 Global Forest Finance Pledge; Garrett et al., 2022). For example, the global demand for carbon offset credits in the voluntary carbon market reached USD 6.7 billion in 2021 (Forest Trends' Ecosystem Marketplace, 2021). Although, in practice, skimming through administrative procedures has proven a daunting enterprise in many regions, and incentives do not yet reach many local communities, it is expected that these markets will grow greatly in the coming years. It is worth highlighting that intangible, non-marketable goods can also help transition to more sustainable visions (Hölting et al., 2019).

- **Design the size and arrangement of patches in the landscape:** Diversity at the landscape level with different patches emphasizing different NCPs is often most desirable (Grass et al., 2019). An example can include a combination of some patches with greater canopy opening for native fruit production next to others focused on wood production.

5 An iterative and participatory process

The previous objectives can be combined and are not independent of each other, requiring integral management and financial planning to ensure that at all steps of the transition, the activities align with conservation goals, as well as ensuring the livelihoods of the people that depend on the forest ecosystem over time. In this sense, the design and implementation of multifunctional forest systems should always be an iterative and participative process. In the anthromes context (Ellis and Ramankutty, 2008), relational values of people with the forests (e.g., cultural and identity attachment, local knowledge, ownership, and stewardship of lands and landscapes) are key to developing the transition (Fischer et al., 2017). These relational values are multidimensional and variable over time (Chillo et al., 2021), and therefore, approaches to multifunctionality should convene stakeholders from social, economic, governance, and cultural sectors involved at different scales (MEA, 2005) and be flexible enough to adapt to heterogeneous circumstances. Designing and implementing multifunctional landscapes in forested areas requires dealing with governance across sectors and scales and will need contemporizing legislation to accommodate a variety of current challenges, ranging from conservation laws to securing land tenure for local and indigenous peoples.

Given the natural and human-related complexity of forest landscapes, the transition may occur in several distinct phases (Figure 2). The vast assortment of stakeholders, needs, and interests around forest systems calls for flexibility and adaptability in the design and implementation of multifunctional forest systems. Therefore, monitoring, evaluating, and learning are crucial and should be done at different scales; a useful tool for this purpose is the establishment of permanent plots for long-term monitoring (Ceballos et al., 2022). At these steps, there are challenges related to selecting the relevant NCPs to measure and their indicators, assessing the use of and demand for those NCPs, and determining the right scale at which to evaluate multifunctionality (Hölting et al., 2019).

6 Limitations

While the study presents valuable insights into the potential benefits of implementing multifunctional landscape approaches for native forests in Northern Patagonia, several limitations and uncertainties must be acknowledged. Firstly, the study focuses on a specific ecosystem in a particular geographic region, potentially limiting the generalizability of its findings to other forests globally. Variations in climate, soil conditions, species composition, and human interventions may influence the outcomes of multifunctional management strategies differently across diverse ecosystems. Additionally, the study's reliance on data from a single experimental site over a relatively short period (i.e., around 5 years on average) raises questions about the long-term sustainability and robustness of the observed trends. Long-term monitoring and assessment of multifunctional systems initiatives are necessary to evaluate their effectiveness and resilience to changing environmental conditions and management practices. Finally, the proposed recommendations for designing multifunctional forest systems are based on a synthesis of existing literature and expert opinions, lacking empirical validation or stakeholder engagement to assess feasibility and acceptability in real-world contexts. Addressing these limitations and uncertainties through interdisciplinary research, long-term monitoring, stakeholder engagement, and adaptive management approaches will be essential for advancing the implementation of multifunctional forest systems worldwide.

7 Conclusions

Native forest in Northern Patagonia currently display the results of several decades to a little over a 100 years of colonial practices. Faced with ongoing climate and socio-environmental changes that pose serious threats to nature and people, establishing cornerstones for alternative visions is pivotal. We argue that such visions should be founded on landscape multifunctionality and the sustainable management of native species. We advocate for low-density cultivation of native forestry species within the natural forest matrix, while a minor fraction of the landscape can be subjected to greater canopy openness to enhance fruit production of native plants or livestock husbandry. Likewise, a minor fraction of the land can be used for the cultivation of fast-growing forest species. It is important to note that multifunctional landscape design complements but does not substitute the need to establish networks of protected areas, emphasizing distinct objectives (Kremen and Merenlender, 2018; Grass et al., 2019; Tscharntke et al., 2021).

As other authors have stated (e.g., Stanturf et al., 2019), there is no unique solution applicable to all cases of forest management and restoration. We argue for multiple, coexisting possible visions moving into the future, as opposed to a single, nostrum vision. These multifunctional visions foster nature's contributions to people, aiming at dynamic diversification and maintenance of options for a better quality of life, acknowledging and attending to the needs associated with the multiplicity of realities on the territory.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

LG: Writing – original draft, Writing – review & editing. PZ: Writing – original draft, Writing – review & editing. JA: Formal analysis, Writing – original draft, Writing – review & editing. MN: Formal analysis, Writing – original draft, Writing – review & editing. MGG: Formal analysis, Writing – original draft, Writing – review & editing. FF: Formal analysis, Writing – original draft, Writing – review & editing. MA: Writing – review & editing. AA: Writing – review & editing. RM: Writing – review & editing. MF: Writing – review & editing. NF: Writing – review & editing. MCG: Writing – review & editing. SN: Writing – review & editing. MAN: Writing – review & editing. FO: Writing – review & editing. MP: Writing – review & editing. JP: Writing – review & editing.

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Conflict of interest

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1357904/full#supplementary-material

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