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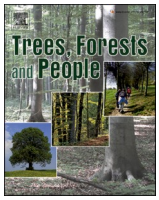

Exploring the multifunctional landscapes model in areas dominated by non-native tree plantations☆

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ABSTRACT

Multifunctional landscapes offer an integrated approach to production, conservation, and human well-being. However, the challenges of implementing them in territories where plantations dominate are yet not well understood. This is the case in Chile, where plantations of non-native pines and eucalypts are extensively planted in its South-Central regions for timber and pulp. The resulting landscape homogenization, environmental degradation, and increased wildfire risk have caused and exacerbated conflicts, impacting biodiversity and the well-being of local communities and the Indigenous Mapuche Peoples.

After the mega-wildfires in the region in 2023, science-policy discourse promoted the multifunctional landscapes model as a way to increase resilience. But what does this multifunctionality mean in challenging social-ecological contexts? Here, we aim to explore and deconstruct the multifunctional landscapes model in the context of the complex social-ecological systems of South-Central Chile. In this study, a review of the literature and semi-structured interviews with regional experts were used to better understand the challenges and opportunities presented by multifunctional landscapes.

The results show a need to deepen the knowledge of how to move the model into practice, such as how to identify and decide compatible activities in the landscape. The thematic analysis of the interviews showed that restoration and water security are shared goals across the diverse actors in South-Central Chile. However, there were significant differences in knowledge, experiences and resources. While a number of landscape initiatives exist in the region, significant work is needed to build a common vision before the potential of multifunctional landscapes can be realized.

1. Introduction

Current research argues that there is a need for integrated approaches to address connected global challenges, such as climate change, food and water security, biodiversity loss, and poverty (Lahoti et al., 2023; Godfray et al., 2010; Reed et al., 2016; Tscharntke et al., 2012). The multifunctional landscape model has gained significant traction in science and policy as an approach that can balance the multiple objectives of agricultural production, biodiversity conservation, and supporting local livelihoods. They are landscapes that are created and managed to integrate human production and use into the ecological fabric of a landscape, while maintaining critical ecosystem function and protecting biodiversity (O'Farrell and Anderson, 2010).

While protected areas remain crucial for conservation, scientific

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research now recommends integrating natural areas into multifunctional landscapes to preserve and restore ecosystem services (Santika, Meijaard, and Wilson, 2015; Fischer et al., 2017; Meyfroidt and Lambin, 2011; Garibaldi et al., 2023). Recent research highlights the importance of traditional and local practices, including local and Indigenous knowledge, in these 'social-ecological productive land- and seascapes.' Well-known examples of these biocultural landscapes include the *dehesa* in Spain and *satoyama* in Japan (Fukamachi, 2020; Campos et al., 2016).

However, in practice, the creation and management of multifunctional landscapes is highly complex. Most examples of working multifunctional landscapes come from developed countries. Studies that have promoted them often overlook the conflicts between traditional subsistence and commercial activities that affect Indigenous Peoples and local communities in developing countries (Israel and Wynberg, 2019). Sharing the landscape is also made more complex due to social-ecological heterogeneity, social and political contestation, and the large and diverse scales of landscapes (Cockburn et al., 2019; Kremen and Merenlender, 2018). Power and resource imbalances among stakeholders can lead to mismatched goals, complicating the co-production and co-design of multifunctional landscapes (Chakraborty et al., 2022).

There are thus significant research gaps that remain regarding the beneficiaries, appropriate scale, and functions needed for landscapes to be considered multifunctional (Stürck and Verburg, 2017; Ekroos et al., 2016; Fischer, Meacham, and Queiroz, 2017), and moving them from research to practice to meet global biodiversity goals (Garibaldi et al., 2023). In this study, we attempt to address some of these gaps by examining the feasibility of increasing landscape multifunctionality in a territory dominated by non-native tree plantations.

Globally, plantation forests span 131 million hectares. Although this covers only about 3 % of the total forest area, the highest share of plantations globally is in South America (FAO 2020). There, they represent 99 % of the total planted-forest area in contrast to other types of "planted forests", which are not intensively managed (FAO 2020). In Chile, the rebound of forest cover after deforestation – also known as the forest transition (Mather, 1992) – has been dominated by non-native tree plantations (Heilmayr et al., 2016). In Chile's South-Central regions, landscapes are extensively cultivated with Monterey Pine (*Pinus radiata*) and eucalypts for timber and pulp, covering 3 million hectares (del Pozo, Catenacci-Aguilera, and Acosta-Gallo, 2024). These monoculture plantations of non-native trees in Chile have heightened wildfire risk, not least because these tree species are highly flammable (Lindenmayer, Yebra, and Cary, 2023; Úbeda and Sarricolea, 2016).

Wildfire risk is also increased by optimal hot and dry conditions due to a prolonged mega-drought, and changing human-nature dynamics in the wildfire-urban interface (Altamirano et al., 2013; Bowman et al., 2019; García et al., 2018; Miranda et al., 2020; Pliscoff et al., 2020; González et al., 2020). This combination of factors culminated in some of the largest and most destructive mega-wildfires between December 2022 to February 2023, where the regions of Ñuble, Biobío and La Araucanía were badly affected, causing the loss of lives and homes. Over 305,869 hectares were burned, and of these, 200,824 (65 %) were in plantations of pines and eucalypts (Laboratorio de Ecología de Paisaje 2023).

In the aftermath of this devastating 2023 summer wildfire season, public discussion, science and policy promoted the idea of making the region's homogenous landscapes more heterogenous and multifunctional, in order to overcome the natural and human-induced hazards in the region (Zurita Arriagiada, 2023; Valenzuela, 2023). But what does this mean in practice, especially in complex social-ecological contexts, such as those in South-Central Chile?

1.1. The social and ecological impacts of plantations in Chilean landscapes

To firstly provide some context about the landscapes in the South-Central Chile region, the forestry sector in Chile expanded rapidly in the region, under the framework of agrarian counter-reform and dictatorship-era legislation during the 1970s. Historically, land was concentrated among wealthy families. Mid-20th century agrarian reforms that aimed to redistribute land were reversed by the Pinochet dictatorship (Robles, 2020). These changes facilitated the shift away from traditional agriculture in rural communities, and the creation of state subsidies to forestry companies (Grosser Villar and Carrasco-Henríquez, 2019; Torres et al., 2015). The legal frameworks that manage land and water rights in Chile are heavily influenced by the country's strong neoliberal approach.

For instance, Chile's Water Code has privatized water rights, allowing individuals and companies to obtain and trade rights to use water, aiming to promote efficient allocation and private investment. However, this has led to overexploitation and prioritizes economic activities over environmental and social concerns (Bauer, 2015; Larrain, 2012). Today, water, land rights and tenure remain contentious issues especially for Indigenous Mapuche communities facing conflicts over their territories, despite legal protections (Bauer, 2016; Meza, 2009).

In terms of environmental impacts, these political legacies and decades of land use change have caused significant impacts to biodiversity, including habitat and species loss associated with the land use change from native forests to monocultures (Miranda et al., 2017; Lara et al., 2009; Zamorano-Elgueta et al., 2015). In addition, pines and eucalypts escape plantations to invade ecosystems in Chile and Latin America, causing harm to native biodiversity (Langdon, Pauchard, and Bustamante, 2023; Pauchard et al., 2009; Simberloff et al., 2010). The Chilean forestry model has also caused significant social impacts, especially toward the Mapuche Indigenous Peoples and local communities who are affected by displacement from their territories, greater poverty, and impacts on their well-being (Andersson et al., 2016; Braun, 2021; Braun et al., 2017; Torres-Salinas et al., 2016; Uribe, Estades, and Radeloff, 2020; Carranza et al., 2020). The South-Central Chilean region, expanding to parts of Argentina, is also known as *Wallmapu*, the ancestral land to diverse groups of Indigenous Peoples, most prominently the Mapuche.

Considering these political, social, and ecological contexts, our main research question is: what are the needs, barriers and opportunities for achieving multifunctional landscapes in South-Central Chile? Here, through our exploratory analysis, we deconstruct the multifunctional landscape model to address this question.

2. Materials and methods

This study has two main approaches to achieve its objectives of better understanding the feasibility of multifunctional landscapes in the region. Firstly, a literature review was conducted to identify recent literature on the multifunctional landscape model. Secondly, key informant (expert) interviews were conducted to identify: (1) existing landscape initiatives aligned with the multifunctional landscapes approach; and (2) the key actors and their activities in the shared landscape, characterizing the interactions between the social and ecological components of the landscape (Fig. 1).

Through these approaches, this exploratory analysis of these landscapes as a social-ecological system aims to contribute insight on the needed transformation of agricultural landscapes in territories where conflicts prevail. The definition of a social-ecological system is taken from Elinor Ostrom's key framework: social-ecological systems are social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units (Ostrom and Cox, 2010). By shedding light on the dynamics of the landscape between people and nature, we hope to emphasize the role of interdisciplinary collaboration in informing decisions that can foster more sustainable and resilient landscapes.

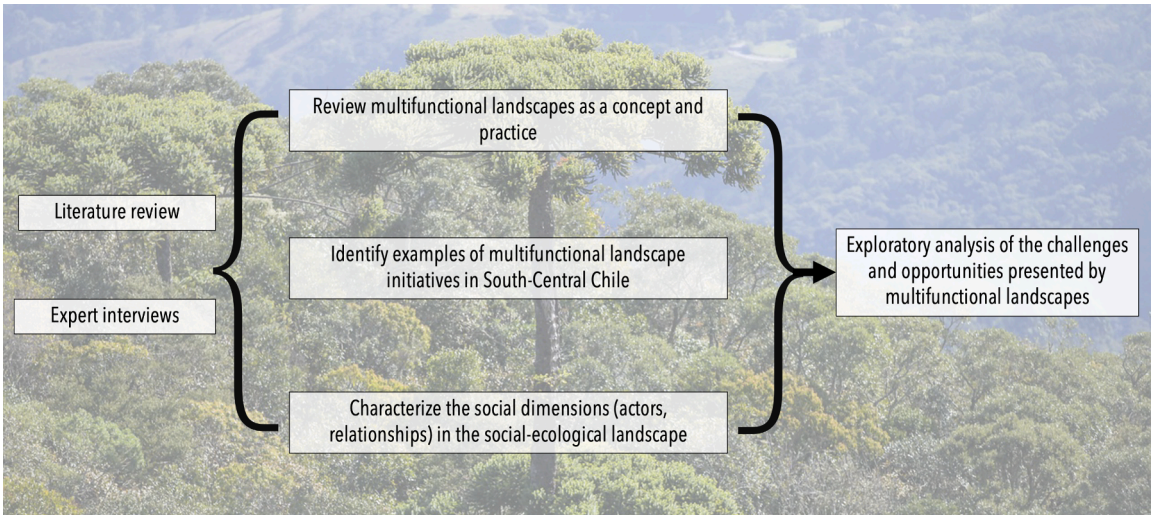

Fig. 1. Study approach and objectives.

2.1. Study region

The analysis focused on South-Central Chile (hereafter, SC Chile), which was defined as the regions of Maule, Ñuble, Biobío and Araucanía, although this regionalization can vary. This region was chosen as it is the forestry heartland of Chile. SC Chile is also a major agricultural zone for crops and fruits. In the SC Chile region, plantations are dominant along the coastal zones, and agricultural use remains in the areas of lower and flatter landscapes (Fig. 2). Major crops include wheat, corn, oats, sugar beets, potatoes and tomatoes, while land in the central valleys of Chile is dedicated to cherry, apple and hazelnut production (Oficina de Estudios y Políticas Agrarias 2022). Traditional agricultural land and native

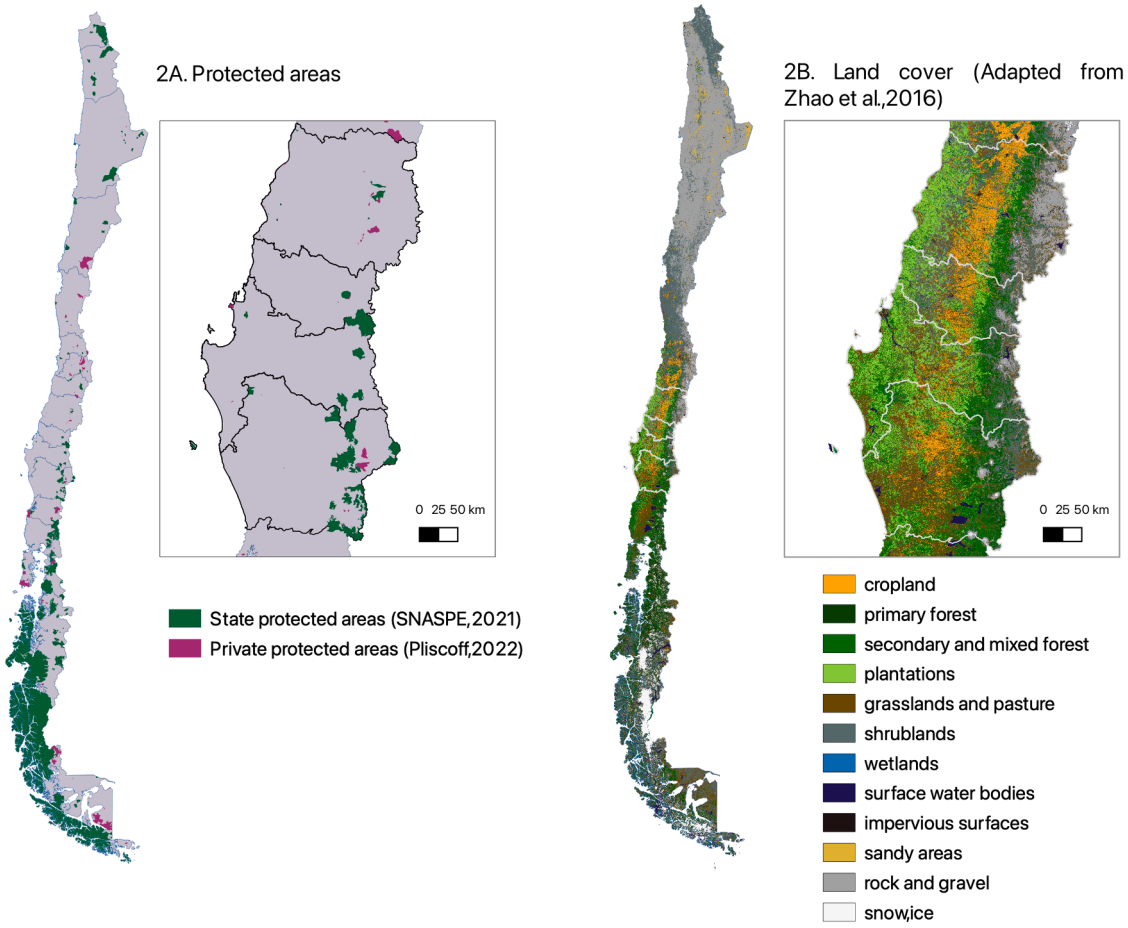

Fig. 2. South-Central Chile (SC Chile) is defined as the regions between Maule, Ñuble, Biobío and Araucanía (Fig. 2A); it has some of the least protected area coverage in the country, and most of these are concentrated in the high-altitude zones approaching the Andes (Servicio Agrícola y Ganadero 2021; Pliscoff, 2022). Fig. 2B shows the broad land uses of the SC Chile region, adapted from (Zhao et al., 2016).

forest have been increasingly replaced by commercial timber plantations (Nahuelhual et al., 2012; Aguayo et al., 2009). Based on satellite imagery, between 1975 and 2018, forest plantations expanded by a rate of approximately 246 % in the Maule and Biobío regions. This was accompanied by up to a 27 % reduction every 10 years in native forest, as well as decreasing field crop coverage (del Pozo, Catenacci-Aguilera, and Acosta-Gallo, 2024).

The macrozone boasts remarkable biodiversity owing to its diverse geographical features, and is considered a biodiversity hotspot (Miranda et al., 2017). Despite its unique ecosystems and species, these regions have some of the least protection and coverage of both public and private protected areas (Servicio Agrícola y Ganadero 2021; Pliscoff, 2022) (Fig. 2A). Remnant native biodiversity thus needs to co-exist in landscapes where there has been, and continues to be, significant land use and change.

2.2. Key informant interviews

Key informant interviews were used to elicit expert knowledge on the perceived challenges and opportunities presented by the multifunctional landscapes model. An interview guide was developed using the Social-Ecological Systems framework (Ostrom, 2009) as a guiding framework. Key informants were identified as experts from the private forestry industry, government agencies, academia, non-government organizations, and local actors. As they were interviewed on their knowledge about landscape initiatives rather than themselves as individuals, it did not constitute as human subjects research.

A participant information sheet and consent form were also developed. Participants were contacted and asked to confirm their willingness to participate. Informed written consent was obtained, and only where this was not possible, the information sheet and consent form were read before the interview, and participants confirmed verbally. A pilot interview, and 13 interviews were conducted. The interviews lasted approximately 60 min. The interviews were conducted in Spanish over the secure online platform Zoom, recorded, and transcribed for facilitating the coding using MaxQDA v22.4.1. Experts agreed to be identified but are anonymized here for clarity.

The number of interviews may be considered small. This number was reached because of practical limits to the authors' network for experts knowledgeable on regional multifunctional landscape initiatives. We endeavored to include key actors and experts to the best of our abilities. The interviews helped to support our exploratory analysis on this emerging theme. Qualitative research sample sizes are an area of rich conceptual debate, and purposive sampling selects interviewees by virtue of their capacity to provide information relevant to the phenomenon under investigation (Vasileiou et al., 2018; Luborsky and Rubinstein, 1995).

The thematic analysis used an inductive approach and was based on grounded theory principles. This method generates theory based on data and is used to uncover social relationships and group behaviors (Noble and Mitchell, 2016), which was deemed appropriate for the study. Conscious of the effect of identity on research (Savin-Baden and Major, 2012), the interviewer's positionality statement is in the Supplementary Information with the interview guide.

3. Results

The results of the review of literature and expert interviews are reported in this section. Firstly, an overview of the multifunctional landscapes concept is presented, and how "multifunctionality" is understood and measured based on the literature. Secondly, existing initiatives in the study area that are aligned with the concept are reported. Then, using the insight from the interviews, we examine the multifunctional landscapes model by characterizing the social-ecological components of the landscape and their interactions to understand the opportunities and challenges in the region.

3.1. Overview of multifunctional landscapes

A first step in the research was to generate a general overview of landscape approaches, and how multifunctionality is characterized. The concept of multifunctional landscapes aligns with integrated, mosaic, mixed, or production landscapes. Landscape approaches are comprehensive strategies designed to bring together stakeholders to address complex environmental, economic, social, and political issues, at a scale that transcends traditional management boundaries (Reed et al., 2016; Reed, Deakin, and Sunderland, 2014). Landscapes have multiple uses and purposes, which are valued in different ways by different stakeholders (Sayer et al., 2013).

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is viewed as essential to creating multifunctional landscapes. In fact, part of the principles of Forest Landscape Restoration includes the promotion of multifunctional landscapes. Activities can include agroforestry, mixed species plantations, and regeneration in areas of low agricultural suitability (Aguiar et al., 2021; Ros-Cuéllar, Porter-Bolland, and Bonilla-Moheno, 2019). A pivotal study in Chile (see Carrasco Henríquez and Mendoza Leal, 2021) demonstrates that restoration initiatives play a crucial role in integrating the varied interests of communities and the private forestry industry. However, these initiatives must also navigate structural inequalities between local communities and the powerful private forestry industry (Carrasco Henríquez and Mendoza Leal, 2021). These dynamics underscore the need include social dimensions into restoration, and emphasize pragmatic goals for human well-being as its driving force (Martin, 2017).

However, despite the importance of social dimensions in both restoration and landscapes (e.g. Sayer et al., 2013; Sayer et al., 2013; Fischer et al., 2021), the most common metrics and indices for multifunctional landscapes are based on quantifying ecosystem services in an area. For example, landscape multifunctionality has been estimated across scales in Europe using alpha and beta indices using ecosystem services (Willemen et al., 2010; Hölting et al., 2019). While this approach is useful, surveys showed that subjectively reported contributions of European multifunctional landscapes were connected to well-being, serenity, and tranquility (Fagerholm et al., 2020). These values are comparatively neglected in the ecosystem services literature (Fagerholm et al., 2020). Using values-based approaches showed that relational values across European multifunctional landscapes were shown to be inversely related to land-use intensity and instrumental values (Riechers et al., 2021; Riechers et al., 2020). This reflects the need to understand nature's diverse values beyond instrumental values (IPBES 2022), and to assess landscapes beyond ecosystem services.

To add insight from the expert interviews in defining and achieving these "multiple" functionalities in landscapes, experts from the conservation and academic community suggested starting with social objectives as the foundation of multifunctionality, while industry experts approached it from a technical perspective. In the forestry industry, optimization tools are used to maximize productive land while designating appropriate areas for conservation. In addition, both private and state forestry experts expressed concerns about the 'romantic' notions of conservation of community actors like NGOs and the academe, emphasizing the practical and difficult realities of land management.

3.2. Identifying multifunctional landscapes in the study region

Turning the focus to Latin America, this study aimed to glean insights from landscape-level initiatives in the study region. Starting with a comprehensive survey which identified more than 100 integrated landscape initiatives in Latin America and the Caribbean, Estrada-Carmona et al. (2014) report that landscape-based approaches are being increasingly employed in the region, with positive outcomes (Estrada-Carmona et al., 2014). There were seven initiatives documented in Chile, with four in the SC Chile region. These were a Model

Forest (*Bosque Modelo*) project, a World Bank-funded infrastructure project, a Mapuche-Pehuenche tourism enterprise, and a private restoration initiative (See Supplementary Information). There was little documentation on these projects, although an ethnographic study analyzed the Mapuche-Pehuenche *Trekaleyin* tourism collective. In their study, Palomino (2012) emphasized the need for a decolonial lens for community-based tourism in the Biobío region to recognize different ontologies and knowledge systems (Palomino, 2012). The other identified projects were of a finite, project-based nature and were no longer active nor available for interviews.

There are examples of successful partnerships in wine-growing landscapes in SC Chile. For example, the program *Vino, Cambio Climatico y Biodiversidad* (Wine, climate change and biodiversity) partners with wine growers throughout Central Chile, including Maule and Ñuble within the study region, to build capacity of wineries in planning, monitoring and implementing interventions to increase biodiversity within their private properties. Lessons can be learned from their engagement process with private owners as partners to enhance multifunctionality and biodiversity in wine-growing landscapes (Durán et al., 2022).

A key effort mentioned by experts are UNESCO Biosphere Reserves, under the Man and Biosphere program, and managed by CONAF in Chile. In a Biosphere Reserve's three zones, the outermost transition zone outside of the core and buffer zones is where productive activities and settlements are permitted (UNESCO 2022; CONAF 2015). This contributes to the vision that Biosphere Reserves are meant to be 'living laboratories' of sustainable development that could serve as models for multifunctional landscapes. However, in Chile their management is faced by significant problems of resources and capacity (Moreira-Muñoz et al., 2019).

Within SC Chile, two Biosphere Reserves exist: Laguna del Laja - Nevados de Chillán, and Araucarias, which cover 565.807 and 1.142.850 hectares in the Ñuble-Biobío and La Araucanía regions respectively (CONAF 2015). Biodiversity in the Araucarias Biosphere Reserve is threatened by human activities such livestock grazing, timber extraction, and wildfires. This is also because of the lack of territorial planning instruments in the buffer and transition areas (Ortega-Alul et al., 2023). In fact, it has been reported that the efforts to establish Biosphere Reserves have not been accompanied by a reduction of threats; social-environmental justice and sustainable development are still far from being achieved in Chile (Moreira-Muñoz et al., 2019).

To expand the search beyond the survey, a number of integrated landscape initiatives were identified north and south of the study area. For instance, south of SC Chile, the Global Environment Facility – Regional System of Protected Areas (GEF-SIRAP) initiative sought to create a decentralized system of governance for biodiversity in a "Landscape of Conservation" in Valle Río San Pedro in the region of Los Ríos. This project emphasized the empowerment of local actors in decision-making in a shared territory (Vergara-Pinto, Albornoz, and Conservación, 2020).

Emphasizing the role of restoration, in North-Central Chile, areas in the Valparaisoregion were identified as "multifunctional hotspots" for forest restoration using ecosystem services (Schulz and Schröder, 2017). This was based on restoration suitability and regeneration potential, and included a number of biophysical and socio-economic factors. While valuable, the study did not consider critical components like the diversity of actors, governance, and stakeholder participation. As natural resource use is intertwined with complex social-ecological systems (Ostrom, 2009), top-down and technical approaches are helpful, but inadequate.

Because of the little documentation on active multifunctional landscape initiatives in the SC Chile region, key informants were asked about their knowledge of projects compatible with the concept. Industry experts mentioned projects in their initial stages, such as private initiatives like the National Greening Program Maule Fund (*Fondo Maule*) which has the Forestry Dialogue, Arauco and CMPC as partners. Government reforestation effort *Más Bosques* (More Forests) is led by the Environment Ministry (MMA), the Forestry Agency (CONAF) and the UN Food and Agriculture Organization. A number of private forestry companies and individuals also own and manage private protected areas, which include public access and outreach activities.

Finally, drawing from the Mapuche perspective, the significance of diversity is engrained in their traditional ecological knowledge. The '*huerta Mapuche*', translated as a Mapuche community garden but varying greatly in size, is rooted in the principle of heterogeneity. Knowledge and practices of Mapuche community gardens can demonstrate the balance and harmony that exist between human and non-human relationships, reflective of the beliefs and cosmovision of the Mapuche (Manosalva, 2017). The Mapuche community gardens differ in composition depending on the geographic zones where they exist, and can be refuges for the conservation of numerous species (Urra and Ibarra, 2018). This was affirmed by an interviewed expert:

[The Mapuche] have never ceased to generate multifunctional landscapes; for example, the huerta mapuche does not have a monoculture, its characteristic is that it has a heterogeneity of crops that ensure the food needs of a family. (Mapuche/ Government interviewee 4)

The results of the search for aligned initiatives showed that there is an understanding and familiarity of the concept and rationale of landscape approaches, including Indigenous knowledge of the value of heterogeneity. However, the general sentiment from the review and experts is that the development and implementation of multifunctional landscapes in SC Chile is in its nascent stage and faces significant challenges.

3.3. Characterizing the social-ecological system: key actors in the landscape

The results of the analysis indicate that there are numerous groups of actors that share and compete for resources within the landscapes of SC Chile. To aid in characterizing the social-ecological system, here they are categorized loosely into four groups, namely productive, state, community-based, and conservation actors. It is important to acknowledge that these groups in reality interact dynamically, and actors may take on different roles or have activities that span different sectors.

Productive actors are people and entities involved in agricultural production and forestry. Many communities have traditionally been dedicated to agriculture, but a recent analysis shows that land dedicated to agriculture to traditional crops in the Biobío region has declined owing to advances in the forestry sector, affecting land, rural development, and employment (Torres et al., 2015). The private forestry industry is a one of the main actors in the SC Chile region, with significant resources, technical capacity, and political influence. Industry and state experts emphasized the role of the forestry industry and their contributions to the economy and employment: 111,000 people were employed in the sector in 2021 (Álvarez González et al., 2022). Therefore, the power of the forest companies is not only over the landscape, but also over all the communities and territories that co-exist with its impacts (e.g. Grosser Villar and Carrasco-Henríquez, 2019; Carrasco Henríquez and Mendoza Leal, 2021).

Another group are state actors, who are capable of making decisions, setting policies, and regulating activities. Interviewees mentioned the ministries for agriculture (MinAgri) and MMA as key agencies related to agriculture, forestry, and biodiversity. This also included CONAF, the Agriculture and Livestock Service (SAG), and the Chilean Forestry Institute (INFOR). Chile's protected areas system (SNASPE), managed by CONAF, manages protected areas in Chile (See Box 1 for acronyms).

Local communities or organizations also have strong connections to the landscape, including participation in water committees or neighborhood associations that help foster a sense of community especially in rural zones. Other actors identified are traditional subsistence communities, including collectors or foragers (*recolectores)*, who gather non-timber forest products such as guavaberry *murtilla* (*Ugni molinae),* Chilean rhubarb *nalca* (*Gunnera tinctoria*), and wineberries *maqui*

Box 1
Commonly used acronyms, with translations from Spanish.

CMPC	*Compañía Manufacturera de Papeles y Cartones* (Paper and Caron Manufacturing Company)
CONADI	*Corporación Nacional de Desarrollo Indígena* (National Corporation for indigenous Development)
CONAF	*Corporación Nacional Forestal* (National Forestry Corporation)
FSC	Forest Stewardship Council
INDAP	*Instituto de Desarrollo Agropecuario* (Agricultural Development Institute)
INFOR	*Instituto Forestal de Chile* (Forestry Institute of Chile)
MinAgri	*Ministerio de Agricultura* (Ministry of Agriculture)
MMA	*Ministerio de Medioambiente* (Ministry of Environment)
NDC	Nationally Determined Contribution, under the Paris Agreement
PROT	*Plan Regional de Ordenamiento Territorial* (Regional Land Management Plan)
SAG	*Servicio Agrícola y Ganadero* (Agriculture and Livestock Service)
SBAP	*Servicio de Biodiversidad y Áreas Protegidas* (Biodiversity and Protected Areas Service)
SNASPE	*Sistema Nacional de Áreas Silvestres Protegidas del Estado* (National System of State Wildlife Protected Areas)
UNESCO	United Nations Educational, Scientific and Cultural Organization

(*Aristotelia chilensis*), for consumption and local commerce (Fig. 3).

For these groups, access to land and nature is essential for their food security, health, and well-being. Part of their objectives are to preserve their cultural heritage, knowledge and traditions. The foragers group view their relationship with nature as part of their history and identity.

I always say to the old collectors, to those who are no longer on this earth […], nobody recognized their work, nobody protected their collection sites. They had to walk around like simple thieves inside the fields, which should not have been. It is very nice to be a collector, because all the problems that you may have at home, being inside a collection site, in the bush or where you can go to collect the product, you feel free, because you hear the birds (Civil Society Interviewee 6).

An important group in the territory and in the country are the Mapuche. The Mapuche were the native inhabitants of central and southern Chile before the Spanish, and then Chilean conquest (Meza, 2009). Their history is closely connected to colonization and persistent land disputes, which have resulted in a deep-rooted and prolonged conflict with the Chilean State (Alberti et al., 2023). Chile's existing legislation is unable to meaningfully respond to Indigenous territorial demands nor state development objectives (Bauer, 2016). The Mapuche conflict has been characterized by violent clashes with forestry companies who occupy their territory (Schmalz et al., 2022).

Lastly, conservation actors and their activities are also instrumental in the landscape. This includes state agencies such as CONAF in its secondary role in managing the protected area system (SNASPE), conservation NGOs, and private conservation actors. New legislation (2023) seeks to centralize the management of biodiversity through a dedicated Biodiversity and Protected Areas Service (SBAP). Local community groups involved in restoration and environmental education also participate in environmental activities and promoting awareness.

To an extent, private forestry companies are also involved in conservation via the Forest Stewardship Council (FSC) certification, which Chile entered into agreement in 2012 after international market pressure (Tricallotis, Gunningham, and Kanowski, 2018; Millaman et al., 2016). Products that bear this certificate must maintain international standards of sustainability, including protecting and restoring important ecological areas in their private land. Private industry involvement in conservation is part of their corporate social responsibility, and the FSC adoption has resulted in forestry companies engaging more with communities, in efforts to become more socially responsible (Carrasco Henríquez and Mendoza Leal, 2021; Tricallotis, Gunningham, and Kanowski, 2018; Millaman et al., 2016). However, while recognizing that private forestry companies do participate in activities related to conservation, this is a fraction of their activity. Indeed, in a recent assessment, conservation areas managed by private forestry companies did not meet the standards for private protected areas conservation (Pliscoff, 2022). Fig. 4 shows a summary of the different social components of the landscape, revealing diverging and converging objectives.

Importantly, the interviews revealed that water security and restoration were two goals common to all actors. Water use is a current and historical source of conflict in Chile (Berasaluce et al., 2021), especially because of its privatization. Water underpins all the activities of the productive sector, and a basic necessity for all communities. Among actors, water security was viewed as an overarching goal, and restoration a means to it. This is a reflection of how ecological restoration has become a crucial part of society's calls for environmental justice.

At present, many restoration initiatives are developed by NGOs,

Fig. 3. From left to right: Murtilla, nalca and maqui are gathered and collected by communities of foragers (recolectores) for domestic consumption and small-scale commerce. Photos shared by study participant and are used with their permission.

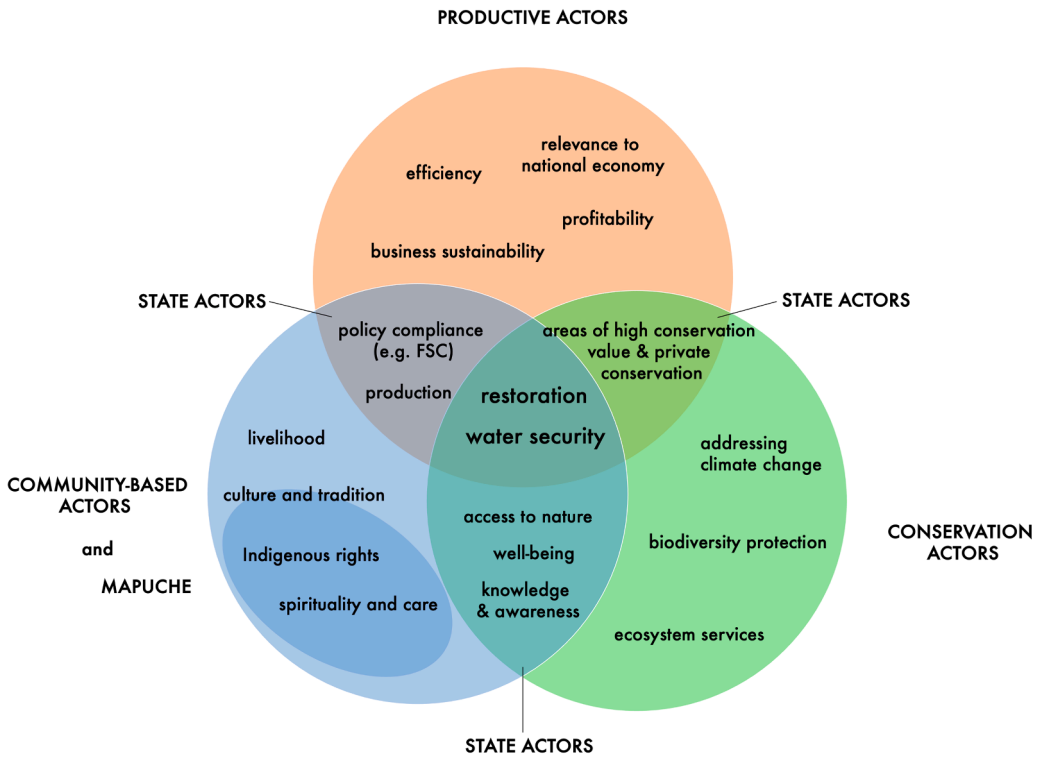

Fig. 4. A simplified representation of the common, diverse, and diverging objectives of the key actors in the landscapes of SC Chile. They are categorized loosely into four groups, namely productive, state, community-based, and conservation actors. These groups in reality interact dynamically, and actors' objectives may span different sectors.

government, forest companies, and universities, and usually take the form of replacing eucalyptus plantations with native species. Many local communities lead self-organized restoration initiatives, based on collective learning and trial and error. However, despite their earnest motivation and commitment, they lack training and experience in ecological restoration, leading them to overlook ecological constraints and set unrealistic goals (Morales et al., 2021). Many efforts are also limited in their scale. It remains a challenge to have access to restoration experts, and also funding restoration activities in Chile (Smith-Ramírez et al., 2015). The new SBAP legislation (2023) hopes to promote the conservation of the country's biological diversity through the preservation, restoration, and sustainable use of species and ecosystems, but its implementing rules and regulations are yet to be developed.

3.4. Interactions within the social-ecological system

The interviews revealed complex interactions between the different actors. A salient aspect of the interviews was the experts' perception of the private forestry industry as either "good" or "bad". Trust, or the lack of it, emerged as an important element of these relationships and perceptions. Power dynamics were evident in the relationships between communities and private land owners. For instance, when asked about why the annual agreements for entry into private properties for collecting non-timber forest products like mushrooms (see Cid-Aguayo et al., 2022, Fig. 2) weren't for longer-term, Civil Society Interviewee 6, a community leader, said that this "was just the way things were done", implying a desire not to disrupt the precarious equilibrium that the FSC has allowed.

In fact, these days, foragers are featured in forestry industry social media accounts and there are dedicated programs to "increase their visibility" and "celebrate their value" (ARAUCO, 2021a). Industry experts reported their shifts to more responsible production, and even saw themselves as a force of good. Forestry company Arauco adopted a strategy to rename its territories as "protected and productive landscapes" (In Spanish, *paisajes productivos protegidos)* which are designed to incorporate sustainability, combining the needs of industrial production with the protection of ecosystem services in the landscape (ARAUCO, 2021b). CMPC has adopted a similar strategy to promote mosaics of landscapes and ecosystems that contribute to the long-term value of plantations (CMPC, 2023). These changes reflect recent strategic shifts in the discourse of the forestry industry as a result of the FSC and other policy changes. Industry experts point out that their companies have gone above and beyond the FSC mandate.

There are certain commitments of the [FSC] certification which are very clear […] we have to conserve certain species and certain ecosystems within the properties or when the property is occupying part of it. On the other hand, there is commitment that is more is voluntary, not related to the certification. It does not require it, but it promotes it, which is to restore a certain proportion of what is owned by the company. (Industry Interviewee 2)

However, despite the FSC existing for around a decade, and these changes being enacted, there is still a tangible sense of distrust. There remains a more profound rejection of the hegemonic neoliberal model in Chile represented by industrial forestry plantations.

So on the one hand there is this issue of how to generate multifunctional landscapes, but this should occur from the conformation of shared visions for development and we have never had that, since this neoliberal economic model was implemented in Chile […] we need to generate these shared visions of development in the territories. (Mapuche/ Government interviewee 4)

Here, the relationship between the industry and state actors is important, as agencies like CONAF act as regulators of the otherwise powerful and expansive industry. But the contributions of the forestry industry to the national economy and local employment have also created a reliance on the industry, including to meet climate change objectives. For instance, Chile's updated Nationally Determined Contribution (NDC) under the Paris Agreement commits to a 200,000-hectare increase in the area under forest management plans by 2030.

In the NDC, the role of non-native tree plantations is vague. While the NDC promotes the use of native tree species over non-native species,

it also explicitly counts plantations as part of its mitigation strategies (Gobierno de Chile 2020; Hoyos-Santillan et al., 2021). Multifunctional landscapes are also referred to in the NDC: *"[Chile will] contribute to the organization and restoration of forest landscapes, promoting a mosaic distribution, which allows increasing the scenic value of territories, generating and maintaining biological corridors, improving wildfire prevention […]* (Gobierno de Chile 2020).

All of these nuanced dynamics and relationships contribute to the complexity of the social-ecological systems in SC Chile. This complexity implies that the life in these territories is under constant pressure from the tension between ecosystems and human communities.

4. Discussion

To respond to our main research question, which is to identify the needs, barriers and opportunities for achieving multifunctional landscapes in SC Chile, the results are discussed in the context of the wider literature on multifunctional landscapes. Enabling factors toward multifunctionality are then recommended.

4.1. Challenges in implementing multifunctional landscapes in SC Chile

The challenges in implementing multifunctional landscapes in SC Chile stem from both conceptual and practical considerations. On the conceptual side, the literature review and expert interviews reveal that there is significant knowledge and experience in landscape approaches, with some new and existing initiatives in the region. However, in the case of a "multifunctional" landscape, there are uncertainties as to its proportion of the multiple functions in a landscape, how this can be approached from bottom-up or top-down methods, and how this is measured, and eventually, monitored.

These uncertainties and differences in approach are a reflection of the diverse knowledge, ways of knowing, values and experiences of different actors in the landscape. Indeed, the understanding of landscapes is subjective and value-laden (Löfgren, 2020). Rather than seeking to homogenize this diversity of approaches, transforming landscapes towards sustainability requires the nurturing of the broad range of sources of knowledge and embracing a diversity of knowledge systems (Tengö et al., 2014).

In this regard, knowledge co-production has gained significant traction in solving sustainability challenges. Knowledge co-production is a set of iterative and collaborative processes that involve diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future (Norström et al., 2020). The spirit of collaboration and relational, pluralistic approaches to knowledge have also been emphasized as particularly crucial for stewardship of multifunctional landscapes (Cockburn et al., 2019).

However, in practice, its application is not simple: in a co-production process in making farmland into more multifunctional landscapes in Aotearoa New Zealand, there remained significant difficulties in addressing questions of values, objectives, and inclusion. Despite co-production being centered in the process, there remained glaring power inequalities across stakeholders (Chakraborty et al., 2022). Power inequalities also means that "green development strategies" may utilize industrial tree plantations to perpetuate the extractivist model. This is the case in Lao PDR where private, foreign, and state/military-controlled industrial plantations of rubber, eucalyptus and acacia dominated their tree-cover transition (Pichler and Ingalls, 2021).

Displacement and power imbalances were also observed in ancestral lands in Tshidzivhe, South Africa where commercial pine plantations replaced subsistence agriculture (Israel and Wynberg, 2019). Historical land grabs, slavery, and colonialism resulted in Brazilian maroon communities and landscapes of the Malhada Grande being impoverished by a plague that affected cotton monocultures, followed by deforestation for eucalyptus plantations (Ayaviri Matuk et al., 2019).

Underlying conceptual approaches have promoted multifunctional landscapes as a way to integrate various scientific fields, Indigenous knowledge, and global and local needs (e.g. Lahoti et al., 2023). However, these examples show that in practice, disintegrated approaches to bridge actors and disciplinary gaps, as well as the failure to properly address trade-offs between global and local needs, sometimes cause landscape approaches to work against their intended purpose instead (Ayaviri Matuk et al., 2019; Ayaviri Matuk et al., 2020). Overall, while research has highlighted state interventions as drivers of the recovery of forest cover (the forest transition, see Mather, 1992), less attention has been given to the messy, power-laden pathways through which these transitions actually occur (Pichler and Ingalls, 2021).

Thus, when designing and implementing multifunctional landscapes, special care must be taken to avoid increasing or perpetuating existing conflicts. Practitioners should pay attention to the historical reasons for heterogeneous landownership and consider social safeguards if conservation incentives, such as payment for ecosystem services, threaten to reinforce inequalities (Nyanghura, Biber-Freudenberger, and Börner, 2024). There are also many practical land management challenges to consider, such as the encroachment of small land parcels (*parcelas*) close to privately owned forest areas and public land, including national parks; violent conflicts and arson attacks, including between Mapuche and private companies; and organized crime related to timber theft (*robo de madera*). And while wildfires are often framed as a problem of climate change, nearly all (>99 %) of fires in Chile are caused by people, and up to nearly 50 % of fires between 1985 and 2018 were started intentionally in the industrial forestry territories of Biobío and La Araucanía (González et al., 2020; Villagra and Paula, 2021). All of these conflicts indicate profound and difficult challenges that will not be easily resolved.

4.2. Identified needs towards increasing multifunctionality in SC Chile

Based on our analysis and interviews with experts, we identify five enabling factors for multifunctional landscapes as: (1) Platforms for participation for trust-building and goal-setting that recognize the diversity of approaches, knowledge and values; (2) Resources and incentives for participation in conservation; (3) Supportive policy frameworks; and (4) Good, working governance. A fifth enabling factor was (5) time, a factor that wields great influence over outcomes (Table 1).

Time is required for landscape approaches to bear fruit. In the literal sense, it is needed for trees to grow in restoration projects, for promoting change, and for perceptions and relationships to shift. Short-sighted views of territorial planning and the short return period of wildfires thus limit and set back progress. For instance, restoration in affected regions of SC Chile is hindered by destructive wildfires, which are increasing in intensity and frequency (Úbeda and Sarricolea, 2016; McWethy et al., 2018). Wildfires also threaten efforts towards climate change, as an analysis showed that the extreme fire season approximately every seven years puts Chile's climate change mitigation plans at risk due to loss of carbon stocks (Benavides et al., 2021).

Time constraints were also identified as challenges to development programs more broadly, as the completion of initiatives frequently marks the termination of collaboration among stakeholders. Funding is typically not given on the long-term timescales needed to realize and monitor progress. For example, in Arauco, Biobío, a program for territorial development in lagging zones (*Programa de Gestión Territorial para Zonas Rezagadas*) ran between 2014 and 2018. This is a province where the forestry industry exerts great control. In these zones, socio-economic progress is constrained by centralized decision-making and ineffective public policies. While progress was made in the generation of social fabric and infrastructure, the limited scope of the project did not permit structural change (Grosser Villar and Carrasco-Henríquez, 2019).

Medium-term regional planning tools enable a broader vision to be realized, coordinating regional actors to achieve development goals. In

Table 1
Interviewees' key identified needs, and support from the review of literature.

Identified enabling factors	Key support from literature
1. Platforms for participation for trust-building and goal-setting that recognize the diversity of approaches, knowledge and values	• Previous initiatives have shown that multi-stakeholder participation platforms and cooperation with civil society organizations can help to overcome landscape challenges (Manríquez et al., 2019; Ratner et al., 2022; Kusters et al., 2020; Doyle--Capitman, Decker, and Jacobson, 2018). Initiatives with more objectives, investments, and stakeholders tend to yield greater positive outcomes (Estrada--Carmona et al., 2014). • These platforms must allow space for diverse ways of knowing, values, and experiences of different actors, acknowledging difference knowledge systems through dialogue and co-production. (Löfgren, 2020; Tengö et al., 2014) • Co-production of multifunctional landscapes is an imperfect and challenging process (Chakraborty et al., 2022). However, it allows for dialogue, which is important for trust-building. Trust between stakeholders is a key ingredient in the development of social capital and social networks, and enables collaboration towards multifunctional landscapes (Cockburn et al., 2019).
2. Resources and incentives for participation in conservation	• Private actors can play important roles in supporting conservation in Chile (Martinez-Harms et al., 2021), not only to provide financial resources, but to realize the potential of productive actors, including the private forestry industry, to leverage their knowledge, technology, and resources to meet agreed goals, particularly for biodiversity. • However, uptake has also been slow for private conservation in the region. Currently, the private protected areas law (*Derecho Real de Conservación*) lacks financial incentive, as it depends on voluntary partnerships (Así Conserva Chile and Fundación Austral, 2020).
3. Supportive policy framework	• A policy and legal framework that explicitly supports landscape-based approaches is needed. There is little by way of legal mechanisms and policies in Chile that explicitly support landscape development and planning (Armenteras and de la Barrera, 2023) There is a recently completed process (2023) within Chilean legislation to create a dedicated Biodiversity and Protected Areas Service (SBAP), which provides opportunities for more integrated policies and management of biodiversity. However, much remains to be seen as to how the SBAP will change relationships and dynamics within landscapes.
4. Good, working governance	• Governance failures remain the fundamental challenge of most landscape approaches (Sayer et al., 2017). However, governance is essential in managing natural resource use in social-ecological systems (Ostrom, 2009; Sayer et al., 2013; Sayer et al., 2017).
5. Time	• Time is a crucial factor for the success of landscape approaches, necessary for project evolution and landscape restoration, and building trust. However, short-term projects and frequent wildfires hinder efforts to improve social-ecological landscapes (Grosser Villar and Carrasco-Henríquez, 2019; Úbeda and Sarricolea, 2016), and also threaten climate change initiatives by jeopardizing carbon stock levels (Benavides et al., 2021).

Chile, tools like the Regional Land Management Plan (*Plan Regional de Ordenamiento Territorial,* or PROT) have a vision and duration of 15 years (e.g. 2015–2030). However, a recent study reveals that the PROT had no power whatsoever in the plantation-dominated coastal zones of SC Chile, where the private forestry industry and the ministries vetoed the PROT's terms for the regulation of forestry activities (Catalán Ovalle and Valenzuela Van Treek, 2021). An ideal multifunctional landscapes approach both builds on and breaks away from conventional planning cycles to achieve long-term goals (Fig. 5). However, existing tools and policy instruments need to function as crafted in the first instance, emphasizing the need for good governance to implement tools and policies.

4.3. *Moving forward: what lies ahead for multifunctional landscapes in Chile?*

The review of literature and interviews present a mixed picture of what lies ahead in the complex landscapes of SC Chile. Interviewees' visions for the territory reflect a blend of cautious optimism and awareness of complex challenges. Decades of land use change, the extractivist forestry model, wildfires and climate change have all caused serious degradation of its landscapes. In fact, integrated landscape approaches in Latin America share a number of the challenges we identified: the lengthy time required for significant impact, inadequate policy frameworks, and struggles in involving the private sector and key stakeholders (Estrada-Carmona et al., 2014). In Chile, as we have also identified, challenges revolve around perceived conflicts in human-nature relationships and diverging interests seen as non-compatible extremes between development and sustainability (Manríquez et al., 2019).

It could be argued the landscapes of SC Chile are already "multifunctional", in the sense that they provide multiple functions and ecosystem services. This has supported actors' diverse objectives thus far. However, the activities of actors in this shared territory continue to take place separately, that is, without strategic coordination nor planning. This means that production and conservation occur in SC Chile landscapes as competing interests, rather than compatible objectives. This perpetuates conflicts over land and water between local and Indigenous communities, private, and state actors, simultaneous with the continued loss of biodiversity.

The analysis and other studies reviewed here point to restoration and water security as possible starting points for addressing the region's challenges and creating multifunctional landscapes, respecting the rights of the Mapuche and those of local communities. Recovering the quality and quantity of water is an interest that manages to involve both community-based and productive actors (Carrasco Henríquez and Mendoza Leal, 2021). There are still remaining important questions, including: restoration to what state? Can multifunctional landscapes also address conflicts and promote social-environmental justice?

It is evident that inter- and transdisciplinary approaches, not just in research but in practice, are needed to understand both the social and ecological domains of the landscape. Collaborating across disciplines and communities may be able to contribute to the development of a common vision that can help realize the goal of multifunctional landscapes.

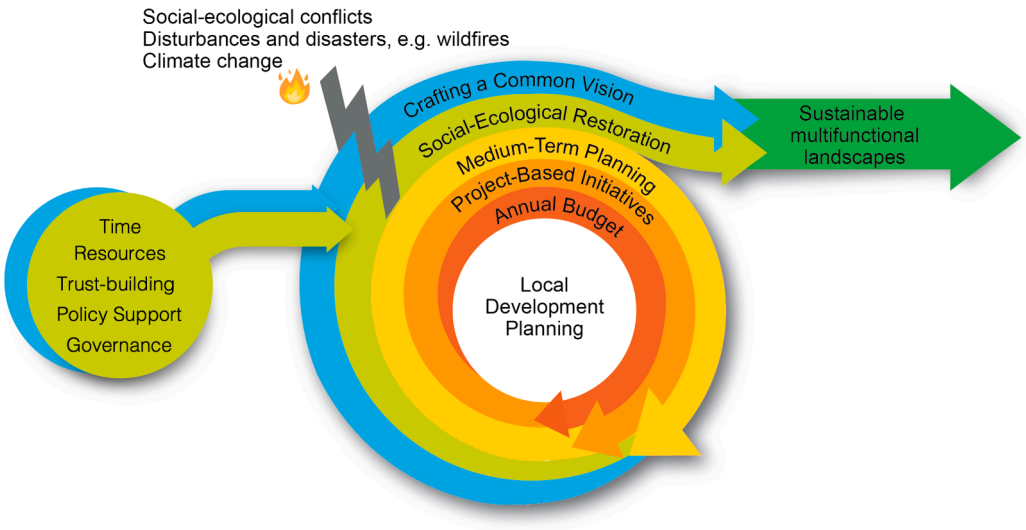

Fig. 5. Charting the path to sustainable multifunctional landscapes will require building upon and going beyond the cyclical local development to achieve long-term progress in the face of conflicts, disturbances and disasters, and climate change. Restoration and crafting a common vision are essential pathways towards sustainable multifunctional landscapes. These require time, resources, platforms for participation, policy support, and good governance.

4. Conclusions

Multifunctional landscapes are positioned as an approach to resolve the competing interests of production, conservation and social needs in a shared landscape. Local, Indigenous and recent scientific approaches have shown that heterogeneous and more diverse landscapes better support both people and nature. However, complex relationships and conflicts in the degraded landscapes of SC Chile make progress toward greater multifunctionality difficult.

The multifunctional landscapes model has been promoted as having great potential to make the activities of different actors more compatible through activities like forest restoration and regeneration, agroforestry, and mixed species plantations. However, the analysis underscores the critical importance of considering the social dimension of landscapes as social-ecological systems: that is, that they are dynamic, complex systems of resources, actors and their relationships, governance, and legal frameworks. These include legacies and current problems with Chile's neoliberal policies toward conservation, water, and land management that continue to affect Indigenous Peoples and local communities that depend on nature for its multiple services and values. In the pursuit of greater multifunctionality, it is essential not to gloss over the deep-rooted conflicts caused by contrasting worldviews and knowledge systems in the SC Chile region. These include strong opposition to the current forestry model, and the perspective that land is merely a resource to optimize.

Despite these distinct perspectives, the analysis reveals that water security, and restoration as a means to it, are common goals among productive, state, conservation and community actors. This will require platforms for dialogue, resources and incentives for participation in conservation, a more supportive policy framework, and good governance to implement changes in a region that urgently requires measures to increase its resilience and halt its degradation. Time is also required for trust-building and for restoration activities to take root. However, considering the urgent need for the protection of precious remaining biodiversity in the region, there is little time to waste.

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Author contributions

AMDO formulated the article with meaningful feedback and support from all the authors: EG, AP, NCH and BJH. AMDO worked with BJH on the interview guide. AMDO conducted the interviews and led the writing, including the figures, except for Fig. 3 which was contributed by a participant. All authors read, contributed to, and revised the manuscript.

CRediT authorship contribution statement

Andrea Monica D. Ortiz: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Eugenia M. Gayó:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Noelia Carrasco Henríquez:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Bárbara Jerez Henríquez:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Aníbal Pauchard:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Supplementary materials

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