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POLICY ARTICLE

Linking people and riparian forests: a sociocultural and ecological approach to plan integrative restoration in farmlands

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Global initiatives to restore habitats aim to improve ecosystem health; however, restoration programs are challenged with balancing human needs with ecological restoration objectives. To advise programs that aim to restore forest in farmlands and complement other analyses on ecologically-based reference sites, we (1) identified species with sociocultural importance, termed as "priority species"; (2) developed an integrative index to find habitats where priority species coincide with healthy ecological conditions (i.e. relatively high diversity, specific plant composition, etc.); and (3) evaluated whether sociodemographic profiles of landowners influenced their plant knowledge and ecological condition of habitats. Our approach was applied to riparian forests in farmlands of the Toltén watershed in southern Chile. We conducted structured interviews to gather information on traditional uses and management of trees in riparian habitats from 45 landowners. We developed an integrative index by combining sociocultural information from interviews with existing vegetation data. From the list of 65 trees provided by landowners, we selected five priority species based on their high saliency, multiple uses, and known management. Only 6 out of 98 sites had high integrative index scores, with the majority showing low values for sociocultural and ecological conditions. Except for a difference in ecological criteria and gender, the evaluation of landowners' knowledge level with sociodemographic profiles did not show significant relationships. These findings suggest that our integrative index can guide the design of restoration objectives, emphasizing on species that are important to local communities by providing information on the ecological conditions in which these plants co-occur.

Key words: agriculture, forest, local knowledge, policy, social–ecological restoration

Implications for Practice

- To study riparian habitats in farmlands, ecological attributes alone are likely to be insufficient when trying to comprehend sociocultural aspects that conform ecosystems and directly affect restoration programs.
- Structured interviews can be applied to identify species that are important and useful to people (i.e. priority species).
- Restoration planning should innovate and develop inclusive approaches that encourage landowners to participate and that better reflect diverse social realities.
- The integrative index provided in this study serves as a valuable tool for identifying habitats with important sociocultural species and healthy ecological conditions.

Introduction

Riparian habitats are social–ecological systems that contribute to the quality of life of people through food provision, firewood supply, water purification, reduction of pest damage, erosion control, climate regulation, fire mitigation, mental well-being, and recreational opportunities (Díaz et al. 2018; Dunham et al. 2018; Riis et al. 2020). Despite their recognized importance, human activities and conversion to intensive agriculture have caused habitat loss and degradation of these ecosystems (Gennet et al. 2013). New scientific and practical approaches have advanced in stream restoration techniques and integrative management to restore riparian habitats in farmlands (González et al. 2017; Singh et al. 2021). Still, restoration of these ecosystems is challenging to coordinate across farmers with diverse cultural backgrounds and sociodemographic

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profiles, and where centuries of land use change make it unrealistic to set restoration goals based on predisturbed reference sites (Stahl et al. 2020).

Restoration approaches, where social and ecological processes are simultaneously restored, offer a solution to this challenge, by focusing on people's cultural values, livelihood needs, and empowering local communities' governance (Fernández-Manjarrés et al. 2018). These approaches can involve assessing people's preferences towards certain woody species because these species often fulfill some part of their livelihood (e.g. medicines, food, spiritual value, and timber; Celentano et al. 2014; Raj et al. 2018; Ibarra et al. 2022). These uses or cultural significance of plants are related to different sociocultural factors, such as ecological saliency, potential utility, and individual knowledge (Turner 1988). Therefore, restoration goals that integrate these factors or preferences may increase landowners' willingness to participate, improve restoration outcomes by empowering landowners to support restoration programs and reduce conflict with people's demands for forest goods (Allen et al. 2010; Meli et al. 2017*a*, 2017*b*; Sigman 2021).

Indigenous people and local communities have been previously integrated into ecological restoration initiatives by considering culturally important species, informing historical reference sites, monitoring processes, and assisting in the management of species for restoration programs (Uprety et al. 2012; Reyes-García et al. 2019). For instance, the integration of plant community diversity and structure with existing ethnobotanical knowledge has helped to plan more inclusive restoration goals, as is the case for the Ayuquila river which has a long history of land use (Allen et al. 2010). However, many regions have experienced colonization processes that have transformed how people relate to native plants (Barreau et al. 2016). Furthermore, it is not always clear how local knowledge associates with relatively higher ecological integrity and ecosystem health (Berkes et al. 2000). While many authors have supported that local knowledge can have a positive effect on ecological diversity because of the diversity of uses (e.g. Joa et al. 2018), others have shown that degradation of ecosystems is triggered when local populations increase demand for forest goods (Hens 2006; Joa et al. 2018). In fact, other sociodemographic profiles of landowners, such as age, gender, education, and property size, may modulate how people manage species and ecosystems (Zoderer et al. 2016; Poderoso et al. 2017). Understanding and integrating knowledge of these complex social–ecological systems and peoples' use of forest goods can help in the development of restoration objectives that are feasible and meaningful to local realities (Dunham et al. 2018; Anderson et al. 2019).

Although social–ecological studies have grown (e.g. Uprety et al. 2012), the inclusion of social dimensions is challenging, particularly for large-scale restoration programs (e.g. Ceccon et al. 2015; Meli et al. 2017*a*, 2017*b*; Sigman & Elias 2021). These programs often set restoration goals to meet countries' reforestation pledges (e.g. based on the number of hectares and trees planted) and where social elements are reduced to productivity-based incentives (e.g. improve livelihood by increasing local income or productivity of the land; Sigman & Elias 2021). Progress on this matter has focused on making restoration more participatory and engaging with minority communities. For example, restoration standards developed by the Society for Ecological Restoration (hereafter, SER) suggest that goals must include indicators to meet higher local participation (e.g. neighbors comprise 80% of volunteers in stewardship programs; Gann et al. 2019). However, such focus on participation does not account for locals' motives and benefits, which are key factors affecting local communities' engagement in restoration programs (e.g. Hartman & Cleveland 2018). Additionally, the worldwide restoration program "Reducing emissions from deforestation and forest degradation" (hereafter, REDD-plus) aims to mitigate carbon emission by increasing reforestation and reducing forest degradation. In Chile, a new REDD-plus program commits to reduce inequalities by working with small landowners, women, and Indigenous communities to restore and improve the management of native forests (Moraga & Sartori 2017). While governmental institutions are hopeful that this program will bring substantial benefits to native forest and local well-being, concerns arise that this large-scale program could miss sociocultural aspects surrounding restoration (Sigman 2021).

Accordingly, new approaches are needed to help reduce asymmetries in power, improve inclusion of different social perspectives (e.g. Indigenous and local knowledge), involve contextual sociodemographic profiles, and address livelihoods of local communities (Meli et al. 2017*a*, 2017*b*; Díaz et al. 2018; Sigman 2021). For this reason, our goal was to develop an integrative index (containing sociocultural and ecological information) that can identify priority species important for local livelihoods and determine social–ecological conditions of existing habitats. Given that riparian habitats are highly degraded in Chile and there is an urgent need to protect both forest and water resources (Fierro et al. 2017; Rojas et al. 2020), we applied our approach to landowners living adjacent to riparian habitats. Our objectives were, (1) to evaluate the sociocultural importance of woody species that are common along riparian habitats; (2) to create an integrative index of sociocultural and ecological information to identify riparian habitats with a relatively high presence and abundance of priority species, diversity of trees with multiple uses and known management practices, ecological diversity, and ecological structure; finally, (3) to assess how sociodemographic profiles of landowners are associated with sociocultural and ecological conditions of riparian habitats. This study was based in farmlands of southern Chile, an area that contains temperate forests within one of the 35 Global Biodiversity Hotspots (Myers et al. 2000) and where the REDD-plus program will be implemented (Moraga & Sartori 2017).

Methods

Study Area

We conducted our research in the Toltén watershed in the La Araucanía region of southern Chile (Fig. 1), an ancestral Mapuche territory (Spirito et al. 2022). The watershed is characterized

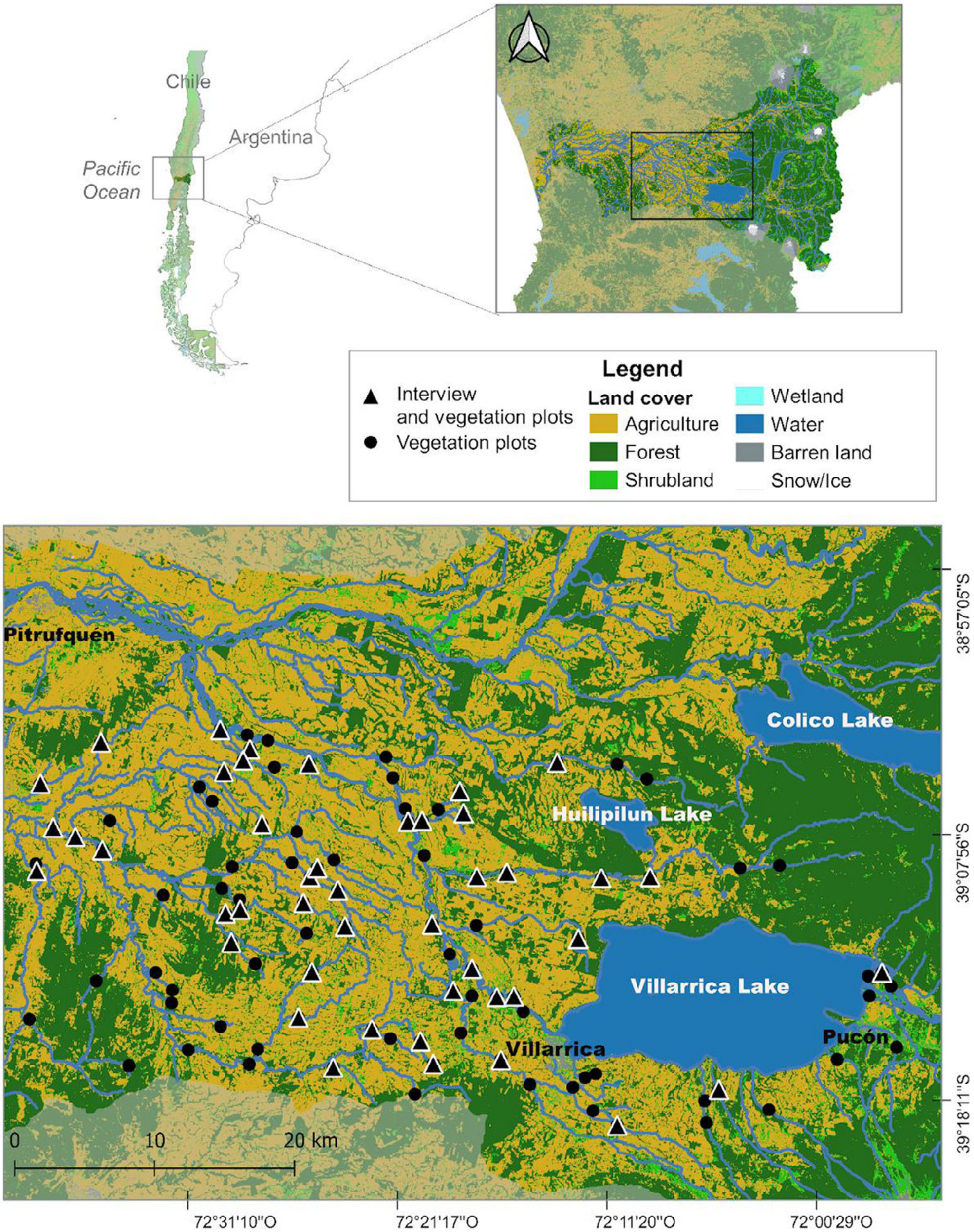

Figure 1. Land cover map of the study area that corresponds to 98 sites with vegetation plots and a subset of 45 sites with interviews in the central valley of the Toltén watershed in the La Araucania Region of Chile. This map was developed using Chile's land cover with 30-m resolution from satellite data (Zhao et al. 2016).

as rural and has a diversity of cultures including Chileans and Mapuche people (INE 2017). Currently, most local communities practice agriculture as a source of economic income and often depend socially and economically on forest goods (Torri 2010; Barreau et al. 2016). The predominant land use is agriculture, where pastures for livestock grazing is the dominant open land cover (Zhao et al. 2016). Other land uses include annual cultivars of cereals and tree orchards, with small remnants of secondary native forest, many left along watercourses (Miranda et al. 2015; Rojas 2019). Secondary native forests are frequently dominated by beech trees (*Nothofagus obliqua* [Mirb.] Oerst. and *Nothofagus dombeyi* [Mirb.] Oerst.), and a wide diversity of tree species that co-occur as result of the abundant precipitation (mean annual precipitation 2000 mm) and productive soils from volcanic origin (Luebert & Pliscoff 2006).

Site Selection

We used vegetation data from 98 sites that were selected at random from a previous study (Rojas 2019). These 98 random points were generated using a software for the analysis of spatial data (ESRI 2016) within 200-m from a national hydrographic network map (Ministry of Agriculture 2011). A minimum distance of 1 km between random points was applied to minimize spatial autocorrelation. Then, we selected a subset of 45 sites to conduct the interview based on sites previously studied by Rojas (2019) (Fig. 1). The interviews were limited to 45 sites because not all landowners had willingness to participate or could be found during our field work.

Local Knowledge of Plants

Our research and interview tools were approved by the Scientific Ethics Committee for the Social Sciences, Arts, and Humanities of the Catholic University of Chile, Number 201012006. Prior to interviews and photographs, each participant signed an informed letter of consent agreeing to publication of the results (Free Prior Informed Consent, FPIC). To collect local knowledge of tree species, we applied a structured interview with closed questions to 45 landowners (Supplement S1). The interview included questions related to (1) sociodemographic profiles; (2) free listing of tree species belonging to riparian habitats; (3) uses of these woody species for the following eight categories: food, construction, crafts and textiles, firewood, fodder, ornamental, medicinal, veterinary, and spiritual (Focho et al. 2009; Oliveira Trindade et al. 2015); and (4) management of these species in terms of previous experience of landowners propagating, pruning, planting, or collecting seeds for each species.

Vegetation Data

We characterized the riparian vegetation of 98 sites, using vegetation data from a previous study (Rojas 2019). A circular plot (452 m^2 area or 11.5 m in radius) was used to collect the following ecological attributes: number and composition of woody species (trees and shrubs) and diameter at breast height of trees >12 cm in diameter. Vegetation cover of three height classes (0–5, 5–8, <8 m) was estimated visually in a smaller subplot (5.75 radius) (Rojas 2019). With this information, we calculated species richness, Simpson index, proportion of exotic species, tree density (ind/plot), and average vegetation cover. These ecological attributes are frequently used to characterize sites and set restoration goals (Matthews et al. 2009; Pennington et al. 2010).

Objective 1: Analysis of Sociocultural Importance of Tree Species

To identify the relative importance of species, we used the free list method that allows us to identify locally important elements that belong to a cultural domain (Newing 2010). We asked each participant "what trees and shrubs grow in riparian zones?". From this question we generated a free list, and later computed a Smith's Saliency Index for each species (Smith 1993):

$$S = ((\Sigma(L - Rj + 1))/L)/n \tag{1}$$

where S is the average rank of a species in all the lists, weighted by the length of the lists in which the species actually appears; L is the length of each list for each participant; Rj represents the rank or order of a species j in the list (first = 1); and n is the number of lists in the sample (Smith 1993).

We asked each participant if these species are "used for any purpose" and if they "reproduce, prune, plant or collect them." With this information we calculated the percentage of mentions for each species, where i corresponds to a species:

$$\%\text{Frequency of mentions of use}_i = \left(\frac{\text{Number of mentions of type of use}_i}{\text{Total number of mentions of type of use across all species}}\right) \times 100 \tag{2}$$

We added the frequency of mentions of each type of use to obtain a total use value for each species, and the same was done to calculate the total management of each species. We defined priority species as those with the highest saliency, total use frequency values, and total management frequency values.

Objective 2: Identifying Habitats with Sociocultural and Ecological Criteria

In our study, we defined four major criteria that can guide the definition of restoration objectives: Dominance of cultural woody vegetation (C_P), Use and management of woody vegetation (C_U), Diversity of woody vegetation (C_D) and Structure and composition of woody vegetation (C_E). Each of these criteria was built integrating metrics that are frequently used to characterize the sociocultural and ecological value of plants and forests. We described and justified each of the criteria and associated indicators as follow:

Dominance of priority species (C_P): This criterion quantifies the dominance of priority species for each habitat, based on presence and abundance. Priority species were defined as those that have high sociocultural importance because of their high value of the Smiths' saliency index and the frequency of mentions in use and management

$$C_P = I_{Presence} + I_{Abundance}$$

Use and management (C_U): This criterion quantifies for each habitat the presence of species that are frequently used and managed by landowners. We summed the frequency of mentions for use and management of all species present at each site

$$C_{\mathrm{U}} = I_{\mathrm{Use}} + I_{\mathrm{Management}}$$

Diversity of trees (C_{D}): Species diversity is a good indicator of ecological health. For instance, in Temperate Regions, tree species richness is well associated with the diversity of multiple taxa, such as birds, ferns, mammals (e.g. Hansen et al. 1991; Díaz et al. 2018; Caviedes & Ibarra 2017). For this criterion, we summed the Simpson index and richness of native species. We subtracted exotic species to highlight habitats that contain mostly native species. The exotic richness was multiplied by 0.3 since the average proportion of exotic species in sites was equivalent to 3/9

$$C_{\mathrm{D}} = (I_{\mathrm{Native\ richness}} - 0.3 \times I_{\mathrm{Exotic\ richness}}) + I_{\mathrm{Simpson}}$$

Structure of woody vegetation (C_{E}): Plant communities with complex structures are well associated with several metrics of ecological health (Caviedes & Ibarra 2017). We built a criterion to characterize each habitat's structural complexity by combining a metric of dominance of tree species and the average percentage of understory and canopy cover. Species dominance was determined by calculating the relative sum of density, frequency, and diameter at breast height across all species, and then dividing the result by three (based on the formula of Curtis & McIntosh 1951):

$$C_{\mathrm{E}} = I_{\mathrm{Dominance}} + I_{\mathrm{Vegetation\ cover}}$$

To combine indicators within each criterion, we rescaled indicators using min-max formula to generate values between 0 and 1, for each habitat i (3). Since all criteria contained two indicators of maximum values of 1, criterions had a maximum value of 2:

$$x_i = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{3}$$

To identify habitats that have high values for each of the criteria, we aggregated the four social–ecological criteria. We ranked and mapped habitats using the following index:

$$\text{Integrative index} = C_{\mathrm{P}} + C_{\mathrm{U}} + C_{\mathrm{D}} + C_{\mathrm{E}}$$

We used descriptive statistics to summarize indicators across the 98 sites, and generated histograms to evaluate the variability of conditions for each criterion and the integrative index. Finally, we mapped our results to visually assess where the sites with higher values for each criterion and the integrated index were located.

Objective 3. Relationship of Sociodemographic Profiles of Landowners with Sociocultural and Ecological Conditions of Riparian Habitats

To evaluate how sociodemography may influence the results of the integrative index, we assessed the relationship between sociodemographic profiles of 45 landowners with their knowledge of plants (derived from the interview) and the ecological condition of their riparian habitats (derived from our assessment of the ecological conditions of riparian habitats). We analyzed the relationship between five sociodemographic variables (gender, cultural origin, education level, age of landowners, years of residence, and property size) with each of our response variables. Landowners' individual knowledge of plants was measured based on the number of known tree species, number of uses of these species (known uses), and number of management practices (known management) mentioned during the interview. The ecological conditions of riparian habitats were characterized using the same indicators employed in objective 2 (average vegetation cover, woody species dominance, total species richness and the integrated index).

Prior to the multiple regression analysis, we assessed the correlation between independent variables (Supplement S2). As we found little correlation among independent variables, we included all these variables in a multi-regression analysis (Table S5). Generalized linear models (GLM) were used, with a Poisson distribution of the error term for count response variables (known species, known uses, known managements, and total species richness) and a Gaussian distribution for other variables (average vegetation cover, woody species dominance, total species richness, and the Integrated index). GLM models were estimated using maximum likelihood (Bates et al. 2015). The stepwise variable selection procedure was conducted using a global model with all independent variables included and applying the dredge function (Barton 2016). Model fit was evaluated using the Akaike information criterion corrected for small sample sizes (Mazerolle 2016). Candidate models with ΔAICc < 2 from the top ranked were considered, (Table S6), and the models with the smallest number of parameters were selected based on parsimony criteria. If two competing models had the same number of parameters, we selected the one with the smallest AICc as the best model. Significant relationships were visualized using graphs. Our analysis was performed in R, version 3.2.1 (R Core Team 2016), using the packages lme4, MuMIn, and AICcmodavg. Graphs were generated using the ggplot2 package (Wickham 2016).

Results

We interviewed 45 landowners, 27 men and 18 women. The age of the landowners ranged from 19 to 85 years (mean $\pm$ SE = 60 $\pm$ 14.9 years). 85% of the landowners defined themselves as Chilean, 15% as Mapuche, and 55% of the total number of landowners worked as farmers. Education varied widely; the majority of landowners had only primary (20) or secondary (17) education, four had higher education, and three technical education. Property size ranged from 0.15 ha to 1,500 ha (median = 30 ha and average = 104 ha).

Obj. 1. Sociocultural Importance of Tree Species

In response to the free list exercise, landowners mentioned 65 species belonging to 30 families (including Rosaceae

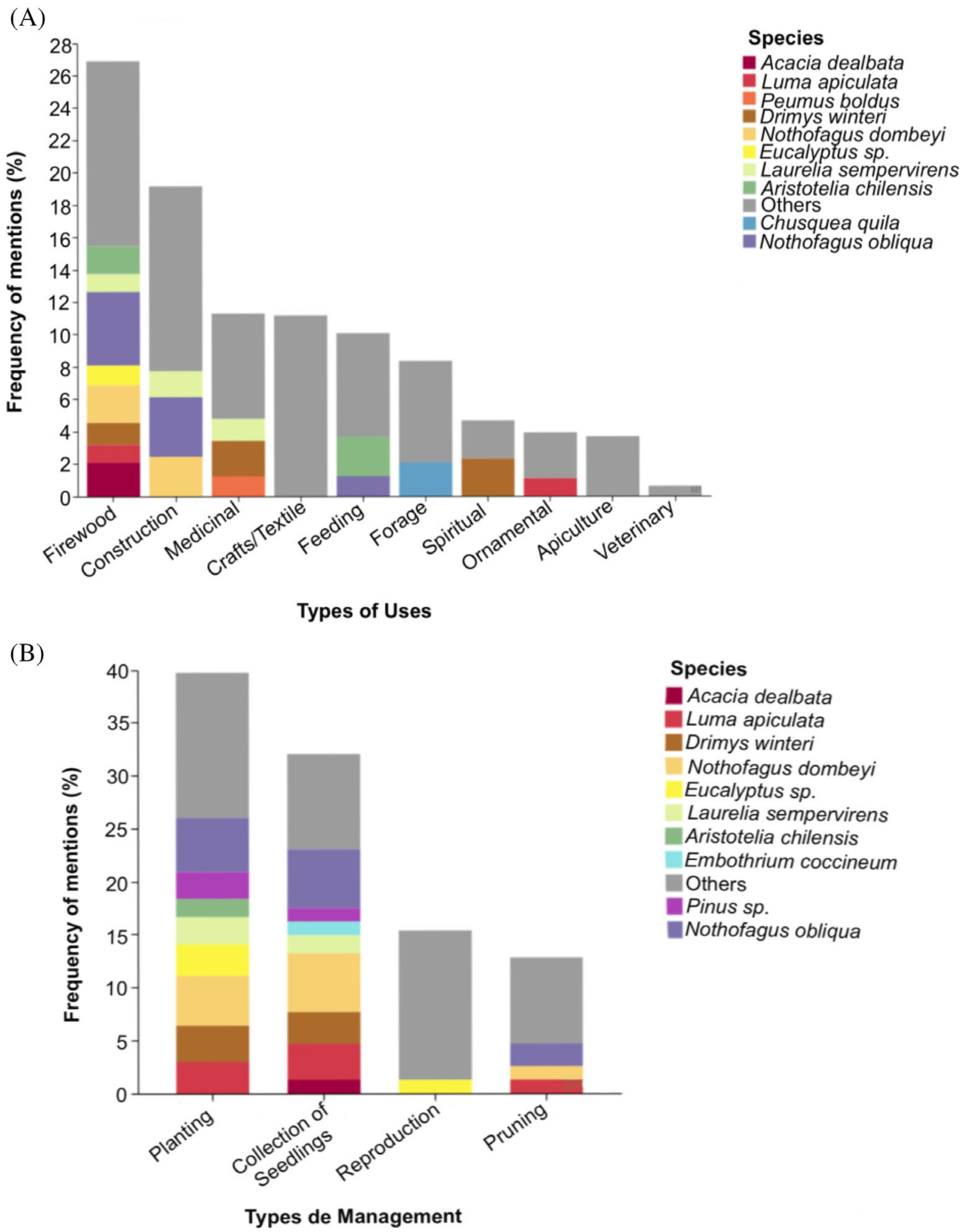

Figure 2. (A) Frequency of mentions (%) of different uses of woody plants known by landowners from free list exercise. Species that obtained a frequency above 1% are shown in color. Species with less than 1% are "others". (B) Frequency of mentions (%) of different types of management of woody plants known by landowners from free list exercise. Species that obtained a frequency above 1% are shown in color. Species with less than 1% are "others."

11.7%, Myrtaceae 10%, Fabaceae 8.3%, Protoceae 6.7%, Salicaceae 6.7% and Nothogafaceae 5%; Table S1). The species with the highest saliency were roble beech (*Nothofagus obliqua*, Smith's saliency index, $S = 0.62$) and coihue beech (*Nothofagus dombeyi*, $S = 0.45$), both predominated in uses for firewood and construction (Fig. 2). Other species with high saliency were Chilean myrtle (*Luma apiculata*, $S = 0.32$), canelo (*Drimys winteri*, $S = 0.31$), frequently mentioned for medicinal and spiritual use, and chilean laurel (*Laurelia sempervirens*, $S = 0.24$). The most frequent management practices were the collection of seedlings and the planting of trees for ornamental purposes where roble beech, coihue beech, chilean myrtle, and canelo predominated (Fig. 3). Based on these results, we selected the following as priority species: roble beech, coihue beech, chilean myrtle, canelo, and chilean laurel (Table 1).

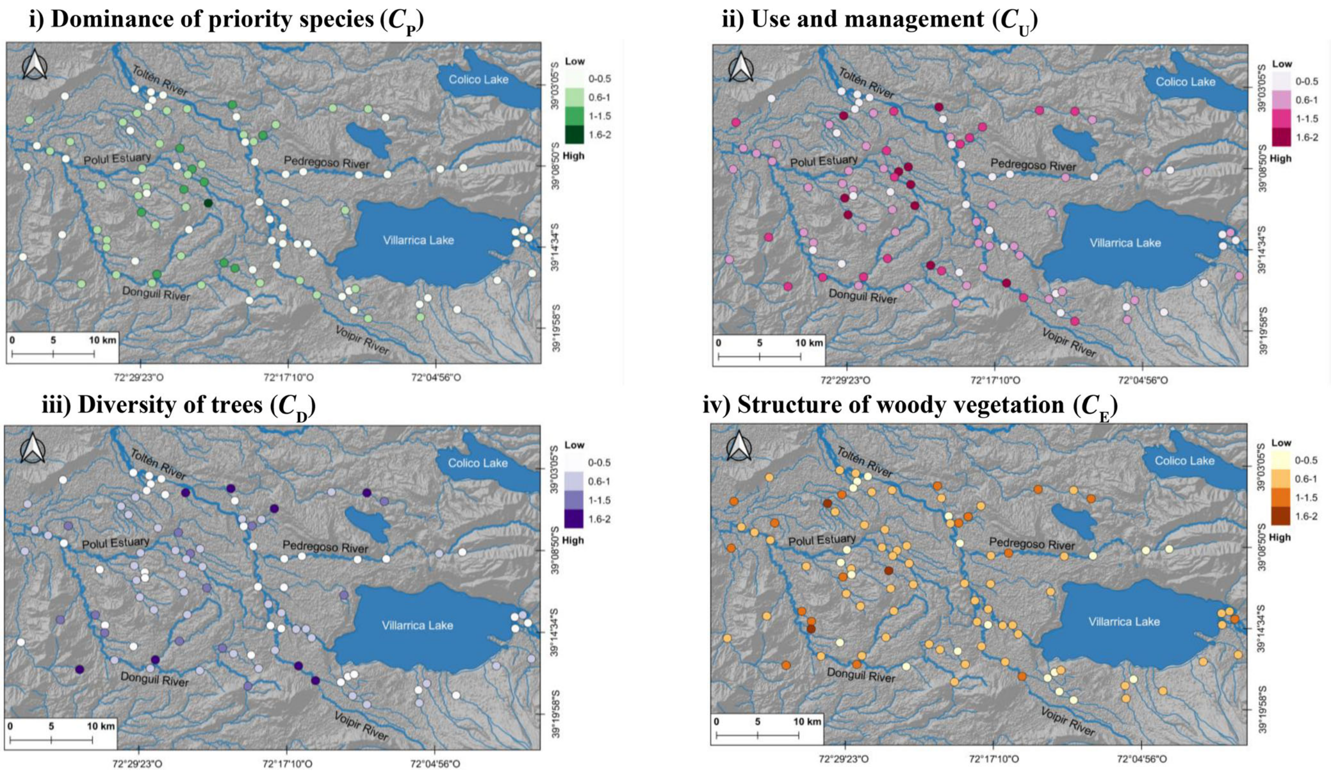

Figure 3. Scores of 98 riparian habitats in the Toltén watershed based on sociocultural criteria, (A) dominance of priority species (C_P) and (B) use and management (C_U); and ecological criteria, (C) diversity of trees (C_D) and (D) structure of woody vegetation (C_E).

Table 1. Priority species are defined for their highest cultural values in: Smith's saliency index (*S*), frequency of total use (FU), and frequency of total management (FM).

Scientific name	*Common name*	S	*FU (%)*	*FM (%)*
Nothofagus obliqua	Roble beech	0.622	10.94%	13.68%
Nothofagus dombeyi	Coihue beech	0.446	6.32%	12.39%
Luma apiculata	Chilean myrtle or arrayan	0.318	5.53%	7.69%
Drimys winteri	Canelo	0.306	8.21%	7.69%
Laurelia sempervirens	Chilean laurel	0.244	5.66%	5.12%

Obj. 2. Variation of Sociocultural and Ecological Criteria across the Landscape

Our maps of criteria showed that sociocultural and ecological conditions varied widely across the landscape, where some habitats had high value in one criterion but not in others (Table S2; Figs. 3, 4 & S1). Despite this variation, we found the following general patterns: First, the dominance of priority species was generally low, as no habitat presented the five priority species. Most habitats contained up to 1.4 of these species on average and the habitat with the highest number of priority species had four (roble beech, coihue beech, arrayan and canelo; Fig. 3A). Second, regarding the diversity of tree species criteria, we found that most habitats had low tree species richness (median = 2.5). The habitat with highest richness had up to nine tree species. Third, most habitats exhibited low values for vegetation structure criteria, with a median vegetation cover of 45%.

Integrative Index

We found that no habitat had maximum values in all four criteria (Table S2; Fig. 4). The habitat with the highest integrative index score (site 71) had a high value of dominance of priority species and species with diversity of uses and managements ($C_D = 1.5$, $C_U = 2$; Fig. 3E). Five habitats had relatively high values across the criteria (e.g. site 26 had an integrative index score of 5.5; Table S2). Top ranked sites are characterized by having only native species, high diversity, and high density of woody species. In addition, the vegetation structure of these sites had higher values of vegetation cover than most sites (e.g. site 71 had 67% average vegetation cover). All top ranked sites had at least three priority species, along with other native species such as piñol (*Lomatia dentata*), avellano (*Gevuina avellana*), olivillo (*Aextoxicon punctatum*), ulmo (*Eucryphia cordifolia*), boldo (*Peumus boldus*), and pitra (*Myrceugenia exsucca*).

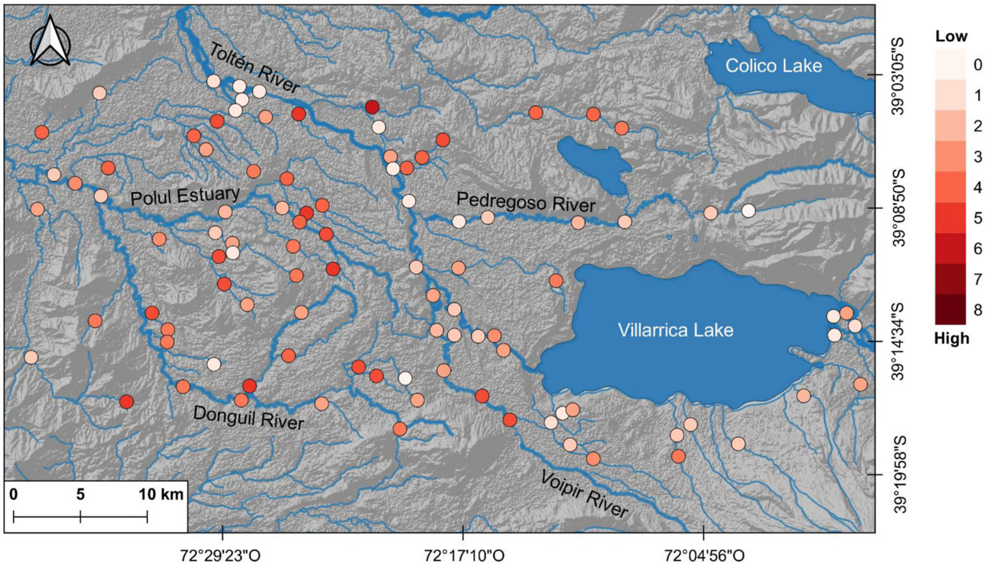

Figure 4. Scores of 98 riparian habitats based on integrative index.

Obj. 3. Relationship of Sociodemographic Profiles of Landowners with Sociocultural and Ecological Conditions of Riparian Habitats

We found that most of the sociodemographic variables included in the models did not have a strong relationship with landowners' plant knowledge and the ecological characteristics of riparian habitats (Table S6). We found that the null model was either top-ranked or had a ΔAICc < 2 from the top ranked model for Known species, Vegetation cover, Woody species dominance, and Structure of the vegetation. However, for known uses, the best model indicated a significant relationship with education level and gender (Fig. 5). Landowners who had completed only primary education exhibited the highest known uses (mean $\pm$ SE $= 19.3 \pm 9.54$ known uses, z-value $= 2.337$, p value $= 0.019$), and Mapuche landowners (mean $\pm$ SE $= 17.1 \pm 8.26$) had slightly higher known uses than Chilean landowners (mean $\pm$ SE $= 15.8 \pm 8.67$, z-value $=$ 2.266, p value $= 0.0234$; Fig. 5). Known management was best explained by the age of landowners, with younger landowners (20–40 years) reporting a high level of known management than

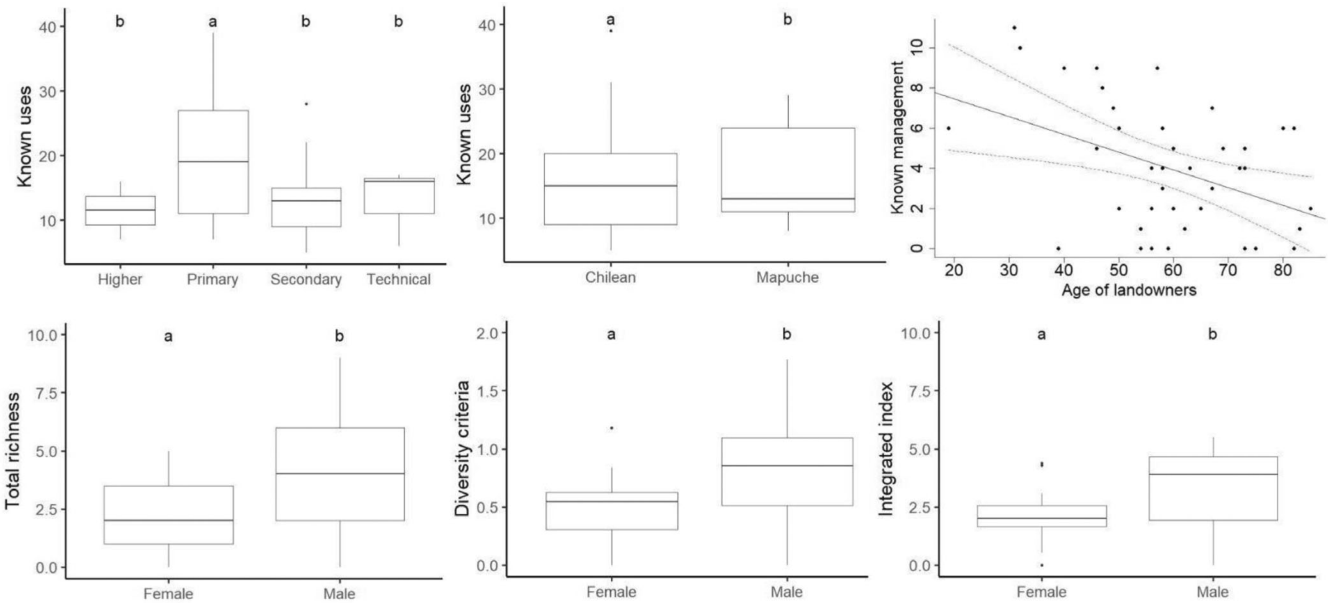

Figure 5. Relationship between sociodemographic variables selected in the best models for landowners' plant known uses and management (top section) and social–ecological characteristics of riparian habitats in landowner properties (bottom section). See main text and Table S6 for results of model ranking using AICc values.

older landowners (estimated coefficient ± SE = − 0.088 ± 0.03, z-value = −4.123, p value ≪ 0.01). Lastly, gender emerged as the top-ranked model for total richness, diversity, and integrated index criteria. In all these cases, males had significantly higher values than females (Table S6; Fig. 5).

Discussion

The integrative index proposed in our work provided original information on the sociocultural and ecological value of riparian habitats by simultaneously integrating insights about trees that are important to people while addressing the ecological condition of riparian forests in a Global Biodiversity Hotspot. This index showed a few riparian forest sites with high scores, but also pointed out sites that require protection within farmlands. For example, the ecological indicators (species dominance, richness, and canopy cover) tested allowed us to identify six habitats with high diversity and complex structure of native forest, which is known to help maintain faunal biodiversity and ecosystem functioning (Pennington et al. 2010; Caviedes & Ibarra 2017). However, most habitats we studied showed low presence of priority species and poor ecological conditions. This finding is consistent with previous studies characterizing plant communities in riparian habitats in farmlands (e.g. Gennet et al. 2013; Fierro et al. 2017; Rojas et al. 2020). Low levels of important ecological conditions may also imply the deficit of sociocultural value of riparian habitats, as priority species and other species known by locals are missing when degraded conditions prevail. Using an integrative index to distinguish between relatively good and poor conditions could help identify ecological attributes of habitats where priority species co-occur that can be integrated into restoration objectives (Hawkins et al. 2010; Ode et al. 2016; Meli et al. 2017*a*, 2017*b*).

Landowners had detailed knowledge of trees that grow in their riparian habitats. Most landowners were able to report multiple uses and common management practices for many tree species that belong to the native temperate forests of southern Chile (Luebert & Pliscoff 2006); although priority species stood out from the rest for their frequency in mentions and therefore have greater cultural significance (Turner 1988). Landowners described the uses of priority species similar to those of previous studies. For example, canelo tree has been historically recognized as sacred for Mapuche people and has medicinal uses in treating diseases associated with the skin, rheumatism, and as an antifungal (Villagrán 1998; Fernández 2015). However, our results indicated that firewood was by far the most important use. Some communities, such as the case of locals in this study area, rely on firewood and other forest goods to meet social and economic needs (Kusel 2001). Overseeing the use of trees for firewood within restoration programs could greatly affect the extent that local communities engage in restoration actions and in the success of these programs (Reyes et al. 2018; Fischer et al. 2021; Singh et al. 2021). Furthermore, our results also indicated that our priority species are also pioneer species. Research has suggested that pioneer species, like roble and coihue beech in our study area, grow faster than other native species and are commonly used in restoration projects because they are used for initial vegetation establishment (Donoso et al. 2018). Other studies have shown that pioneer species have been managed to endure anthropogenic degradation and natural disturbances, like frequent floods, making them more frequent within the landscape (Stella et al. 2011).

The evaluation of sociodemographic profiles of local communities helps validate and support the integration of diverse sociocultural contexts in restoration objective design (Zoderer et al. 2016). For example, two *Nothofagus* species were consistently identified as highly important for landowners with varying sociodemographic profiles, highlighting their significance for the local community as a whole. Our assessment of landowners' knowledge level and the ecological condition of their riparian habitats across various variables (cultural origin, age, education, years of residence, and property size) generally revealed no significant relationships. This finding supports the inclusion of priority species as a key criterion in the integrative index, indicating that these species hold representative cultural value among a diverse community of landowners. Our analysis also uncovered two key findings. First, landowners with primary education and of Mapuche ethnicity tended to have higher knowledge of plant uses. Second, there was a significant difference in total richness, diversity criteria, and the integrated index when compared to gender, where riparian habitats owned or managed by men exhibited higher levels of these ecological conditions compared to women. Previous research shows that gender is a key factor in determining ecological knowledge and practice, where women tend to have a more positive or caring attitude towards the environment (e.g. Zoderer et al. 2016). However, the way men and women manage the environment could vary across diverse social–ecological systems, especially at the farm-level where sociodemographic differences may exert a stronger influence (Poderoso et al. 2017). Our results should be analyzed with caution as the observed relationship does not imply causation between variables. For example, women in our study area may have inherited more degraded properties than men in their family. Further investigation using open interviews or participatory tools would provide a better understanding of these differences, particularly when considering potential sociodemographic influences at the farm-level.

Our approach proved valuable in identifying the sociocultural importance of common species in riparian habitats within the study area and offers a framework for integrating this knowledge into decision-making. However, focusing on the species-level limited our ability to assess the ecological importance of less diverse and rare plant communities, such as key freshwater forested wetlands or "swampy forests" (Correa-Araneda et al. 2011). The same note of caution can be made when evaluating sociocultural values at the ecosystem-level or ecotopes to determine places that are relevant to people and culture (Poderoso et al. 2017). Additionally, our approach can be expanded or complemented with other methods that consider various biophysical attributes typically used in reference site analysis, such as geographic variability, land use change, geomorphic setting, chemical, and hydrological attributes (Hawkins et al. 2010).

While the use of historical reference sites to construct restoration goals is a valid method, farmlands tend to escape from predisturbed conditions and possess a relevant long-standing human dimension that cannot be ignored. Social–ecological approaches, like the one we presented here, help identify nuances of the functioning of social-ecological systems that are necessary to consider when designing restoration programs. For this case study, priority species had a synergy in their sociocultural importance and ecological attributes that characterized them as pioneer species. Although this synergy could favor both social and ecological restoration goals, the species identified are also used frequently for firewood and may limit or condition restoration success, if restored forests are not managed accordingly. In Chile, large- and small-scale restoration initiatives are still insufficient due to lack of both funding and national policies that promote ecological restoration projects (Smith-Ramírez et al. 2015). Furthermore, local communities are hardly considered within local and regional governance (Guerrero-Gatica et al. 2020). Our integrative index could support this social inclusion by finding habitats where these sociocultural species co-occur in the landscape. Our work supports previous studies (e.g. Sigman 2021; Singh et al. 2021) that value the ecological and sociocultural importance of these habitats even when they do not fully resemble historical conditions. Moreover, it is important to develop approaches that promote and cultivate people's willingness to maintain diverse and complex ecosystems. By doing so, we can encourage global, national, and local restoration agendas to persistently innovate in approaches and tools that incorporate people from the beginning.

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Supporting Information

The following information may be found in the online version of this article:

Supplement S1. Interview questions.
Supplement S2. Analysis of relationship between independent variables.
Figure S1. Number of sites for sociocultural criteria.
Figure S2. Relationship between continuous independent variables and three categorical variables.
Table S1. List of 35 tree species mentioned in free list exercise and ordered by Smith's saliency index.
Table S2. Minimum–maximum
Table S3. Number of participants and their reported sociodemographic profiles.
Table S4. Pearson's Correlation Index between continuous variables.
Table S5. Summary table with Estimated coefficients, Standard errors, *t*-values and *p*-values that resulted from assessing the relationship between independent variables.
Table S6. Results of multiple regressions and stepwise model selection approach for landowners' plant knowledge, socioecological conditions of riparian habitats and their sociodemographic profiles.

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