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Where Forest Policy and Social Support Collide: Perceptions and Knowledge of Landholders About Forest Management in Central Chile

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Abstract
Public perceptions and knowledge of forestry institutions are key for effective governance. Drawing from research among landholders in Chile through structured questionnaires, we examine the role that knowledge of forest regulations and agencies plays in relation to public perceptions of the forestry agency, and how tenure of forest land affects this association. Multivariate regressions showed a U-shaped relationship between perceptions and knowledge, explained by ownership of forested land. Landholders with more hectares of native forest reported a negative relationship between knowledge and perception, whereas landowners with fewer hectares of native forest reported a positive association. Our results suggest a forest management paradox: forestry institutions are established to sustainably manage and conserve biodiversity, especially for native threatened forests; nonetheless, the perceptions of landholders with greater areas of forest, who should be the targeted partners of these institutions, appear to become more negative as their knowledge of forestry institutions increased. Our results provide key information for adapting forestry institutions to socio-ecological contexts to produce effective outcomes..

Keywords Local perceptions · Knowledge · Attitudes · Land ownership · Forest institutions · Native forest · Chile

Introduction

Local perceptions influence public support of environmental governance and are a key issue in designing effective institutions to manage local territories (Alvarez et al., 2021; Bennett, 2016; Garau et al., 2021; Haines et al., 2019; Liu et al., 2020; Macura et al., 2011; Verbrugge & van den Born, 2018). Forest institutions are regularly assessed by local communities in terms of their achievement of their stated objectives (Cortner et al., 1998; Davenport et al., 2007; Gray et al., 2012; Haines et al., 2019; Östrom, 2005; Stickler et al., 2013), and their effectiveness depends on how they are perceived these stakeholders (Enqvist et al., 2018). In fact, stakeholders' perceptions have been discussed as one of the underlying anthropogenic factors or ultimate causes affecting biodiversity (Bennett, 2016; Diaz et al., 2015), which has been emphasized in several international agreements (Diaz et al., 2015). We contribute to understanding why a given institution seems to work in some settings and not in others. This is a pivotal issue for the success of forest management at the local level and may greatly affect the ability to reverse

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biodiversity loss and adapt to climate change (Badura et al., 2021; CDB, 2010; Diaz et al., 2015; Haines et al., 2019).

Conventional models of rational decision-making fail to capture important aspects of forest management that extend beyond simple assessments of a cost–benefit analysis; these models must consider other elements, such as the values that local communities assign to forests or their perceptions of forest institutions and agencies (Bartel & Barclay, 2011; Begum et al., 2022; Östrom, 2005; Reyes et al., 2021; Stern & Baird, 2015; Verbrugge & van den Born, 2018). People's perceptions regarding environmental issues can reliably indicate social cohesion, local expectations, and the potential support of decision-making processes (Badura et al., 2021; Bennett, 2016; Enqvist et al., 2018; Haines et al., 2019). Hence, while public agencies are pivotal components of the forest institutions that operationalize the rules-in-use for the access to forest assets (Östrom, 1990, 2005), landholders' perceptions regarding a given forest agency could affect the operational rules of the institution. Landholders' perceptions are based upon their observations regarding the effectiveness and consistent performance of agencies, as well as their demonstrated ability to enforce regulations (Enqvist et al., 2018; Stern & Baird, 2015). The close association between perceptions and regulations have been emphasized for several natural assets worldwide. For instance, Mae Klong River Fishers in Thailand have reported that a combination of locally created and governmental regulations is more readily complied with, making the regulations more suitable for local fishery management than government-imposed regulations alone (Pramitasari et al., 2015; see also Rivaes et al., 2022). Thus, stakeholders' perceptions ultimately influence social support towards the management of biodiversity (Bennett, 2016) and inform social adaptations to the changes in environmental institutions.

There is increasing recognition that landholders' knowledge of regulations and agencies, as well as their local impacts, could affect their perceptions, expectations, and the meaningful personal relationships they develop with forest institutions (Enqvist et al., 2018; Gray et al., 2012; Haines et al., 2019; May, 2004; Stern & Baird, 2015). Strategies should provide public access to high-quality information about the conditions and consequences of forest management (Östrom, 2005), but sometimes the outcomes are paradoxically not positive even in countries with large and often overarching agencies. If forest landholders who are actively managing their forests do not understand how particular combinations of regulations affect actions and outcomes in forest management, unexpected and, at times, disastrous outcomes or undesired effects can result, such as illegal hunting or logging (Alvarez et al., 2021; Bennett, 2016; Beratan, 2007; Berkes, 2010; Cortner et al., 1998; Davenport et al., 2007; Haines et al., 2019; Hilborn et al., 2006; Östrom, 2005; Verbrugge & van den Born, 2018). Landholders could potentially break rules, though this is associated with the risk of being monitored and sanctioned by an environmental agency (Östrom, 2005; Root-Bernstein et al., 2020). The knowledge that landholders have regarding regulations and agencies appears to be a key issue in their relationships with institutions. Indeed, increased knowledge among landholders may lead to more positive perceptions or societal responses, but this general assumption depends on several underlying factors.

In territories where interests regarding the forest are more diverse, even when constant mean opinions are held, landholders' perceptions of these institutions can differ strikingly (Bennett, 2016; Bodonirina et al., 2018; Macura et al., 2011). Indeed, perceptions regarding forest institutions may vary between rural landholders and large companies. How rural landholders perceive forest agencies could be associated with their assessment of costs and benefits (Bodonirina et al., 2018; Sørensen & Torfing, 2006), as well as their evaluations of shared experiences, perceived shared identities, or assumptions that forest institutions and stakeholders hold similar (or dissimilar) salient values (Davenport et al., 2007; Gray et al., 2012; Stern & Baird, 2015). Empirical evidence has shown that local knowledge of sustainable harvesting methods and compliance with forest departments' directives can foster conservation of forest resources and wildlife protection (Begum et al., 2022; Pramitasari et al., 2015). Landholders who perceive that forest agencies share their values and goals regarding the use of forest assets demonstrate more positive perceptions and favourable attitudes towards environmental institutions and the likelihood of compliant behaviours (Gray et al., 2012; Macura et al., 2011) and coordination among these stakeholders also increases (Gray et al., 2012; Haines et al., 2019; Östrom, 2005). On the other hand, if forest institutions do not account for landholders' values of natural assets they will potentially lose their credibility and legitimacy (Begum et al., 2022; Gigante et al., 2021; Maryudi et al., 2017; Rivaes et al., 2022) and be viewed negatively by landholders. For example, the tenure of forested land defines the way in which forest institutions affect landholders and, therefore, how landholders perceive their values and interests are reflected in the regulations and rules. Consequently, increased knowledge as a mechanism for building positive relationships between landholders and environmental agencies might not be a panacea, and may even have negative effects if other related factors are not considered.

We examine the role that rural landholders' knowledge regarding a forest agency plays in relation to their perceptions. Particularly, we assess the association between perceptions and knowledge and analyse the tenancy of native forest as a plausible determinant factor in this relationship. For the empirical analysis, we used the case of a Chilean forest institution and rural landholders from central Chile,

and focused on landholders from rural communities rather than large forestry companies because manageable native forests are owned by thousands of individual stakeholders throughout the country (Reyes, 2021; Reyes & Nelson, 2014). Specifically, individual landholders own more than 62% of the native forest under formal tenure in central Chile (Reyes, 2021). Moreover, landholders have been directly impacted by the negative externalities produced by forest policies (Reyes & Nelson, 2014; Rubilar et al., 2022). Rural landholders have also reported frequent conflicts with large forestry companies in the context of an unequal power distribution (Rubilar et al., 2022). Despite the importance that landholders have in the sustainable management of native forests in Chile, evidence is still lacking. Our analyses can provide key evidence essential for designing strategies focused on building positive relationships between forest agencies and diverse landholders.

Methodology

Chilean Forest Institution

Chile has been recognized worldwide for its hard-line free market economic policies on forest management, with public and private decisions regarding the use of native ecosystems based primarily on economic considerations (Manuschevich, 2016; Manuschevich & Beier, 2016; Nahuelhual et al., 2007; Reyes & Nelson, 2014; Reyes et al., 2014). Forest policies were adopted to promote fast-growing exotic tree plantations to supply a forest market focused on exports, recognized as the afforestation model (Reyes & Nelson, 2014). While Chilean forest policies have been successful in generating economic benefits, the unequal distribution of wealth, as well as the impacts on native ecosystems and indigenous populations are the root of several conflicts in forested territories (Manuschevich, 2016; Reyes & Nelson, 2014; Rubilar et al., 2022). The increase of exotic tree plantations has caused the permanent loss of native forest (Miranda et al., 2017) and associated environmental and poverty problems (Alfonso et al., 2017; Hofflinger et al., 2021; Manuschevich, 2016; Rubilar et al., 2022). As a consequence, Chilean forest policy is characterized by a dichotomy between export-oriented tree plantations with high productivity and economic benefits and native forests with rudimentary management or protection (Nahuelhual et al., 2007; Reyes & Nelson, 2014). Historically, native forests have not been considered a potential source of export earnings or for generating economic wealth (Manuschevich, 2016; Reyes & Nelson, 2014), although, paradoxically, local households depend on forest products for their livelihoods (Zorondo-Rodriguez et al., 2019).

The management of native forest is regulated by the Native Forest Law (Law 20,283), which is overseen and enforced by the National Forest Corporation (CONAF in Spanish) (MINAGRI, 2009). The Native Forest Act is currently the tool that CONAF uses to regulate the management of native forests (Pellet et al., 2005), which was created specifically to protect native forests replaced and degraded by agricultural use, cattle raising, fires, forestry, urbanization, and an increasing demand for firewood (Pellet et al., 2005). This Act establishes a forest management plan as an instrument allowing for sustainable management of forest assets through subsidizing silvicultural activities (thinning, pruning, etc.). While the act considers economic benefits for management plan holders, they are difficult to obtain due to a complex application process, where the amount of money owners receive is less than other benefits from the forest sector, such as planting exotic tree species (Reyes et al., 2014).

The Act and its forest management plans establish how landholders can access forest resources for their own use and/or for economic profit. The Act also includes monetary penalties or even imprisonment depending on the extent of damage and which species have been affected by unauthorized felling. Also, if a landholder does not comply with the management plan, they are fined, lose their benefits, and are obliged to return any subsidy they received (Reyes et al., 2014). This law states that forest management plans must be designed by academic forestry professionals focusing only on western-based scientific management (Manuschevich, 2016; Reyes & Nelson, 2014; Reyes et al., 2014). It remains unclear how peasants, indigenous people, and forest dwellers would claim agency within this expert-based approach to forest management (Manuschevich, 2016).

The impact of the Native Forest Law on forest management is still unclear. Forests with management plans could be better economic options for forest owners and managers than forests without management plans or with unsustainable extraction practices (Nahuelhual et al., 2007). However, landholders receive little or no compensation for the services that native forests generate for society and consequently have little incentive to conserve them (Nahuelhual et al., 2007; Reyes & Nelson, 2014; Reyes et al., 2021). In particular, small and medium landholders have not been interested in applying for this subsidy to manage their forests, mainly because of the bureaucratic and uncertain process that inevitably includes a high cost for the silviculture required in native forest management, in addition to the reduced amount of money they can obtain from a forest management plan compared to other subsidies for agriculture and exotic tree plantations. Also, peasant and landholder organizations have been historically marginalized and do not have a legitimate space to claim political power based on their own construction of forestry and collective needs (Manuschevich, 2016). Currently, a large area of native forest still belongs to small

and medium landholders (Reyes, 2021). Hence, the feasibility of moving from the present situation of unsustainable use and destruction of native forests in Chile towards their conservation and sustainable management largely depends on the adequate implementation of the Native Forest Law with the support of landholders. Considering that CONAF is the only Chilean agency responsible for effectively administrating forest law, the relationships between landholders and CONAF is a key factor for the successful management of native forests.

Study Site

The native ecosystems in central Chile (32º S to 36ºS) are considered global priorities for biodiversity conservation due to their exceptional combination of a high concentration of endemic species and high level of threat (Brooks et al., 2006; Myers et al., 2000). However, they have a very low priority of representation in the national system of protected areas (Squeo et al., 2012). The main forest types include sclerophyllous forest dominated by *Crinodendron patagua, Cryptocarya alba, Lithrea caustica, Persea lingue, Peumus boldus* and *Quillaja saponaria*, and deciduous forest dominated by different species of the genus *Nothofagus*. Forest ecosystems in central Chile represent around 20% of Chile's total native forest (CONAF, 2021). These native forests suffer the greatest land use pressures in the country due to the high concentration of some of Chile's principal economic activities, and forest loss reported was around 40% between 1970 and 1990, and around 20% of the forest remnants between 1990 and 2010 (Miranda et al., 2017). Today, the IUCN list several sclerophyllous- and *Nothofagus*-type ecosystems are classified as critically endangered or endangered (Alaniz et al., 2016). Clearing for agriculture and pasture was the main land use cover change between 32º and 34ºS, while exotic tree plantations are the main forest convertions between 35° and 36º S (Miranda et al., 2017). Small-scale landholders in central Chile continue to practise subsistence agriculture, but are unable to compete in the export market and increasingly enter into dependent relationships with large landowners and multinational agrobusinesses (Murray, 2002, 2006).

We conducted our study in three districts: Paine (33º 84' S; 70°45′W) and Alhué (34°02′ S; 71°06′ W), both located in the Metropolitan Region and Pelluhue (35º 88' S; 72º 53' W) in the Maule Region (Fig. 1). Paine and Alhué are located in the Cantillana Mountain-Range, where Mediterranean deciduous forests with coastal sclerophyllous forests persist. Critically endangered species in the Cantillana Mountain-Range include *Avellanita bustillosi, Beilschmiedia berteroana* and *Adiantum gertrudis*.

More than 7% and 40% of deciduous and sclerophyllous forests, respectively, were burnt for arable and grazing

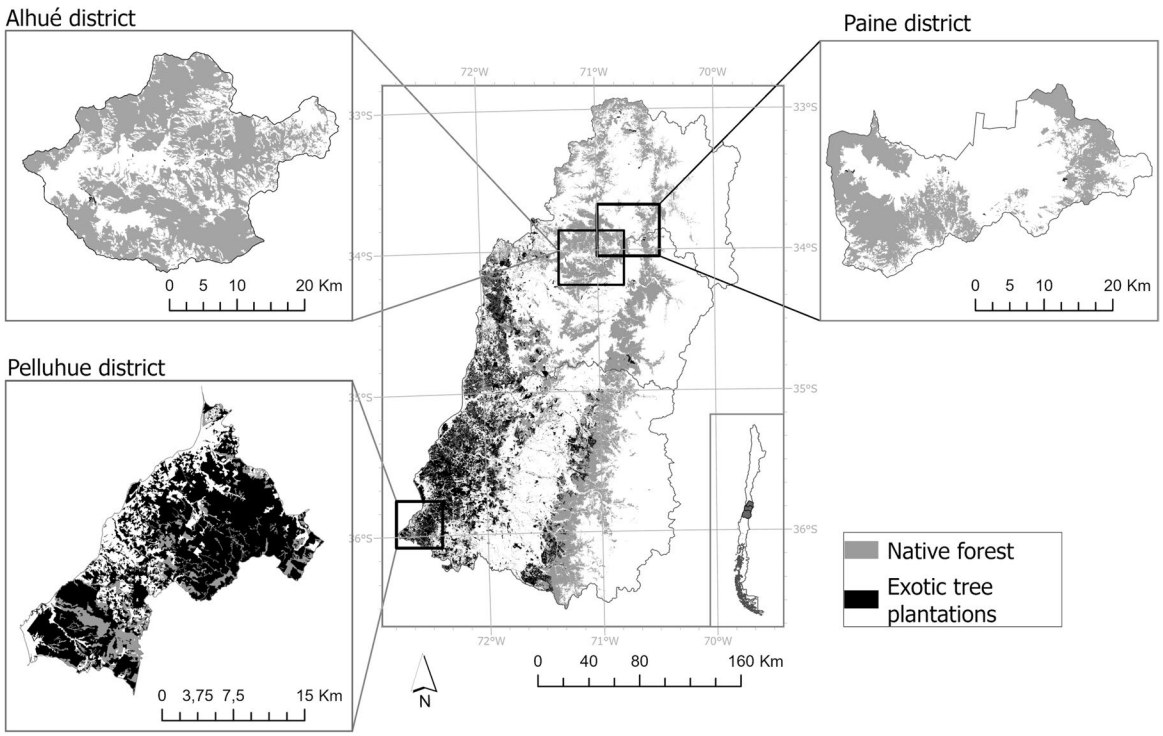

Fig. 1 Study site: Location of the districts of Alhué and Paine in the Metropolitan Region, and district of Pelluhue in the Maule Region of Chile

lands, construction of towns and infrastructure (e.g., railway lines, highways, and roads), which together with reduction in extensive silvopastoral pasturing of livestock, and incentives for industrial agriculture (mainly fruit and wine production) have shaped the current landscape (Miranda et al., 2017). Less than 10% of the deciduous and sclerophyllous forests are currently in protected areas (Echeverria et al., 2006; Miranda et al., 2017; Schulz et al., 2010). A total of 9490 hectares of native vegetation along the Cantillana Mountain-Range in Paine and Alhué are officially conserved in six protected areas, Roblería Cobre de Loncha National Reserve, Palmas de Cocalán National Park, Cerro Poqui Natural Sanctuary, Altos de Cantillana – Horcón de Piedra – Roblería Cajón de Lisboa NS, San Juan de Piche NS, and Horcón de Piedra NS (MMA, 2023). Alhué has been defined as a category V- type management area (Root-Bernstein et al., 2022). The main livelihood activities are agriculture, livestock production, and mining, with an important gold mine and the tailings dam from the largest copper mine in Chile within the district. Most agriculture is on small landholdings with the support of the government's small landholder development office (CED, 2014; CEDEUS, 2014). These rural households practice subsistence agriculture, but also depend on the collection of forest products (e.g., leaf litter, leaves for herbal tea, and tree bark for soap production) (Root-Bernstein et al., 2020, 2022).

Pelluhue district retains fragments of Maulino forest, an endemic deciduous forest dominated by the genus *Nothofagus* (San Martin & Donoso, 1996), which has decreased by more than 80% of its original distribution mainly due to agricultural expansion and replacement by exotic *Pinus radiata* and *Eucalyptus globulus* tree plantations (Echeverria et al., 2006; Miranda et al., 2017; Schulz et al., 2010; Uribe et al., 2020). The remnant native forest is highly fragmented and less than 1% of its current surface area is located in protected areas (Bustamante & Castor, 1998; Uribe et al., 2020). In Pelluhue district, only 218 hectares of native forest are conserved in three protected areas (Los Ruiles National Reserve, Los Queules NR, and Arcos de Calán NS), while 423 hectares are protected in private conservation initiatives (MMA, 2023). These protected forests are not large enough to ensure biodiversity conservation, which makes the support of local small landholders essential although they may have negative attitudes towards some native species (Zorondo-Rodriguez et al., 2014). Further, rural households in Pelluhue are not necessarily aware of changes in forest cover and water provisioning, or how these changes may affect their well-being (Alfonso et al., 2017). Similar to Alhué and Paine, small landholders in Pelluhue practice a subsistence economy based on governmental subsidies, smallscale agriculture, and the collection of forest products (including charcoal, Gevuina's nuts, mushrooms, and timber). Forest products may represent a third of a local household's income (Zorondo-Rodriguez et al., 2019).

Data Collection

Sampling We administered a structured questionnaire between April 2015 and April 2017 to owners or household heads from rural communities in Pelluhue, Alhué, and Paine; large forestry companies were not included in this study. We followed a systematic protocol to visit 141 landholdings or rural households. Participation in the study was voluntary and no compensation was provided to participants. We defined the owner or household head as the sample unit because Chilean forest regulations are strongly based on individual property rights, where each landholding is managed according to the owner's will and CONAF's control is largely influenced by the amount of access that each owner authorizes (Manuschevich, 2016; Reyes & Nelson, 2014). We used a systematic sampling strategy because it does not require a sampling frame or complete lists of the households in the communities (Babbie, 2017; Newing et al., 2011). Estimating a total of 1000 rural households in the study site and assuming the same probability of selection, we calculated a 5% error in our sample size. The response ratio of households was around 0.25. We obtained informed consent from the participants included in the study, which was revised and approval by the Ethics Committee at the Universidad de Santiago de Chile (Ethics Report #733).

Data Collection The semi-structured questionnaire was pretested on a different sample of landholders in order to confirm the wording of questions and the correct use of local words to represent concepts associated with our variables. The questionnaire included three sections for data on the outcome, explanatory, and control variables.

1. Outcome variables: Perceptions of CONAF

We expected perceptions to proxy the kind of relationship between landholders and CONAF from the landholder's perspective, based on people's judgement of the agency's past effectiveness and consistent performance (Bennett, 2016; Enqvist et al., 2018; Gray et al., 2012). We prompted interviewees to score from 1 to 7, where 1 indicated a totally negative perception and 7 a completely positive perception.

2. Explanatory variables: Knowledge about agency and regulations

To evaluate interviewees' knowledge of CONAF, we asked seven questions concerning the agency's duties. We

asked if the interviewee knew when CONAF must act and when they are not obliged to act, according to Chilean regulations. We included questions regarding CONAF's responsibilities in the control of deforestation, administration of protected areas, endorsement of forest management plans, control of wildfires, agricultural production, trade of wood or coal, and support of forest companies' work. Based on these answers, we created an index coding correct answers as 1 and incorrect answers or "I do not know" as 0.

Knowledge of Chilean Forest Act We asked interviewees five questions about the Native Forest Act (MINAGRI, 2009): under what circumstances they could receive benefits or be fined for management practices, such as developing actions to conserve biodiversity, logging trees without a permit, failing to comply with a forest permit, transporting forest products, and organizing a cooperative among forest owners. Based on these answers, we created an index coding correct answers as 1 and incorrect answers or "I do not know" as 0.

Knowledge of Management Plans We asked interviewees nine questions about CONAF's management plans: which practices are permitted or forbidden in the native forest with or without management plans in diverse situations. We included practices such as grazing livestock in the forest, gathering firewood, wood extraction, charcoal production, hunting wild animals, gathering medicinal plants, and selective cutting. Based on these answers, we created an index coding correct answers as 1 and incorrect answers or "I do not know" as 0.

Forest Surface Area We also recorded the self-reported number of hectares of native forest owned by each interviewee.

3. Control variables: Socioeconomic attributes

The questionnaire also included a set of landholder socioeconomic attributes: age (in years), gender (female = 1), household size (number of individuals permanently living in the household), property area (in hectares), and community of residence.

Data Analysis

To estimate whether there was an association between landholders' perceptions of CONAF and their knowledge of CONAF and the Native Forest Act, we adjusted a set of ordered probit regressions. For the explanatory variable we also used the square of knowledge to estimate non-linear associations. We controlled the associations among outcomes and explanatory variables with a set of socioeconomic attributes (Ln of total surface area of the property, age, gender, household size, and a set of dummy variables for the community of residence). We adjusted the regressions using the Huber sandwich estimator of variance in order to estimate the robust standard error in case some misspecification arose from our variables. We also clustered the regressions by district of residence to ensure that the standard errors allowed for intragroup correlation, relaxing the usual requirement that the observation be independent. In other words, the observations were independent across districts, but not necessarily within groups, thus allowing us to capture external factors that could influence the associations among outcomes and explanatory variables at district or upper levels. We used the corrected Akaike Information Criterion for small sample sizes (AICc) to select the regression model from within the model set that lost the least information about the "full" reality, given the data and the current model set (Burnham et al., 2011). We ranked models according to AICc values and defined the core model as the top-ranked model with the smallest value of AICc. We also selected the best candidate model set that included those with a difference of AICc values lower than 2 compared to the AICc's best model. We used software Stata 14.1.

Results

Descriptive Statistics

Landholders in the sample: All participants self-reported their occupation as farmer, which includes the management of native forest on the property. Also, all landholders resided in the visited properties. Women composed 58.2% (n = 82) of the sample. The average age of participants was 54.1 years with a range from 20 to 88 years (Table 1). The property area of participants was 39.2 hectares, on average, with a range from 0 to 5305 ha, and the average surface of forest was 37.3 hectares (min = 0, max = 5200). Lastly, the participants' households had, on average, 3.4 members (from 1 to 10).

Perception of CONAF: On average, interviewees reported a positive level of perception of CONAF, with a value of 5.4 out of 7 (s.d. = 1.5) (Table 1). A total of 118 (84%) respondents perceived CONAF positively (values equal or higher than 5 on our scale), whereas only nine landholders gave a score lower than 4.

Knowledge Regarding CONAF On average, interviewees answered 5.7 out of 7 (s.d. = 1.2) questions correctly. A total of 31% (n = 44) of respondents answered all of the questions correctly, whereas 26% (n = 37) and 31% (n = 43) of interviewees had 6 and 5 correct answers, respectively. Most landholders knew that CONAF controls forest fires (n = 138,

Table 1 Definition and descriptive statistics of the variables gathered from landholders (n = 141) in rural communities in central-southern Chile

Variables	Definition	Mean (sta. dev.)	Min–max
Outcome			
Perception of CONAF	Perception of the National Forest Corporation (CONAF) based on a score from a totally negative (value = 1) to totally positive perception (value = 7)	5.4 (1.5)	1–7
Explanatory			
Knowledge regarding CONAF	Index of individual knowledge concerning CONAF. The index was estimated by adding the correct answers to seven questions regarding CONAF's duties (see Table 2)	5.7 (1.2)	1–7
Square of knowledge regarding CONAF	The square of the individual index of knowledge about CONAF	33.9 (12.3)	1–49
Knowledge of the Forest Act	Index of individual knowledge about benefits and restrictions as stipulated in the Chilean Forest Act (Law 20,283). The index was estimated by adding correct answers to 5 questions about the Act (see Table 2)	3.1 (0.9)	1–5
Square of knowledge of the Forest Act	The square of the individual index of knowledge regarding the Chilean Forest Act	10.0 (5.3)	125
Knowledge of management plans	Index of individual knowledge about practices and uses of native forest under the Chilean Forest Act (Law 20.283). The index was estimated by adding the correct answers to 9 questions about the Act (see Table 2)	6.3 (1.5)	3–9
Control			
Gender	Individual's gender (female = 1)	58.2%	
Age	Age of individual, in years	54.1 (16.4)	20–88
Total surface area of property	Total number of hectares of the property	39.2 (446.6)	0–5305
Ln of the total surface of property	Natural logarithm of the reported total surface area of property	0.85 (1.06)	0–8.58
Surface area of forest	Total number of hectares of forest on the property	37.3 (437.9)	0–5200
Ln of the forest surface	Natural logarithm of the reported surface area of forest on the property	0.25 (0.85)	0–8.56
Household size	Number of members in the household	3.4 (1.6)	1–10

98% of landholders), illegal logging (n = 132, 94%), and the use of native forests (n = 128, 91%), as well as approving management plans (n = 128, 92%), and administering publicly protected areas (n = 121, 86%). Nonetheless, some landholders mistakenly believed that CONAF also facilitates and promotes agricultural production (n = 79, 56%) and the trade of native forest products (n = 77, 55%) (Table 2).

Knowledge of Native Forest Act Our index of knowledge regarding the Native Forest Act had an average of 3.1 out of 5 points (s.d. = 0.9). Only 5 interviewees answered all of the questions correctly. A total of 107 landholders (74%) answered three or more questions correctly. Most landholders were aware that if a management plan was not respected they could be fined (97%, n = 137). Also, 69% (n = 97) of landholders knew that an economic subsidy can be obtained from a management plan that aims to protect biodiversity. However, the equity of economic subsidies across diverse types of landholders was still unknown among landholders. Results showed that 64% (n = 90) of landholders knew that economic subsidies vary across landholders; and 53% (n = 75) were aware that fines apply to all who do not implement a management plan, rather than to a single type of landholder. Lastly, few landholders (23%, n = 32) knew that, as well as single landholders, a collective group can also apply for a forest management plan (Table 2).

Knowledge of Management Plans The index had an average of 6.3 out of 9 points (s.d. = 1.5). Only nine landholders (6.4%) answered all of the questions correctly. A total of 92 landholders (65%) answered six or more questions correctly. Most landholders, 74% (n = 104), knew that CONAF is the institution in which they should apply for a forest management plan. A total of 129 (91%) and 118 (84%) interviewees knew that a management plan is required to cut trees and/or remove wood from the native forest, respectively. Most landholders knew that a management plan is required to extract timber (92%, n = 129), coal (85%, n = 120), and medicinal plants (71%, n = 100), but only 50% (n = 70) of the respondents knew that hunting wild animals is prohibited. Slightly less than half of landholders, 46% (n = 64), knew that a management plan is not required to allow livestock into the forest. Only 36% (n = 50) of landholders knew that a management plan is required to gather firewood (Table 2).

Table 2 Knowledge concerning the National Forest Corporation (CONAF) and the Chilean Forest Act among landholders (n = 141) from rural communities in central-southern Chile. This table shows the set of questions used to estimate each individual's a) knowledge regarding CONAF, b) knowledge about the Chilean Forest Act, and c) knowledge concerning management plans

Question (and correct answer)	n	%
a) Knowledge regarding CONAF		
Is it CONAF's duty to		
i) control wildfires? (yes = 1)	138	98
ii) control illegal logging? (yes = 1)	132	94
iii) control uses of the native forest? (yes = 1)	128	91
iv) approve native forest management plans? (yes = 1)	130	92
v) manage publicly protected areas in the Chilean National System of Protected Areas? (yes = 1)	121	86
vi) facilitate and realise agricultural production? (no = 1)	79	56
vii) trade native forest products? (no = 1)	77	55
b) Knowledge of the Forest Act: benefits and fines		
Is the following statement correct?		
i) Landholders who do not respect their management plans could be fined. (yes = 1)	137	97
ii) Economic subsidies are available when the management of forest aids in the protection of native fauna and flora. (yes = 1)	97	69
iii) According to the Forest Act, small landholders receive the same economic subsidy as large landholders. (no = 1)	90	64
iv) Fines due to the non-compliance of a forest management plan are only for small landholders. (no = 1)	75	53
v) A management plan can be applied only by single landholders, not by an associative group of landholders. (no = 1)	32	23
c) Knowledge of management plans		
i. When a landholder needs a forest management plan, to which agency must the landholder apply? (CONAF = 1)	104	74
Is the following statement correct?		
ii. It is not imperative to apply for a management plan to cut trees from the native forest (no = 1)	129	92
iii. A permit is imperative to transport wood or other forest products (yes = 1)	118	84
For which uses is it imperative to apply for a forest management plan?		
iv. for extracting wood to produce timber? (yes = 1)	129	92
v. for extracting wood to produce coal? (yes = 1)	120	85
vi. for gathering medicinal plants? (yes = 1)	100	71
vii. for hunting wild animals? (no = 1)	70	50
viii. for allowing livestock into the forest? (no = 1)	64	45
ix. for gathering firewood? (yes = 1)	50	36

Testing Associations Between Perception and Knowledge Regarding Forest Institutions

The core model included the Ln of the total surface area of the property, age, gender, household size and community of residence as control variables (AICc = 393.88). The set of three candidate models (AICc differences < 2) excluded the variables i) Ln of the total surface area of the property, ii) household size, and iii) both Ln of the total surface area of the property and gender (Table S1). In general, the sign, magnitude and significance level of coefficients did not vary among the set of candidate models, suggesting that coefficients of associations were sufficiently robust. In the results section, the coefficients of associations for the core model were reported.

1. Non-linear association between the perception of CONAF and knowledge regarding CONAF

Models suggest a U-shaped association between landholders' perception and knowledge. In the first part of the curve, landholders' perception worsened as their knowledge regarding CONAF increased (coefficient = -1.00, p = 0.01, row [a] of Table 3). However, after a value of 5.0 was reached in our index of knowledge, the perception of CONAF improved as knowledge regarding this agency increased (coefficient = 0.10, p = 0.002, row [b] of Table 3) (Fig. 2).

Cells show the coefficients of ordered probit models and, in parenthesis, the standard error. The model also included the community of residence as a set of dummy variables. This model is the best fitted model from a set of candidate models selected by Akaike's Information Criterion (see Table S1). *, **, and *** show the significance levels at 10%, 5%, and 1%, respectively. For the definitions of variables see Table 1.

We then divided landholders into two groups and generated a dichotomous variable with an index of knowledge less

Table 3 Association of the perception of the National Forest Corporation (CONAF) and the knowledge regarding CONAF, knowledge of the Native Forest Act, and knowledge of management plans, among landholders (n = 141) from central-southern Chile

Variables		Outcome variable: Perception of CONAF		
		Coefficient	95% Conf. Interval	
		(Standard error)	Min	Max
I. Explanatory variables:				
Knowledge regarding CONAF	[a]	-1.00 (0.39)**	-1.77	-0.23
Square of knowledge regarding CONAF	[b]	0.10 (0.03)***	0.04	0.17
Knowledge of the Forest Act	[c]	-1.89 (0.64)***	-3.15	-0.62
Square of knowledge of the Forest Act	[d]	0.28 (0.11)***	0.07	0.48
Knowledge of Management plans	[e]	-0.09 (0.05)*	-0.18	< 0.01
II. Control variables				
Age	[e]	0.02 (0.01)***	0.01	0.03
Gender (female = 1)	[f]	-0.21 (0.14)	-0.49	0.07
Household size	[g]	0.11 (0.06)*	-0.01	0.22
Ln of total surface of property	[h]	-0.08 (0.04)**	-0.15	-0.01

(value = 0, or less-knowledgeable landholders, n = 60) and more than 5.0 (value = 1, or knowledgeable landholders, n = 81). The group of less-knowledgeable landholders (value = 0) included the landholders from the negative association between perception and knowledge regarding CONAF, while the group of knowledgeable landholders (value = 1) included the landholders from the positive association part of the curve. We then adjusted a discrete probit regression to test the hypothesis that the landholders on the U-shaped curve of the association between perception and knowledge of CONAF differed in terms of the number of hectares of native forest on their properties (in logarithm)

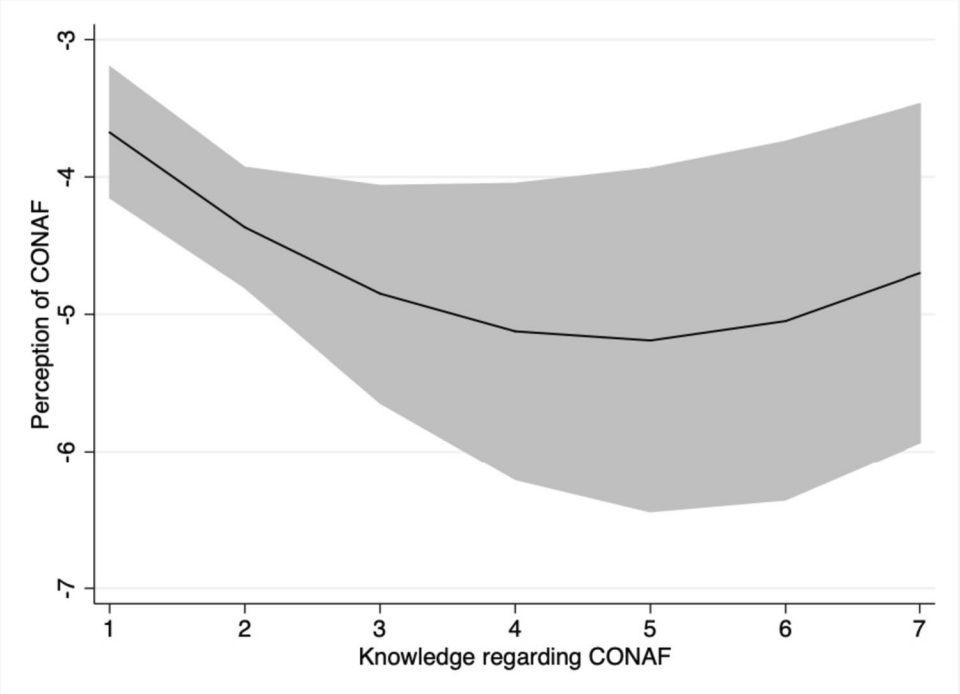

Fig. 2 Adjusted predictions (with 95% of Confidence Intervals) for the quadratic model of the relationship between knowledge of Chilean National Forest Corporation (CONAF) and perception of CONAF among rural landholders (n = 141) from central-southern Chile. The quadratic model includes the perception of CONAF as an outcome variable, and knowledge of CONAF as an explanatory variable, controlled by knowledge of the Chilean Forest Act, knowledge of management plan, age, gender, household size, total surface area of property, and settlement of residence as a set of dummy variables. The linear component of this figure, ranging from values of 1 to 5.0 in knowledge of CONAF, is -1.00 (std. err. = 0.39, z = -2.55, p = 0.01) and suggests a decrease in estimated values of perception. The quadratic component, from 4.9 to 7 in knowledge of CONAF, is 0.10 (std. err. = 0.03, z = 3.15, p = 0.002) and suggests an increase in estimated values of perception. See Table 1 for definition of variables and Table 3 for results of the overall model

and their knowledge regarding management plans, while controlling for knowledge about the Forest Act, age, gender and household size (Table 4). The core model to test this hypothesis, selected by the AICc approach (AICc = 91.59), included the variables of age, gender, and district of residence. Results suggest that the group of less-knowledgeable landholders had more hectares of native forest than the knowledgeable landholders (coefficient = -0.08, p = 0.07, row [a] column [1] of Table 4). The group of less-knowledgeable landholders had an average of 87.1 hectares (sdt. dev. = 671.3; min = 0; max = 5200) of native forest, while the knowledgeable landholders had an average of 0.44 hectares (sdt. dev. = 1.4; min = 0; max = 7) of native forest. Also, our results suggest that the group of landholders with a value lower than 5.0 on our index of knowledge regarding CONAF also had less knowledge about management plans than landholders with a value higher than 5.0 (coefficient = 0.08, p = 0.01, row [b] column [1] of Table 4).

For both outcome variables, the landholders were divided into two groups with high and low knowledge to create dichotomous variables. For knowledge regarding CONAF (column 1), the knowledgeable landholders included those with a value higher than 5.0 on our index of knowledge about CONAF. For knowledge about the Forest Act (column 2), the knowledgeable landholders grouped individuals with a value higher than 3.4 on our index of knowledge.

Cells show the coefficients of discrete probit regression models and, in parenthesis, the standard error. The models are the best fitted models for each outcome variable from a set of candidate models selected by Akaike's Information Criterion (see Table S2). In column (1), models include the district of residence as a set of dummy variables. ^ refers to variables that were intentionally omitted. *, **, and *** show significance levels at 10%, 5%, and 1%, respectively. For definitions of the variables see Table 1.

2. Non-linear association between the perception of CONAF and knowledge of the Forest Act

We also found a U-shaped association between the perception of CONAF and knowledge of the Native Forest Act. On the first part of the curve, landholders' scores of perceptions worsened as knowledge of the Native Forest Act increased (coefficient = -1.89, p = 0.003, row [c] of Table 3); however, scores increased after a value of 3.4 on our index of knowledge of the Native Forest Act (coefficient = 0.28, p = 0.009, row [d] of Table 3) (Fig. 3).

We then adjusted a discrete probit regression to test the hypothesis that the landholders under two parts of the U-shaped association between perception of CONAF and knowledge of the Native Forest Act had a different number of hectares of native forest on their properties (in natural logarithm) and knowledge about management plans (Table 4). We also created a dichotomous variable among those who reported an index of knowledge lower (value = 0, n = 99) and higher than 3.4 (value = 1, n = 42).

The AICc approach suggested a core model that included the variables of knowledge regarding CONAF, age, gender, and household size (AICc = 168.22) (See Table S2). Our results suggest that landholders with a value lower than 3.4 on the index of knowledge of the Native Forest Act had significantly more hectares of native forest than respondents with a value higher than 3.4 (coefficient = -0.09, p < 0.01, row [a] column [2] of Table 4). Our results also showed that landholders with a value lower than 3.4 on the index of knowledge of the Forest Act had less knowledge about management plans than landholders with a value higher than 3.4 (coefficient = 0.01, p = 0.02, row [b] column [2] of Table 4).

3. Association between the perception of CONAF and knowledge of management plans

Table 4 Association of knowledge regarding the National Forest Corporation (CONAF), the Chilean Forest Act, the hectares of native forest on the property, and knowledge about forest management plans, among landholders from central-southern Chile (n = 141)

		Outcome variables			
		(1) Knowledgeable landholders about CONAF		(2) Knowledgeable landholders about Forest Act	
Variables		Coef. (Std. err.)	95% CI (min; max)	Coef. (Std. err.)	95% CI (min; max)
I. Explanatory:					
Ln of Forest surface area	[a]	-0.08 (0.04)*	-0.17; < 0.00	-0.09 (0.01)***	0.06; 0.12
Knowledge of management plans	[b]	0.08 (0.03)**	0.02; 0.15	0.01 (0.01)**	0.00; 0.02
II. Control					
Knowledge of the Forest Act	[c]	^	-0.06; 0.14	^	^
Knowledge regarding CONAF	[d]	^	^	0.04 (0.01)***	0.01; 0.06
Age	[e]	-0.01 (0.01)**	-0.01; < 0.0	- < 0.01 (< 0.01)	-0.01; 0.00
Gender (female = 1)	[f]	-0.21 (0.09)**	-0.38; -0.02	-0.04 (0.02)*	-0.09; 0.01
Household size	[g]	^		-0.05 (0.01)***	-0.07; -0.03

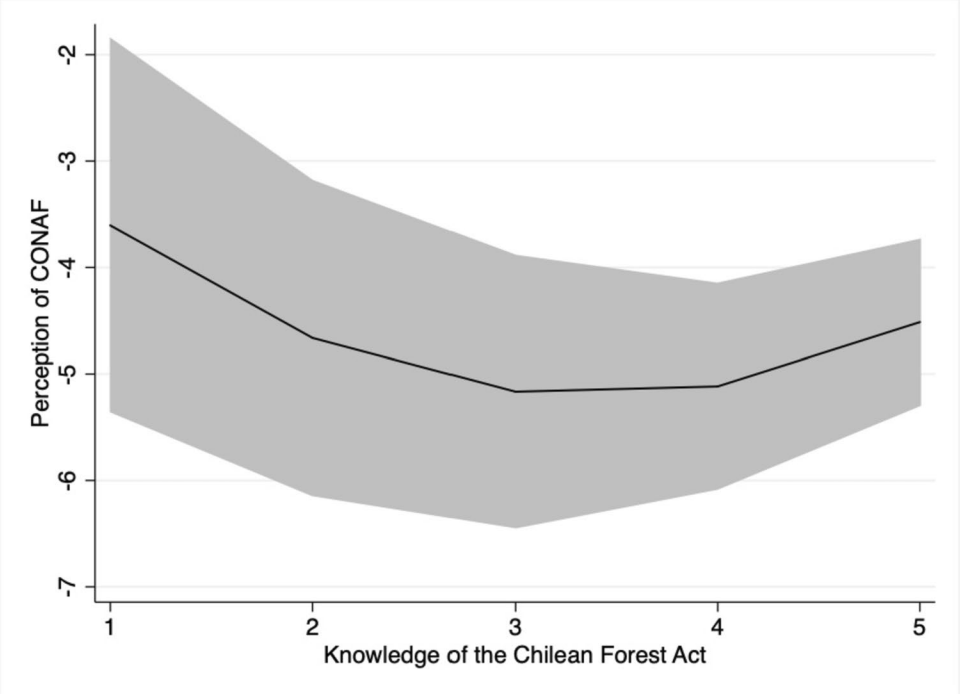

Fig. 3 Adjusted predictions (with 95% of Confidence Intervals) for the quadratic model of the relationship between knowledge of the Chilean Forest Act and perception of CONAF among rural landholders (n = 141) from central-southern Chile. The quadratic model includes perception as an outcome variable, and knowledge of the Forest Act as an explanatory variable, controlled by knowledge of Chilean National Forest Corporation, knowledge of management plan, age, gender, household size, total surface area of property, and settlement of residence as a set of dummy variables. The linear component of this figure, with values ranging from 1 to 3.4 for knowledge of the Forest Act, is -1.88 (std. err. = 0.64, z = -2.93, p = 0.003) and suggests a decrease in estimated values of the perception. The quadratic component, from 3.5 to 5 for knowledge of the Forest Act, is 0.27 (std. err. = 0.11, z = 2,60, p = 0.009) and suggests an increase in estimated values of the perception. See Table 1 for the definition of variables and Table 3 for results of the overall model

The multivariate regression showed a linear relation between the perception of CONAF and knowledge regarding management plans (Fig. 4). Respondents with better knowledge regarding management plans had a negative perception of CONAF compared with those with less knowledge (coefficient = -0.09, p = 0.05, row [e] of Table 3).

Potential Biases and Limitations of the Study

Our findings are valuable to understand a complex phenomenon; however, they must be considered in light of some limitations and biases. Although the questionnaire was previously tested to a large extent to avoid errors, we are aware that our results may still suffer due to measurement errors in the explanatory and outcome variables, biases because of omitted variables, and lack of an endogeneity control. For instance, a measurement error could have occurred when some participants were better able to understand the questions than others. In some cases, the questionnaire may have captured the level of understanding rather than knowledge. Also, the perception of CONAF could have suffered thanks to social desirability or conformity biases, some participants might have answered questions to be viewed favourably by others or to coincide with their perceived mainstream answer regarding CONAF. Also, statistical models could fail to include one or more important confounding variables to control the associations between the perception of CONAF and knowledge. We have included several control variables that research suggests are factors in perceptions and knowledge, but we cannot rule out the possibility of the existence of other omitted variables. Our protocol for the model selection also allowed us to observe that the sign, magnitude, and significant level of explanatory variables were similar and consistent across different models. Lastly, we found no instrumental variables to deal with endogeneity in our models, hence our results were interpreted as an association of variables rather than a cause-effect relationship.

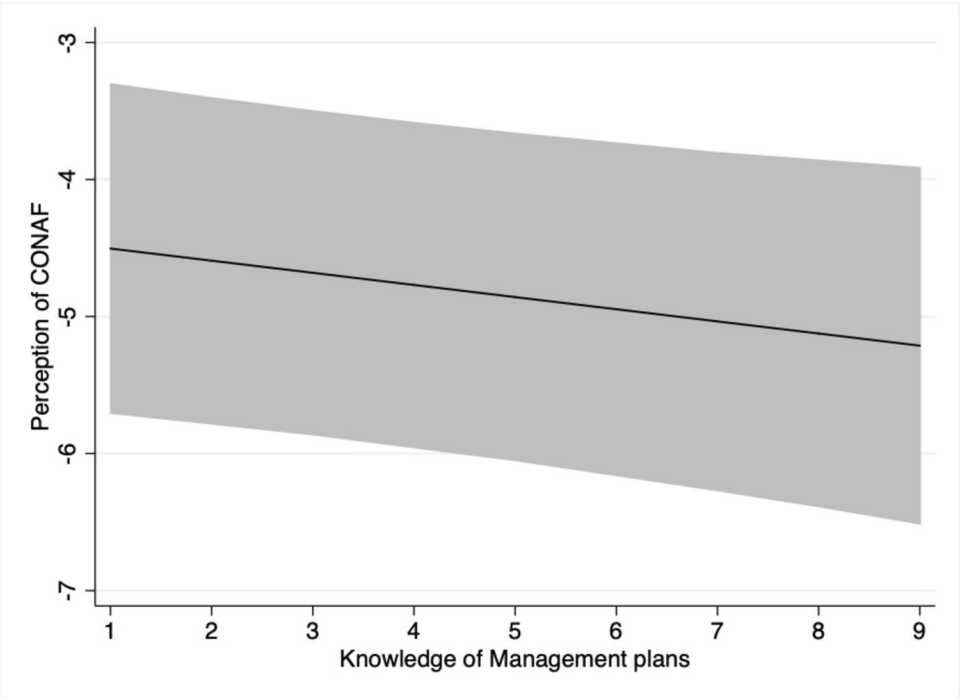

Fig. 4 Adjusted predictions (with 95% of Confidence Intervals) for the linear model of the relationship between knowledge of forest management plan and perception of CONAF among rural landholders (n = 141) from central-southern Chile. This model includes perception as an outcome variable, and knowledge of management plan as an explanatory variable, controlled by knowledge of Chilean National Forest Corporation, knowledge of the Chilean Forest Act, age, gender, household size, total surface area of property, and settlement of residence as a set of dummy variables. This figure shows that as knowledge of the Forest Act increases, the estimated values of perception decrease (coef. = -0.09, std. err. = 0.05, z = -1.91, p = 0.05). See Table 1 for the definition of variables and Table 3 for results of the overall model

Discussion

A lack of knowledge or misunderstanding of the factors that affect the relationship between landowners from rural communities and forest institutions could have several implications for environmental governance, including inaccurate decisions in public policies or a lack of compliance as well as the erosion of the legitimacy of institutions (Bartel & Barclay, 2011; Davenport et al., 2007; Gray et al., 2012; Östrom, 2005). This study suggests that Chilean landholders report overall positive perceptions of CONAF, although, paradoxically, associations between the perceptions of CONAF and knowledge regarding this forest agency and regulations form a U-shaped curve. The U-shaped associations are explained by the size of a landholder's native forest and their knowledge regarding forest management plans. Our results bring provide key insights for environmental governance among a social group historically marginalized from decisions regarding forest policies and with limited space to claim political power based on their own construction of forestry and collective needs (Manuschevich, 2016).

We emphasize that landholders' overall positive perceptions of CONAF could increase the perception of legitimacy of forest regulations and thus facilitate the observance of norms related to native forest management (May, 2004). This finding may be a consequence of past positive relationships between CONAF and landholders (Stern & Baird, 2015). These constructive relationships in a formal institutional context may have emerged, on average, from social interactions among landholders, clear expressions of similar values, or the demonstration of active listening and responsiveness among stakeholders in institutions (Bodonirina et al., 2018; Haines et al., 2019; Macura et al., 2011; Stern & Baird, 2015). These positive perceptions of the forest agency may also facilitate pro-environmental behaviours that respect the norms and rules of forest management. However, although our results point out a generally positive perception, they also demonstrate that these relationships did not prove to be similarly positive for different types of landholders. The heterogeneous local perception found in this study obliges the forest agency to understand the underlying determinants and to adapt to social-ecological contexts in order to guarantee effective management, as has been suggested in previous research (Bartel, 2014; Root-Bernstein et al., 2020). These heterogeneous local perceptions could also suggest that

there are different local ways in which forests meet local needs and maintain human wellbeing that should be taken into account by the forest agency. Our results may also suggest that a missing, or weak, incorporation of local needs could lead to negative perceptions among some landholders, which could hinder forest agencies' effective management of ecosystems (Bartel, 2014; Stern & Baird, 2015). Addressing both the positive and negative local perceptions found in this study could facilitate an effective performance of institutions and good governance (Badura et al., 2021; Bennett, 2016; Cortner et al., 1998; Haines et al., 2019; Stern & Baird, 2015), shaping public support for environmental decisions (Davenport et al., 2007), and ultimately, expanding the overall robustness and resilience of socio-ecosystems (Östrom, 2005).

Our results also suggest that landholders' perception of the forest agency is closely related to the level of knowledge regarding CONAF and the Chilean Forest Act, and that these relationships do not have a lineal association but form a U-shaped curve. The perception of CONAF became more negative as the level of knowledge regarding CONAF and the Chilean Forest Act increased in the first part of the curve, while after an inflection point, the perception of CONAF became more positive as knowledge increased. While several authors have described that as knowledge of environmental laws and regulations increases, positive perceptions of environmental agencies also improves (Barnes-Mauthe et al., 2015; Beitl, 2014; Berkes, 2010; Fairbrother, 2017; Harring, 2014; Macura et al., 2011), our finding advances and complements current literature suggesting that a negative relationship between perception and knowledge may arise previous to a positive association. Our results emphasize the key role of the landholders' knowledge about forest agencies and norms as an underlying factor on how they perceive these agencies. This finding also complements the literature, suggesting that landholders' enhanced comprehension also increases their trust in environmental agencies and thus compliance with regulations (Macura et al., 2011; May, 2004; Östrom, 2005; Winter & May, 2001). Thus, assessment of users' knowledge of regulations is critical for effective strategies for compliance with environmental management goals.

Our results show, on average, a medium-level of knowledge regarding CONAF and the Chilean Forest Act among landholders. Nonetheless, they also indicated important deviations from the mean in the levels of knowledge. Considering the pivotal role that knowledge plays in local perceptions, agencies, such as CONAF, must provide more effective communication to address the existing gaps among landholders. One explanation is that knowledgeable landholders are able to develop relatively accurate mental models of how to comply with forest regulations to obtain the best benefits without breaking rules. Landholders' familiarity with the body of regulations could influence whether they feel a moral obligation to obey them (Winter & May, 2001). The existing literature has focused on the positive association between knowledge and perceptions or behaviours arguing that, for instance, when people are aware of environmental regulations, negative perceptions and illegal actions may be reduced due to the risks of noncompliance (Winter & May, 2001). Nevertheless, our findings suggest that in ranges of low levels of knowledge the relationships between knowledge and perceptions of such agencies may be negative.

This U-shaped association could suggest that forest institutions may produce local resistance and hinder the desired forest management among some landholders, possibly reflecting a breakpoint in the shared salient values between landholders and the institution, which is explained by the ownership of native forest and knowledge regarding management plans. It could also suggest that CONAF and one group of landholders have co-cultivated shared salient values, whereas those who own more native forest might not. A plausible explanation is that CONAF's general message about regulations and how native forests should be managed is easily accepted by landholders without forest because they may not have contradictory values, interests, and/or knowledge about its uses and potential benefits, whereas landholders with forest aim to obtain benefits from their forest according to their own interests and knowledge, which are not addressed in the forest regulations. This is also a forest management paradox in the normative institutional model because those who own more native forest and can thus have the greatest impact on biodiversity conservation through the sustainable management are those who more negatively perceive the environmental agency in charge of management plans and are hence more prone to noncompliance (Fairbrother, 2017; Hilborn et al., 2006; Lindenmayer et al., 2006). This paradox is crucial in the case of central Chile, since the last remnants of native forest belong to private owners (Reyes, 2021) so their support is particularly key to achieve biodiversity conservation goals. Our study does not address the relationships of large companies with forest policies, in which the "Chilean forestry model" and forest regulations have brought advantages in terms of the distribution of wealth and power in policy decisions. (Manuschevich, 2016; Manuschevich & Beier, 2016; Manuschevich et al., 2019; Reyes & Nelson, 2014), at the expense of rural communities and native forest (Alfonso et al., 2017; Hofflinger et al., 2021; Manuschevich, 2016; Rubilar et al., 2022).

The forest management paradox suggests that forest owners and institutions have disparate values regarding environmental management particularly when it comes to values concerning the redistribution of forest benefits and the role of government institutions in forest management. There are different values associated with forest management when the forest provides commodities and amenities

and the basic conditions of livelihood and existence (Martinez-Alier, 2009). The tensions between landholders and CONAF may result from a perceived violation of the social contract or lack of legitimation of certain valuations of the forest (Martinez-Alier, 2009; Rothstein & Uslaner, 2005). In fact, landholders from rural communities have described themselves as feeling abandoned by the (welfare) state and its forest policies (Manuschevich, 2016). The forest institution may be perceived as unfair by landholders with forest because they feel the pressure to manage the native forest in a more restrictive manner than previous generations or large companies (Manuschevich, 2016; Manuschevich et al., 2019; Rubilar et al., 2022). Also, landholders with forest usually claim that they must assume the negative externalities of historical management, or lack thereof, of native forest (Manuschevich, 2016). These perceived inequalities are frequent causes of environmental conflicts among stakeholders (Martinez-Alier, 2009; Rubilar et al., 2022). Furthermore, the possible differences in values related to forest management and products between CONAF and landholders could create greater uncertainty regarding the behavioural predictability of landholders, as well as increasing negative perceptions (Misztal, 1996), resulting in low social cohesion (Putnam, 2000) to achieve its objectives. As we have noted, the Chilean Forest Act could be a fundamental factor affecting landowners' perception of this forest agency. This scientific evidence could be enriched by understanding the mechanisms or underlying factors that affect how the tenancy of forest is associated with the perception of landholders, as well as how other factors are involved in building positive relationships between landowners and environmental institutions.

According to the principles of smart regulation, not only can the Chilean government enforce the regulations of the Chilean Forest Act, but second and third parties who act as surrogate regulators could also carry them out (Gunningham & Sinclair, 2017; Tricallotis et al., 2018, 2019). While second parties can self-regulate, third parties refers to a variety of actions carried out by commercial or non-commercial actors. The Chilean Forest Act is enforced by CONAF and fails to include second and third parties. While government involvement in forest management is valuable and guarantees some forest governance, including second and third parties in forest management may be a suitable strategy to address the range of neglected interests claimed by landholders (Tricallotis et al., 2018, 2019). Also, the forest management paradox may be addressed through various complementary instruments that could compensate for the weaknesses of standalone forest policies, as proposed by smart regulation (Gunningham & Sinclair, 2017). The Chilean Forest act is based on a limited set of instruments for those who voluntarily apply for a management plan, including command-and-control regulations and economic instruments with financial supply-side incentives provided by the government (Gunningham & Sinclair, 2017). Our results suggest that the Chilean Forest Act fails to impose predetermined environmental outcomes and does not include instruments capturing the diversity of interests and values concerning forest management. Landholders reported that they are not free to make independent judgements for forest improvement or their desired level of forest use. Also, the economic instruments are perceived to have very low marginal benefits and, consequently, do not support decisions focused on sustainable management. Indeed, other strategies could enhance the effectiveness and efficiency of Chilean forest policy to achieve the compliance of landholders, for instance, forest management based on local and traditional ecological knowledge, which remains excluded from forest management standards (Herrmann, 2005, 2006; Herrmann & Torri, 2009; Root-Bernstein et al., 2022; Tricallotis et al., 2018). Also, current subsidies appear to be insufficient in those cases where other land uses are more profitable, such as in central Chile. Indeed, the strengthening of educational and information-based instruments, as well as monitoring and enforcement strategies could help to enhance compliance with regulatory rules. Most analyses, including this study, suggest that forest policy is either inherently counterproductive or, at the least, suboptimal (Lara et al., 2010; Manuschevich, 2016; Manuschevich & Beier, 2016; Reyes & Nelson, 2014; Reyes et al., 2014). Therefore, the forest policy should embrace pluralism, engaging a range of third parties as surrogate regulators as well as complementary instruments under an evidence-based adaptive strategy (Gunningham & Sinclair, 2017).

In summary, our study shows a novel case of a U-shaped relationship between the perception of a forest agency and knowledge regarding this agency and its regulations. We conclude that a negative relationship arose at low levels of knowledge, while a positive association occurred at higher levels of knowledge regarding this forest agency and its regulations. The breakpoints were determined by ownership of native forest and the knowledge regarding management plans. This U-shaped association suggests a forest management paradox: forest institutions are established for managing and conserving biodiversity, especially for those who own native forest, but the negative perceptions of forest landowners who should be the targeted partners of these environmental institutions, proved to increase their as their knowledge regarding this forest agency and its rules increased. We also emphasize the need to increase scientific knowledge regarding the mechanisms and underlying factors associated with the perception of environmental institutions. Our results provide evidence that adapting public policies in accordance with diverse socio-ecological contexts is

essential because the incorporation of these concerns, values and interests should increase landholders' positive perceptions and, therefore, the opportunities to achieve effective environmental management.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-023-00465-2.

Author Contributions FZR and MRB conceived the research. FZR, AB, NG, FA, AA, GCO, and GRG, conducted fieldwork, analysed and interpreted the data. FZR, GRG and NG wrote the manuscript. MRB and CG provided advice, discussion of results and editing of the manuscript. All authors reviewed the manuscript.

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Data Availability The data that support the findings of this study are available on request from the corresponding author, FZR. The data are not publicly available because they contain information that could compromise the privacy of research participants.

Declarations

Ethical Approval This study was revised and approved by the Ethics Committee at the Universidad de Santiago de Chile (Ethics Report #733).

Competing Interests The authors have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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