UNIVERSIDAD DE CHILE -FACULTAD DE CIENCIAS -ESCUELA DE PREGRADO

"Implications of water provision loss to human well-being: a case study in rural communities of Pelluhue district, Maule Region, Chile "

Seminario de Título entregado a la Universidad de Chile en cumplimiento parcial de los requisitos para optar al Título de Bióloga con mención en Medio Ambiente.

Amanda Alfonso Herrera

Co-Director: Francisco Zorondo Rodríguez

Director: Javier A. Simonetti

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INFORME DE APROBACIÓN SEMINARIO DE TITULO

Se informa a la Escuela de Pregrado de la Facultad de Ciencias, de la Universidad de Chile que el Seminario de Título, presentado por la Srta Amanda Alfonso Herrera:

"Implications of water provision loss to human well-being: a case study in rural communities of Pelluhue district, Maule Region, Chile"

Ha sido aprobado por la Comisión de Evaluación, en cumplimiento parcial de los requisitos para optar al Título de Título de Bióloga con mención en Medio Ambiente.

Dr. Javier A. Simonetti
Director Seminario de Título

Dr. Francisco Zorondo Rodríguez
Co-Director Seminario de Título

<u>Comisión de Evaluación</u>

Dr. David Veliz
Presidente Comisión

Dr. Manuel Contreras
Evaluador

Santiago. Octubre 2015

A Hortensia

Quien no conoce el bosque chileno, no conoce este planeta.

De aquellas tierras, de aquel barro, de aquel silencio,

he salido yo a andar, a cantar por el mundo.

Pablo Neruda

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ÍNDICE DE CONTENIDOS

ÍNDICE DE TABLAS

ÍNDICE DE FIGURAS

RESUMEN

Los servicios ecosistémicos son determinantes para el bienestar humano. El servicio de provisión de agua es fundamental para la sociedad por ser esencial e insustituible para la vida y el funcionamiento de los ecosistemas. En Chile, este servicio ecosistémico se ha visto reducido por los cambios en el uso del suelo, específicamente, la sustitución de bosque nativo por *Pinus radiata*. Este estudio evalúa la percepción de la población local sobre cambios en la superficie de bosque nativo y provisión de agua, y estima la asociación entre estas variables y el bienestar humano. El estudio se llevó a cabo en 65 personas de comunidades rurales de la comuna de Pelluhue, Chile, donde se preguntó sobre cambios en superficie de bosque nativo, cantidad de agua, calidad del agua, y bienestar subjetivo, en los últimos 20 años. Las personas percibieron una disminución en la superficie de bosque y cantidad de agua, pero una mejora en la calidad del agua. Un mejor bienestar subjetivo fue asociado a un aumento en la calidad del agua, pero no fue asociado a cambios en superficie de bosque ni cantidad de agua.. La disociación de la pérdida de bosque nativo y la percepción de provisión de agua sugieren que las consecuencias de la pérdida de dicho servicio sobre el bienestar podrían estar siendo amortiguadas por el acceso a otros tipos de capital, como la infraestructura de agua potable.

ABSTRACT

Ecosystem services are determinants to human well-being. Water provision is fundamental for society to be essential and irreplaceable for life and the functioning of ecosystems. In Chile, water provision has been reduced by land use changes, specifically the replacement of native forests by *Pinus radiata*. This study evaluates the perceptions of local people on changes on forest surface and water provision, and estimates the association between those variables and human well-being. The study area was the rural communities at Pelluhue district, Chile. People were interviewed about the change native forest cover, water quantity, water quality, and well-being within the last 20 years. Informants perceived a decrease in forest cover and water quantity, but an improvement in water quality. A better subjective wellbeing was only associated to an improvement of water quality. The disassociation of forest loss and perceived water provision suggest that the consequences of water provision loss over well-being might be buffered by the access to other types of capital, such as water infrastructure.

INTRODUCTION

Changes in ecosystem services affect human well-being through variations in the quality and quantity on the provision of goods necessary for life, health, and good cultural and social relations (MA, 2005). Land use change, through habitat loss and degradation, is currently one of the major drivers of global biodiversity loss (Haines-Young, 2009; Pereira et al., 2012). Combined with the pressure of climate change in ecosystems (Schröter et al., 2005), land use change is affecting ecosystem functioning and the provision of ecosystem services (Turner et al., 2007), having implications on human well-being (Balmford and Bond, 2005; Pereira et al., 2005; Costanza et al., 2007). The relationship between ecosystems, their services, and human well-being, is considered a keystone for the agenda on environmental management, being included as an Aichi target in the Strategic plan for Biodiversity by the Convention on Biological Diversity (CBD).

Ecosystem services are product of natural capital, the stock of components and interactions between abiotic and biotic ecosystem processes (Ekins et al., 2003). Part of the natural capital, the critical natural capital, would be essential for human life and the functioning of ecosystems (De Groot et al., 2003). Any reduction of this critical natural capital, would eventually decline the flow of essential ecosystem services, affecting the people's well-being. Despite the importance of the topic, most of the research destined to study the links between ecosystem services and well-being assume a reduction in human well-being with the decrease in ecosystem services (Díaz et al., 2006; Guo et al., 2010; McNeely, 2010; Keeler et al., 2012), or stays in theoretical ground (Summers et al., 2012; Wu, 2013), and few empirical analysis have been focused on this link.

Water provision is a critical ecosystem service. It is fundamental for society for being essential and irreplaceable for life and the functioning of ecosystems (Russi et al., 2013; MA, 2005). The loss of water provision determines a decrease in well-being. For instance, in rural areas of Iran and Indonesia, the loss of water provision is associated with a decline in health, due to an increase in diseases related to quality and availability of water, such as diarrhea (Meijer & Hajiamiri, 2007; Pattanayak & Wendland, 2007). In Tanzania, change in water provision is associated with changes in well-being through recreation, leisure and socialization, and spiritual and religious uses (PBWO-IUCN, 2007). Despite the importance of water provision to human well-being, it is expected that 47% of world population will be living in areas of high water stress to the year 2030 (WWAP, 2009). In rural areas, people have access to drinking water through water community systems. A committee formed by community members is responsible for the intake, treatment, storage, distribution, and administration of the system, along with different level of support and contact with local government (Harvey & Reed, 2007).

In Chile, water provision has been negatively impacted by the replacement of native forests by *Pinus radiata* plantations. Plantations create a greater demand for water supply; annual runoff decrease as the area of plantations increase, while the inverse relationship was found with native forest (Lara et al., 2009). Also, native forests, in comparison with pine plantations, have a better regulatory effect on the basins allowing a continuous supply of water, preventing floods in winter and allowing availability of water during the dry summer months (Otero, 1994; Gayoso & Iroumé, 1995; Huber et al., 1995; Little, 2009). Particularly, the Maulino forest, located in the coastal range of central-south of Chile, has faced up a heavy replacement by pine plantations, with an estimated annual deforestation rate of 4.5% (Echeverria et al., 2006). The impact in the loss of water supply would be even greater in the context of global change. Predictions for this area indicate a rainfall reduction of 15% by the year 2030 (MMA, 2014),

This study evaluates the perceptions of local people on changes on forest surface and loss of water provision and estimates the association between those variables and human well-being. The area of Pelluhue district in Central Chile is taken as study case. The need to address the consequences of the loss of ecosystems in order to ensure the continued provision of ecosystem services is recognized by the Adaptation Plan to Climate Change in Biodiversity, as well as the Organization for Economic Cooperation and Development (OECD). This study contributes to the knowledge on the links between ecosystem services and human well-being, as well as to address the recommendations of the OECD.

METHODS

2.1. Study site

The study area is located in Pelluhue district, in the coastal mountain range of the Maule Region in central south of Chile. To the year 2013, the surface of pine plantations in the region had a 27-fold increase in comparison to 20 years before (INFOR, 2014). Particularly in Pelluhue district, 55% of the surface were plantations in the year 2012, in comparison to the 14% of native forest cover (CONAF, 2015). Nowadays, the landscape is characterized by forest fragments scattered across a matrix dominated by pine plantations and agricultural lands (Figure 1).

2.2 Water community system

Households on the study area have access to drinking water through three different types of water systems.

First, families can be part of a Rural Drinking Water Committee (CAPR, in its Spanish acronym). CAPRs are non profit, community run organizations, in charge to provide drinking water to members of the community. The committee is responsible for administration, operation and maintenance of the infrastructure, water sanitization, and setting the rates for water consumption (MOP, 2007). Rural Drinking Water Committees are supported by government institutions for building the infrastructure and training members regarding administration and water sanitization, and provide subsidies for maintaining or improving the facilities (Figure 2, a).

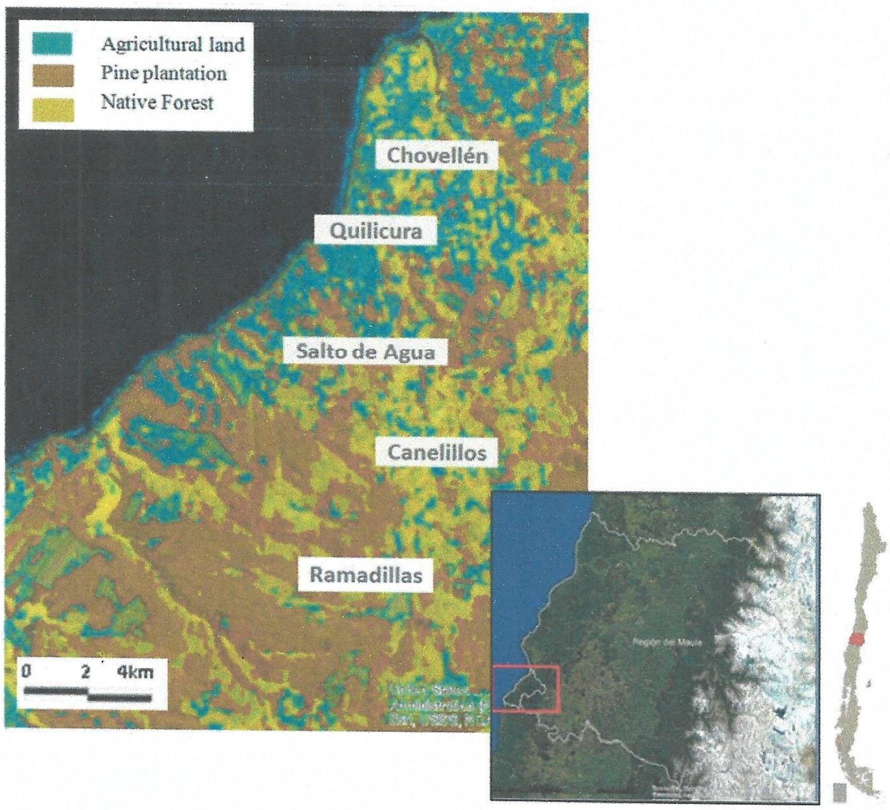
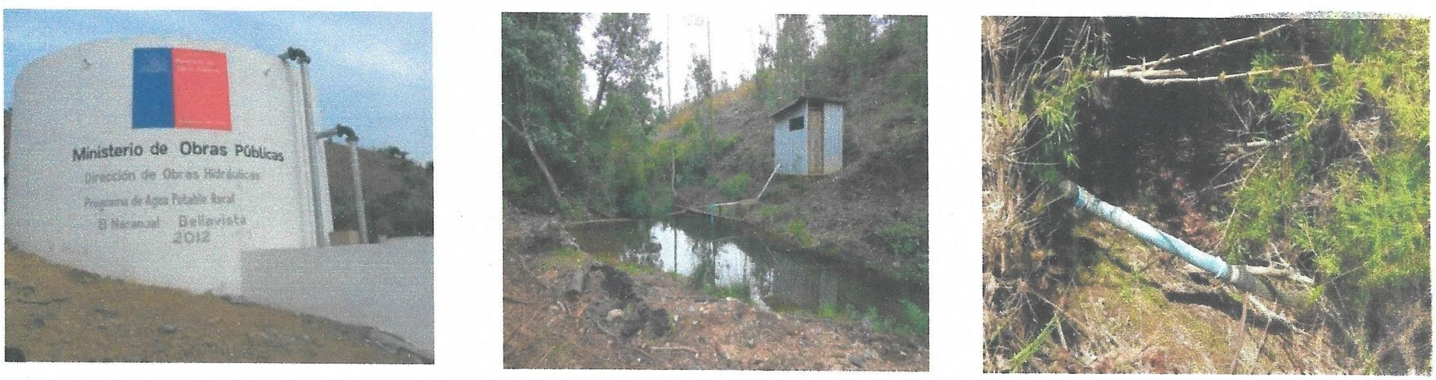


Figure 1. Study site. Landscape of study site, Maule Region, Chile. The figure shows forest fragments, pine plantations, agricultural lands, and location of communities. (Source: image from Global Land Survey (GLS) datasets 2010, modified according to Google; Digital Globe, Terrametrics and CNES, 2015)

Second, locals can be part of Neighbor Associations dedicated to water supply of the community. These associations depend on their own capacity for water catchment and distribution, sanitization, administration, and response to contingencies. They do not receive support from government institutions, since they do not meet all the criteria needed, as the ownership of water rights for the water they consume. (Figure 2, b)

Finally, households that are not part of a CAPR nor a Neighbor Association destined to water supply, rely on self provided water, obtained from wells or springs near the household. In these cases, all the infrastructure building, storage and maintenance is done by household members, and the absence of pipes, water faucets inside the houses and lack of sanitization is usual (Figure 2, c).



a) Rural Drinking Water Committee

b) Neighbor Associations for water supply

c) Self provided water supply

Figure 2. Water catchment for the three drinking water systems present in the study area.

2.3. Data collection

In order to evaluate local's perception on forest surface change and loss of water provision, and to estimate the association between those variables and human well-being, a semi-structured questionnaire was conducted between October and December 2014, among five rural communities from Pelluhue. The communities included Ramadillas, Canelillos, Salto de agua, Quilicura, and Chovellén.

The questionnaire included four sections; change in native forest, change in water quantity and water quality, change in human well-being, and socioeconomic attributes.

To evaluate change of forest surface and water provision, informants were asked to compare the current state of these variables with the state of 20 years ago. A 20-year period was choose in order to capture an amount of time long enough to landscape change to be perceived. Because of this, the questionnaire was applied to one household head willing to answer the survey, that would be at least 30 years old, and that have been living for at least 20 years on the community, or within the district. A total of 65 randomly selected households were visited.

2.3.1. Change in native forest

To proxy replacement of native forest by pine plantations, informant's perceptions were asked regarding the current native forest surface around their community, in comparison with 20 years ago. A scale from 1 to 6 was used, being 1 "much less surface than 20 years ago" and 6 "much more surface than 20 years ago" (Figure 3). Also, effects of native forest loss on the informants and their family were asked, being 1 "extremely negative" and 6 "extremely positive" on the scale. Finally, informants were asked about the consequences this land change has brought to them and their families, as an open question.

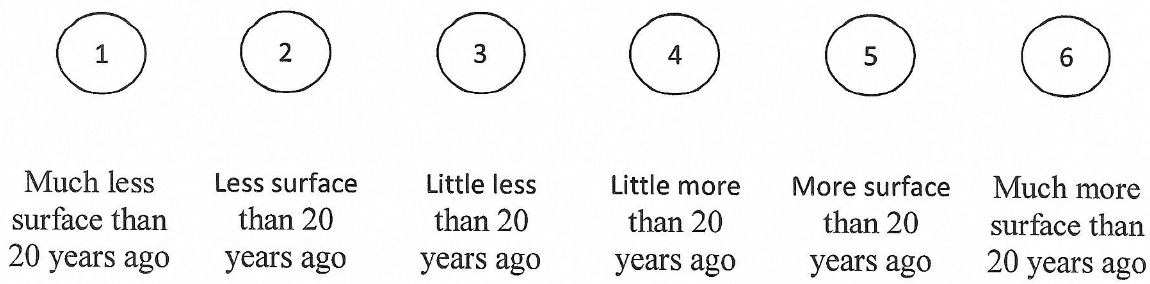


Figure 3. Scale used for assessing perception of change in native forest surface.

2.3.2. Change in drinking water quantity and quality

People were asked to compare the current quantity and quality of drinking water with the one available 20 years ago. Specifically, the question "Compare the current quantity of water, with the quantity of water available 20 years ago. How would you describe it?" was asked. The same question structure was asked to estimate change in water quality. The answers were on a scale of six values from 1 to 6, following the same scale structure of change in native forest, being 1 "completely worst than 20 years ago" and 6 "completely better-off than 20 years ago". In addition, informants were asked about the factor they relate this change to, as an open question.

2.3.3 Change in Human Well-being

As a proxy of human well-being, the personal overall satisfaction to individual's life was captured among informants, called subjective well-being (Easterling, 2003; Layard, 2010). The question followed the structure advanced by Reyes-García and colleagues (2015a) for gathering individual's appreciation on their life satisfaction at the current time compared to a previous time. Specifically, the question "Thinking in all the good and bad aspects, how would you describe your life compared with 20 years ago?" was asked. The answers were on a scale of six values from 1 to 6, being 1 "completely worst than 20 years ago" and 6 "completely better-off than 20 years ago". The informants were asked to name the reason of change in subjective well-being.

2.3.4 Socioeconomic attributes

To estimate association between subjective well-being and changes in forest surface and water provision, some socioeconomic attributes were used as control variables in the statistical models, that according to the literature would be associated to subjective well-being. (Dolan et al., 2008; Frey & Stutzer, 2002; Easterling, 2003). Informants were asked about i) sex, ii) age, iii) change in economic income, and iv) type of water supply system (Rural Drinking Water Committee, Neighbor Associations for drinking water, and self provided drinking water). i) Since women would be the main users of water for the household economy, as well as responsible for water collection (Singh et al., 2005, Mehta, 2014), sex was included as a control variable. Also, studies show that, traditionally, women have a role in maintenance and management of community water supplies (Valdivia & Gilles, 2001). ii) Since older individuals have probably experienced landscape change for longer time, informants with different ages could differ on the perception of change of forest surface and water provision within the last 20 years. iii) Change in economic income within the last 20 years was included as a control variable, considering that variations in household economic income could have changed the access to drinking water, through water tanks, dams, pipes or water faucets. To capture this variable, the same question and scale structure for change in water provision was used. iv) Differences in water community systems might influence how water provision is perceived by informants.

2.4. Data analysis

In order to assess significant differences in change in water quantity, water quality and subjective well-being within the three types of water supply, Kruskal-Wallis and Dunn's test for multiples comparisons was conducted.

To test the association between change in subjective well-being (outcome variable) and change forest surface, and change in water quantity and in water quality (explanatory variables), a set of multivariate regression was ran while controlling the socioeconomic attributes. Since subjective well-being is a discrete ordered categorical variable, an Ordered Probit model was used. The regressions were ran using the Huber variance estimator.

Last, to assess the consistency of the results, and discard they are not cast out by chance, a robustness analysis was carried out (Sheldon et al., 1997; Masferrer-Dodas et al., 2012; Reyes-García et al., 2013b; Zorondo-Rodríguez et al. 2015). The robustness analysis included a set of disturbances on the core model. i) Dropping some control variables that could affect the association (age, sex and type of water system), ii) Using parts of the sample; selecting by sex, and age. When selecting by age, the sample was divided in individuals younger and older of 65 years old, the retirement age, at the moment of the interview. Studies have shown that this shift in the daily routine may affect how individuals perceive themselves and their quality of lives (Kim & Moen, 2001). iii) Using Ordinary Least Square instead of Ordered Probit Regression, to assess concordance of the results even if the model assumptions are not fulfilled.

RESULTS

3.1. Descriptive statistic and bivariate analysis

3.1.1. Description of the sample

More than half of the people interviewed were woman (62.6%). The average informant was 57.5 years old (min=30, max=87), that has lived an average of 47.9 years on the district (SD= 20.4). Of the total of 65 informants, 19 were not part of any kind of committee (self provided water supply), 22 were members of an informal committee (community arranged water supply) and 24 were part of a formal committee (water supply supported by institutions) (Table 1).

3.1.2. Change in native forest surface

A total of 62 individuals (95.4%) perceived less forest surface than 20 years ago; of them, 43 (78.2%) considered this decrease of forest surface have had a negative consequence for them or their family. From all the answers, 16% identified the reduction of water provision as a consequence of forest surface lost. Other consequences mentioned were the reduction on household income (29%), less available food and material provision, (27%) and a decrement on cultural ecosystem services (14%). Nevertheless, 14% identified the forest loss as a positive consequence, since the replacement by pine plantations represented more job opportunities for them (Figure 4).

Table 1. Definition and descriptive statistics of variables used in regression analysis (n=65).

Variable	Definition	Mean (SD)	Min Max
I. Outcome variable			
Change in Human Wellbeing	Current overall individual life satisfaction compared to 20 years ago	4.18 (1.29)	1-6
II. Explanatory Variables			
Change in water quantity	Current water quantity compared to 20 years ago	3.08 (1.56)	1-6
Change in water quality	Current water quality compared to 20 years ago	4.26 (1.29)	1-6
Change in native forest surface	Current native forest surface compared to 20 years ago	1.62 (1.14)	1-6
III. Control Variables			
Change in economic income	Current economic household income compared to 20 years ago	4.11 (1.09)	1-6
Age	Age of the person, in years	57.52 (15.74)	30- 87
Woman	Individual's gender (1=female)	62,6%	
Committee type			
No committee	Households with self supply drinking water.	29.23%	
Informal committee	Rural Drinking Water Committee, not recognized by external institutions.	33.85%	
Formal committee	Rural Drinking Water Committee, formally recognized by external institutions.	36.92%	

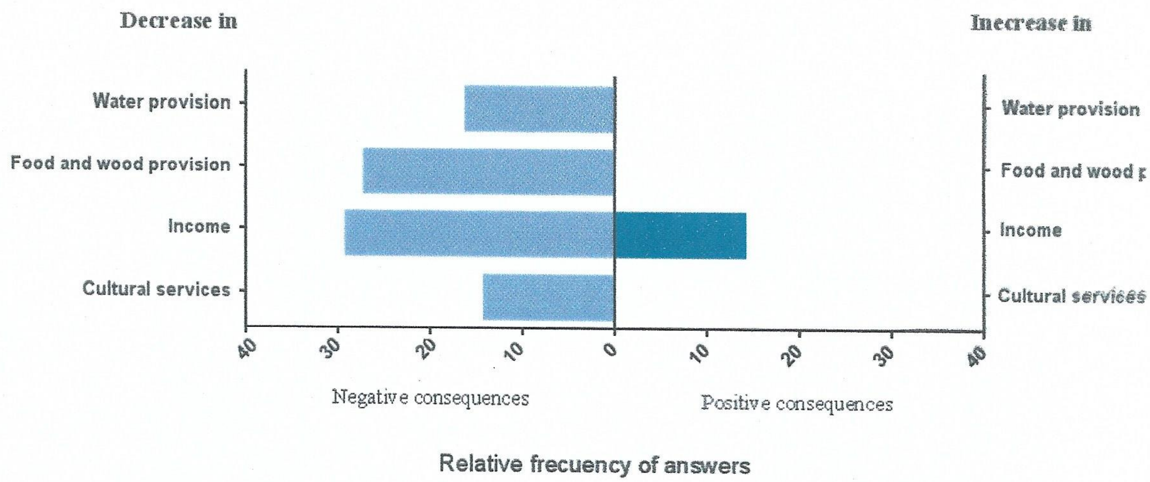


Figure 4. Perception of consequences of native forest replacement by pine plantations (n=58). The answers are divided according to those who reported the change had negative consequences (left side of the axis,) and those who reported it had positive consequences (right of the axis).

3.1.3 Change in water quantity and water quality

A 67.7% (n=44) of the informants reported that there is less water available than 20 years ago. When asked for the reasons of the change, 28% of the answers associated the decrease of water quantity to pine plantations (Figure 5). Nevertheless, 32% of the informants perceived more water than 20 years ago. In this case, the single reason mentioned was more access to drinking water (specified as sanitization, pipes, tanks, and water faucets inside the house). Even though most of the informants (71.4%) that perceived more water than 20 years ago were associated to a CAPR or a Neighbor

Association for water supply, there were not statistically significant differences on perception of change in water quantity among households according the type of water system (Kruskal Wallis test, coefficient=2.83, p=0.24).

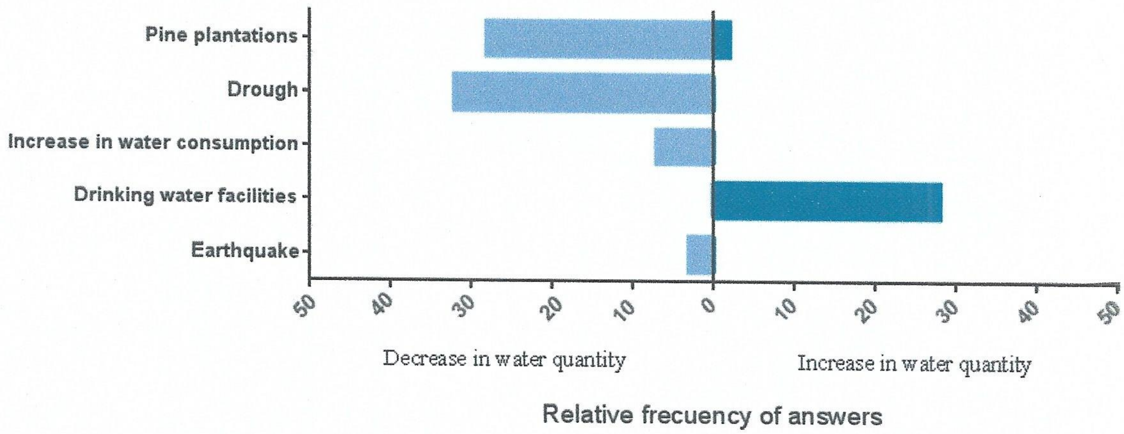


Figure 5. Perception of drivers of water quantity change. (n=60) The figure shows the drivers perceived to water quantity change. The answers are divided according to those who reported a decrease in water quantity (left side of the axis,) and those who reported an increase in water quantity (right of the axis).

A total of 45 individuals (67.8%) reported that quality of water is better-off than 20 years ago, and only 5 (7.7%) reported the quality of water as much worst or completely worst. People associated water quality improvement to water sanitization and drinking water infrastructure; they specifically referred to having drinking water access near or inside their house. Only 4% of the answers associated the decrease in water quality with the replacement of native forest by pine plantations (Figure 6). There were significant differences on perception of water quality among types of committees (coefficient=13.40, p=0.001). Individuals from CAPRs reported a better water quality, in comparison with members from Neighbor Associations (Dunn's test, p<0.005) and individuals with self provided water supply (Dunn's test ,p<0.001). There were no significant differences between the lasts two groups.

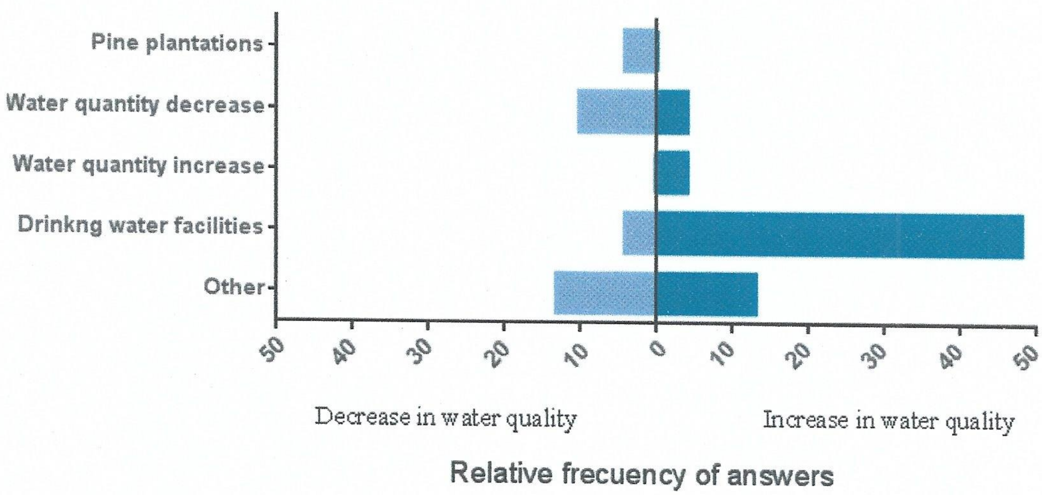


Figure 6. Factor of water quality change (n=44). The figure shows the factors informants related to water quantity change. The answers are separated according to those who reported a decrease in water quality (left side of the axis) and those who reported an improvement in water quality (right of the axis).

3.1.4 Change in subjective well-being

The average change in subjective well-being was 4.2 (SD=1.3). On the range from 1 to 6, more than half of the informants (61.5%) reported their life as being much or completely better-off at the time of the interview compared to 20 years ago. Only 3 of the informants (4.6%) reported their life is completely worst off. From all the answers, 5% mentioned the improvement of water quantity and quality as a reason for being better-off (Figure 7). There were not significant differences on changes in wellbeing among households pertaining to a kind of Rural Drinking Water Committee, or self water supplied households (Kruskal Wallis test, coefficient= 1.23, p= 0.54).

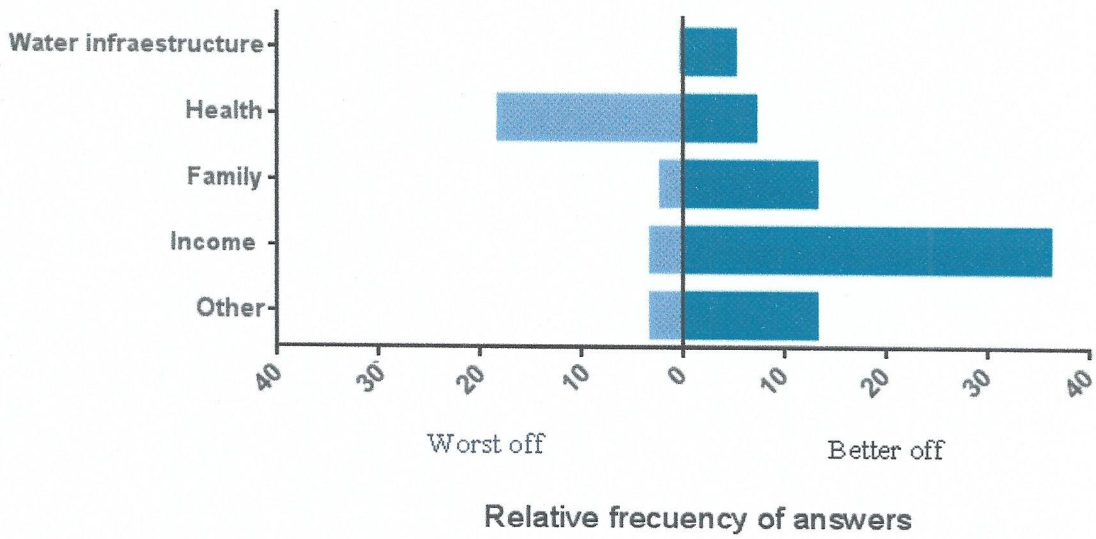


Figure 7. Drivers in subjective well-being. (n=56) The responses are separated between those who reported being worse off than 20 years before, and those who reported being better off than 20 years ago.

3.2. Association between forest surface, water provision and subjective well-being.

A better water quality is associated to better subjective well-being (Ordered Probit model, coefficient=0.26 p=0.03). The data did not show significant association between change in subjective well-being and change in water quantity, nor change in forest surface (Table 2).

Table 2. Association between change in well being and change water provision.

Explanatory variables	Change in Subjective Well-being
Change in native forest surface	0.043
	(0.105)
Change in water quantity	-0.063
	(0.096)
Change in water quality	0.259**
	(0.117)
Control variables	
Change in economic income	0.191
	(0.163)
Age	-0.039***
	(0.011)
Woman	-0.297
	(0.281)
No committee	0.735*
	(0.415)
Informal committee	0.410
	(0.293)
Formal committee	-

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.3. Robustness analysis

The sign, and significance level of some associations changed across models in the robustness analysis (Table 3). When using only the sample of women, change in water quality kept to be positively associated to subjective well-being (coefficient=0.423 p=0.026) (model 3), whereas when using only the sample of men, the association was not significant (coefficient=0.177, p=0.302) (model 4). Nevertheless, the sample of only men shows a negative association with change in water quality (coefficient=-0.290, p=0.085) and positive association with change in forest surface (coefficient=0.301, p=0.003) in a significant way. The significance was lost when dropping the type of water supply as control variable (model 5). Results of robustness analysis suggest that association between change in subjective well-being and change in water quality it is modulated by other variables, such as age and committee type.

Table 3. Robustness analysis for association between change in well being and change in water quality, water quantity, forest surface and economic income.

Models		Explanatory variables		
		Change in water quality	**Change in water quantity**	**Change in forest surface**
		(a)	(b)	(c)
Core Model	(1)	0.259** (0.117)	-0.063 (0.096)	0.043 (0.105)
Dropping control variable:				
Committee type	(2)	0.131 (0.108)	-0.049 (0.097)	0.022 (0.106)
Using part of the sample:				
Woman	(3)	0.423** (0.190)	-0.039 (0.140)	-0.091 (0.142)
Men	(4)	0.177 (0.171)	-0.290* (0.169)	0.301*** (0.102)
Younger than 65 years old	(5)	0.428** (0.174)	-0.178 (0.141)	0.110 (0.128)
Older than 65 years old	(6)	0.110 (0.115)	-0.031 (0.178)	0.0633 (0.239)
Using other models:				
OLS	(7)	0.200 (0.120)	-0.062 (0.096)	0.035 (0.102)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

DISCUSSION

Ecosystem change might affect human well-being through the loss of ecosystem services (MA, 2005). Water provision is a critical ecosystem service, therefore, a reduction in its provision be it quantity or quality ought to be associated with a decrease in well-being. In rural areas, where water provision is bounded to forest cover (Lara et al., 2009), deforestation will infringe upon well-being. In fact, many social conflicts due to pine plantation related drought have taken place in south central Chile within the last years (Frêne et al., 2014). However, although rural people do perceive a decrease in forest surface and water quantity, they also perceive an increase in water quality, which was directly associated to well-being. The uncoupling of forest loss and perceived water provision suggest that the consequences of water provision loss over their well-being might be buffered by the access to other types of capital, such as water infrastructure.

The substitution of natural capital by other types of capital would cover up the decrease on the provision of ecosystem service. For instance, increase in water quality is achieved by the construction of water tanks, pipes or water faucets (manufactured capital), support through subsidies (social and organizational capital), and the training on water sanitization (human capital). However, despite of how strong is the substitution, this would just temporarily mask the deterioration of the ecosystem service (Ekins et al., 2003). These capitals in play would only buffer the effects of water provision loss until a threshold of criticality is reached, where well-being is inevitably affected (De Groot et al., 2003; Ehrlich & Goulder, 2007). Therefore, under the current practice to cope with water provision decrease, characterized by technical solutions, there would be a time lag after ecosystem degradation, before human well-being is negatively affected (Raudsepp-Hearne et al., 2010b).

Additionally, the replacement of natural capital, such as forests, could only be partial, since ecosystem services provide multiple benefits, unlike the flow of other types of capitals (Fisher & Turner, 2008, Raudsepp-Hearne et al., 2010a). Therefore, the benefits provided by other types of capital might be unable to fully replace all the benefits that water provision provided to users before ecosystem degradation. For instance, water trucks would only extend the benefit of drinking water for household consumption, since it is unlikely that it provides the water needed for crops in a rural area. Moreover, such substitution is often expensive, both in terms of the development of substitutes and maintenance costs (MA, 2005).

The buffering effect of other capitals could also mislead the perception of the role of natural capital as a determinant in human well-being. When addressing a decrease in human well-being due to changes in ecosystem services, policy makers often direct the efforts to the replacement of natural capital by other capital (Ang & Passel, 2012), instead to forest conservation. For instance, in Chile, the strategy for facing drought is focused in the construction of dams, pipelines and canals for inter-basin water transfers, and desalinization programs, while ecosystem management is nowhere on the picture

(Ministerio del Interior, 2015). Places such as China, India, and Australia have also followed this approach, including river diversions and water grids as well (NDRC, 2007; NAPCC, 2008; QWC, 2008). Investment in manufactured capital has also been adopted as a strategy for coping with climate change, even though infrastructure lacks of the capacity to adapt to water provision changes, of unknown magnitude and timing (Frederick, 1997).

As human well-being is a main concern in sustainable development, governments are recognizing ecosystem services as an approach to address sustainability challenges (Wong et al. 2015). When addressing sustainability challenges, ecosystem management should take into account that other types of capital may buffer the effects of ecosystem service loss over human well-being, and therefore, covering up ecosystem degradation.

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